SOILS AND LAND-USE PLANNING IN THE HOWICK EXTENSION AREA

by

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"Treat each field and pasture - each acre - of every farm according to its individual needs and capability for producing different crops"

HUGH H. BENNETT (1958)

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INTRODUCTION

The Howick Extension Area is 742 square miles in extent and incorporates both the Lions River and Mooi River Valley[1] soil conservation districts (Map 1). The Area, situated within the Natal Midlands, has immense potential for intensive agriculture, forestry and other uses. However, in the course of his extension duties, the writer soon became aware of several inherent limitations that had a profound influence on farming practice. Most of these were associated with the soil resources. Many abortive attempts to produce high yielding crops and pastures were the result of extreme acidity and low plant nutrient status. In the drier parts, unfavourable physical characteristics of the soils such as droughtiness, waterlogging and high erosion hazard gave rise to problems of particular importance. At that time very little was known of the soils in the Area and, even less, of their influence on land-use practice.

Furthermore, experience in the Area had indicated that a purely 'physical' approach to farm planning was futile. It was clear that if the conservation campaign was to reach its ultimate goal, greater emphasis would have to be placed on 'planned farming'. The needs of the farming community were such that extension activities had to be directed to those matters relating to farm production and management. To meet these needs soil survey procedures (preferably with pedological significance) had to be introduced into the farm planning exercise. In effect, something had to be done to prevent 'planning' becoming a 'faceless' word (Phillips, 1966).

These then were the problems that stimulated the writer's interest in this field of study and led finally to a survey of the soil resources. Early attempts at surveying were primitive - a simple recording of red soils, brown soils and 'vlei' soils. Eventually the survey, based on

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[1] Prior to boundary adjustment in 1966

modern procedures, was completed with the assistance of Mr. R. Ludorf, soil scientist at Cedara (Ludorf & Scotney, 1965). The resulting information including a soil map produced at a contact scale of 1:50,000, forms the basis of this dissertation. It provides not only a sound basis for planning land use and research but also a powerful extension 'tool' for use by field officers.

The writer's prime interest, however, extends beyond the permanent record or inventory of soils. It lies mainly in the assessment and interpretation of the data for land-use planning. Ensuring that maximum use would be made of the hard won facts was a challenge that had to be accepted. Vink (1963) provides clear illustration of this point in his statement that "the surveyor who produces only a beautiful soil map to hang on the wall is doing something which is just as expensive as the buying of an old masterpiece". The surveyor should make clear to those that follow, the significance of his data. Interpretation is thus an important objective of this endeavour.

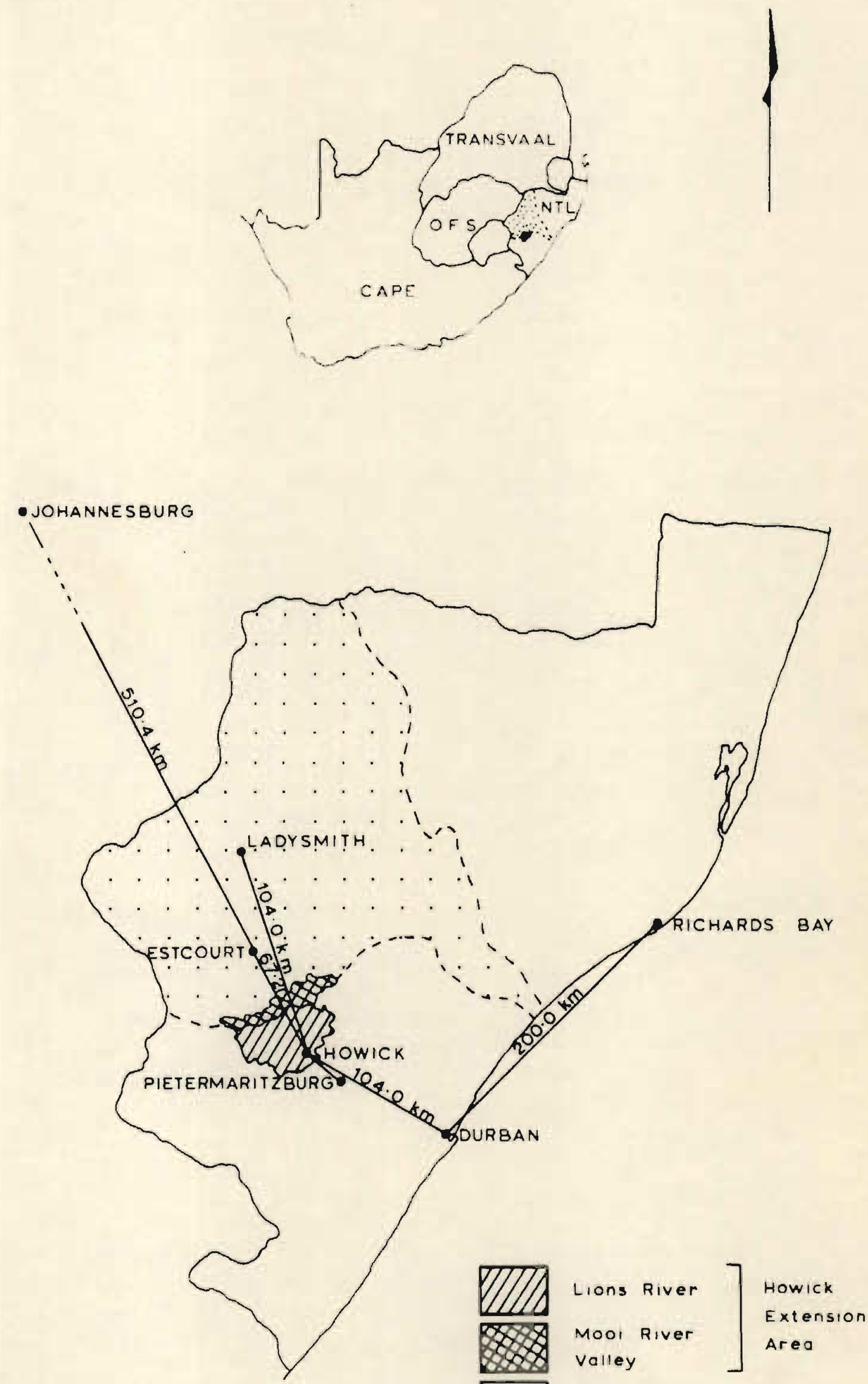
According to Thomas (1960) growing populations and the corresponding rise in land pressure gives timely warning of the need for planned land-use on the basis of rational selection. The presence of much denuded and severely eroded land, not only in the Area but also throughout the Republic, bears witness to the inadequacy of traditional methods for selecting land for agricultural use. Land classification is widely accepted as the starting point in land-use planning (Jacks, 1946). It is seen as a valuable means of directing agricultural endeavour to land of highest potential and preventing over-exploitation of marginal land. Thus, the classification of land can contribute much to the conservation of natural resources. It is, however, less complete and detailed than soil classification.

Land-use planning requires that consideration be given to <u>all</u> natural features of the environment, not only soils. For this reason, all other natural features of the Area together with important economic factors were studied in detail. In presenting this information and discussing its influence on agricultural development the writer has relied heavily on the ecological approach to land-use planning and has taken many related principles into consideration (Graham, 1944; Phillips, 1959; Hills, 1961).

Three parts are presented. The first deals specifically with the soil resources of the Area, their assessment and interpretation and several studies designed to aid the assessments. Detailed descriptions of each soil series are, however, purposely omitted. The second provides an account of all other factors affecting land use and the interrelationships between them. Finally, attention is given to land classification and land-use planning as they apply to the Area as a whole and to individual farms.

Throughout this work an attempt is made to present principles and, in places, procedures that are basic to sound land-use planning. These are intended for those engaged in this field of activity. It is also hoped that the information will be of direct benefit to the farmers themselves. Much of the discussion is perforce subjective and, as a result, the writer is open to criticism. However, it is essential that a start be made to record all available soils information, no matter how meagre. It is hoped that others will follow and provide the necessary factual data. If, in time, this endeavour results in improved farming practice and conservation in the Area the writer will be more than satisfied.

In the Natal Region recent developments in pedology have had a considerable impact on all spheres of agricultural activity. These have done much to expand the outlook of extension officers, research workers and farmers. A similar experience in Rhodesia was attributed to "eyes being opened to secrets lying unsuspected beneath their feet on many a problem field" (Thomas, 1960). Added interest has followed publication of the "Soils of the Tugela Basin" by J.J. van der Eyk, C.N. MacVicar and J.N. de Villiers (1969). For obvious reasons, every effort has been made to relate the soil series described in this dissertation to those of the major reference work. Throughout the text 'operative' soil series names are given in capital letters. Names, which in terms of the Tugela Basin report are now 'redundant', are given in lower-case letters. A complete check list of operative and redundant series names is presented in Appendix 1. Since much of the study was completed prior to metrication South African units that were then in use appear in some tables and diagrams. For this reason, conversion tables are given in Appendix 18.



Map 1 : Location of Howick Extension Area

PART 1

SOILS: THEIR ASSESSMENT AND INTERPRETATION

CHAPTER 1

SOIL RESOURCES OF THE AREA

1.1 Soil survey

The soil survey of the Area was conducted at a time when South Africa was experiencing a phenomenal upsurge in pedological interest. Prior to 1958 the progress in soil classification was relatively slow although surveys had been completed for parts of the sugar belt and several irrigation projects (MacVicar, Loxton and van der Eyk, 1965). Modern techniques were used to survey the soil resources of the Area and the 'soil series' concept was accepted as sound. Many workers have stressed the value of soil series for practical use in agriculture and numerous studies have confirmed their importance (Clarke, 1951; Kellog, 1951; Soil Survey Staff, 1951; Odell, 1958; Rennie & Clayton, 1958; Murdoch, 1961, 1965; Riecken, 1962; Ball, 1965; Hill, 1965; Loxton & MacVicar, 1965; Orchard, 1965; Cunningham & Wells, 1966; Glover, 1967).

Despite the general support for this concept, Stamp (1959), Butler (1964) and Northcote (1964) questioned its soundness since few good correlations between soil series and production levels had been established and many of the studies were indecisive. Although such argument may hold where fertility of the topsoil is the main concern, the writer contends that the soil series is of the utmost importance where erosion hazard and other physical attributes influence land-use planning.

An account of the classification, description and distribution of the soils is given in this section. No attempt is made to discuss soil formation since much relevant information has already been presented by de Villiers (1962), MacVicar (1962), Roberts (1964) and van Rooyen (1964).

1) Objectives of the survey

Soil surveys have many uses and benefits and may serve many people (Hockensmith, 1958; Klingebiel, 1963). Robinson (1951) considered that the best service the surveyor can render the would-be planner is to provide an accurate soil map with clear explanations of its significance. Since each kind of soil has its own set of characteristics, data should be provided for grouping soils according to those properties important to soil use. Soil surveys can also be of particular value for research. According to Kellog (1951), soils accurately defined and named in a standard system of classification are the only reliable bases yet found for selecting samples of soil and landscape for experimental study.

The objectives of the survey were to provide:

(a) a permanent record, or inventory, of the soil resources of the Area that would permit efficient planning of the agricultural land;

(b) the basic data for the accurate assessment and interpretation of the soils in terms of their potential, limitations and management needs;

(c) a means for planning research projects and to indicate important 'bench mark' soils requiring intensive study;

(d) a link between research and individual farm fields; and

(e) the basis for teaching non-specialists about the soils and, in so doing, provide a valuable extension tool.

2) Methods

The procedures and terminology adopted for the survey are fully described in the Soil Survey Manual (Soil Survey Staff, 1951). They are similar to those used by MacVicar (1962) and van der Eyk et al. (1969). Soil colours were recorded in terms of the Munsell Soil Colour Charts (1954).

(i) Field procedures

The project commenced with a reconnaissance survey of the entire Area during which over 400 soil profiles were described in detail. In addition, numerous augerings were made to permit a thorough appreciation of the entire range of soils and their locations. For this purpose the Eykelkamp auger proved most efficient, especially in highly leached soils. Based on the initial investigation, 91 'type' profile pits were sited. These were carefully described and sampled for chemical, mechanical and clay mineralogical determinations. The descriptions and supporting analytical data provided the basis for defining the soil series and phases. Mapping units comprising soil associations were then established. Several soil phases and miscellaneous land types considered significant for land-use purposes were mapped separately.

Photo mosaics constructed by the Department of Land Survey at the University of Natal were used for the mapping exercise. A spare set of aerial photographs was used for stereoscopic study and to finalize the field-drawn soil and land type boundaries. In this exercise the Casella pocket stereoscope proved most useful. At the time of the survey, two sets of air photo coverage were available. One at a contact scale of 1:20,000 and dated 1944 covered the entire Area while the other, at 1:36,000 and dated 1959, covered only the Lions River district. The lack of up to date coverage of suitable scale and quality complicated the compilation of the map. High quality aerial photography is of inestimable value for soil surveys and map production (Soil Survey Staff, 1951; Stephens, 1953; Buringh, 1954).

Prior to the mapping phase, a small 'key' area near Howick was chosen for training a team of post-graduate students who mapped a large part of the Area. Within this area a further 150 profile pits were sited and described. In this way the survey team became acquainted with the entire range of soils and their pattern of distribution. The value of 'key' areas in soil survey procedures was stressed by Robinson (1951) and MacVicar (1962) and has been adequately demonstrated in the Tugela Basin survey.

Soil and land type boundaries, established by auger traverses and air-photo interpretation, and other relevant information such as streams, communications and townships, were marked on the mosaics. This information was then transferred to individual photographs which were checked and edge-matched. The photographs were later dispatched to the Department of Land Survey where the soil map was compiled at an exact scale of 1:50,000. The map was again checked prior to the final drafting. Funds for the production of the soil map were provided by the Natal Town and Regional Planning Commission. A portion of the Mooi River Valley district, situated to the north-east of the town, was mapped by van der Eyk et al. (1969) at a scale of 1:100,000. These boundaries had first to be transferred from the uncontrolled mosaics to accurate 1:18,000 topo-cadastral series maps and thence to the 1:50,000 map. Greater accuracy was achieved in this way.

(ii) Laboratory methods

Accurate soil series definitions require criteria other than morphological characteristics. For this reason, samples collected from the 'type' pits were transported in air-tight polythene bags to the laboratory at Cedara for detailed analyses. These samples were air dried, sieved to 2mm, 1mm and 90 mesh fractions and the hydroscopic moisture determined by drying for two hours at a temperature of 135°C. Mechanical analyses were then undertaken and textural classes designated according to the modified chart drawn up by Loxton (1961).

The following broad textural designations are used in this study:

clayey: containing more than 35% clay

loamy: containing less than 35% clay
but less than 65% sand

sandy: containing more than 65% sand.

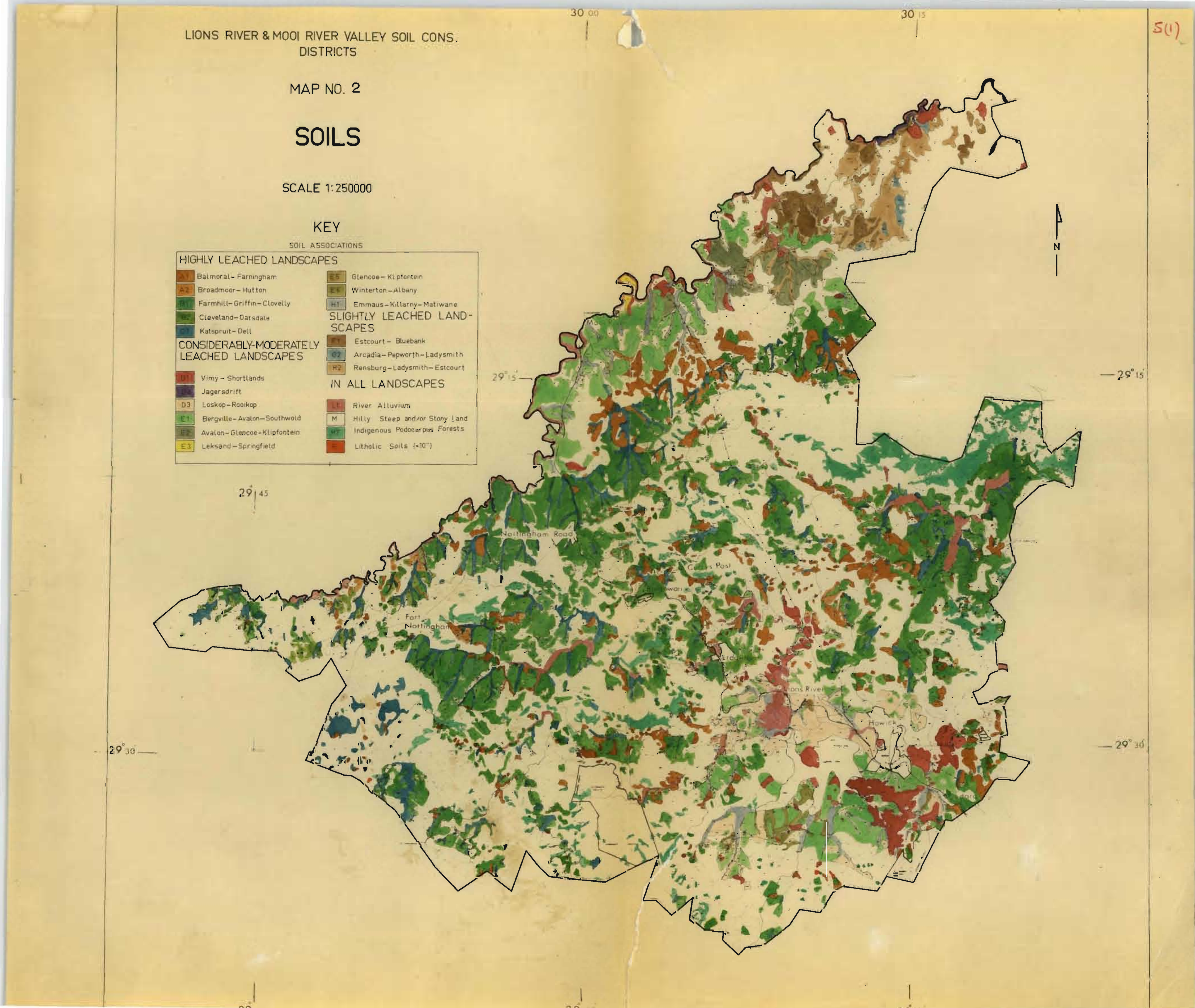
Finally, chemical and clay mineralogical properties were investigated. The former included soil reaction (pH), total exchange capacity and the content of nitrogen, organic carbon and exchangeable cations. Details of the laboratory methods and the results obtained for many individual profiles were presented by Channon (1962) and Ludorf and Scotney (1965). Channon also correlated chemical analyses with parent materials, altitude and climatic conditions.

1.2 Soil map and legend

The soil map comprises nine hand coloured sheets at a scale of 1:50,000. The location and numbering of the individual sheets are indicated on the map folder. However, to permit an overall appreciation of the soil resources and to indicate patterns of soil distribution, a composite 1:250,000 map (Map 2) was compiled by photographic reduction. This map also facilitates a comparison between soils and other natural features of the Area.

Despite its many advantages, the soil map does not obviate the need for detailed soil investigation at the farm level since, at a scale of 1:50,000, one square inch represents an area of approximately 400 acres. The soil map does, however, indicate those soils likely to occur on the farm and, in so doing, simplifies the planning procedure. Although the map suggests sharply defined soil boundaries, they seldom occur unless coincident with abrupt changes in climate, topography or parent material. They are largely arbitrary and at best can provide an approximation (Robinson, 1951).

According to van der Eyk et al. (1969) a soil map should delineate areas of soil that are meaningful in terms of the objectives of the survey. This principle was followed in creating the mapping units which comprises 18 soil associations, five soil phases and three miscellaneous land types. Soil associations are named after the most important soil series comprising them and are indicated by capital letters and arabic numbers e.g. A1, B2, C1, etc. Subscript lower-case letters denote the soil phases. These include a humic phase (h - organic carbon $>$ 5%), a shallow phase (o - depth of 10" to 20"), a slope phase (s - $>$ 8% slope) and sheet (x) and gully (y) erosion phases. The erosion phases include land which, by stringent conservation measures, can be reverted once more



5(1)
LIONS RIVER & MOOI RIVER VALLEY SOIL CONS. DISTRICTS
MAP NO. 2
SOILS
SCALE 1:250000
KEY
SOIL ASSOCIATIONS
HIGHLY LEACHED LANDSCAPES
Balmoral-Farningham
A2 Broadmoor-Hutton
Farmhill-Griffin-Clovelly
Cleveland-Oatsdale
Katspruit-Dell
E5 Glencoe-Klipfontein
Winterton-Albany
H1 Emmaus-Killarny-Matiwane
SLIGHTLY LEACHED LANDSCAPES
Estcourt-Bluebank
Arcadia-Pepworth-Ladysmith
H2 Rensburg-Ladysmith-Estcourt
CONSIDERABLY-MODERATELY LEACHED LANDSCAPES
Vimy-Shortlands
Jagersdrift
D3 Loskop-Rooikop
E1 Bergville-Avalon-Southwold
Avalon-Glencoe-Klipfontein
E3 Leksand-Springfield
IN ALL LANDSCAPES
River Alluvium
M Hilly Steep and/or Stony Land
Indigenous Podocarpus Forests
Lithotic Soils (-10")
N
30 00
30 15
29 15
29 30
29 45
Nottingham Road
Fort Nottingham
Howick

to a productive state. The miscellaneous land types include steep and/ or rocky land, (M) generally regarded as non-arable, indigenous Podocarpus forests (MF) and litholic soils (R) of less than 10 inches deep.

1.3 Physiographic classification of the soils

Farmers have long recognized different kinds of soil through bitter experience. Many terms expressing crop suitability and soil conditions indicate the long-felt need for a system of classification. By this means a farmer can apply to a particular soil, the ideas and experiences of others. Thus, Riecken (1962) considered that one of the main functions of soil classification was to serve as a basis for applying technology to farming. He concluded that the lowest category in the system (soil series) was the most useful.

Classification brings order into the study of the soil mantle or 'continuum of variation' (van der Eyk et al., 1969). By establishing classes that subdivide the existing range of variation in soil conditions, an otherwise incomprehensible mass of data is simplified and made easy to remember. Classification also provides a framework by which the position of an individual soil in the whole spectrum of known classes can be established. For practical purposes an arbitrary limit to soil depth is set at 48 inches.

The physiographic classification presented here is similar to that originally developed by van der Eyk (1965b). By giving attention to the geographic distribution of soils the classification was designed to serve as a soil mapping legend that would best meet the immediate needs.

It is not offered as an alternative to the soil series - soil form approach adopted by van der Eyk et al. (1969) or to a taxonomic system such as the 7th Approximation (Soil Survey Staff, 1960). The soils of the Area have been related to those of the Tugela Basin by indicating the relevant soil forms in Table 2 and Appendix 1. Although no attempt is made to establish the relation between the soils of the Area and those of the American (Soil Survey Staff, 1960) and S.P.I. systems (D'Hoore, 1964), this was done for some Natal soils by de Villiers (1962) and van der Eyk (1965a).

Many important morphological and chemical soil properties provide the criteria for determining the categories of the classification system. Although single criteria such as texture and base status are important differentiae at the series level, due regard should be given to the principle of covariance. As explained by van der Eyk et al. (1969), covariance applies equally well to individual morphological properties as it does among morphological and chemical properties, colour excepted.

Climate has an overriding influence on the formation and distribution of soils within the Area and, since climate itself is strongly influenced by local physiography, the system used is termed a physiographic classification. Because of the importance of climate as a factor of soil formation much attention is given to the extent to which the upland soils have been leached by natural processes. Degree of leaching not only reflects broad genetic relationships between soils and the direction of their development, but also has important practical implications. Clear definition of the terms used in this text is thus necessary.

1) Definition of the degrees of leaching

The degree to which the upland soils have been leached is essentially a chemical characteristic and is indicated by the base status of the B-horizon. Table 1 shows the five main categories defined and the relevant chemical criteria of each group.

Highly leached soils are associated with intense weathering, rapid removal of soluble products and a very low base status. The clay fraction consists mainly of kaolinite, halloysite and halloysitic allophane although even these may be lost (van der Eyk et al., 1969). According to van der Eyk (1965a) the increase in free iron (Fe_2O_3) with depth, especially in the 'yellow-over-red' profiles, also points to the current illuviation of iron. Characteristically, clay minerals of the B-horizon have a low, pH-functional, cation exchange capacity (CEC). Furthermore, iron and

Table 1 : Degrees of leaching in upland soils, in terms of chemical properties of the B-horizon (van der Eyk, 1965b)

Degree of leaching	Total extractable bases (me%)	Base saturation (%)	Reaction pH
Highly leached	less than 1.5	less than 20	below 5.5
Considerably leached	1.5 - 5.0	20 - 50	5.0 - 6.0
Moderately leached	5.0 - 15	50 - 90	5.5 - 7.0
Slightly leached	10 - 30	80 - 100	7.0 - 8.0
Hardly leached	15 - 30	100 (+ free salts)	above 8.0

aluminium compounds released by weathering are relatively immobile and tend to accumulate residually. Applied soluble phosphate is thus immobilized to a marked extent in many of these soils. The problem of Al-toxicity is equally important.

Covariant with the chemical features are characteristic morphological properties. The soils are generally deep, friable and well-drained but lack visible macro-structure (i.e. apedal). The rapid permeability and high porosity of red soils is ascribed to a micro-aggregating effect of coatings of oxides of Fe and Al on primary soil particles, the absence of 2:1 lattice clays and the presence of materials that do not favour orientated packing (van der Eyk et al., 1969). Nevertheless, some soils of this group are less 'open'. A high (3 - 6%) content of organic carbon in the topsoil is also a characteristic feature of these soils.

In the considerably leached soils the weathering process has been somewhat restricted, resulting in a slightly higher base status. Although structural development may be slightly improved, apedal B-horizons predominate. A noticeable feature of some of these soils is the presence of contemporary iron-manganese concretions which represent an accumulation of sesquioxides due to hydromorphic influence. In this case, periods of water surplus alternate with those of near defiency.

With drier conditions the leaching process is interrupted to a greater extent and moderately leached soils predominate. Weathering has generally progressed to the stage of appreciable, but not complete, breakdown of primary minerals. As a result expandible 2:1 lattice clays are common and these, in turn, generate structure when the soils dry out (van der Eyk et al., 1969). Strong structural development is thus one of the most important morphological characteristics of this group.

Other features covariant with the high base status include hydromorphic segregation of iron oxides, especially among soils derived from Karroo shale and sandstone, contemporary iron-manganese concretions, ferruginous hardpans (hard plinthite) and a low content of organic carbon. Hydromorphism is the result of waterlogging in summer and droughty conditions in winter. Strong mottling and concretions are indicative of these conditions. The red soils of this group are reputed to have a relatively low capacity for phosphate fixation since the free iron oxides are highly crystalline (van der Eyk et al., 1969).

Slightly leached soils occur in the driest parts of the Area. They are generally fully saturated and lime concretions are especially common in the lower slope position. Appreciable amounts of exchangeable sodium may be present in the duplex or claypan soils. The clay fraction is also dominated by montmorillinite with the result that many soils reveal a high swell-shrink potential. Strong blocky and prismatic structure is common. Typical diagnostic horizons include vertic and melanic A-horizons (margalitic soils) and prismatic textural and cutanic B-horizons. Dark coloured clay skins, the result of appreciable clay illuviation, are also common. Soils with vertic A-horizons occur mostly in the bottomland position where there is an abundant supply of soluble silica and divalent bases. Self-mulching properties and slickensides are exhibited by these soils. Superficial leaching in the duplex soils (e.g. ESTCOURT series) gives rise to slightly acid conditions in the topsoil (van der Eyk, 1965a).

Hardly leached soils are not widespread in the Area but may occur under very hot and dry conditions. Since near drought conditions are seldom relieved the weathering process is severely retarded. The soils are often fully saturated with free salts present throughout the profile. A high degree of structural development is associated with this group.

The term 'partially leached', as used in this dissertation, refers to all groups other than the highly leached soils. Landscape position may, however, also influence base status. For example, bottomland soils associated with highly leached upland soils usually have a high base status. Even soils adjoining the bottomlands (lower slope) have been found with a higher base status than is normally expected (i.e. over 1.5 me%).

The influence of lime and fertilizer application on the chemical composition of the B-horizon, and hence classification, though not investigated in this study, warrants further attention.

2) Categories of the classification and miscellaneous land types

The categories or classes into which the soils are assembled include, in descending order, landscape groups, landscape position, major soil groups, soil associations and soil series. Soil phases and miscellaneous land types are used to meet practical needs.

(i) Landscape groups

The influence of physiographic-climatic features on the pattern of soil distribution provides a basis for defining three main landscape groups. These are qualified in terms of degree of leaching of the upland soils. The complex pattern of soil distribution brought about by many small variations in local climate, makes it necessary to define the landscape groups in rather general terms i.e. a wide range in degree of leaching. In the Lions River district, however, detailed climatic and pedological data make it possible to define the landscape groups with greater accuracy. The groups, which differ slightly from those defined by van der Eyk (1965b), include the following:

Group I - <u>Landscapes characterized by highly leached soils</u>

In this group, the water balance provides a large moisture surplus during the rainy season and, in terms of Thornthwaite's (1948) method, has a moisture index in excess of 20. Since moisture utilization never exceeds the total storage capacity of the soils they remain moist throughout the dry season. A high degree of leaching is thus attained. In general, the climate is humid and mild to cool with an annual rainfall exceeding 900 mm (± 35 inches). This group includes the Highland Sourveld and Midlands Mistbelt areas (Pentz, 1949).

Group II - <u>Landscapes characterized by considerably to moderately leached soils</u>

The climate of this group varies from moist sub-humid and mild to slightly dry or dry sub-humid and cool. The annual rainfall is mostly between 750 and 900 mm and the moisture index lies between -5 and +20 (Thornthwaite, 1948). The vegetation comprises ecotonal grasslands and moist transitional Tall Grass Veld. In the moister parts, although water need exceeds precipitation, deficiency is seldom reached (i.e. moisture index of +5 to +20). In the driest parts, soil moisture reserves are exhausted during the dry season but the period of moisture deficiency is generally short (i.e. moisture index of -5 to +5). Despite the somewhat droughty conditions, these landscapes are not sufficiently dry to induce the formation of margalitic or claypan soils.

Group III - <u>Landscapes characterized by moderately to slightly leached soils</u>

A dry to very dry sub-humid and mild to very warm climate prevails in these landscapes. The annual rainfall is usually less than 750 mm and the moisture index is mostly between -15 and -5 (Thornthwaite, 1948). Soil moisture is never fully charged during the rainy period and there is a prolonged period of moisture deficiency during the dry season. This group includes the dry Tall Grass Veld and the Thornveld areas. Margalitic and claypan soils are particularly common and, in fact, constitute important criteria for defining this group.

(ii) Landscape position

Topographic features within each landscape group influence soil formation markedly and provide a natural basis for grouping soils. Two easily recognized positions are defined viz. uplands and bottomlands:

Uplands - undulating, rolling or hilly, but sometimes nearly level areas stretching away from, and rising well above, the local drainage ways.

Bottomlands - the level or nearly level areas along, and on a level with, the local drainage ways, receiving run-off and seepage water from adjacent uplands.

Upland and bottomlands are the complementary portions of one and the same landscape (van der Eyk, 1965c).

(iii) Major soil groups

Major soil groups indicate essential trends in soil formation and broad genetic relationships between soils. Differentiating criteria for this category consist of the most striking morphological characteristics such as colour, structure, consistence, effect of iron oxide segregation, clay illuviation, lime accumulation, gleying and the degree of leaching. Ten major soil groups, designated by capital letters, are recognized. Six comprise upland soils and four, bottomland soils (including river alluvium). Neutral to alkaline bottomland soils (H^{1}), associated with red (D) and grey-brown (E) partially leached upland soils, are separated from the margalitic and claypan bottomland soils (H^{11}) of major groups F and G. This division is a departure from the major soil groups defined by van der Eyk (1965b).

(iv) Soil associations

The major soil groups each comprise a number of soil associations and form the actual mapping units. Soil associations comprise soils that are regularly associated in a particular landscape, have formed contemporarily under similar climatic-physiographic conditions and usually originate from similar parent materials. The association is a conceptual unit representing a collection of concrete soil populations (van der Eyk, 1965b). Soil characteristics such as texture, stage of development and minor drainage effects provide the essential criteria for distinguishing between the associations. Associations may, or may not, bring together closely related soils.

A total of 14 upland and 4 bottomland associations are recognized in the Area. Of these, the D2-, D3-, E6- and H2-associations are different from those established by van der Eyk et al. (1969). The E5-association, which includes soils with ferruginous hardpans, was mapped throughout the Area including the high rainfall areas. This association does not, therefore, differentiate between highly and partially leached soils. Although highly leached soils with hard plinthite are not common they do occur in the Karkloof area.

(v) Soil series

The soil series is "a collection of soil individuals essentially uniform in differentiating characteristics and arrangement of genetic horizons" (Soil Survey Staff, 1960). They form the lowest and most important category of the classification. Each series has a limited range of properties and a homogeneity that permits effective advisory services and well-planned research. A clear and concise explanation of the soil series is given by van der Eyk et al. (1969).

The complex nature of soil forming factors within the Area is reflected in the large number of upland (56) and bottomland (8) series that were recognized during the survey. A total of 15, 32 and 9 upland series occur in landscape groups I, II and III respectively. Approximately half the total number of series are of common occurrence. Ten of the series had not previously been encountered in the Tugela Basin (van der Eyk, 1965b).

Phases of series were recognized to facilitate greater accuracy in the prediction of soil behaviour and management. For example, humic phase soils were recognized since they are associated with specific problems and require special treatment. Mapping this phase was thus considered justified.

(vi) Miscellaneous land types

In addition to the categories already listed several miscellaneous land types were mapped. Aerial photography proved extremely useful for this purpose. A more detailed investigation of the land types could not be justified on account of their generally low agricultural potential. Hilly, steep and/or stony land (M) is the most important and widespread land type occurring throughout the Area. Satisfactory series identification within this land type is often made difficult by the presence of much colluviated material and poor profile development. Palatability and carrying capacity of the natural sward varies considerably within this type.

Very shallow or litholic soils (R) and the indigenous Podocarpus forests (MF) were also regarded as miscellaneous land types and mapped accordingly. A permanent record of the location and extent of the indigenous forest areas was also considered most desirable since they face extinction unless specially protected (Scotney, 1964).

Table 2 summarizes the classification and inventory of soils in Howick Extension Area. It includes a complete list of the soil series and associations, and indicates the main differentiating criteria and the relevant soil forms. Where series names have become redundant, the operative names in capitals are shown immediately below.

3) The need for refinement

The need to refine existing soils data to permit greater accuracy in the prediction of soil behaviour was stressed by Riecken (1962). Thus, the list of series should not be regarded as final. Further subdivision or grouping will be necessary as information is gained through experience. Several examples are given to illustrate the need for refinement.

Yellow-over-red and red highly leached soils often lose their

Table 2 : Physiographic classification of soils in the Howick Extension Area and guide to the main soil forms

Major soil group	Soil association (Mapping unit)	Soil form	Soil series		Differentiating characteristics
I. Landscapes characterized by highly leached soils (S-value of B-horizon less than 1.5 meq/100g)					
(1) UPLAND SOILS					
A Red, highly leached soils. Colour of apedal upper B-horizon of hues 5 YR, 2.5 YR or 10 R.	A1 Balmoral-Farningham Clayey soils Texture of B-horizon: Clay content > 35% Sand " < 50%	HUTTON	A1-1	BALMORAL	Clay content of upper B-horizon > 55%. Immediate subsoil colour usually hue of 2.5 YR. C-horizon of weathered dolerite.
			A1-2	Tabamhlope (FARNINGHAM)	Clay content of upper B-horizon 35-55%. Upper profile mostly drift material resulting in A1-horizon colour of hues 10 YR or 7.5 YR. C-horizon of weathered dolerite.
			A1-3	FARNINGHAM	Clay content of upper B-horizon 35-55%. Frequently overlies weathered shale with red colours less intense.
	A2 Broadmoor-Hutton Loamy soils Texture of B-horizon: Clay content 15-35% Sand " > 50%	HUTTON	A2-1	Broadmoor (HUTTON)	Upper profile mostly of drift material with C-horizon of weathered dolerite.
			A2-2	HUTTON	Red colours usually less intense when overlying weathered sandstone
B Yellowish-brown, highly leached soils. Colour of yellow apedal upper B-horizon mostly of hues 10 YR with values of 4 or more and chromas of 6 or more or 10 YR 4/4, or hues of 7.5 YR with values of 5 or more and chromas of 6 or more or 7.5 YR 4/4.	B1 Farmhill-Griffin-Clovelly Clayey soils Texture of B-horizon: Clay content > 35% Sand " < 50%	GRIFFIN	B1-1	FARMHILL	Clay content of yellow apedal B-horizon > 55%. C-horizon mostly weathered dolerite.
			B1-2	Helpmekaar (GRIFFIN)	Clay content of yellow apedal B-horizon 35-55%. C-horizon mostly weathered dolerite.
			B1-3	Lidgetton (FARMHILL)	Clay content of yellow apedal B-horizon > 55%. C-horizon mostly weathered shale.
			B1-4	GRIFFIN	Clay content of yellow apedal B-horizon 35-55%. C-horizon mostly weathered shale.
		CLOVELLY Yellow apedal B never redder than 7.5 YR. Orthic A dark brown to very dark brown.	B1-5	Cranwell (BALGOWAN)	Clay content of yellow apedal B-horizon > 55%. C-horizon of weathered shale.
			B1-6	CLOVELLY	Clay content of yellow apedal B-horizon 35-55%. C-horizon of weathered shale.
		MISPAH	B1-7	MISPAH (clayey)	Clay content of A-horizon 35-55%. S-value of lower A-horizon mostly 1.5 meq/100g. C or R of highly weathered shale.
	B2 Cleveland-Oatsdale Loamy to sandy soils Texture of B-horizon: Clay content < 35% Sand " > 50%	GRIFFIN	B2-1	CLEVELAND	Clay content of yellow apedal B-horizon 15-35%. C-horizon mostly weathered sandstone.
		CLOVELLY	B2-2	OATSDALE	Texture as for CLEVELAND. C-horizon of weathered sandstone.
		MISPAH	B2-3	MISPAH (loamy)	Clay content of A-horizon 15-35%. S-value of lower A-horizon mostly < 1.5 meq/100g. C or R of weathered sandstone.

Table 2 contd

Major soil group	Soil association (Mapping unit)	Soil form	Soil series	Differentiating characteristics
(2) <u>BOTTOMLAND SOILS</u>				
C Acid, hydromorphic soils including A-C or O-A-C strongly gleyed profiles. S-value of the G-horizon less than 15 meq/100g. Matrix colours with values 4 to 6 and chromas 0 to 1 for subsurface horizons are diagnostic.	C1 <u>Katspruit-Dell</u> Clayey to loamy soils	CHAMPAGNE O-horizon contains > 10% organic carbon 18 inches or more. pH of upper G < 7.0.	C1-1 IVANHOE	O-horizon plastic. Clay content and pH of upper G-horizon usually over 35% and less than 6.0 respectively.
			C1-2 CHAMPAGNE	O-horizon friable. Clay and sand content of upper subsoil usually < 20% and > 50% respectively. pH of G-horizon usually < 6.0.
		KATSPRUIT pH of upper G < 7.0	C1-3 KATSPRUIT	Organic carbon content of A1-horizon usually 2-5%. Clay and sand content of upper G-horizon > 35% and < 50% respectively. pH of A1- and G-horizons usually 4.5-5.5 and < 6.0 respectively. S-value and base saturation percentage of G-horizon usually < 12 meq/100g and < 75% respectively.
			C1-4 Emmaus (KATSPRUIT)	Texture similar to KATSPRUIT series but pH of G-horizon usually exceeds 6.0. S-value and base saturation of G-horizon usually > 12 meq/100g and > 75% respectively.
		FERNWOOD	C1-5 Dell (HARRIS)	Clay and sand content of G-horizon < 35% and > 50% respectively. pH of G-horizon usually < 6.0.
II. <u>Landscapes characterized by considerably to moderately leached soils</u> (S-value (B-horizon) of considerably leached soils 1.5-5.0 meq/100g) (" " " moderately " " 5.0-15.0meq/100g) (1) <u>UPLAND SOILS</u>				
D Red, considerably to moderately leached soils. Colour of upper subsoil of hues 5 YR, 2.5 YR or 10 R.	D1 <u>Vimy-Shortlands</u> Clayey soils (excluding MSINGA series) Texture of B-horizon: Clay content > 35% Sand " < 50%	HUTTON	D1-1 VIMY	Clay content and S-value of upper B-horizon > 55% and 1.5-5.0 meq/100g respectively. C-horizon mostly weathered dolerite.
			D1-2 Weston (DOVETON)	Clay content and S-value of upper B-horizon 35-55% and 1.5-5.0 meq/100g respectively. C-horizon mostly weathered dolerite.
			D1-3 DOVETON	Clay content and S-value of upper B-horizon 35-55% and 1.5-5.0 meq/100g respectively. Frequently overlies weathered shale.
			D1-4 MSINGA	Clay content and S-value of upper B-horizon 15-35% and 1.5-5.0 meq/100g respectively. Structure apedal or weak blocky.
		SHORTLANDS	D1-5 RICHMOND	Clay content and S-value of upper B-horizon > 55% and 1.5-5.0 meq/100g respectively.
			D1-6 SHORTLANDS	Clay content and S-value of upper B-horizon > 55% and > 5.0 meq/100g respectively.
			D1-7 Bellevue (GLENDALE)	Clay content and S-value of upper B-horizon 35-55% and > 5.0 meq/100g respectively.

Table 2 contd

Major soil group	Soil association (Mapping unit)	Soil form	Soil series	Differentiating characteristics
II. Landscape characterized by considerably to moderately leached soils (S-value (B-horizon) of considerably leached soils 1.5 - 5.0 meq/100g) (" " " moderately " " 5.0-15.0 meq/100g) (1) UPLAND SOILS				
D	D2 Jagersdrift Clayey to loamy soils of the alluvial terraces	HUTTON	D2-1 Jagersdrift (SHORROCKS)	Clay and sand content of B-horizon 15-35% and > 50% respectively. S-value > 5.0 meq/100g.
	D3 Loskop-Rooikop Clayey to loamy soils with ferruginous mottles and/or concretions (soft to hard plinthite)	HUTTON	D3-1 Loskop (DOVETON)	Clay, sand and silt content of upper B-horizon > 35%, < 50% and > 10% respectively. S-value 1.5-5.0 meq/100g. Soft and hard plinthite present in B-horizon.
			D3-2 Rooikop (MSINGA)	Clay, sand and silt content of upper B-horizon 15-35%, > 50% and < 10% respectively. S-value mostly 1.5-5.0 meq/100g.
E Yellowish-brown to grey-brown, considerably to moderately leached soils with soft or hard plinthite. Colours of yellow apedal B-horizons as for soil group B. Colour criteria for drainage class as follows: Well-drained soils: Values of 4 to 5 and chromas 4 to 8 in upper B-horizon most usual. Surface horizons mostly 10 YR 5/4 to 5/8 or 10 YR 6/6 to 6/8. Poorly-drained soils: Values of 4 to 6 and chromas of 1 to 2 in upper B-horizon most usual. Surface horizons mostly 10 YR 4/1 to 4/2 or 10 YR 3/1 to 3/2 Subsurface horizons frequently 10 YR 5/1 to 5/2 or 10 YR 6/2 to 6/3	E1 Bergville-Avalon-Southwold Clayey to loamy soils without ferruginous hardpans Texture of B-horizon: Clay content > 15% Sand " < 65% Silt " > 10%	AVALON Moderately well-drained soils with distinct red or dark red mottles, often with black centres, in lower B-horizon. Consistence may become firm with depth. Orthic A mostly dark grey-brown.	E1-1 NORMANDIEN	Clay content and S-value of upper B-horizon > 35% and < 1.5 meq/100g respectively.
			E1-2 BERGVILLE	Clay, sand and silt content of upper B-horizon > 35%, < 50% and > 15% respectively. S-value 1.5 to 5.0 meq/100g.
			E1-3 RUSTON	Clay, sand and silt content of upper B-horizon 15-35%, < 65% and < 15% respectively. S-value < 1.5 meq/100g.
			E1-4 AVALON	Clay, sand and silt content similar to RUSTON series but S-value 1.5-5.0 meq/100g. (See Melrose E3-1.)
		CLOVELLY Moderately well-drained soils with mottled appearance due to fragments of ferruginized shale. Gravel line of fossil concretions and pebbles often present. Friable B-horizon merges into C-horizon mostly at depth of 20 - 36 inches.	E1-5 NEWPORT	Clay content of upper B-horizon > 35%. S-value 1.5 to 5 meq/100g.
			E1-6 SOUTHWOLD	Similar to NEWPORT but clay, sand and silt content of upper B-horizon 15-35%, < 65% and > 10% respectively.
		CARTREF	E1-7 Shandon (ARROCHAR)	Clay content of P-horizon > 15%. Can be considered as a poorly drained variant of the SOUTHWOLD series. Usually 20"-36" deep.
			E1-8 ARROCHAR	Clay content of P-horizon > 15%. Depth to C-horizon mostly 10"-24". C-horizon not highly weathered.
		MISPAH A-horizon of "grey" colour.	E1-9 MISPAH (clayey)	Clay content of A1-horizon > 15%. Profile shallow (6"-12") overlying unweathered shale or sandstone.
		GEMVALE At 20"-36" profile generally becomes strong blocky and firm to very firm with clear transition. Clay skins prominent.	E1-10 Majuba (GEMVALE)	Clay content of A1-horizon > 35%. S-value mostly > 5.0 meq/100g.
			E1-11 Frere (WILLIAMSON)	Clay content of A1- and B-horizons 15-35% and mostly > 30% respectively. S-value > 5.0 meq/100g.

Table 2 contd

Major soil group	Soil association (Mapping unit)	Soil form	Soil series	Differentiating characteristics
II. Landscape characterized by considerably to moderately leached soils (S-value (B-horizon) of considerably leached soils 1.5 - 5.0 meq/100g; " " " moderately " " 5.0-15.0 meq/100g) (1) UPLAND SOILS				
E 'Perched gley' horizons have typical grey colours: 1) Where hue is 10 YR, value is 4 or more and chroma 1 to 2, or value 5 or more and chroma 3, or value 6 or more and chroma 4. 2) Where hue is 7.5 YR, value is 4 or more and chroma 0, or value 5 or more and chroma 2, or value 6 or more and chroma 4.	E2 Avalon-Glencoe-Klipfontein Clayey to loamy soils with and without ferruginous hardpans	This mapping unit applies where complex soil patterns prevent the mapping of individual soil associations at a scale of 1:50,000.		
	E3 Leksand-Springfield Sandy soils without ferruginous hardpans. Large Fe/Mn concretions may be common. Texture of B-horizon: Clay content < 15% Sand " > 65% Silt " < 10%	AVALON	E3-1 Melrose (AVALON)	Clay content of yellow B-horizon 20-35% but sand and silt content < 15% and > 65% respectively (see AVALON series). S-value 1.5-5.0 meq/100g.
			E3-2 LEKSAND	Clay content of yellow B-horizon < 15%. Sand and silt content > 65% and < 5% respectively. Dominant grade of sand medium.
		CLOVELLY	E3-3 SPRINGFIELD	Clay, sand and silt content of upper B-horizon < 15%, > 65% and < 10% respectively. Dominant grade of sand medium.
		LONGLANDS Sandy, poorly drained soils. Depth to C-horizon mostly 30"-50". Non-calcareous.	E3-4 LONGLANDS	Clay, sand and silt content of P-horizon < 15%, > 75% and < 10% respectively. Dominant grade of sand medium.
		MISPAH	E3-5 MISPAH (sandy)	Clay content of Al-horizon < 15%. Profile shallow (6"-12") overlying unweathered sandstone.
	E5 Glencoe-Klipfontein Loamy to sandy soils with ferruginous hardpans (contemporary and fossil)	GLENCOE Hard plinthic B-horizon should be third in vertical sequence and is contemporary. Moderately well-drained soils mostly 20"-30" deep.	E5-1 GLENCOE	Clay content and S-value of yellow B-horizon 15-35% and 1.5-5.0 meq/100g respectively.
			E5-2 WESSELSNEK	Clay, sand and silt content of yellow B-horizon < 15%, > 75% and < 10% respectively. Dominant grade of sand is coarse. (Occurrence of DUNBAR and DRIEPAN series rare.)
		WASBANK Poorly drained non-calcareous soils.	E5-3 WARRICK	Clay content of P-horizon 15-35%. Dominant grade of sand medium.
			E5-4 WASBANK	Clay, sand and silt content of P-horizon < 15%, > 75% and < 10% respectively.
		MISPAH Shallow (6"-15") poorly drained soils on iron hardpan.	E5-5 MISPAH (clayey)	Clay content of Al-horizon > 15%.
			E5-6 KLIPFONTEIN (sandy)	Clay content of Al-horizon < 15%.
	E6 Winterton-Albany Clayey to loamy poorly drained soils as evidenced by grey colours and strong hydromorphic sesquioxide segregation.	LONGLANDS	E6-1 WINTERTON	Clay and silt content of P-horizon > 35% and > 10% respectively.
			E6-2 ALBANY	Clay, sand and silt content of P-horizon 15-35% < 65% and>10% respectively.

Table 2 contd

Major soil group	Soil association (Mapping unit)	Soil form	Soil series	Differentiating characteristics
II. Landscape characterized by considerably to moderately leached soils (S-value (B-horizon) of considerably leached soils 1.5 - 5.0 meq/100g) (" " " moderately " " 5.0-15.0 meq/100g) (2) BOTTOMLAND SOILS				
H^1 Neutral to alkaline hydromorphic soils. Total extractable bases of G mostly > 15 meq/100g	H1 Emmaus-Killarney-Matiwane Clayey, very poorly drained soils occurring in nearly level, clearly defined bottomlands.	KATSPRUIT pH of upper G > 7.0	H1-1 KILLARNEY	pH value in A1- and upper G-horizon > 6.0 and 7.0-8.0 respectively. S-value " " " " " " > 15 meq/100g. Non-calcareous.
			H1-2 Emmaus (alkaline variant) (KILLARNEY)	pH value in A1- and upper G-horizon < 6.0 and > 7.0 respectively. S-value " " " " " " < 15 meq/100g and > 15 meq/100g respectively.
			H1-3 Matiwane (KILLARNEY)	pH value of G-horizon > 8.0. Calcareous.
III. Landscapes characterized by moderately to slightly leached soils (S-value (B-horizon) of moderately leached soils 5.0-15.0 meq/100g) (" " " slightly " " 10.0-30.0 meq/100g) (1) UPLAND SOILS				
F Grey-brown moderately to slightly leached "duplex" or claypan soils. A1-horizon never darker than 10 YR 3/2 - 4/1. Colour of prismatic textural B-horizon darkened by clayskins and is usually 10 YR 3/1 - 3/2 or 10 YR 2/1 - 2/2.	F1 Estcourt-Bluebank Loamy soils with claypans. B-horizon has at least moderately developed prismatic or columnar structure and usually an absolute clay increase of at least 10 per cent over A1- or P-horizon. Transition to prismatic textural B-horizon abrupt. Depth to claypan usually less than 20 inches.	ESTCOURT P-horizon may be discontinuous. S-value and pH of A1-horizon mostly 1-5 meq/100g and 4.9-6.7 respectively. B-horizon values mostly 4-16 meq/100g and 5.7-7.6 or more respectively. Lime concretions may, or may not, be present.	F1-1 ESTCOURT	Clay content of A1- and B-horizon usually > 15% and > 30% respectively. Dominant colour of G-horizon olive-brown (2.5 Y 4/2 - 5/2) with no distinct red mottles.
			F1-2 Bluebank (AVOCA) (Operative AVOCA series belongs to Kroonstad form.)	Clay content of A1-horizon > 15%. Dominant colour of G-horizon usually 10 YR 4/1 - 5/1 with distinct red mottling. A1-horizon usually > 20" deep.
G Black, slightly leached margalitic soils including soils with vertic and melanic topsoil horizons. A1-horizon colours mostly 10 YR 2/1 - 2/2.	G2 Arcadia-Pepworth-Ladysmith Clayey, slightly leached margalitically, darkened soils. Clay content of A1-horizon usually > 40% with a predominance of montmorillinite.	ARCADIA	G2-1 RYDALVALE	S-value and percentage base saturation of A1-horizon > 20 meq/100g and 80-95% respectively. Depth to C-horizon (weathering dolerite) usually 10"-20". Non-calcareous.
			G2-2 ARCADIA (Includes redundant Pepworth series on unweathered shale or sandstone.)	Similar to RYDALVALE series but S-value and pH of A1-horizon 25 meq/100g and > 7.0 respectively. Calcareous.
		KIORA	G2-3 UMLAAS	Clay content of A1-horizon > 35%. B-horizon non-calcareous.
			G2-4 KIORA	Clay content of A1-horizon 15-35%. B-horizon non-calcareous.
		RENSBURG A1-horizon has strong blocky structure, self-mulching properties and slickensides. G-horizon is gleyed, calcareous pedisediment.	G2-5 RENSBURG	Clay content of A1-horizon usually > 50%. A1-horizon 20"-36" deep and upper G-horizon calcareous.
			G2-6 PHOENIX	Similar to RENSBURG series but upper G-horizon non-calcareous.
			G2-7 Ladysmith (ESTCOURT) (Ladysmith species belongs to ESTCOURT form, but occurs with margalitic soils.)	Clay content of A1-horizon 30-45%. Colour of A1-horizon mostly 10 YR 2/1, 2/2 or 3/2. Self-mulching not evident and morphology similar to ESTCOURT series. A soft surface covering or 'crust' often present but may be discontinuous.

Table 2 contd

Major soil group	Soil association (Mapping unit)	Soil form	Soil series	Differentiating characteristics
III. Landscapes characterized by moderately to slightly leached soils (S-value (B-horizon) of moderately leached soils 5.0-15.0 meq/100g) (" " " slightly " " 10.0-30.0 meq/100g) (2) <u>BOTTOMLAND SOILS</u>				
H[11] Neutral to alkaline margalitic and duplex or claypan soils.	H2 <u>Rensburg-Ladysmith-Estcourt</u> Clayey and loamy moderately deep somewhat poorly drained margalitic and claypan soils. Bottomlands often not clearly defined but merge gradually into uplands.	These bottomlands consist of the Estcourt-Rensburg-Ladysmith soil series in complex soil patterns.		
IV. <u>Soils common to all landscapes</u>				
L Young bottomland soils in recent river alluvium. Matrix colours with values 3 or more and chromas 2 or more for sub-surface horizons diagnostic.	L1 Clayey, loamy and sandy soils characterized by the considerable variability in texture, depth, and drainage.	DUNDEE With improved drainage conditions matrix colours become distinctly browner.	L1-1 Clayey alluvium	Clayey (> 35%) to a depth of at least 36". Sand and silt content between 15 and 50% and 15 and 35% respectively. Somewhat poorly drained.
			L1-2 Loamy alluvium	Loamy to a depth of at least 36". Clay and sand content less than 35% and 65% respectively. Moderately well-drained to well-drained.
			L1-3 Sandy alluvium	Sandy to a depth of at least 36". Sand content exceeds 65% and as a rule there is < 15% clay. Well to somewhat excessively drained.

NOTE:
1) Tabamhlope, Broadmoor, CHAMPAGNE and Dell series are not widespread.
2) Soil forms which may also occur in the area include the KRANSKOP form (KIPIPIRI, KRANSKOP and LIDGETTON series), MAGWA form (MILFORD, MAGWA and FRAZER series), INANDA form and the WILLEMSDAL form (CRANWELL series).
3) Humic phase soils of the B1-association soils are recognized and mapped separately. The organic carbon content of the topsoil exceeds 5% but since the depth of the humic horizon does not exceed 18" these soils do not qualify for the KRANSKOP or MAGWA forms.
4) NORMANDIEN and RUSTON series may occur in this landscape but are rare.
5) Weston and MSINGA series uncommon. Rare occurrence of calcareous FERRY and SUNVALLEY series likely within the Thornveld.
6) Majuba and Frere series placed in GEMVALE form due to cutanic B-horizon. There is also close relation to NEWPORT and SOUTHWOLD series of the CLOVELLY form.
7) Rare occurrence of Kroonstad form possible.
8) See E6-association for soils of E1-association mapped separately.
9) WINTERTON and ALBANY series normally in E1-association but are mapped in a separate association (6) of poorly drained gray-brown soils in the Lions River district.
10) Natric soils and soils of F2-association (sandy soils with claypans) not recorded in area.
11) UMLAAS and KIORA series are not widespread in the area.
12) Soil series are not defined for L1-association. Three categories are recognized to meet practical objectives.

intense red colours under very moist conditions. This occurs especially where they are located on level terrain or in a lower slope position. Dark brown colours of 10 YR 4/3 or 7.5 YR 4/2 tend to predominate and despite the moist conditions mottling is absent. For the time being these soils are deemed 'yellow-brown' although they are not necessarily associated with shale. It may be possible at a later stage to recognize these soils as a separate series. Similarly, separation of the yellow-over-red soils on a colour basis may be justified. In this case, soils with intense red colours in the B-horizon (2.5 YR or redder) are distinguished from those with paler colours (not redder than hues of 5 YR). At the present time such refinements cannot be justified in terms of land use.

Gleying has been observed at depths greater than 4 feet in some typical upland soils of the Midlands Mistbelt. Although no apparent influence on crop growth or other morphological properties results from this condition, the growth of deep rooted plants such as trees might be affected. These soils are not extensive. An extremely acid, clayey soil, tentatively named the Braco series, was located near the Yarrow river in the Karkloof area. Despite the level terrain and wet conditions there were no indications of hydromorphic influence. In the absence of more critical data this soil was mapped as the BALGOWAN series.

Yellow-brown and yellow-over-red soils analogous to the BALGOWAN and FARMHILL series occur in certain slightly dry areas adjacent to the Midlands Mistbelt proper. Analytical data proved these soils to be 'considerably' and not 'highly' leached. Although they are typical of the B1-association soils, they were mapped as E1-association soils. In this instance further refinement may well be justified since the writer has observed similar soils elsewhere in Natal. Furthermore, in these slightly drier areas soils with soft plinthic B-horizons are sometimes observed which do not indicate the maximum degree of hydromorphism normally associated with soils of the AVALON form. Though mottled, they generally lack the overall grey matrix colours and may later require re-classification.

Soils of the ARROCHAR and MISPAH series cover a wide range of texture above the 15 percent clay limit. Marked textural differences occur especially between soils in the vicinity of Mooi River and those in the Merrivale valley. The reason for this is probably the textural differences between the parent shales. In such cases further refinement may be justified since erosion hazard and many important management practices are strongly influenced by texture. It would also be desirable to study in detail the topsoil characteristics of soils currently grouped as 'Orthic -Al' soils since they differ widely in base status, carbon content, texture and colour.

1.4 Description and properties of the soils

No attempt is made to present detailed definition, description and analytical data of each soil series since much relevant information is already published or is readily available (MacVicar, Loxton & van der Eyk, 1965; Ludorf & Scotney, 1965; van der Eyk, 1965c; van der Eyk et al., 1969). Additional information is to be found in a number of reports and theses (Channon, 1962; de Villiers, 1962; MacVicar, 1962; le Roux, 1964, 1966; Roberts, 1964; Skeen, 1964; van der Bank, 1964; van Rooyen, 1964; Verster, 1964; van Reeuwijk, 1967). Furthermore, le Roux and Scotney (1970) compiled a key to the soils of Natal based on the major reference work by van der Eyk et al. (1969), which is intended to aid the identification of soils in the field.

Important properties of each soil series can also be gleaned from Table 2 and the information presented in Chapter 3. However, in this section several features are discussed in very general terms and a short account is given of the forest soils which, to date, have received little attention.

1) Soils common to the Area

The extent to which the main landscape groups may be characterized in terms of chemical soil properties is reflected in Table 3. The analytical data for numerous modal profiles were used for this purpose.

Table 3 : Mean values of selected chemical criteria for soils in the Howick Extension Area

Landscape group	I	II	III
Degree of leaching	High	Considerable - moderate	Moderate - slight
Total extractable bases (me%)			
A-horizon	2.6	5.1	19.1
B-horizon	1.3	4.4	21.7
Base saturation (%)			
A-horizon	15.9	57.5	81.7
B-horizon	10.6	57.5	83.0
pH (topsoil)	5.2	5.6	6.3
Organic carbon content (%)			
Topsoil	3.9	2.0	1.8

The marked reduction in total bases from the A- to B-horizons and the low base status of the latter are particularly noteworthy among the highly leached soils. This difference is not as great in the partially leached group. It is interesting to note that in landscape group II the total bases and base saturation values for topsoils of D1-association soils are 7.3 me% and 64.6% respectively whereas, for E1-association soils, the values are 3.6 me% and 52.7% respectively. In contrast, the mean topsoil value for total bases among margalitic soils in landscape group III is 24.3 me%. Table 3 also shows that the highly leached soils have a higher content of organic carbon than the partially leached soils. Mean values are higher in the Highland Sourveld than in the Midlands Mistbelt and, in landscape group II, the mean content of organic carbon is higher in the D1-association soils (2.3%) than in the E1-association soils (1.5%). Very low values of approximately 0.5 percent characterize the sandy E3-association soils while values of the F1- and G2-association soils rarely exceed 1 percent and 2 percent respectively.

The different nature of problems associated with highly and partially leached soils is important for practical reasons. In the former group, problems are generally related to chemical characteristics while among the partially leached soils, physical properties are more important. Properties such as effective depth, moisture characteristics, drainage and erosion hazard often render the latter soils unsuitable for intensive arable use. This major difference between the groups will be stressed many times in the following chapters.

Certain physical properties of practical significance, though seldom noted in series definitions, are important among many E1- and F1-association soils. These soils, especially the AVALON, SOUTHWOLD, ARROCHAR and ESTCOURT series, exhibit 'cloddiness' and a tendency to 'puddle' when wet. When rain follows cultivation, they also tend to pack and form a thin, hard, surface crust which favours run-off and surface erosion, and may jeopardize the successful establishment of small-seeded crop and pasture species. Such features increase the need for timeous soil preparation and special tillage operations. Although the same need applies to margalitic soils, the nature and cause of the problem are very different.

Stonelines or carpedoliths, evidence of lithological discontinuity (de Villiers, 1962), are widespread throughout the Area. For example, rubble horizons consisting of fossil Fe/Mn concretions, quartz pebbles and fragments of ferruginized shale, hard plinthite and petrified wood are frequently observed in profiles, especially in the vicinity of Mooi River. Fragments of petrified wood have also been found near the Lions River station and on several occasions were encountered in highly leached soils. The latter supports the finding reported by MacVicar (1962). Stonelines in A1- and D1-association soils generally consist of small dolerite boulders. Many B1-association soils, especially in the Midlands Mistbelt, exhibit a thin gravelly layer consisting of fossil Fe/Mn concretions and shale fragments coated with a hard, glossy patina. This layer usually occurs between the yellow and red apedal B-horizons and also suggests lithological discontinuity. However, such evidence is not always present in the yellow-over-red soils.

Several studies of selected soils have demonstrated that many chemical and physical soil properties are directly related to predominant clay minerals (le Roux, 1964; Roberts, 1964; Skeen, 1964, 1967; van Rooyen, 1964; Verster, 1964; van Reeuwijk, 1967). For this reason, clay mineralogical analyses were made for each of the main soil series and the information used as covariant criteria for establishing the main degrees of leaching. An indication of the chief clay minerals of each soil series is given in existing series definitions (MacVicar, 1962; de Villiers, 1962; Ludorf & Scotney, 1965; van der Eyk, 1965c).

Soil fauna and flora are active factors in soil formation. Conversely, soil characteristics may influence the growth and movement of epigeic animals and organisms (Kevan, 1955; Murphy, 1962). This field of study in relation to soils of the Area has, however, received very little attention although de Villiers (1962) noted that faunal pedoturbation by the snouted termite, Trinervitermes, may result in carpedoliths being formed below the level of lithological discontinuity. Termite activity is particularly noticeable in the drier landscapes where mounds are common on the shallow and droughty E1- and F1-association soils. A wide range of soil fauna and flora occurs among the highly leached soils where the biosphere contributes much to the accumulation and breakdown of organic matter. Moles and other rodents are plentiful, especially in virgin soils, and crotovinas are frequently observed in freshly dug profile pits. Edwards (1969) observed that where no lime or nitrogenous fertilizer is applied the mole, Cryptomys hottentotus, is particularly active. In many highly leached soils, especially in the yellow-over-red members, an abundance of small round holes is frequently observed in the B-horizon. Despite numerous inspections of freshly exposed profiles during the survey the casual organisms were never encountered. These holes undoubtedly enhance the overall drainage conditions in the soils.

2) Forest soils

The Podocarpus forests occupy 4.7 percent of landscape group I. They predominate on steep, south-eastern slopes and experience a mean annual rainfall of at least 1,000 mm (± 40 inches). The soils on these boulder-strewn slopes are of very mixed origin and vary considerably in texture and depth. Outcrops of dolerite are common and are generally associated with dark, reddish-brown and yellow-brown soils (5 YR 3/4 - 4/6) of clayey texture and strong blocky structure. Structural development is atypical among highly leached soils but, according to Joffe (1949), is characteristic of forest soils. Outcrops of Ecca and Beaufort sandstone are also common within the forest areas.

Preliminary investigations during the reconnaissance survey indicated that the soils of the forests were very different from those of the adjacent grasslands, especially with regard to degree of leaching. For this reason, the writer collected B-horizon samples from paired sites; one within the forest, the other from the adjacent grassland. The sites were never separated by more than 200 metres. The grassland sites were mostly situated within the forest margin typified by tall grasses such as _Hyparrhenia spp._, _Miscanthidium capense_ and _Cymbopogon spp._ The analytical data for the samples are presented in Table 4 and profile data are given for the Kipipiri sites.

In all instances the forest soils reflect a lower degree of leaching. The grassland sample of site 5 was situated in a hayfield of long standing which probably accounts for the very low base status. It is also reasonable to surmize that, because the grassland sites were probably themselves at one time under climax forest, vegetation can influence soil forming processes over a relatively short period of time.

Joffe (1949) cited several studies that illustrate the effect of forests on precipitation, soil moisture content and ground waters, all of which are related to the leaching process. For instance, it was revealed that up to 25 percent of the rainfall may be intercepted by the forest canopy although Daubenmire (1948) suggested that the canopy might

Table 4 : Analytical data for soils of the Podocarpus forests and adjacent grasslands in the Howick Extension Area

Site	Total bases (me%)	Exchange capacity (me%)	Base saturation (%)
1) Kipipiri			
F 0-10"	11.28	23.70	77
10-31"	11.06	16.20	68
31-50"	8.05	11.30	71
G 0-9"	2.44	17.00	14
9-21"	0.58	7.05	8
21-39"	0.64	2.35	27
2) Maritzdaal			
F	28.42	38.12	75
G	6.47	12.45	52
3) Newstead			
F	15.74	31.52	50
G	0.77	5.43	14
4) Karkloof			
F	8.84	20.85	42
G	4.69	15.01	31
5) The Start			
F	5.29	20.89	25
G	0.37	11.64	2
6) Fort Nottingham			
F	4.97	11.24	44
G	4.21	16.16	26

F - forest
G - adjacent grassland

prevent as much as one third of the precipitation from reaching the soil. High transpiration losses tend to offset the gains accruing to low surface evaporation within the forest. Absorption by the forest litter may also account for considerable quantities of water. Ground water tables are generally lowest within areas of forest. Augering in a forest or exotic plantation inevitably reveals a state of dryness in the soil profile. The moisture status is thus considerably influenced by the presence of trees. Since the leaching process is retarded the soils are inherently more fertile than those of the surrounding areas. This is probably one reason why many of the forest areas were clearfelled by early settlers and Bantu for the production of crops.

1.5 Distribution of soils in the Area

The pattern of distribution and extent of soils in the Area was determined planimetrically using the 1:50,000 soil maps. Each soil unit, over 2,500 in all, was measured at least three times to obtain a reliable reading. The hilly steep and/or stony land (M) was determined by subtraction from the total area.

For the purpose of expressing the distribution of selected categories of the classification in the Lions River district, boundaries of each individual degree of leaching were established. Soil criteria, together with a knowledge of the climate and vegetation, were used to determine these boundaries. Where necessary B-horizon samples were collected and analyzed and the degree of leaching accurately determined. The boundary between highly leached and considerably leached soils near Lions River was determined in this manner. These boundaries are shown on Map 4 (Chapter 4).

1) Distribution of soils and miscellaneous land types within landscape groups

The distribution of soils within the main landscape groups, expressed as a percentage of the Area as a whole, is indicated in Table 5. The distribution of uplands, bottomlands and non-arable classes is also shown. It will be noted that the Lions River and Mooi River Valley districts are treated separately. Greater detail is presented for the former district where the distribution of the various categories in the Highland Sourveld and Midlands Mistbelt is indicated.

Table 5 reflects a predominance of highly leached soils (72.5%) and a relatively high proportion (54.5%) of land unsuitable for regular arable use. The large area of hilly, steep and/or stony land and the small percentage of bottomlands within the Midlands Mistbelt bears witness to the broken topography. The high (20.8%) proportion of bottomlands in the dry, lower reaches of the Mooi River Valley district is significant since the soils of these bottomlands are noted for their

Table 5 : Distribution of soils and miscellaneous land types within the main landscape groups in the Howick Extension Area

Landscape group	Total % of Area	Miscellaneous land types (%)			
		Uplands	Bottom-lands	M + MF	MF
Lions River district					
Group I					
1) Highland Sourveld	38.1	32.7	8.4	59.9	2.1
2) Midlands Mistbelt	34.4	32.2	4.4	63.4	7.6
Total	72.5	32.6	6.5	60.9	4.7
Group II					
1) Considerably leached	8.5	47.5	8.7	43.8	-
2) Moderately leached	4.5	49.5	7.0*	44.4	-
Group III	0.3	-	3.6	96.4	-
Mooi River Valley district					
Group II	6.4	55.3	11.8	32.9	-
Group III	7.8	28.0	20.8	51.2	-
Total for Area	100.0	37.0	8.5	54.5	-

* excluding area flooded by Midmar dam
MF indigenous forest
M hilly, steep and/or stony land

very high erosion hazard (Table 10). Approximately 75 percent of the indigenous forests (MF) occur in the Midlands Mistbelt.

2) Distribution of soil associations

Distribution of the soil associations is expressed as a percentage of the total area of uplands and bottomlands for selected landscape groups. Highly and partially leached soils are treated individually. The distribution of upland and bottomland soil associations in landscape group I is presented in Table 6 which also shows the distribution of lithosolic soils (R). Data for the Highland Sourveld and Midlands Mistbelt are presented separately.

The most striking feature of Table 6 is the complete dominance of B1-association soils. Apart from the A1-association soils, which occupy approximately 20 percent of the uplands, all other upland associations are

Table 6 : Distribution of upland and bottomland soil associations in landscapes characterized by highly leached soils (Group I)

Landscape group	Soil associations (%)							
	Uplands						Bottom-lands	
Group 1	A1	A2	B1	B2	E5	R	C1	L1
1) Highland Sourveld	19.7	1.0	65.2	3.6	-	0.5	89.0	11.0
2) Midlands Mistbelt	23.5	-	75.6	0.5	0.2	0.2	57.2	42.8

relatively unimportant. The occurrence of the loamy A2- and B2-association soils in the Highland Sourveld is due to the presence of the Beaufort and Stormberg sediments. The small area of B2-association soils in the Midlands Mistbelt occurs above the scarp of the Umgeni gorge and is associated with Middle Ecca sandstone. The predominance of the acid hydromorphic 'vlei' soils (C1-association) within the Highland Sourveld is particularly noteworthy. As would be expected the extent of river alluvium increases at lower elevations.

Table 7 shows the distribution of upland soil associations within landscape groups II and III. The Lions River and Mooi River Valley districts are again treated separately.

Table 7 : Distribution of upland soil associations in landscapes characterized by partially leached soils (Groups II and III)

Landscape group	Upland soil associations (%)						
	D1	D3	E1	E5	E6	F1	G2
Lions River district							
Group II 1) Considerably leached	23	42	33	2	-	-	-
2) Moderately leached	23	11	52	3	11	-	-
Mooi River Valley district							
Group II	7	-	76	16	1	-	-
Group III	10	5	9	19	-	52	5

In all but the driest parts of these landscapes the E1-association soils are the most widespread. However, in the Thornveld area of the Mooi River Valley district it is significant that highly erodible claypan soils (F1-association) occupy over 50 percent of the uplands excluding the hilly, steep and stony land. Although not indicated in Table 7, the H2-association, comprising the RENSBURG, ESTCOURT and Ladysmith series, occupies 87 percent of the bottomlands. In fact, this association occupies 18 percent of the total area of Thornveld. In the moister landscapes the H1-association occupies approximately 60 percent of the total area of bottomlands. The remainder comprises river alluvium (L1-association).

3) Distribution of soil phases

Distribution of the soil phases is expressed as a percentage of the total upland area of individual soil associations. Table 8 reflects the distribution of the slope phase in the Lions River district. This phase includes all upland soils with a slope in excess of 8 percent but excludes all hilly, steep and stony land (M).

Table 8 : Distribution of the slope phase (exceeding 8%) in the Lions River district

Landscape group	Slope phase (%)			
	Uplands	Soil associations		
Group I		A1	B1	
1) Highland Sourveld	47	66	47	
2) Midlands Mistbelt	53	53	51	
Group II		D1	D3	E1
1) Considerably leached	29	32	1	49
2) Moderately leached	4	10	-	2

Table 8 shows that approximately 50 percent of highly leached soils occur on slopes exceeding 8 percent. The relatively high percentage of the slope phase among the A1-association soils is attributed to the hilly outcrops of dolerite.

Humic phase soils are confined to landscape group I and especially to the Highland Sourveld where climate and topography are conducive to organic matter accumulation. The distribution of this phase in the Lions River district is shown in Table 9.

Table 9 : Distribution of humic phase soils in the Lions River district

Landscape group	Humic phase (%)				
	Uplands	Soil associations			
Group I Highly leached soils		A1	A2	B1	B2
1) Highland Sourveld	15.8	3.4	-	17.9	-
2) Midlands Mistbelt	0.3	-	-	0.4	-

The humic phase is most often associated with the B1-association soils, especially the GRIFFIN and CLOVELLY series where these occur in a lower slope position or in local depressions. Here there is a tendency for organic materials to accumulate by wash from the surrounding uplands.

Table 10 shows the distribution of the eroded phase in the Mooi River Valley district. Gully erosion is confined mainly to the bottomlands.

Table 10 : Distribution of the eroded phase soils in the Mooi River Valley district

Landscape group	Eroded phase (%)						
	Uplands				Bottomlands*		
	Total	Soil associations			Total	Soil associations	
						H2	
		D1	E1+E2	F1		sheet	gully
Group II	18.8	-	24.0	-	-	-	-
Group III	38.0	12.7	27.8	52.8	92.5	3.1	89.4

* excluding river alluvium

In landscape group II erosion is confined almost entirely to the grey-brown soils and soils with ferruginous hardpans. Table 10 also reflects the seriousness of the erosion problem in the drier parts, where approximately 38 and 93 percent of the uplands and bottomlands respectively are severely eroded. Furthermore, it shows that erosion is particularly widespread among the claypan soils (F1-association) which occupy over 50 percent of the uplands (Table 7). The need for stringent conservation and reclamation measures in this landscape group is thus obvious. Reclamation is a special need in the bottomlands where severe gully erosion has destroyed all but a small percentage of this important class of land. It may be inferred from Table 10 that the D1-association soils are relatively stable in comparison with other upland soils.

Determining the distribution of soils permitted the average size of individual mapping units to be calculated. The average size of the Area as a whole was 146 acres. In the Midlands Mistbelt the size is 113 acres which indicates the broken nature of the terrain. Furthermore, the average size of units comprising A1-association soils is smaller than that for the B1-association soils and is probably the result of the many isolated intrusions of dolerite. The average size of individual forest areas is considerably larger in the Midlands Mistbelt (142 acres) than in the Highland Sourveld (53 acres). On the other hand, the average size of 'vlei' areas (C1-association) is greatest in the Highland Sourveld (120 acres).

CHAPTER 2

AN INVESTIGATION OF SOME SOIL PROPERTIES RELATED TO LAND USE

The information gained from the soil survey provides a logical basis for selecting and planning the soil studies. Since over 70 percent of the Area comprises highly leached soils associated with inherent fertility problems, further study in this field is easily motivated. Furthermore, there are a number of important physical limitations associated with the partially leached soils that affect farming practice. Although many of these deserve intensive study, those relating to soil moisture are of particular interest. This chapter deals with investigations of both chemical and physical soil properties. The prime objective of these studies is to characterize the soils in terms of selected parameters and to provide information for their overall assessment.

2.1 Studies of ionic equilibria in selected soils

Ionic equilibria are basic to fertility problems since they govern the ability of a soil to supply a particular nutrient. The so-called 'supplying power' of a soil is determined by both the amount of nutrient present and the energy level at which it is supplied. An adequate amount of nutrient at an available energy level throughout the season is required for satisfactory plant growth (Sumner, 1965a).

There is thus a need to classify soils in terms of their exchange properties and to direct study to adsorption equilibria for different nutrients (Schuffelen & Bolt, 1958; le Roux, 1966). It is generally accepted that, since the soil system is chemical in nature, a parameter with thermodynamic significance should be used to characterize the energy level, viz. thermodynamic potential. Thus, a given soil system can be characterized by the amount of nutrient present and its thermodynamic potential.

The prime objective of this particular study is to characterize the most important soils in terms of potassium and lime status. For this purpose several parameters are used, namely, quantity-intensity relations (Q/I), energies of exchange (ΔF), and lime potential (LP). In view of the main objective the choice of parameters is relatively unimportant. Those selected are, however, theoretically sound (Woodruff, 1955; Schofield & Taylor, 1966b; Beckett, 1964b). A component study is aimed at determining the influence of current land-use practice on the K and lime status of cultivated soils throughout the Area. In this case it is suggested that much can be learnt from the study of selected farm fields.

1) Theoretical considerations

Lengthy discussion of the theoretical concepts concerning ionic equilibria is avoided since many local workers including Sumner (1965a & b), le Roux (1966), Koch (1968), Reeve (1968) and Skeen (1968) have reviewed the literature and summarized many relevant studies. They point out that Schofield (1947), Eriksson (1952), Overbeek (1952) and Bolt (1955) have shown that the original double layer theories and early equations can be developed to provide a fundamental approach to the problems of ionic equilibria.

Schofield's Ratio Law is basic to many theoretical equations and modern concepts (Schofield, 1947). The soundness of the Law has been confirmed many times (Schofield & Taylor, 1955b; Beckett, 1964a; Tinker, 1964; le Roux, 1966) although Taylor (1958) and Skeen (1968) reported specific instances when it was not obeyed.

The parameters used in this study are based on the concept that, in a solution in equilibrium with the activity ratio (AR_e), $a_{M^+}/\sqrt{a_{M^{++}}}$, provides an estimate of the relative activity of the monovalent cation (M^+) on the solid phase. Thus, in the case of potassium (K) a measure of its potential or availability can be obtained. In most soils calcium (Ca) and magnesium (Mg) are the dominant complementary ions and, for practical purposes, they can be treated as a single ionic species (Schofield & Taylor, 1955a & b). In a study of Natal soils le Roux (1966) found that the ion pair K-(Ca+Mg) conformed to the Ratio Law and, for the reason, a similar procedure was followed in this study. It should be noted, however, that Skeen (1968) found the ion pair K-Al preferable for the study of very acid soils.

The following is a brief description of the three parameters used in this study:

Quantity-Intensity (Q/I) relations of labile potassium: A technique for measuring the relationship between the amount, or quantity (Q), of potassium and its degree of availability, or intensity (I), was developed by Beckett (1964b). It consists of equilibrating a number of samples of the same soil with a series of solutions containing variable amounts of KCl in $CaCl_2$ solutions. For each suspension, the difference between the K concentration in the initial and final solution gives the amount by which the soil gains or loses exchangeable K in reaching eqilibrium with the final solution ($\pm \Delta K$). Activity ratios for each value of K are calculated from the composition of the resulting equilibrium solutions.

At equilibrium, the activity ratio, $a_K/\sqrt{a_{Ca+Mg}}$), or AR_e^K, is a measure of the intensity of labile K in the soil. However, soils with the same AR_e^K value do not necessarily possess the same capacity for maintaining AR_e^K, or releasing K to the plant. Thus, to fully describe the K status it is necessary to know the current K potential and the way in which the potential depends on the quantity of K in the pool. A characteristic Q/I relationship is shown in Fig.1.

Fig.1 illustrates how AR^K $(\text{moles/litre})^{\frac{1}{2}}$ in the soil solution depends on the exchangeable K content of the soil represented by ΔK (meq/100g) which is the change in exchangeable K relative to the value of exchangeable K at AR_e^K. The slope of the curve, Q/I, gives the amount of K that can be removed before AR^K decreases by more than a given amount. Beckett (1964b) defined this as the Potential Buffering Capacity (PBC^K) of the soil for K. It is dependent on the amount of exchangeable (Ca+Mg)

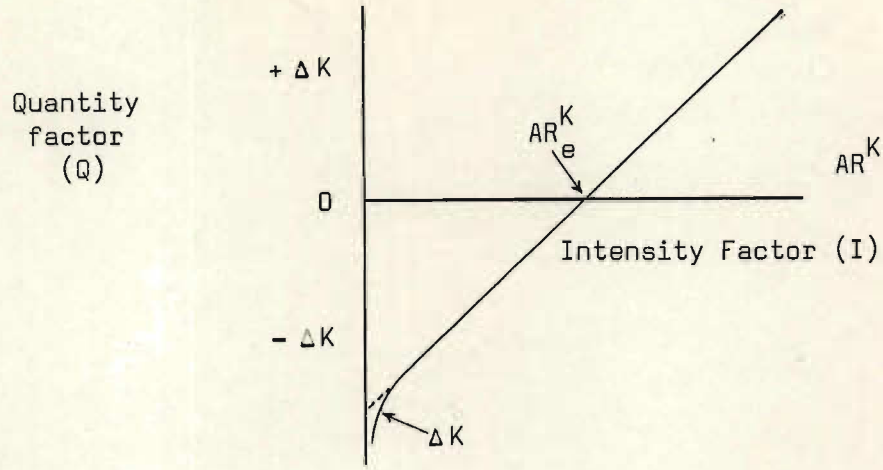


Fig. 1 : A characteristic Q/I relation

and was shown by le Roux (1966) to be a function of the type of clay mineral and its surface area, and to be highly correlated (r = 0.97***) with cation exchange capacity.

By exterpolating the linear portion to the point where $AR^K = 0$, a value of ΔK^o, or a measure of the labile pool, is obtained. The lower part which curves asymptotically to the Q axis, is indicative of the release of non-exchangeable K, or specifically adsorbed K when little K is present in the soil solution. This phenomenon helps explain why determinations of exchangeable K by extraction methods may lack precision. Although a good correlation (r = 0.94***) between $-\Delta K^o$ and exchangeable K as measured by 0.2 N NH_4Cl extraction was established by le Roux (1966), it was found that K extracted by NH_4Cl always exceeded the pool of labile K measured by the Q/I technique. In fact, the ratio obtained indicated that roughly half the exchangeable K is truly labile. Skeen (1968), who reported specific adsorption sites for K in several acid Natal soils, also found $-\Delta K^o$ to be a reliable measure of the labile pool. However, recent work[1] indicates that extraction with neutral normal NH_4OAc is as good a measure of plant available K as any of the Q/I parameters. With the Q/I technique the K status of a soil is fully described by any two of the following parameters: $-\Delta K^o$, AR^K_e, and PBC^K (meq/100g x (moles/litre)$^{\frac{1}{2}}$).

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[1] M.P.W. Farina, Dept. Agric. Technical Services, Natal Region - personal communication.

Energies of exchange: Woodruff (1955) introduced the concept of energies of exchange or replacement (ΔF). It is a measure of the intensity factor in the delivery of cations from the exchange complex of the soil to the plant. The measure, in terms of K and (Ca+Mg), is computed in calories per equivalent from the equation

$$\Delta F = RT \ln {}^{a}K/\sqrt{{}^{a}(Ca+Mg)} \qquad (1)$$

At equilibrium, ΔF represents the total energy for the transfer of one chemical equivalent of (Ca+Mg) from the standard state to the soil in return for one chemical equivalent of K from the soil. Negative values imply that the reaction between the soil and the standard state would proceed spontaneously. Determination of ΔF in this study also attempts to establish the relationship between energies of exchange and the Q/I parameters. For practical purposes the former is the more attractive because of the relatively simply procedure.

Woodruff (1955) also showed that ΔF could be used as a criterion of the balance of cations for plant nutrition and suggested that it could be universal in scope and applicable to all types of exchange materials. He established broad limits which indicate that ΔF values of between -2500 to -3000 calories per equivalent are optimum for balanced plant nutrition. Values in excess of -3500 calories are associated with calcium deficiencies and those of -2000 calories or less, are generally associated with calcium deficiencies created by excessive amounts of potassium. Koch (1968) found that the minimum value for maize grown on the Clifford series was between -3140 and -3260 calories per equivalent.

Energies of exchange are presented only for those samples included in the study relating to land-use.

Lime potential: Lime potential (LP) was originally described by Schofield and Taylor (1955b). If the relationship between hydrogen and Ca is considered, then theoretically, the activity ratio, ${}^{a}H/\sqrt{{}^{a}Ca}$, has a constant value in any solution in equilibrium with a soil containing Ca as the main exchangeable cation. Precise meaning can be given to the ratio by multiplying the numerator and denominator by the activity of any anion present, thus:

$$\frac{a_H}{\sqrt{a_{Ca}}} = \frac{a_H\ a_{Cl}}{\sqrt{a_{Ca}\ a_{Cl}}} = \frac{a_H\ a_{OH}}{\sqrt{a_{Ca}a_{OH}}} \qquad (2)$$

from which it can be seen that, since the product $a_H\ a_{OH}$ is constant, the ratio $a_H/\sqrt{a_{Ca}}$ is a direct function of the activity of $Ca(OH)_2$ in the system (Sumner, 1965c).

The ratio is generally measured in the form $a_{HCl}/\sqrt{a_{CaCl_2}}$ and, since both are electrical neutral substances, their activities may be expressed without any of the ambiguity associated with the activities of individual ions.

Equation (2) may be re-written in the form:

$$pH - \tfrac{1}{2}pCa = p(HCl) - \tfrac{1}{2}p(CaCl_2) = \tfrac{1}{2}\log a_{Ca(OH)_2} + 14.2 \qquad (3)$$

where p = negative log of the activities of the ions and molecules in the equilibrium solution and 14.2 = ionic product of water at $20^{o}C$. Equation (3) provides a measure of the chemical potential of $Ca(OH)_2$ in the system.

In an equilibrium solution composed of a mixture of Ca and Mg salts the relation between pH and the total electrolyte concentration is given by the value of $pH - \frac{1}{2}p(Ca+Mg)$ which is known as lime potential. The ratio, $a_H/\sqrt{a_{Ca+Mg}}$, in any solution in equilibrium with a soil containing Ca as the main exchangeable cation has been shown to have a constant value (Schofield & Taylor, 1955b; Nichol & Turner, 1957, 1958; Webster & Harward, 1959).

The importance of the LP parameter lies in the fact that it is independent of salt concentration and is, therefore, a more fundamental indication of lime status than pH alone (Schofield & Taylor, 1955b; Nichol & Turner, 1958, Russell, 1961). Reeve (1968) recommended that lime requirements should preferably be based on LP values since they provide a less empirical measure of the intensity of acidity than pH values. Turner and Nichol (1962b) also found a direct relationship between LP and base saturation although it was stressed that LP is not a true measure of the degree of saturation.

2) Materials and experimental procedure

Soil samples were collected in accordance with the pattern of soil distribution and were then analyzed. Representative profile pits of all the major soil series were sampled. For the study related to land use, samples were taken from selected fields using a six-inch core sampler. Paired samples of the same soil series from virgin and cultivated fields were studied. A sampling depth of six inches was considered adequate since Krantz and Chandler (1954) had shown that, in the case of maize, the bulk of the roots (43%) are located in the top six inches.

The parameters were also related to more accurate field data by sampling several maize experiments. Two of these on the Loskop series were situated at Cedara and one, on the CLOVELLY series (humic phase), at Nottingham Road. Selected treatments with different levels of K and lime were sampled.

Time of sampling is an important factor in the study of Q/I relations since $-\Delta K^{o}$ values are influenced by crop removal and K-fixation subsequent to fertilization. Skeen (1968) showed that, in certain Bl-association soils, the pool of labile K increased after prolonged equilibration. It can be inferred from this that a transfer of K from the fixed to the exchangeable phase takes place over the winter period, a phenomenon confirmed by Koch (1968). All samples included in the study were collected at the end of the growing season (April) and were air dried, gently ground and passed through a 60 mesh sieve.

A procedure, similar to that described by Matthews and Beckett (1962) and Beckett (1964b), was followed in determining the Q/I relations. Varying amounts of soil were weighed out into a series of 100 ml centrifuge tubes and 50 ml 0.002 M $CaCl_2$ solutions containing different amounts of KCl were added to the samples as indicated in Table 11.

The samples were equilibrated on an end-over-end shaker at 20 rpm for 15 hours after which they were centrifuged at 1500 rpm for three minutes. The supernatant equilibrium solutions and the original

Table 11 : Soil weights and solutions for determining Q/I relations

Tube	Weight of sample (gm)	Solution	KCl Conc. (M)	$CaCl_2$ Conc. (M)
1	7	E	0.0010	0.002
2	7	D	0.0007	0.002
3	7	C	0.0005	0.002
4	7	D	0.0002	0.002
5	4.75	A	No KCl	0.002
6	1.5	A	No KCl	0.002

solutions were analysed for Ca, Mg and K on a Beckman D.U. flame spectrophotometer.

Activity ratios were calculated from the composition of the supernatant solutions and activity coefficients determined according to the Debye-Hückel equation. Calculation of the ionic strength of the equilibrating solution did not include exchangeable sodium since le Roux (1966) had found very small amounts in many soils similar to those included in this study. The gain (+ ΔK) or loss (- ΔK) of potassium was obtained by subtracting the concentrations of the solution before and after equilibration. The Q/I relation was obtained by plotting the ΔK values for each sub-sample against the concomitant computer-calculated AR^K values.

Energies of exchange in calories per chemical equivalent at 20°C, were computed from the relation:

$$\Delta F = 1341 \log {}^{a}K/\sqrt{{}^{a}(Ca+Mg)}$$

using the data for tube 5 as shown in Table 11.

Lime potential values were determined using standard procedures (Schofield & Taylor, 1955b; Sumner, 1965c). Three separate aliquots from tubes 1, 3 and 5 of each sample were taken after equilibration, but before centrifugation, and the pH values determined on an EIL C33B pH meter. Equilibrium pH values approximate those under field conditions (le Roux, 1966). The value $\frac{1}{2}$p(Ca+Mg) was determined from the total concentration of exchangeable (Ca+Mg) given by the Q/I calculation.

3) Results and discussion

The results are discussed on the basis of the two main issues investigated viz.: (i) series characterization and (ii) the influence of land-use practice on K and lime status.

(i) Series characterization

Table 12 shows the Q/I relations and lime potential values determined for a wide range of soils and a K-supply rating of the soils studied. Typical Q/I curves for selected highly and partially leached soils are presented in Fig. 2.

Q/I relations: The reliability of the Q/I technique is substantiated by the agreement between the results of this study and those presented by le Roux (1966). Average values of the latter are included in Table 12. In most instances the PBC^K values conform to the A1- and B2-horizon standards established by le Roux. PBC^K values are generally regarded as a reliable means for characterizing soils although Koch (1968) was unable to confirm this view. As previously indicated, PBC^K is closely related to clay content and the predominant clay minerals and their exchange properties; specifically CEC and surface characteristics. Le Roux (1966) found PBC^K values for soils containing kaolin as the dominant clay to be between 5 and 15, while those predominated by montmorillinite had high values up to 96. The former clay mineral has a low CEC (1-10 me%) and small surface area (1-40 m^2/gm), the latter a high CEC (± 100 me%) and large surface area (400-800 m^2/gm). It follows from the relationship between PBC^K and clay mineral species that the parameter reflects general trends in soil formation. Thus, the lower the degree of leaching the higher the PBC^K value as indicated by Table 12 and Fig. 2. Furthermore, the mean ΔK^o values for topsoil samples of the highly and partially leached soils were 0.19 me% and 0.29 me% respectively, indicating a more favourable K status in the latter soils.

The results also confirm the soundness and usefulness of the soil classification system although, in some instances, further refinement is

Table 12 : Q/I relations and lime potential values for selected soil series in the Howick Extension Area

Soil assoc.	Soil series	Profile no.	Top soil Q/I relation ΔK^0 me%	AR^K_e	PBC^K	Top soil Lime potential	Upper subsoil Q/I relation ΔK^0 me%	AR^K_e	PBC^K	Upper subsoil Lime potential	Lower subsoil Q/I relation ΔK^0 me%	AR^K_e	PBC^K	Lower subsoil Lime potential	K-supply rating
	(a) Highly leached soils														
A1	BALMORAL	1	0.49	0.033	17	3.30	0.06	0.003	17	3.19	0.03	0.001	22	3.03	M-H
		2	0.15	0.006	24	3.35	(-0.02)	0.001	17	3.14	(-0.01)	0.001	14	3.03	
		3	0.48	0.026	19	3.75	0.00	0.000	17	3.20	(-0.01)	0.001	17	3.04	
		4	0.14	0.015	9	3.00	0.02	0.002	12	3.11	(-0.01)	0.001	13	3.20	
		5	0.08	0.006	12	2.99	0.01	0.001	11	3.21	(-0.02)	0.001	15	3.23	
		6	0.10	0.007	13	3.27	0.04	0.005	13	3.18	0.03	0.002	14	3.40	
		7	0.11	0.006	17	3.21	0.00	0.000	9	3.08	(-0.01)	0.001	10	3.16	
		8	0.08	0.003	24	3.18	(-0.02)	0.002	14	3.06	(-0.03)	0.001	19	2.98	
		Ave.	0.20	0.013	17	3.25	0.01	0.002	14	3.15	(-0.004)	0.001	15	3.13	
	After le Roux (1966)-5 profiles		0.23	0.012	19	-	0.02	0.002	13	-	(-0.02)	0.001	14	-	
	Tabamhlope	9	0.02	0.001	13	3.17	(-0.04)	0.004	11	3.07	(-0.03)	0.003	11	3.09	M
B1	FARMHILL	10	0.44	0.032	16	3.23	0.17	0.016	11	3.23	0.07	0.005	13	3.50	M
	Lidgetton	11	0.42	0.019	22	3.14	0.02	0.002	14	2.90	0.01	0.001	19	2.94	M-H
		12	0.15	0.009	17	2.84	0.04	0.002	15	2.91	0.02	0.001	10	2.83	
	GRIFFIN	13	0.10	0.015	7	2.99	0.03	0.005	6	3.07	(-0.01)	0.001	6	3.30	M-L
		14	0.16	0.024	7	3.10	0.03	0.004	10	3.38	(-0.02)	0.002	8	3.80	
	After le Roux (1966)-6 profiles		0.10	0.007	14	-	(-0.0.)	0.004	11	-	0.06	0.006	11	-	
	Cranwell	15	0.08	0.002	35	2.98	0.01	0.000	26	2.91	0.00	0.000	24	2.87	H
		16	0.08	0.005	17	2.85	0.01	0.003	19	2.89	0.05	0.003	17	2.91	
		17	0.29	0.009	31	3.07	0.06	0.003	23	2.92	0.05	0.002	25	2.98	
	CLOVELLY (humic)	18	0.24	0.19	13	3.12	(-0.02)	0.001	15	3.14	-	-	-	-	M
	(")	19	0.18	0.014	13	2.93	(-0.02)	0.001	14	2.94	-	-	-	-	
	(")	20	0.19	0.016	12	3.29	0.02	0.002	10	3.29	-	-	-	-	
	(humic-deep)	21	0.10	0.005	19	2.98	0.02	0.001	14	2.90	0.00	0.000	14	2.90	
	(" ")	22	0.29	0.021	14	3.13	0.02	0.002	16	3.28	(-0.03)	0.002	16	3.34	
B2	CLEVELAND	23	0.09	0.011	8	3.07	0.02	0.002	7	3.09	(-0.02)	0.002	9	3.11	L
C1	IVANHOE	24	0.09	0.002	43	3.59	0.09	0.001	67	3.47	0.04	0.002	21	3.05	L-VH
	(b) Partially leached soils														
D3	Loskop	25	0.33	0.029	11	3.44	0.09	0.006	15	3.69	0.06	0.005	12	3.47	M
		26	0.48	0.022	22	3.64	0.39	0.019	20	3.31	0.03	0.002	17	3.06	
		27	0.10	0.009	10	3.52	(-0.02)	0.001	16	3.36	0.00	0.000	11	3.15	
		28	(-0.02)	0.001	18	3.24	(-0.02)	0.001	18	3.51	(-0.03)	0.002	14	3.48	
D1	SHORTLANDS	29	0.05	0.001	41	4.08	(-0.02)	0.001	42	3.99	0.04	0.001	71	4.27	H
	After le Roux (1966)-3 profiles		0.62	0.017	37	-	0.22	0.005	42	-	0.07	0.001	70	-	
	Weston	30	0.22	0.007	31	3.57	0.03	0.001	28	3.35	(-0.03)	0.005	54	3.24	H
	Bellevue	31	0.05	0.002	24	3.45	(-0.05)	0.002	28	3.98	0.00	0.000	36	3.76	M-H
		32	0.39	0.028	14	4.09	0.38	0.018	21	4.17	0.15	0.003	47	4.56	
D2	Jagersdrift	33	0.15	0.026	6	3.87	0.08	0.004	19	3.78	0.07	0.002	31	4.06	VL
E1	BERGVILLE	34	0.02	0.001	35	3.75	(-0.01)	0.003	31	3.61	(-0.02)	0.001	36	3.45	H
		35	0.03	0.001	29	3.44	0.01	0.001	28	3.41	0.00	0.000	27	3.22	
	After le Roux (1966)-6 profiles		0.21	0.011	21	-	0.07	0.004	19	-	0.07	0.004	22	-	
	AVALON	36	0.16	0.013	12	3.58	-.02	0.002	10	3.25	(-0.05)	0.003	17	3.57	M
	After le Roux (1966)-6 profiles		0.09	0.006	15	-	0.03	0.003	13	-	0.05	0.005	19	-	
	SOUTHWOLD	37	0.27	0.059	4	3.44	0.19	0.014	13	3.36	0.09	0.004	21	3.94	M-L
		38	0.40	0.038	10	3.59	0.30	0.034	10	3.71	0.15	0.018	9	3.28	
	ARROCHAR	39	0.04	0.015	35	3.87	-	-	-	-	-	-	-	-	M
		40	0.11	0.007	15	3.33	0.05	0.004	14	3.32	-	-	-	-	
E3	LEKSAND variant	41	0.82	0.077	10	3.48	0.47	0.058	8	3.09	0.22	0.038	6	3.14	L
	After le Roux (1966)-3 profiles		0.05	0.014	5	-	0.08	0.014	7	-	0.23	0.008	30	-	
E5	GLENCOE	42	0.17	0.022	8	3.94	0.04	0.003	14	4.20	-	-	-	-	L
F1	ESTCOURT	43	0.10	0.003	33	4.78	-	-	-	-	0.55	0.005	120	6.12	H
	After le Roux (1966)-6 profiles		0.13	0.005	21	-	0.15	0.002	86	-	0.12	0.001	106	-	
G2	RENSBURG (after le Roux 1966)		0.20	0.002	118	-	0.11	0.001	211	-	-	-	-	-	VH
H1	Emmaus	44	(-0.03)	0.001	23	3.71	(-0.05)	0.003	17	4.01	0.02	0.001	57	3.64	M-VH
	Mativane	45	0.26	0.007	45	3.17	-	-	-	-	0.28	0.002	140	5.13	VH
E1	WILLIAMSON[1]	46	0.05	0.007	8	3.67	-	-	-	-	-	-	-	-	L
G2	ARCADIA[1]	47	1.12	0.017	67	4.82	-	-	-	-	-	-	-	-	VH

VH - Very high, H - High, M - Medium, L - Low, VL - Very low

[1] Profiles sampled outside Area

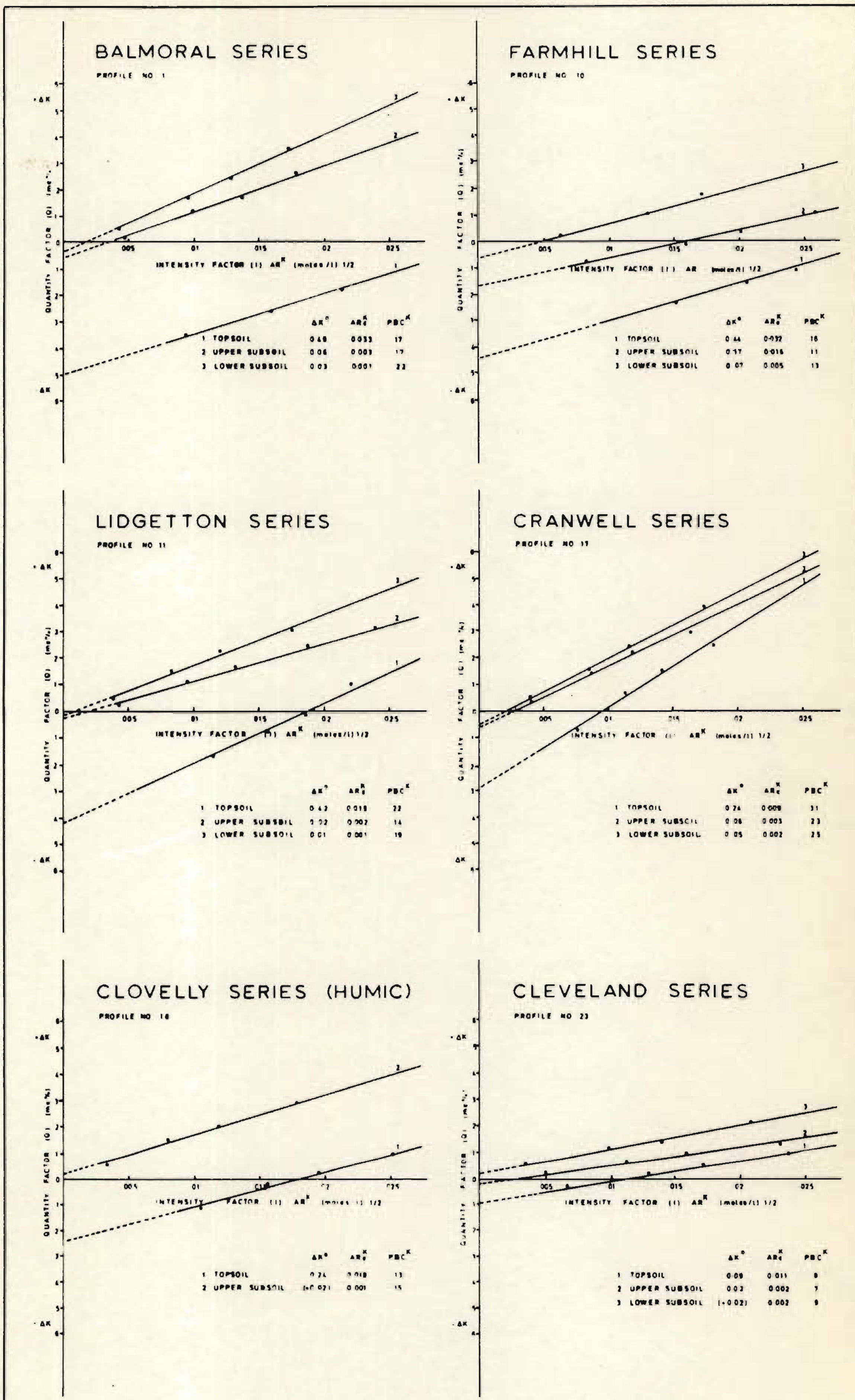

Fig 2 (i): Q/I relations for selected soil series

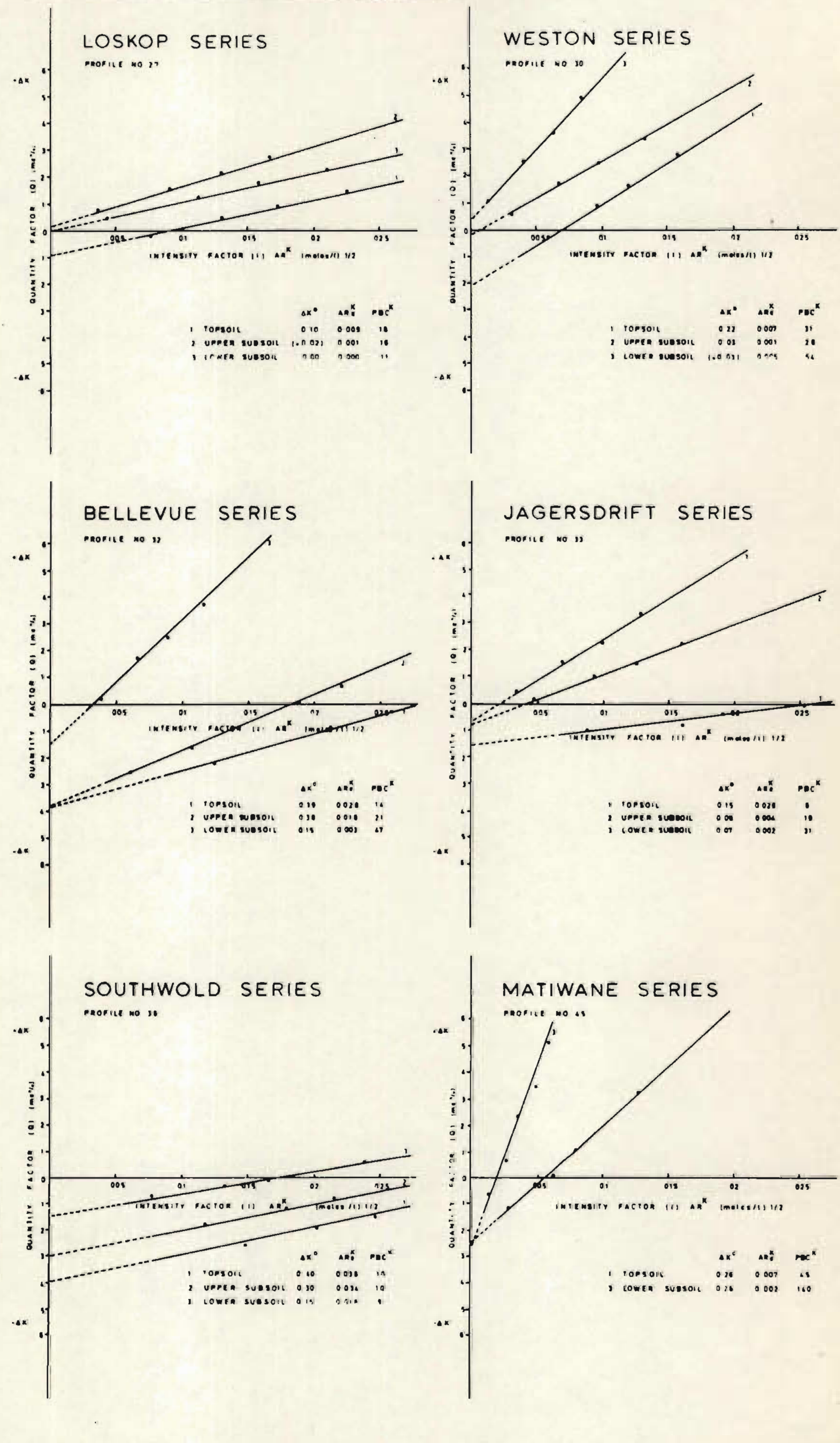

Fig 2 (ii) : Q/I relations for seleted soil series clearly necessary. The Q/I parameters reflect marked differences in soils at both the association and series level. For example, mean PBC^K values of topsoil samples for the A1- and B1-association soils are 19.8 and 17.9 respectively while those for the D1- and E1-associations are 24.0 and 18.0 respectively. These values indicate the more favourable 'supply power' of soils derived from dolerite. Values of bottomland soils are also considerably higher than those of upland soils. This is ascribed to the presence of 2:1 mixed-layer minerals in the former group, even in acid, hydromorphic soils.

Series differences are most obvious among the partially leached soils. The similarity between many highly leached soils, especially those of the same textural class, is attributed to the overriding influence of the leaching process. Skeen (1968) ascribed this to the affinity of these soils for K^+ ions. Textural variations are also reflected by the PBC^K values. Those of the clayey soils (e.g. Cranwell, Lidgetton and SHORTLANDS series) are considerably higher than their lighter textured counterparts (e.g. CLOVELLY, GRIFFIN and Bellevue series).

The very different PBC^K values of samples 39 and 40, both representing the ARROCHAR series, illustrate the need to refine the classification and, as already suggested, are probably due to textural and other differences between the parent shales. The former sample was collected near Merrivale, the latter near Mooi River. It will also be noted that the values of the BERGVILLE samples, also collected near Merrivale, are slightly higher than the mean values established by le Roux (1966). The low PBC^K values of samples 13 and 14 suggests that these soils are marginal members of the GRIFFIN series.

In many partially leached soils there is an increase in PBC^K value with depth (e.g. Jagersdrift series). However, no such increase is noted among highly leached soils which is attributed, in part, to an increase in positive charges in the subsoil horizons. These reduce the effective CEC by neutralizing part of the negative charge (le Roux, 1966).

Reference has already been made to the marked differences in fertility status between topsoil and subsoil horizons, especially among the highly leached soils (Chapter 1). Table 12 also shows a general decrease in ΔK^{o} and AR_{e}^{K} values from topsoil to subsoil horizons. The low organic matter status of the subsoil horizons and the removal of nutrients by leaching and plant uptake, together with the simultaneous enrichment of the topsoil through mineralization of organic matter, contribute much to this finding. The concentration of fertility in the top 6 to 8 inches was also noted by Fisher A. (1955) who described the soils of the Highland Sourveld as having "a superficial skin of fertile topsoil". He added that the problem of getting production from the 'low value' subsoil was virtually insurmountable. In Table 12 the frequent positive values of ΔK^{o} for subsoil samples indicate the extremely low K status of these horizons and suggest adsorption of K from the equilibrating solution into specific sites.

Table 12 also shows considerable variation among the topsoil parameters. This is attributed to soil creep, cultivation and especially erosion. The low ΔK^{o} values for samples 5 and 8 (Balmoral series), both of which reflect a 'below average' labile pool, are probably the result of soil loss since the slopes exceeded 10 percent and there were clear signs of surface erosion. The very low ΔK^{o} values of samples 28 and 44 are probably due to past cultivation although, at the time of sampling, there was little evidence of soil disturbance.

A simple K-supply rating of the soils is shown in Table 12. Despite obvious limitations, and with the absence of sufficient data, this is based primarily on PBC^{K} values. The rating classes and their associated PBC^{K} values are given in Table 13 together with a guide to other characteristics. The associated AR_{e}^{K} values assume a $-\Delta K^{o}$ value of approximately 0.20 me%. Since PBC^{K} is related to clay content the general textural classes are also indicated.

Assessments of K status should, however, consider other criteria. For instance, Zandstra and Mackenzie (1968) showed that PBC^{K} does not

Table 13 : K-supply ratings applied to selected soils and their associated characteristics

K-supply rating	Characteristics		
	PBC^K	AR_e^K ($-\Delta K^o$ = 0.20 me%)	Textural class
Very low	5 - 6	.04 - .033	sand
Low	6 - 10	.033 - .020	loam
Moderate	10 - 20	.020 - .010	clay loam
High	20 - 50	.010 - .004	clay
Very high	over 50	less than .004	heavy clay

indicate the potassium fertility of soils. They preferred potassium potential, or the product of the total amount of exchangeable K (ΔK^o) and PBC^K, to place soils on a comparative basis. K potential was also found to be correlated more closely to crop responses (especially maize) than the other Q/I parameters. Koch (1968) attached more importance to the amount of K in the labile pool than to the current energy level or potential of K. According to the studies of Skeen (1964, 1968), criteria should also include mica content (indicating reserves of non-exchangeable K), presence of sesquioxide gels coating surfaces of clay minerals (influencing specific sites for K), release and fixation of K and the large pH-dependent negative charges. Insufficient data, however, prevented rating or assessing the soils in terms of these criteria. It is suggested that the study of K potential should, however, receive further attention.

Highest ratings in Table 12 are given to soils of the A1-, D1- and G2-associations and the bottomlands. Although releasing large quantities of K, certain of these soils may, however, be associated with a rate of supply too slow for optimum uptake by plants. This problem is likely to occur among some margalitic and bottomland soils and applies equally well to moisture supply. The ability of the RENSBURG series to supply large quantities of K was demonstrated by le Roux (1966) who found that the pool of K was never entirely depleted even after several successive crops. The decline in yield with each successive crop was probably due to the reduction in AR_e^K which reached constancy at a value of 0.001. According to Koch (1968) maize yields on the Clifford series are likely to drop when AR_e^K falls below 0.015 and when the value reaches 0.002 the crop is unable to take up K. Le Roux (1966) also established that soils with low PBC^K values, including the AVALON series, were first to suffer from K deficiency. Such studies should, however, take into account supplies of K from the B-horizon. This is an important consideration when assessing soils of the AVALON form.

Lime potential: The LP values for all soils studied are presented in Table 12. Values of the three sub-samples were found to remain constant over a wide range of soils. Generally, the results confirm the view that LP provides a reliable measure of whether or not appreciable amounts of exchangeable Al are present. Turner and Nichol (1962b) showed that when LP values exceed 3.8 the amounts of Al are negligible. Table 12 shows that the LP values for the majority of highly leached soils are well below this limit and in only one case (profile 14) does the value reach 3.8.

For the purpose of characterizing the soils, a summary of the LP data is presented in Table 14.

Table 14 : Average lime potential (LP) values for soils in the Howick Extension Area

Soil group	LP value		
	Topsoil	Upper subsoil	Lower subsoil
Highly leached soils			
A1-association soils	3.23	3.12	3.12
B1-association soils	3.05	3.06	3.13
Average	3.13	3.09	3.13
Partially leached soils			
D1-association soils D3-association soils	3.65	3.68	3.67
E1-association soils	3.61	3.56	3.49
Average	3.63	3.62	3.58

The overriding influence of the weathering process is clearly demonstrated by the values presented in Table 14. Furthermore, the LP values provide further evidence of major differences at the soil association level. Values for highly leached soils lie mostly between 3.0 and 3.2 with A1-association soils exhibiting a slightly more favourable lime status than the very acid B1-association soils. Series differences among this group are not striking although extremely low values of less than 3.0 are indicated for the Lidgetton and Cranwell series. The average value of humic phase soils is 3.06.

Among the partially leached soils values generally exceed 3.5. Here, too, values for soils of doleritic origin are noticeably higher (over 4.0) than those derived from shales or sandstone (3.5 to 4.0). There is also a tendency for values to decrease with depth in soils exhibiting hydromorphism. Lowest values are associated with horizons of maximum sesquioxide accumulation.

Values of bottomland soils are invariably higher than those of the surrounding uplands. The abrupt transition between horizons of the ESTCOURT series (profile 43) is also well illustrated. Furthermore, the degree to which soil series lying adjacent to one another in the same landscape may differ in lime status, is suitably demonstrated by the values of the WILLIAMSON and ARCADIA series (profiles 46 and 47). The values for profiles 39 and 40 of the ARROCHAR series are 3.87 and 3.33 respectively. These are consistent with the previous finding that E1-association soils near Merrivale are different from those near Mooi River.

ii) <u>The influence of land-use practice on potassium and lime status</u>

Sumner (1965b) stressed the need to establish threshold levels of labile K consistent with optimum crop yields (for each soil series). With this in mind, studies were conducted to investigate the influence of fertilization and current farming practice on the inherent K and lime status of selected farm fields and experimental sites. Woodruff (1955), however, pointed out that the plant, in the final analysis, should be the criterion by which a medium is judged as a suitable substrate for growth. Energies of exchange (ΔF) were also determined in this study.

<u>Studies of selected experimental sites</u>: A number of experimental sites were studied prior to the potassium and lime status investigation of farm fields throughout the Area. Two of these on the Loskop series were long-standing maize experiments at Cedara. Details of the various treatments and the related parameters are summarized in Appendix 3.

The results show that ΔK^{o} increases proportionally to the amount of K applied and support the findings of le Roux (1966) and Skeen (1968). Furthermore, increasing amounts of lime, as expected, reduced ΔK^{o} and AR_{e}^{K} and increased PBC^{K}. The increase in PBC^{K} is explained by an increase in net CEC and saturation with exchangeable (Ca+Mg) (Beckett, 1964b; Tinker, 1964; Skeen, 1968). The dependence of CEC on pH is indicated by the linear relationship (r = 0.903***) between PBC^{K} and pH also shown in Appendix 3.

Exceptionally heavy applications of lime were found to reduce the amount of labile K considerably, even where 150 lb KCl/acre was applied. Although this finding supports previous reports (MacIntire, <u>et al</u>., 1936; Ludorf & Channon, 1965), MacLean (1956) found applications of lime to have little effect on exchangeable K. Skeen (1968) concluded that the labile pool is little affected by liming but noted that heavy applications to acid soils, low in freely available K, may tend to aggravate further the poor supply of K to plants. K fertilizers applied to heavily limed soils generally result in a relatively easier supply of K to plants than under acid conditions. The five-year average yields for the respective treatments given in Appendix 3 substantiate these views.

A marked residual effect of lime was noted in this study. Although in one experiment lime treatment had terminated 9 years prior to sampling, the highest level of lime continued to depress yield. The danger of 'overliming', even the highly and considerably leached clayey soils, is thus evident.

The ΔF values illustrate the importance of a satisfactory balance between K and Ca. In most instances, values of less than -3500 calories, are associated with highest yields. Irrespective of the amount of K applied, the values for the highest levels of lime exceed the threshold value of -3500 calories established by Woodruff (1955) and confirmed by Koch (1968). These values also suggest that K deficiency is one of the main causes of reduced yields on the high lime plots.

An interesting result of the second experiment is the tendency for PBC^K to decrease with increased rates of applied K. This result is not consistent with the findings of other workers and cannot be satisfactorily explained (Beckett, 1964b; Skeen 1968; Zandstra & MacKenzie, 1968). A close relationship between ΔK^o and ΔF was established from the values of samples from this site. The highest mean yield of 25 bags/acre resulting from an application of 150 lb KCl/acre is associated with ΔK^o and ΔF values of 0.22 me% and -3229 calories respectively.

Generally, the Cedara experiments show that, on the Loskop series, highest yields ($\pm$ 25 bags/acre) are associated with ΔK^o and AR_e^K values exceeding 0.20 me% and 0.005 $(moles/litre)^{\frac{1}{2}}$ respectively. By the end of the season, however, $-\Delta K^o$ values are generally between 0.05 and 0.1 me%. Nevertheless, soils differ widely in their ability to supply K. For example, Skeen (1968) established a critical $-\Delta K^o$ value of 0.18 me% for the CLOVELLY series and found that certain highly leached soils could 'fix' between 20 and 40 percent of applied K. Such properties are not normally taken into account in fertilizer treatment. It has also been shown that on the Clifford series the pool of labile K (ΔK^o) should fall between 0.22 and 0.28 me% (i.e. 175 and 225 lb K/acre) for adequate K nutrition of maize (Koch, 1968). This level is, however, dependent on the lime status.

The LP values for samples from both experiments are not consistent for different levels of K but clearly reflect the lime status. Values associated with satisfactory yields lie between 4.0 and 4.5 while values exceeding 5.0 are generally associated with depressed yields resulting from overliming. In a separate experiment investigated at Cedara LP values were found to drop consistently with successive crops of maize following an initial application of lime. The annual drop was approximately 0.1 to 0.2 units. The amount of lime required to maintain a constant LP value would have to be established experimentally.

Studies of selected farm fields: For the purpose of this investigation the paired samples were analyzed. Where possible, all relevant data relating to cropping practice, fertilization and yield were considered. The results, together with details of the most recent cropping practice and the five-year average amounts of K and Ca applied to the cultivated fields, are presented in Table 15. The values for Ca include the small amounts applied in materials other than lime. Fig.3 shows the effect of land-use practice on the Q/I relations of selected soils.

A significant correlation (r = 0.896***) between ΔK^{o} and ΔF was established for the whole range of samples, including soils differing widely in degree of leaching and landscape position. The quadratic regression is presented in Appendix 4. In terms of the fitted curve the optimum range of -2500 to -3000 calories given by Woodruff (1955) corresponds to ΔK^{o} values of 0.70 to 0.35 me% respectively. The mean ΔK^{o} and ΔF values for all fields known to have produced at least 20 bags maize per acre correspond to 0.21 me% and -3300 calories per equivalent respectively. It is concluded from the study that ΔF is a parameter worthy of further investigation as was previously recommended by Koch (1968).

The study of carefully selected farm fields is of particular value in an extension programme. For instance, a most striking feature of the study is the extent to which current farming practice has exploited inherent fertility. In fact, the results amply support the claim by Orchard (1964) that there is urgent need to halt the widespread decline in fertility status in most arable soils. Examples of such exploitation are clearly illustrated in Fig.3(i). Furthermore, a state of extreme exhaustion is indicated by the positive ΔK^{o} values and the

Table 15 : Q/I relations, energies of exchange and lime potential values for selected virgin and cultivated soils in the Howick Extension Area

Soil series	Sample No.	Virgin lands					Sample No.	Cultivated lands					Fertilizer applied				Period cultivated (years)	Cropping programme 1962-1966
		Q/I relations			Energies of exchange ΔF (calories)	Lime potential		Q/I relations			Energies of exchange ΔF (calories)	Lime potential	Ave. annual application (lb/acre)		Application 1965/66 (lb/acre)			
		ΔK^{o} me%	AR^{K}_{e}	PBC^{K}				ΔK^{o} me%	AR^{K}_{e}	PBC^{K}			K	Ca	K	Ca		
(a) Highly leached soils																		
BALMORAL	1	0.08	0.002	33	-3917	3.53	1a	0.51	0.019	27	-2832	3.74	22	36	29	180	10	M Mi M M M*
	2	0.15	0.005	30	-3324	3.46	2a	0.05	0.002	30	-3931	3.15	34	89	-	64	6	M Pt Pt P P
		-	-	-	-	-	2b	(+0.06)	0.001	41	-4475	3.43	1	126	-	130	10	M F P P P
FARMHILL	3	0.52	0.024	22	-2762	3.23	3a	0.25	0.009	27	-3216	3.66	64	426	104	782	3	- - M M M
		-	-	-	-	-	3b	0.13	0.005	25	-3499	3.72	64	388	104	832	3	- - - Mi P
		-	-	-	-	-	3c	0.23	0.028	18	-3503	3.72	82	388	156	518	2	- - - Mi P
Lidgetton	4	0.23	0.011	20	-3236	2.98	4a	(+0.03)	0.002	17	-4256	3.72	27	119	104	176	5	L M P P P
GRIFFIN	5	0.14	0.015	9	-3322	3.12	5a	0.13	0.008	16	-3405	3.79	66	1230	66	822	2	- - - M M
		-	-	-	-	-	5b	0.60	0.18	33	-2824	4.05	71	623	78	899	10	P P Mi M Mi
	6	0.30	0.016	19	-2960	3.22	6a	0.37	0.15	26	-2936	3.39	16	60	-	-	3	- - Pt M P
		-	-	-	-	-	6b	0.20	0.014	15	-3238	3.82	41	216	10	88	10	F F Pt M M
	7	0.04	0.004	12	-3611	2.96		-	-	-	-	-	-	-	-	-	-	Hay Field
	8	0.46	0.027	17	-2800	3.18	8a	0.13	0.004	28	-3633	3.86	81	476	81	96	10	F F M M M
	9	0.21	0.013	17	-3187	2.97	9a	0.16	0.006	31	-3528	3.63	129	271	104	130	10	G G P P P
		-	-	-	-	-	9b	0.23	0.010	24	-3213	3.41	104	442	104	-	6	P P P G G
	10	0.33	0.020	17	-2966	3.36	10a	0.09	0.004	23	-3886	3.04	5	68	-	12	10	P P P P P
CLOVELLY (humic)	11	0.44	0.021	21	-2814	3.19	11a	0.13	0.005	24	-3413	3.06	27	32	-	48	5	P Pt Mi P P
		-	-	-	-	-	11b	0.19	0.009	22	-3288	3.07	57	24	130	-	6	Mi P P P Pt
		-	-	-	-	-	11c	0.26	0.011	22	-3197	3.04	68	-	-	-	3	- - Pt Pt G
KATSPRUIT	12	-	-	-	-	-	12a	0.24	0.003	73	-3387	4.29	-	101	-	48	10	G G P P P
	13	-	-	-	-	-	13a	0.21	0.005	39	-3482	3.82	119	208	104	96	6	G G P P P
(b) Partially leached soils																		
VIMY	14	1.08	0.032	33	-2488	4.16	14a	0.48	0.017	29	-2868	4.04	68	102	40	82	10	M M Mi M M
	15	0.08	0.002	38	-3791	4.09	15a	0.12	0.005	27	-3580	3.64	66	82	164	82	10	P P P P M
Weston	16	0.50	0.019	27	-2789	3.75	16a	(+0.02)	0.001	28	-4480	3.27	8	183	-	32	10	M M P P P
SHORTLANDS	17	-	-	-	-	-	17a	0.64	0.025	26	-2647	3.64	8	-	8	-	10	M M M M M*
Bellevue	18	-	-	-	-	-	18a	0.14	0.007	21	-3387	3.81	40	188	104	-	10	Mi M P P P
	19	0.38	0.010	39	-3015	4.26	19a	0.42	0.015	28	-2882	3.62	23	-	29	-	10	M M M M M
Loskop	20	-	-	-	-	-	20a	0.08	0.006	18	-3499	3.75	58	584	-	96	10	P P M P P
	21	-	-	-	-	-	21a	0.73	0.032	22	-2630	3.81	23	-	23	-	10	M M M M M*
BERGVILLE	22	0.37	0.016	23	-2911	3.54	22a	(+0.05)	0.001	29	-4393	3.27	5	103	-	64	10	M P P P P
SOUTHWOLD	23	0.60	0.048	13	-2612	3.63	23a	0.17	0.016	10	-3290	3.16	45	77	29	32	10	M M M M M
	24	0.37	0.043	9	-2802	3.61	24a	0.03	0.002	13	-3893	3.63	8	153	-	32	10	M M P P P
	25	0.41	0.013	30	-2907	3.74	25a	0.12	0.003	36	-3125	3.54	20	123	23	51	10	M M M M M
ARROCHAR	26	-	-	-	-	-	26a	0.07	0.003	22	-3810	3.86	16	41	-	40	10	M M G G G
	27	-	-	-	-	-	27a	0.34	0.012	27	-3075	3.83	8	-	8	-	10	M M M M M
	28	0.35	0.017	21	-2999	3.36	28a	0.11	0.008	23	-3816	3.22	12	-	12	-	3	F F M M M
	29	-	-	-	-	-	29a	0.13	0.008	11	-3599	3.52	16	111	6	-	10	Mi M M M G
	30	0.52	0.040	13	-2730	3.62	30a	0.15	0.012	13	-3333	4.06	13	5	7	16	10	P P M M M
LEKSAND (variant)	31	0.65	0.078	9	-2509	3.71	31a	0.08	0.012	7	-3577	5.15	1	118	-	72	10	P P P P P
Ladysmith	32	0.33	0.007	23	-3347	4.43	32a	0.04	0.001	24	-3884	4.42	4	-	4	-	10	M L M M M
KILLARNEY	33	0.14	0.005	29	-3555	3.55	33a	0.06	0.003	18	-3710	3.79	52	105	-	60*	10	P P P P P
	34	-	-	-	-	-	34a	0.13	0.003	46	-3748	5.13	86	220	104	208	10	P P P G P
	35	-	-	-	-	-	35a	0.29	0.004	66	-3523	3.92	-	69	-	48	10	G G G G G
Matiwane	36	-	-	-	-	-	36a	0.10	0.005	20	-3596	4.90	40	134	60	40	10	F F G P P

F - Fallow; M - Maize; Mi - Millet; P - Pasture or ley; Pt - Potatoes; G - Grazing crop; L - Legume

* Kraal manure applied

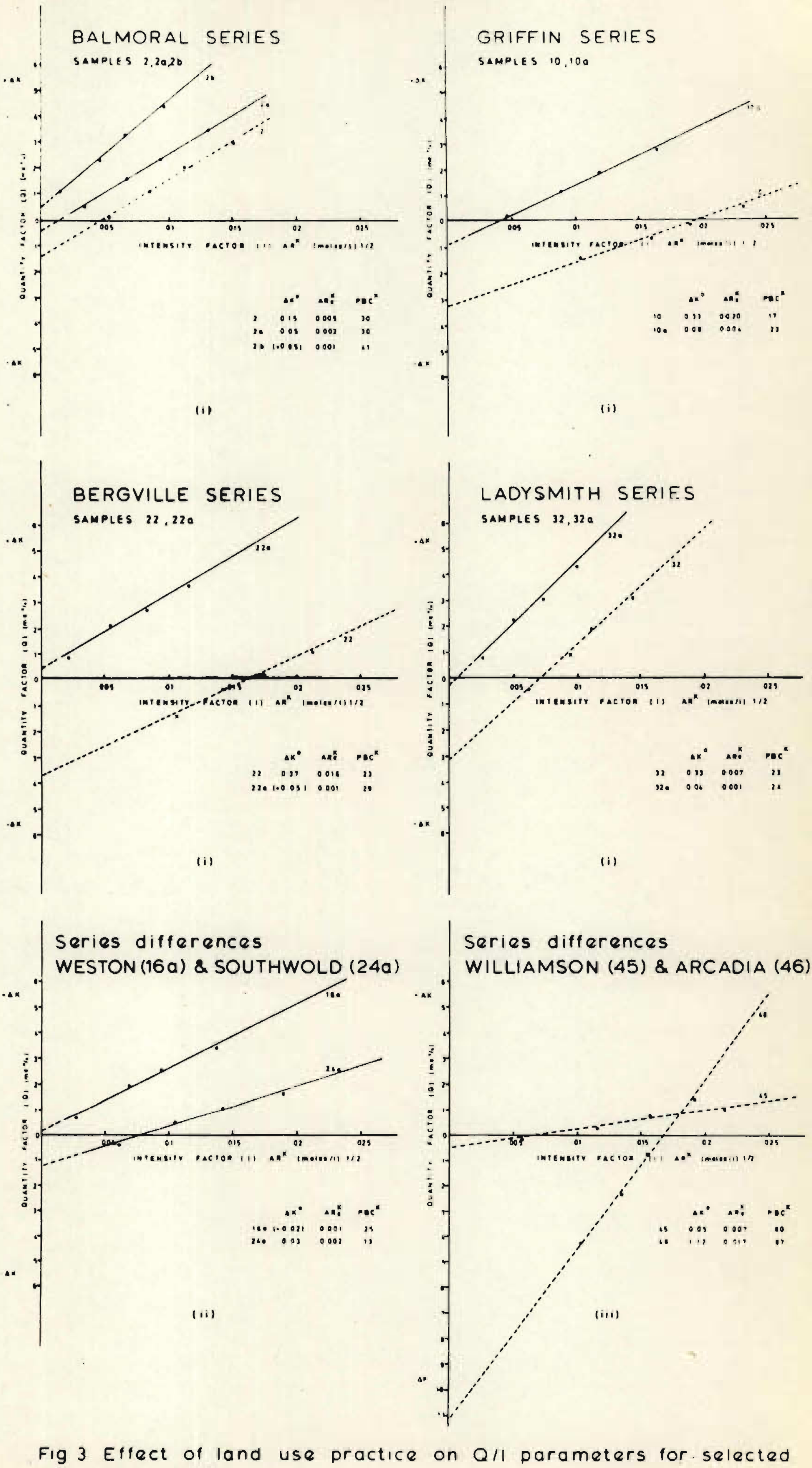

Fig 3 Effect of land use practice on Q/I parameters for selected soil series

---- VIRGIN SOILS —— CULTIVATED SOILS

ΔF values of between -4200 and -4500 calories obtained for several fields. In over 80 percent of the arable fields, the K status is below that of the virgin soils. Mean ΔK^{o} and ΔF values for the cultivated soils are 0.19 me% and -3472 calories respectively. Corresponding values for virgin soils are 0.39 me% and -3050 calories respectively. The largest drop in K status occurs among the partially leached soils and is partly attributed to poor fertilizer practice. The average annual amount of K applied to the highly and partially leached soils was approximately 54 lb and 25 lb K/acre respectively.

In terms of this study the K status should be maintained at a level similar to that of the virgin soils. However, as yield horizons increase these levels may require adjustment. The critical -3500 calorie limit corresponds to a ΔK^{o} value of 0.15 me%.

In 70 percent of the cases PBC^{K} values are highest for cultivated soils. The margin, though small, is attributed to liming and the depletion of K by exhaustive cropping. Liming is commonest among the highly leached soils where the average LP values for cultivated and virgin soil samples are 3.51 and 3.28 respectively. In this case the average amount of lime applied is equivalent to 225 lb Ca/acre. A reverse situation occurs among the partially leached soils. Here, the mean value of the cultivated soils (3.62) is lower than that of the virgin soils (3.74). On the average, cultivated soils received only 91 lb Ca/acre.

Ignoring other principles in liming it is apparent that the inherently low LP values of the highly leached soils (± 3.0) should be raised to at least 3.5 for successful maize production. The relevant farm records suggest that LP values can be raised to this value provided basal applications of lime do not drop below 800 lb Ca/acre or annual applications over several years are not less than 400 lb Ca/acre. These values are, however, lower than lime requirements established by soil testing.

With the partially leached soils LP values should be maintained at, or slightly above, the inherent or natural values viz., between 3.5 and 4.0. Farm experience and recorded data suggest that an annual application of approximately 100 lb Ca/acre will suffice for this purpose. Sample 17a in Table 15 shows that on the SHORTLANDS series a value of 3.5 was recorded despite five years of cropping without lime. In the SOUTHWOLD series (sample 23), however, the value dropped from 3.6 to 3.2 over a period of 10 years, despite an annual application of approximately 77 lb Ca/acre. The need for judicious liming on light textured soils is also indicated by the LP values of the LEKSAND variant. In this case the value increased from 3.7 to 5.2 with an average annual application of only 115 lb Ca/acre. Results for the Ladysmith series indicate the ability of the margalitic soils to maintain a fairly constant LP value despite regular cultivation without lime.

Generally, the bottomland soils have the most favourable K and lime status. The influence of agronomic practice is apparently slight since ΔK^o values for the KATSPRUIT and IVANHOE series were still 0.24 me% and 0.29 me% respectively after at least 5 years of intensive cropping without the application of potassium.

The results of this study also endorse the importance of soil classification. The need for treating individual soil series according to their management needs is well illustrated by the very different K status of the Weston (16a) and SOUTHWOLD (24a) samples shown in Fig.3 (ii). These soils occurred within the same field and received the same treatment for many years. A further example of marked series differences is presented in Fig.3(iii).

The high amount of exchangeable K obtained where manure was applied is an interesting result. The ΔK^o value of 0.51 me% for sample 1a is attributed mainly to the application of 5 tons kraal manure per acre. It is also apparent that the continual removal of veld hay reduces the labile pool markedly as indicated by a comparison between ΔK^o values of samples 6 (0.30 me%) and 7 (0.04 me%). These samples represent grazing and hay camps respectively. The extremely acid conditions of the hay camp sample is also indicated by the very low LP value (2.96). Experience in the Area has shown that crops planted on land previously used exclusively for the production of veld hay often make extremely poor growth until high levels of lime and fertilizer are applied.

The study also shows that critical limits, or low threshold values, should be determined for specific crops. Although fairly precise limits are required for crops such as maize, it is clear that Eragrostis curvula has a remarkable ability to yield satisfactorily over a wide range of soils and plant nutrient status. In many cases the levels of K and lime of fields sown to this grass were much below the threshold values for maize. Table 16 shows the K and lime status of several fields and the yields of hay as measured by the farmers.

Table 16 : Potassium and lime status of selected fields of Eragrostis curvula in the Howick Extension Area

Field (Soil series)	Q/I relations			Energies of exchange ..F	Lime potential	Yield tons hay per acre
	ΔK^o	AR^K_e	PBC^K			
1. BALMORAL	(+0.05)	0.001	41	-4475	3.43	6
2. Lidgetton	(+0.03)	0.002	17	-4256	3.06	4
3. Weston	(+0.02)	0.001	25	-4450	3.27	2.5
4. BERGVILLE	(+0.05)	0.001	29	-4393	3.27	3

The values in Table 16 in no way constitute recommendations for the production of E.curvula, but are shown merely to indicate the ability of the grass to grow satisfactorily under conditions of low fertility and extreme acidity. In each case the fields could no longer support economic returns from maize and were then sown to the ley. The positive ΔK^o values suggest that the grass utilized reserves of K released from specific sites.

The suitability of highly leached soils for potatoes is best illustrated by sample 11b in Table 15. This field, despite an LP value of only 3.1, yielded over 200 bags per acre. The production of clover proved most successful where LP values exceeded 3.5. In general, the K and lime status required for high-yielding clover pasture is similar to that for maize.

2.2 Studies of lime, phosphorus and potassium in selected soils

The low inherent fertility status of the highly leached soils coupled with the lack of elementary scientific information has led to low crop yields, an accelerated rate of erosion and many unprofitable farming ventures. The problem of P-deficiency throughout the Area and the presence of latent toxicities on the highly leached soils, makes the determination of optimum lime and phosphorus application rates for the major soil series an essential first step in promoting improved land-use practice. To investigate these problems and to aid the assessment of the soil resources several pot experiments were planned and conducted under controlled environmental conditions. These were managed in accordance with the procedures outlined by Graven (1967). In each case nutrient additions were applied on the basis of an acre six-inch being equivalent to 2×10^6 lb soil.

It should be noted that the effects of subsoil horizons were not taken into account in these experiments. However, they may influence crop growth considerably by supplementing nutrient elements which may be deficient in the topsoil, or by presenting a highly infertile medium for root growth. Although crops are known to differ widely in their susceptibility to the harmful effects of soil acidity, it was convenient to use a single indicator crop in the three studies undertaken.

1) Crop response to applications of lime, phosphorus and potassium

In this first study the soils were selected to cover a wide range of chemical and morphological characteristics. For this reason, 8 each of highly and partially leached soils were included in the experiment.

(i) Materials and methods

A1-horizon samples (0-8") were collected from representative modal profiles throughout the Area and were screened through a 1 cm sieve before being subjected to chemical and physical analyses. Certain of the measurements were repeated after equilibration with lime. pH values were also recorded at fortnightly intervals throughout the equilibration period. The relevant analytical data are presented in Appendix 5.

The exchangeable aluminium content was determined using the method described by Reeve and Sumner (1969) and high values were obtained for most of the highly leached soils. Only the SOUTHWOLD and ARROCHAR series of the partially leached group contained measurable amounts of aluminium. Values of the unamended samples were also found to increase over the equilibration period. Lime requirements to pH 6.0 were determined using the SMP buffer method (Schoemaker, McLean & Pratt, 1961).

Treatments: Four levels of lime (precipitated $CaCO_3$) were applied to both groups of soils although the rates of application were less in the case of the partially leached soils. The lime was thoroughly mixed with the soil and samples allowed to equilibrate for four months. During this period the moisture content was kept at near field capacity. Details of the lime treatments are given in Table 17 and include the equivalent amounts of commercial lime calculated according to liming factors presented by Reeve (1968).

Table 17 : Quantities of lime (tons/acre) applied to highly and partially leached soils

Treatments	Lime (tons/acre)		
	$CaCO_3$	Agricultural lime	Dolomitic lime
Highly leached soils			
L0	0	0	0
L1	1.0	1.5	2.28
L2	2.0	3.0	4.56
L3	4.0	6.0	9.12
Partially leached soils			
L0	0	0	0
L1	0.5	0.75	1.14
L2	1.0	1.50	2.28
L3	2.0	3.00	4.56

The same rates of phosphorus and potassium were applied to both groups of soils. Four levels of commercial grade powdered superphosphate (8.3%P), were applied at the following rates: 25(P1), 50(P2), 100(P3) and 200(P4) lb P/acre. The potassium treatment consisted of applying muriate of potash at a rate of 150 lb K/acre (K2) to half the number of pots. The remainder of the pots received no potassium (K1). These fertilizers were applied immediately prior to planting. A standard application of nitrogen, equivalent to 1000 lb N/acre, was applied in four equal dressings during the period of growth and all pots received a mixture of trace elements at rates recommended by Graven (1967).

Small undrained pots containing an equivalent of 1 Kg dry soil were used. The pots were rotated at 3-day intervals to reduce the effects of light and temperature gradients in the glasshouse and the moisture content of the soil was kept at field capacity. *Sorghum sudanense* c.v. Trudan was used as the indicator crop. The experiment was harvested 46 days after planting and the material dried to constant weight at $80^{o}C$.

(ii) Results and discussion

(a) Highly leached soils: Problems associated with P-fixation and/or Al toxicity were evident from the results. Very poor growth resulted from the L0 and/or low P treatments and the plants were characterized by isolated water soaked lesions and considerable scorching of the leaf tips. This effect was compounded by the development of an anaemic yellow colour, not unlike iron deficiency in solution culture experiments, where no lime was applied to soils of high exchangeable Al content.

The response of Trudan to lime and phosphorus on a selected number of soils is illustrated in Plate 1. Table 18 shows the mean yields of each of the highly leached soils arranged in descending order. Yield values joined by the same line are not significantly different at the indicated levels.

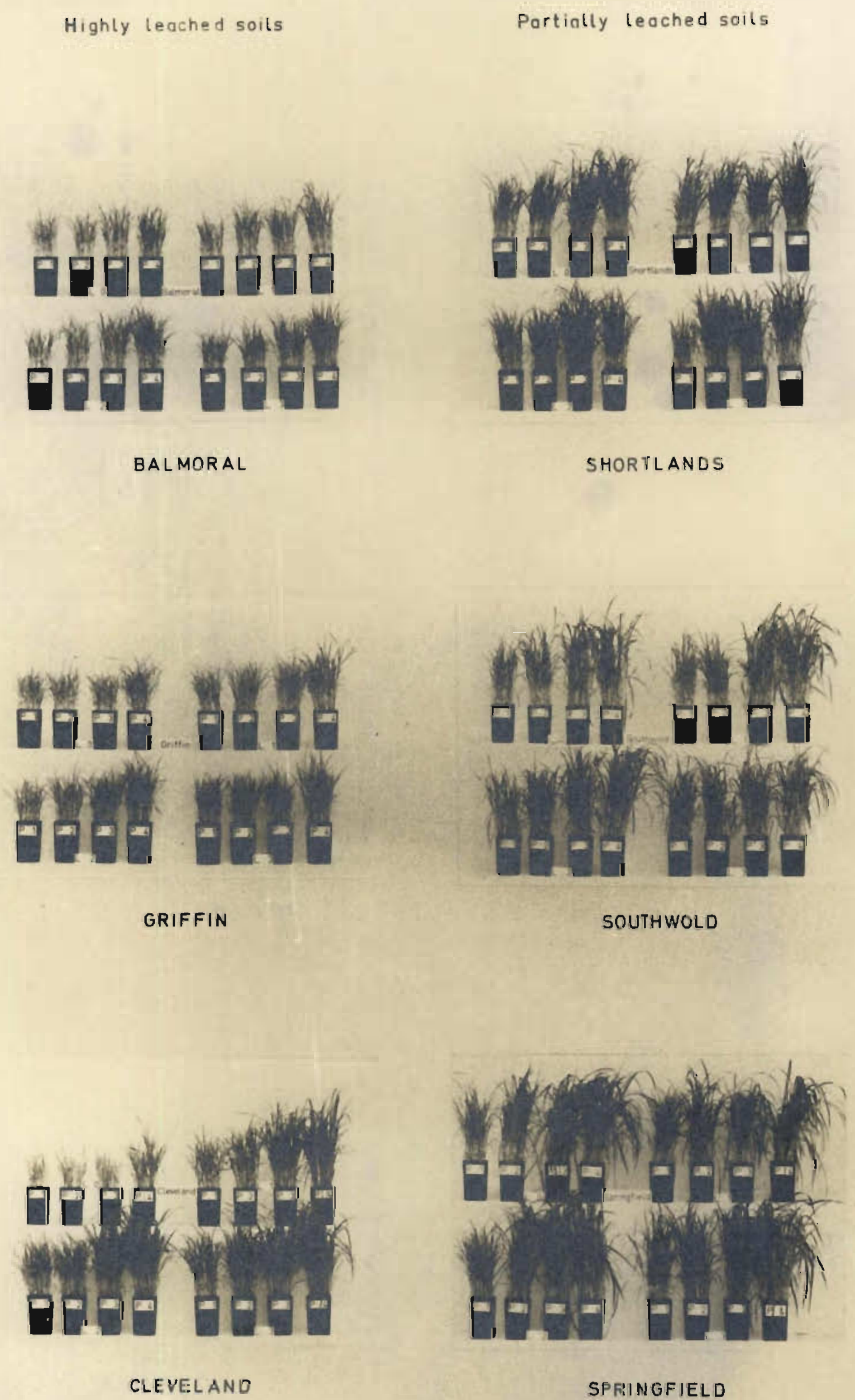

Plate 1. Crop response to lime and phosphorus on highly and partially leached soils.

Table 18 : Mean yields (gm/pot) of Sorghum sudanense grown on eight highly leached soils

Level of significance %	Mean yield (gm/pot)							
	1 CLEVELAND	2 CLOVELLY	3 HUTTON	4 Lidgetton	5 GRIFFIN	6 GRIFFIN (humic)	7 FARMHILL	8 BALMORAL
	3.68	2.82	2.58	2.01	1.95	1.84	1.69	1.54
5.0								
1.0								
0.1								

LSD's: 0.16 ($P<0.05$); 0.22 ($P<0.01$); 0.28 ($P<0.001$)

There is a close relationship between the yields presented in Table 18 and the exchangeable Al values determined for the field samples of each soil. However, since exchangeable Al values for the GRIFFIN (humic), FARMHILL and BALMORAL series (nos. 6 to 8) are all below 0.3 me% and the values for the remainder of the soils all exceed 0.6 me%, and in most cases are above 1.0 me%, the results suggest that P-fixation and not Al toxicity is probably the main cause of the low yields obtained on the named soils. Al toxicity is considered the main limitation on the remaining soils. Both phenomena probably apply in varying degree to all the soils studied (Reeve & Sumner, 1969). The high yields obtained on the CLEVELAND and HUTTON series indicate that certain corrective treatments can render these light textured soils highly productive. Fig.4 illustrates the most important interactions resulting from this experiment.

On the average there was a very highly significant ($P < 0.001$) increase in yield for each additional ton of lime applied although the response was curvilinear (L1 - L0 = 0.799**, L2 - L1 = 0.135*, L3 - L2 = 0.011^{NS}). Lowest and highest yield responses to lime were obtained at the P1 and P4 levels of application respectively with the largest yield increases occurring at the L1 - L0 level (Fig.4a). The significant

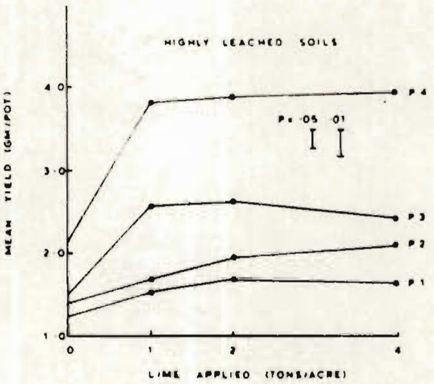

Fig 4 (a) Effect of lime at different levels of phosphorus.

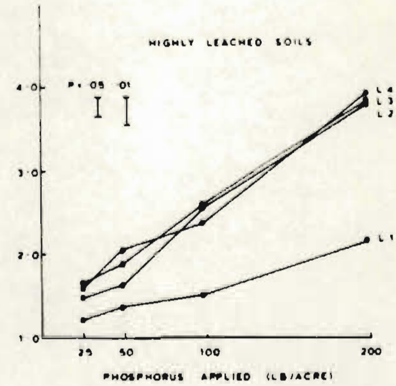

Fig 4 (b) Effect of phosphorus at different levels of lime.

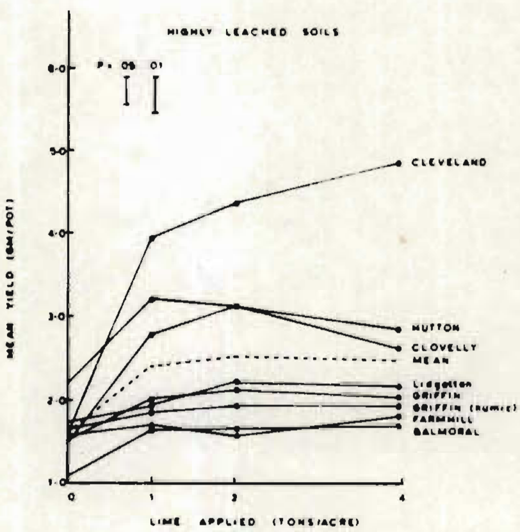

Fig 4 (c) Effect of lime on selected highly leached soil series.

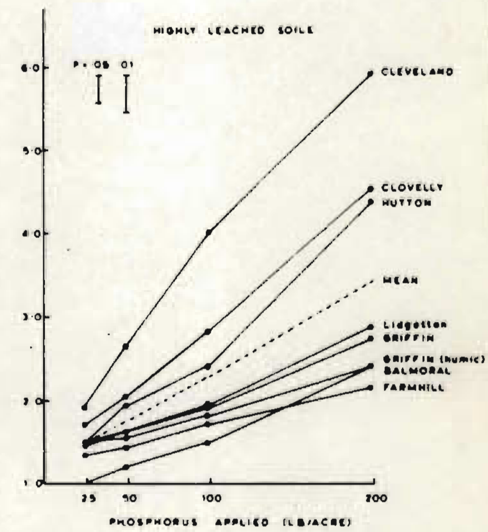

Fig 4 (d) Effect of phosphorus on selected highly leached soil series.

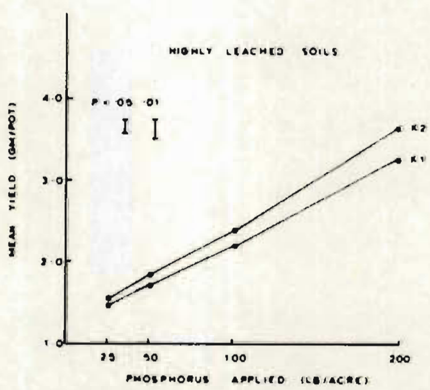

Fig 4 (e) Effect of phosphorus at different levels of potassium.

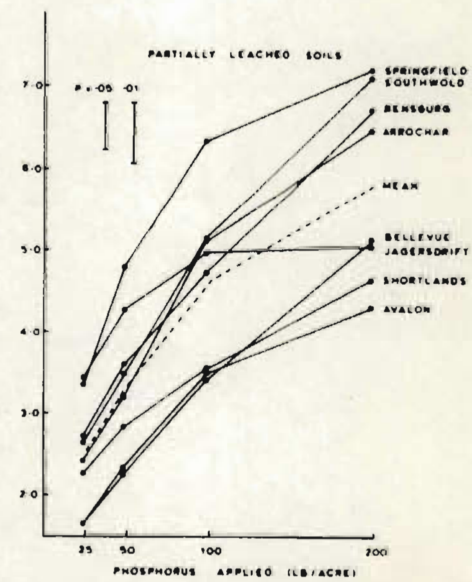

Fig 4 (f) Effect of phosphorus on selected partially leached soil series.

Fig 4 Crop response to lime, phosphorus and potassium on selected soil series.

increases in yield resulting from added increments of P, for each level of lime, are shown in Fig.4b. The average response to lime was not consistent for all soils and is indicated by Fig.4c. The average response to 1 ton of lime applied was significant for the CLEVELAND ($P < 0.001$), HUTTON ($P < 0.001$), BALMORAL ($P < 0.01$), Lidgetton ($P < 0.01$) and GRIFFIN ($P < 0.05$) series. The CLEVELAND ($P < 0.01$) and HUTTON ($P < 0.05$) series were the only soils to respond significantly to the L2 - L1 level and only the former ($P < 0.01$) to the L3 - L2 level. A significant ($P < 0.01$) negative response was obtained at the L3 - L2 level in the case of the CLOVELLY series. Several of the other soils showed similar trends although the results were not significant. It appears, therefore, that there is a potential danger of 'overliming' some highly leached soils when the rate of application approaches 4 tons $CaCO_3$/acre. Highest yields were generally associated with an application of 2 tons $CaCO_3$/acre, although higher levels were required to produce maximum yields on the CLEVELAND and GRIFFIN (humic) soils.

One of the main effects of the lime treatment was to reduce Al toxicity. Exchangeable Al values associated with the highest yielding lime treatments were, in each case, found to be less than the 'critical value' of approximately 0.2 me% established by Moschler, Jones and Thomas (1960) and Reeve (1969). Beneficial effects of liming are commonly ascribed to the immobilization of Al (Jackson, 1967). In similar vein Reeve and Sumner (1970), who studied a similar range of Natal soils, claimed that the primary function of ameliorants was to eliminate Al toxicity. They found amelioration of little effect on P 'availability'. On the other hand, several workers including Robertson, Neller and Bartlett (1954), have reported an increase in P 'availability' following the liming of soils high in sesquioxides. However, the effect of lime on P 'availability', did not form part of this investigation but warrants further investigation. Furthermore, no attempt was made to study the influence of iron compounds on P-fixation although it is likely, especially among the red soils (e.g. BALMORAL series), that these compounds are closely related to the problem.

No definite explanation can be offered for the reduction in yield at the highest levels of lime. Such results are generally associated with either the precipitation of relatively insoluble P-compounds or trace element deficiencies. At first glance, the former reason would seem the most plausible since a standard dressing of trace elements was applied to all soils. However, despite having applied all essential trace elements to their experiments, Reeve and Sumner (1970) offered induced trace element deficiency as the most likely explanation for the depressed yields they obtained.

The very marked increases in yield resulting from added increments of P are shown in Fig.4d. A very highly significant ($P < 0.001$) increase per 25 lb/acre increase in applied P was obtained for the whole experiment although the response was not the same for all soils. It did not appear as though the upper limit for the highly leached soils had been reached even at the P4 level (200 lb P/acre). Furthermore, the yield response at this level was particularly noticeable when no lime was applied. In this respect it should be noted that the addition of P to acid soils can overcome toxic effects of Al (Jackson, 1967). Woodruff (1967) suggested that the concentration of soluble P modifies Al toxicity through the co-precipitation of compounds having very low solubilities. This effect, and the increase in plant available P, offer likely explanations for the observed increases in yield for the L0P4 treatment.

The HUTTON ($P < 0.01$), CLEVELAND ($P < 0.01$), CLOVELLY ($P < 0.01$) and GRIFFIN ($P < 0.05$) series responded significantly to applied K. The initial level of K in each of these soils was less than 0.4 me% or amounted to less than 3 percent of the cation exchange capacity. On the basis of these values the GRIFFIN (humic) soil should also have responded to K yet no significant increase in yield was observed on this sample. It should be noted, however, that the response to K was influenced by the level of P. Fig.4e shows clearly that the addition of 150 lb K/acre produced significant increases in yield only at the P3 ($P < 0.05$) and P4

(P < 0.001) levels. Where threshold values are to be established they should therefore be related to the level of P. The average response to 25 lb P was very highly significant for both potassium treatments.

(b) Partially leached soils: By comparison with the former group, these soils produced higher yields and showed poorer response to lime. There were no significant responses to potassium. Fig.4f shows that all soils responded significantly to phosphorus although, at the P4 level, the upper limit had apparently been reached. The Jagersdrift series was the only soil for which the yield increase at the P4 - P3 level was not significant. Crop responses to lime and phosphorus on a number of partially leached soils are also shown in Plate 1.

The mean yields of dry material from the eight partially leached soils are presented, in descending order, in Table 19.

Table 19 : Mean yields (gm/pot) of *Sorghum sudanense* grown on eight partially leached soils

Level of significance %	Mean yield (gm/pot)							
	1 SPRINGFIELD	2 SOUTHWOLD	3 RENSBURG	4 Jagersdrift	5 ARROCHAR	6 SHORTLANDS	7 Bellevue	8 AVALON
	5.44	4.58	4.47	4.46	4.33	3.34	3.14	2.99
5.0		———	———	———	———	———	———	———
1.0	- - -	- - -	- - -	- - -	- - -	- - -	- - -	- - -
0.1		———	———	———	———	———	———	———

LSD's: 0.28 (P<0.05); 0.37 (P<0.01); 0.49 (P<0.001)

The generally high yields are attributed mainly to the absence of Al toxicity and less severe P-fixation. The low yields from the SHORTLANDS and Bellevue series are, however, probably the result of P-fixation. Contrary to expectations the AVALON series produced poorly. Reasons for this include unfavourable physical characteristics of the soil resulting in severe compaction, overliming and the possibility of trace element deficiency or Mn toxicity. The very high yield obtained from the SPRINGFIELD series again reflects the less complex fertility problems associated with the light textured soils.

Responses to lime were not generally significant although increases in yield at the lower levels of application were noted on some soils. The average response per ton of lime applied was significant only in the case of the SOUTHWOLD series which was also the only partially leached soil to contain a moderate level of exchangeable Al. On the other hand, highly significant negative responses to liming were recorded on the AVALON ($P < 0.001$) and Jagersdrift ($P < 0.01$) series. In the case of the RENSBURG series a significant negative response occurred at the L3 - L2 level. There is, therefore, a potential danger of overliming certain partially leached soils by using standard rates of application. The study indicates that in most cases applications of lime should not exceed 1 ton $CaCO_3$/acre. Requirements are generally between 0.5 and 0.75 tons lime/acre.

The results again confirm that one of the main functions of liming is to eliminate Al toxicity. As with the highly leached soils the higher levels of lime were associated with reduced yields. The reasons for this can also be ascribed to either a reduction in P 'availability' or an induced trace element deficiency. Robertson et al. (1954) reported that liming soils low in sesquioxides had no effect on P 'availability'.

The overall mean yields for the highly and partially leached soils were 2.26 and 4.09 gm/pot respectively. The severity of P-fixation and Al toxicity associated with the former group is thus clearly indicated. It should also be noted that several studies supervized by Sumner[1] have shown that P-fixation in acid soils can be extremely rapid, even within hours after fertilizer application. P-fixation is apparently most severe on the red, clayey soils and humic phase soils.

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[1] M.E. Sumner, Dep. Soil Science, University of Natal - personal communication

Responses to lime on these soils were not as marked as those on the yellow-brown (B1-association) soils, which are more aluminous in character. According to van der Eyk et al. (1969) the capacity for P-fixation on the red, highly leached soils is primarily a function of the degree of crystallinity rather than of the total quantity of free sesquioxides. Generally, crystallinity increases and P-fixing capacity decreases as the degree of leaching becomes less intense. The yield data suggest that the grey-brown soils such as the SOUTHWOLD, ARROCHAR and SPRINGFIELD series are least associated with the harmful effects of P-fixation or Al toxicity.

Since the B1-association soils are particularly widespread in the Area, liming will be an essential corrective treatment on many farms. The writer supports Reeve and Sumner (1970) in their claim that recommendations for liming should, to a large extent, be based on the amount of lime required to inactivate the exchangeable Al. In practice lime should be well mixed with the soil and should be placed as deep as possible (Reeve, 1964). However, because of their extremely infertile subsoils, deep ploughing cannot be strongly recommended for highly leached soils unless, in doing so, all of the tilled soil is adequately ameliorated.

Measurements of pH show that there is little advantage in liming the highly leached soils to a value above pH 5.5, corresponding to a base saturation of approximately 40 percent. A similar 'critical pH level' has already been noted by other workers (Adams & Pearson, 1967; Fisher, 1969; Reeve, 1969). On the average one ton $CaCO_3$/acre increased the pH value of the clayey and loamy highly leached soils by 0.15 to 0.2 units and 0.2 to 0.4 units respectively. Corresponding values for the partially leached soils were approximately double these amounts while for sandy soils the rise was between 0.7 and 0.9 units per ton. Generally, the amounts of lime associated with the highest yields were approximately a third of the values calculated by the SMP method. Similar findings were reported by Reeve and Sumner (1970).

The relationship between several physical and chemical criteria and yield were determined by multiple regression analysis. The result of one of these determinations, in which the data for both groups of soils were pooled, is presented in Appendix 6. A significant ($P < 0.01$) negative correlation between yield and organic carbon content is particularly noteworthy and supports the writer's views that this aspect warrants further investigation. A similar correlation was determined between yield and exchangeable Al content. Significant positive correlations were established between yield and base saturation and pH. Significant correlations between the soil criteria themselves require no further explanation.

Certain conclusions drawn from this study may be invalidated since the growth of Trudan on many of the soils was extremely poor. Nevertheless, the marked linear responses of all soils to applications of phosphorus up to 200 lb P/acre suggest that a different method of application could result in more economical fertilizer programmes. This aspect forms the basis of the following study.

2) Crop response to different methods of applying phosphorus to selected highly leached soils

Following the poor growth observed on the highly leached soils in the previous study it was decided to compare the effects of two methods of applying the phosphorus.

(i) Materials and methods

The eight highly leached soils from the previous study were again used after most of the root material had been removed by screening through a 1 cm sieve.

Treatments: Despite the somewhat low pH values recorded at the termination of the previous study, probably the result of acidification due to cropping and salt effects, no additional lime was applied. Thus, the four original levels of 0(L0), 1(L1), 2(L2) and 4(L3) tons $CaCO_3$/acre were retained. Four levels of phosphorus (powdered commercial grade superphosphate - 8.3% P) were either broadcast (B1) and thoroughly mixed with the soil or were placed in a narrow concentrated band (B2) one inch below the seed. The levels were 25 (P1), 50 (P2), 100 (P3) and 200 (P4) lb P/acre and a total 1000 lb N/acre was applied in four equal dressings during the growth period.

Twenty seeds of Sorghum sudanense c.v. Trudan were planted directly above the band of P-fertilizer and thinned, as soon as possible, to a final stand of 15 plants per pot. The same planting method was adopted for the broadcast treatments. The crop was harvested 46 days after planting and the material dried to a constant weight at 80°C and weighed.

(ii) Results and discussion

A mean difference of 2.43 gm/pot between the two methods of application was obtained and was very highly significant ($P < 0.001$) in favour of band placed fertilizer. This result was similar for all the soils and again indicated the severity of P-deficiency among the highly leached group. The marked increase in yield resulting from the band treatment is attributed mainly to the reduced surface contact between soil and fertilizer.

Plate 2 illustrates the general crop response to the two methods of applying phosphorus and to various levels of lime and superphosphate on the GRIFFIN series. It will be observed that the no lime - low P broadcast treatments again resulted in extremely poor growth. The plants revealed an anaemic colour similar to that reported in the previous study.

Special note is made of an abnormal leaf symptom observed on plants grown on the no lime - banded treatments. These symptoms were particularly evident on the CLEVELAND, GRIFFIN and GRIFFIN (humic) soils. Although the growth was much improved at higher levels of P the symptoms remained. However, at the P4 level, or, where lime had been applied, the symptoms were hardly noticeable. The general chlorotic appearance of the leaves at the P1 and P3 levels of banded fertilizer is shown in

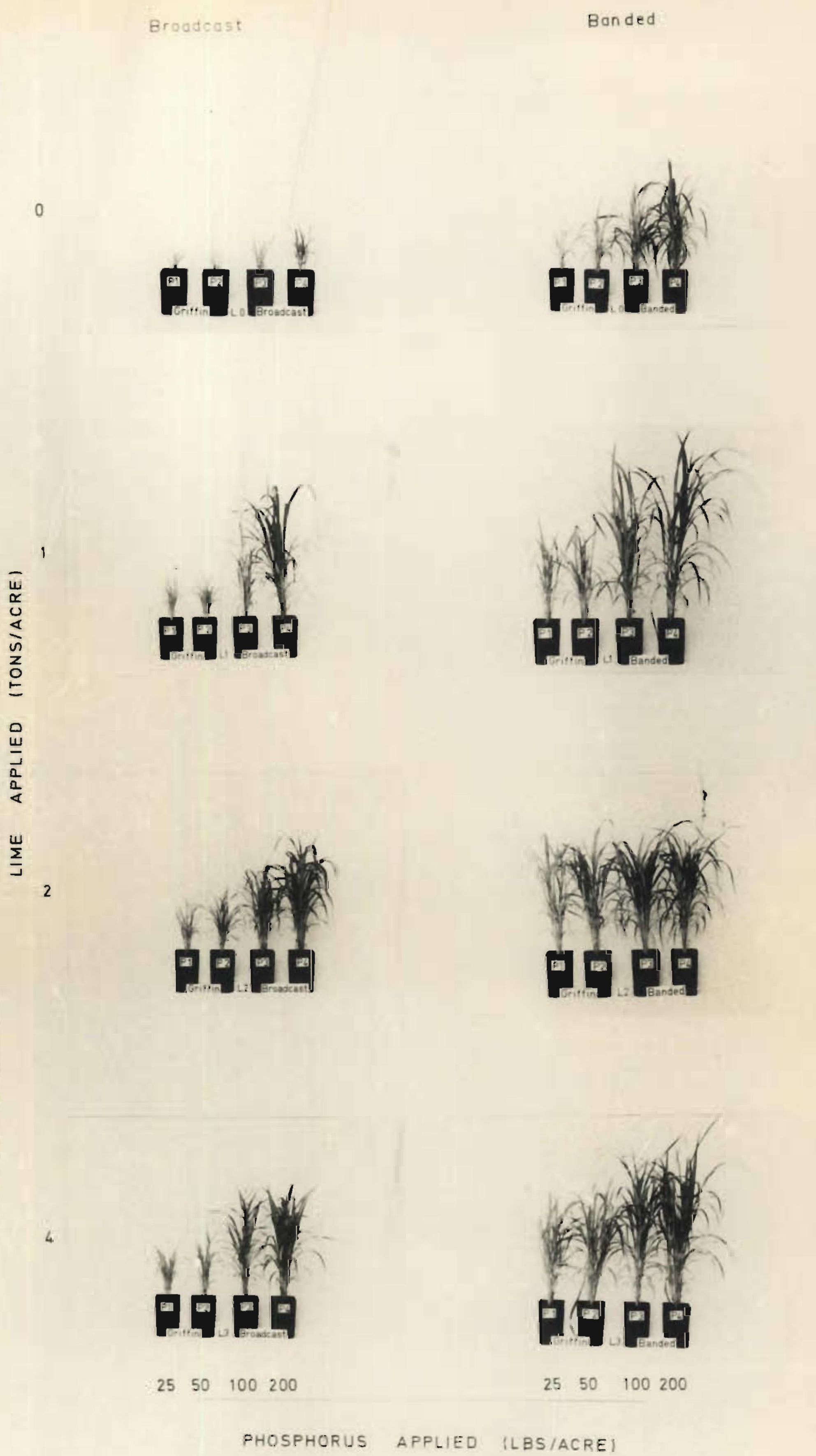

Plate 2. Response of Trudan (Sorghum sudanense) to different methods of applying phosphorus - GRIFFIN series.

Plate 3 : Typical chlorotic appearance of Trudan (Sorghum sudanense) associated with a no lime - banded phosphorus (P1) treatment - CLEVELAND series

Plate 4 : Chlorotic appearance of Trudan (Sorghum sudanense) leaves associated with a no lime - banded phosphorus (P3) treatment - GRIFFIN (humic) series

Plates 3 and 4 respectively.

Manifestation of these symptoms is difficult to explain but may be related to Al toxicity or a particular trace element deficiency (e.g. Zn, Mo, Mg, etc.) Apparently the chlorosis was not the result of Fe/Mn antagonism since analysis of the plant material revealed values well below the critical levels reported by Somers and Shive (1942).

The mean yields for each soil (in descending order) and for both methods of application are shown in Table 20. The differences in yield due to method of application were very highly significant for each soil.

Table 20 : Effect of two methods of applying phosphorus on the mean yields (gm/pot) of Sorghum sudanense c.v. Trudan on selected highly leached soils

Soil series	Mean yield (gm/pot) (1)	Method of application		
		B2 Broadcast	B2 Banded	Difference in yield (2)
1. FARMHILL	2.96	1.26	4.65	3.39 (1)
2. GRIFFIN	2.90	1.66	4.14	2.48 (4)
3. CLOVELLY	2.85	1.78	3.92	2.14 (6)
4. HUTTON	2.80	1.45	4.14	2.69 (2)
5. CLEVELAND	2.79	1.61	3.97	2.36 (5)
6. Lidgetton	2.28	0.97	3.60	2.63 (3)
7. BALMORAL	2.16	1.29	3.04	1.75 (8)
8. GRIFFIN (humic)	1.94	0.95	2.92	1.97 (7)

(1) LSD's: 0.32 ($P < 0.05$); 0.43 ($P < 0.01$); 0.56 ($P < 0.001$)
(2) LSD : 0.76 ($P < 0.001$)

The marked response to band placed P-fertilizer on all soils is reflected in Table 20 and Fig.5a. The mean yields of the first five soils (1 to 5) are not significantly different from one another and suggest that banding, to some extent, eliminated the effects of the individual soil characteristics previously observed. The response to band placement was greatest on the FARMHILL series which in the previous study was associated with severe P-fixation. In contrast, the responses on the BALMORAL and GRIFFIN (humic) soils, also associated with severe P-fixation, were the poorest of the group. Although the reasons for this were not established it is possible that other factors, such as iron and organic compounds, influenced the availability of phosphorus.

Fig.5 illustrates the interactions that attained significance. On the average there was very highly significant ($P < 0.001$) response to each 25 lb/acre increment of P for both methods of application over all levels of lime. Fig.5a shows that, with the exception of the P2 - P1 level of the broadcast treatment, yield increases were highly significant for all other levels of P, irrespective of the method of application. Fig.5b shows the effect of P at different levels of lime for both methods of application. The results of the broadcast and banded treatments on individual soils are shown in Fig.5c and Fig.5d respectively.

Clearly, method of application on the highly leached soils has important economic implications. Within certain limits, highest economic returns from the use of limited quantities of soluble P-fertilizer result from band placement. It has been shown in other studies that half as much P-fertilizer is generally required to produce a given increase in yield if it is banded rather than broadcast (Tisdale & Nelson, 1966). Fig.5a shows that, on the average, scarcely more than 50 lb P/acre banded was required to produce a similar yield to 200 lb P/acre broadcast. Furthermore, the upper limit had apparently been reached with a rate of 200 lb P/acre when the fertilizer was banded (Figs. 5a, 5b and 5d). This was not the case when the fertilizer was broadcast (Fig.5a).

On the average there was a very highly significant increase in yield for each additional ton of lime applied although the response was not consistent over all levels (L1 - L0 = 0.95***, L2 - L1 = 0.28*, L3 - L2 = 0.23*). The effect of lime was essentially similar to that observed in the previous study and suggests a considerable residual effect from the original lime treatments. The average response to a one ton

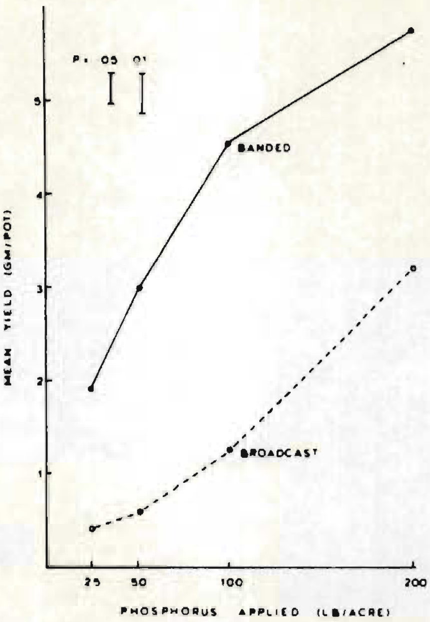

Fig 5 (a) Effect of phosphorus on different methods of application.

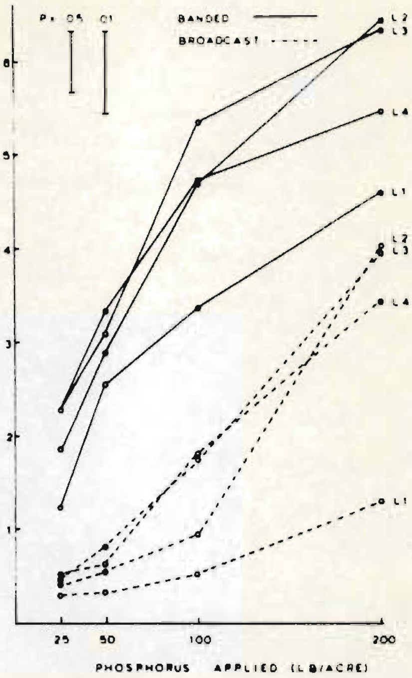

Fig 5 (b) Effect of phosphorus at different levels of lime for two methods of application.

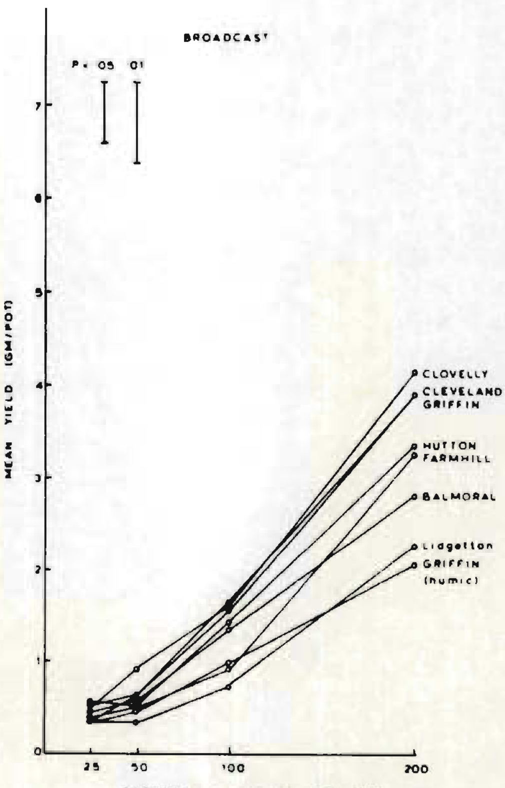

Fig 5 (c) Effect of phosphorus (broadcast) on selected highly leached soils

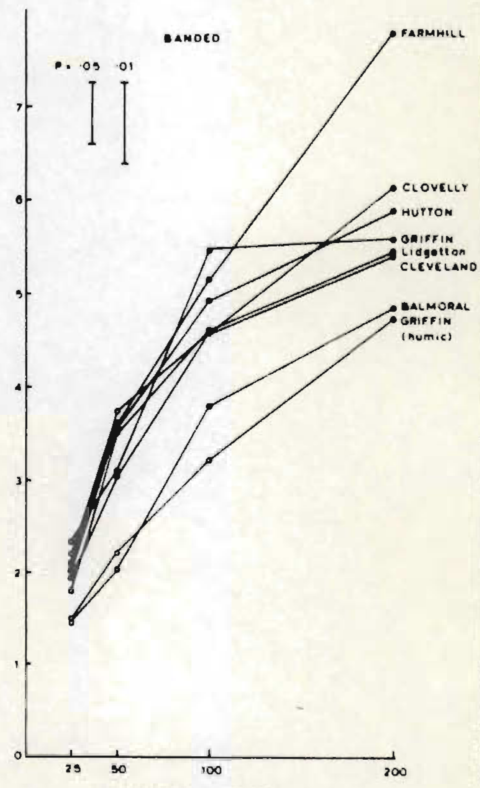

Fig 5 (d) Effect of phosphorus (banded) on selected highly leached soils.

Fig 5: Crop response to different methods of applying phosphorus on highly leached soils.

per acre increase in lime was not consistent for all soils but significant responses were obtained on the HUTTON ($P < 0.001$), GRIFFIN ($P < 0.001$), CLEVELAND ($P < 0.001$), CLOVELLY ($P < 0.001$) and GRIFFIN (humic) ($P < 0.05$) series. There was a general depression of yield at the L3 - L2 level but was significant only in the case of the CLEVELAND series ($P < 0.01$). This result was particularly noticeable at the higher levels of P.

A significant ($P < 0.05$) negative response resulted from an average application of one ton $CaCO_3$/acre on the BALMORAL and FARMHILL series when the P-fertilizer was banded. This was probably due to either the immobilization of P in the presence of added calcium or an induced trace element deficiency. It is possible that the amounts of trace elements applied to the experiment were inadequate since, in a recent study supervised by Graven[1], zinc was found to become deficient in maize despite an initial application similar to that used in this investigation.

The benefits of band placement were particularly noticeable where no lime was applied. Reasonable explanation for this is offered by the findings of Ragland and Coleman (1959). They found that plants having part of their root system in a non-toxic medium which favours growth are better able to withstand the adverse effects of Al concentrations in the vicinity of the other roots. Furthermore, it is likely that the toxic effects of Al would have been reduced in the zone of the band by the high concentration of soluble P (Jackson, 1967; Woodruff, 1967). This phenomenon also partially explains the marked increase in yield and improved root growth associated with no lime - P4 broadcast treatments over lower levels of broadcast P.

Plate 5 illustrates the effect of selected treatments on root development in the GRIFFIN series. The beneficial effect of banding in the absence of lime and the improved root growth resulting from high

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[1] E.H. Graven, Dept. Crop Science, University of Natal - personal communication

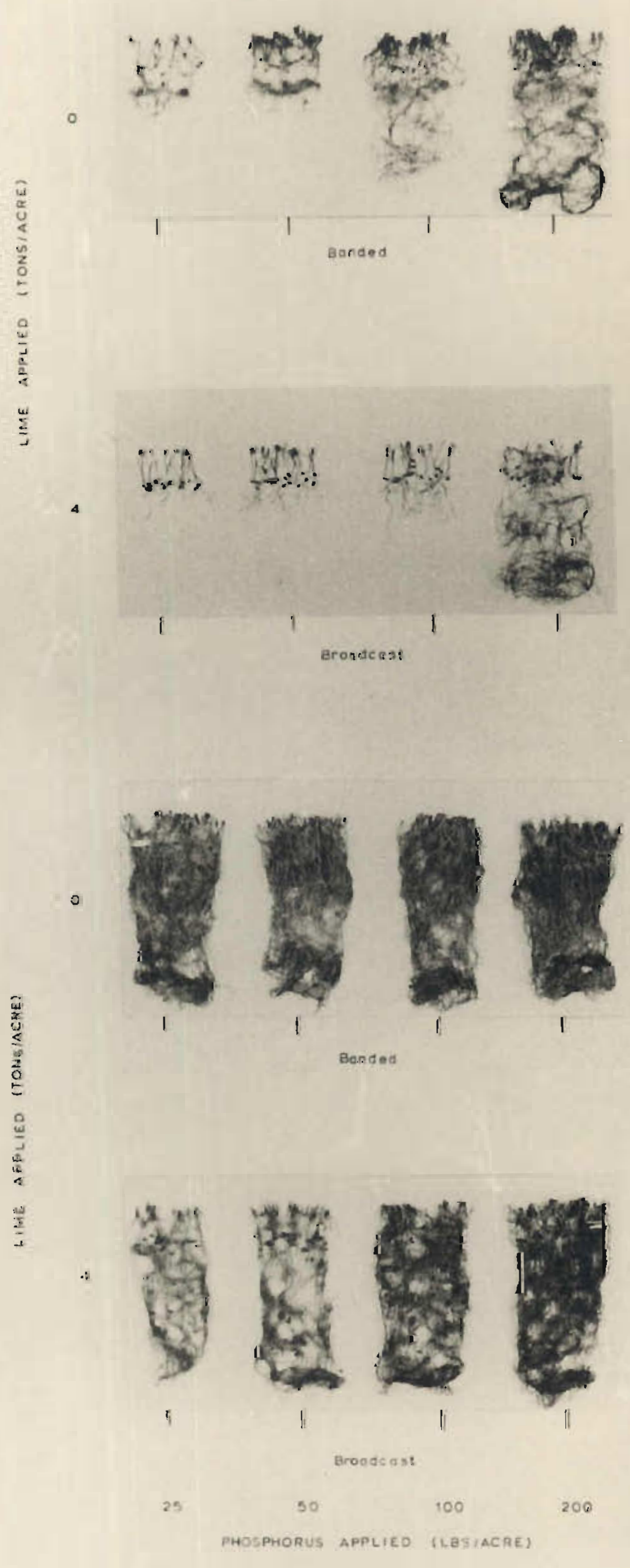

Plate 5. Effect of different methods of applying phosphorus on root growth of trudan (Sorghum sudanense) - GRIFFIN series.

levels of broadcast P and lime can be seen. The poor development in the unlimed soil is mainly attributed to the high concentration of Al, a phenomenon also reported by Graven and Theron (1969).

It is concluded from the results of this study that band placement of P-fertilizer can be strongly recommended for the highly leached soils. However, the effects of Al toxicity should first be eliminated by liming. A critical appraisal of the economic aspects related to the method of applying phosphorus is most desirable and applies equally well to the partially leached soils although, in this case, a repeat of the spectacular results obtained on the highly leached soils is unlikely. Furthermore, broadcast application of P on the droughty, partially leached soils would have the advantage of encouraging a deep, well-distributed root system.

Many related aspects require further study. These include acidulation within the band, the use of granulated fertilizer which has a similar effect to banding if the granules are large (Tisdale & Nelson, 1966) and the various methods and depths of applying different types of P-fertilizer and lime. An economic study of the use of different types of P-fertilizer is of particular importance since the practice of applying less soluble forms of P-fertilizer (broadcast) is common throughout the Area.

3) Clover response to lime and phosphorus on a humic phase soil

Humic phase soils occur extensively in the Highland Sourveld (Chapter 1) where they are used for the production of potatoes and high quality pastures. Field experience shows that the clover constituent of many mixed pastures swards soon dies out after establishment or produces poorly throughout the life of the pasture. On the basis of the previous studies it is obvious that the problem is most likely associated with severe P-fixation. A preliminary investigation was planned since clover-based pastures are strongly recommended for these soils. The object was to determine the response of ladino clover (*Trifolium repens*) to lime and phosphorus when grown on a loamy, humic phase soil of the CLOVELLY series.

(i) Material and methods

The study comprised two simple pot trials each with two replicates. A bulk soil sample of the A1-horizon (0-9") was collected from a modal profile and analyzed. Several important features were revealed including an extremely high organic carbon content (8.2%), a low plant nutrient status and very acid conditions. The percentage base saturation was 12 percent.

Treatments: Treatments for each of the two trials were:

Trial 1: Five levels of lime corresponding to 0(L0), 1(L1), 2(L2), 4(L3) and 8(L4) tons/acre of commercial agricultural lime were applied. The neutralizing value of the lime containing 28.8 percent calcium and 0.35 percent of magnesium was 16.4 me/gm. After applying the lime the soil was equilibrated for a period of 90 days during which regular pH measurements were made. A standard dressing of phosphorus, equivalent to 200 lbs P/acre, was applied to all pots just prior to planting. Finely granulated superphosphate (8.3% P) was used.

Trial 2: Superphosphate was thoroughly mixed with the soil just prior to planting at the following rates: 0 (P0), 50 (P1), 100 (P2) and 200 (P3) lbs P /acre. All pots received a standard dressing equivalent to three tons agricultural lime per acre and were then equilibrated for a 90 day period.

Undrained plastic pots containing an equivalent of 3 Kg dry soil were used in both trials. Ladino clover seed was inoculated and equal amounts were planted in each pot. The moisture content in the pot was kept at near field capacity throughout the investigation. The clover was harvested at 60 and 96 days after planting and the material oven dried at 80^{o}C and weighed.

Several addendum treatments were also included in the investigation.

(ii) Results and discussion

The mean pH values of the five lime treatments at the end of the equilibration period were: 4.55, 5.15, 5.25, 5.55 and 5.80 respectively. The considerable drop in pH from an initial value of 5.15 to 4.55, where no lime was applied, is attributed to the formation of organic acids. With 1 ton of lime/acre the original value was maintained and with 4 tons/acre the pH rose to 5.55, the value above which there is a low probability of significantly increasing yield by liming (Adams & Pearson, 1967; Fisher, 1969; Reeve, 1969). The yields obtained verified this threshold value.

Fig.6 and Plates 6 and 7 illustrate the main effects of lime and phosphorus on the yield of clover.

In trial 1, the average response per one ton increase in lime was very highly significant ($P < 0.001$) although the response was not consistent over all levels. Fig.6 shows that the optimum level was approximately 4 tons of lime/acre although the response at the L3 - L2 level was not significant.

Despite the application of 200 P/acre the clover made very poor growth in the absence of lime. Apart from exceptionally severe P-fixation it is also probable that the survival and multiplication of the Rhizobia were also prevented by the lack of lime. Benefits accruing to lime are thus associated with the neutralization of the extreme acidity, the improved calcium status of the soil and the improved functioning of the Rhizobia.

In trial 2 the average increase in yield per 50 lb/acre increase in P was very highly significant ($P < 0.001$). Fig.6 shows that maximum clover yields resulted from the application of 200 lb P/acre although at this level it was apparent that the upper limit had not yet been reached. Furthermore, it can be seen that higher yields would probably have resulted had the lime treatment been increased from 3 to 4 tons/acre.

Plate 7 shows the response pattern to added increments of P. Where no phosphorus was applied the clover died out soon after germination. The high P treatment with adequate lime resulted in rapid establishment

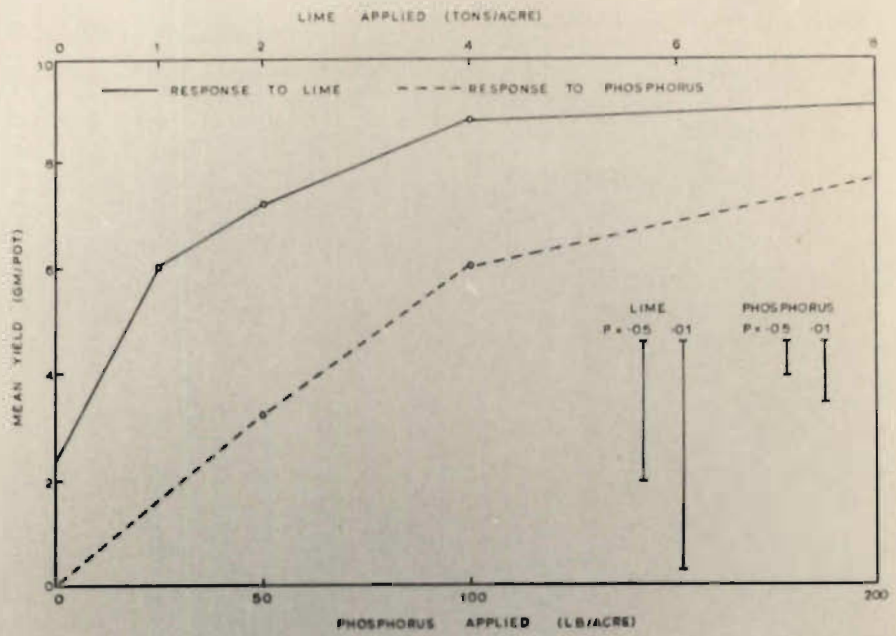

Fig 6. Response of clover to applications of lime and phosphorus on a humic phase soil - CLOVELLY series.

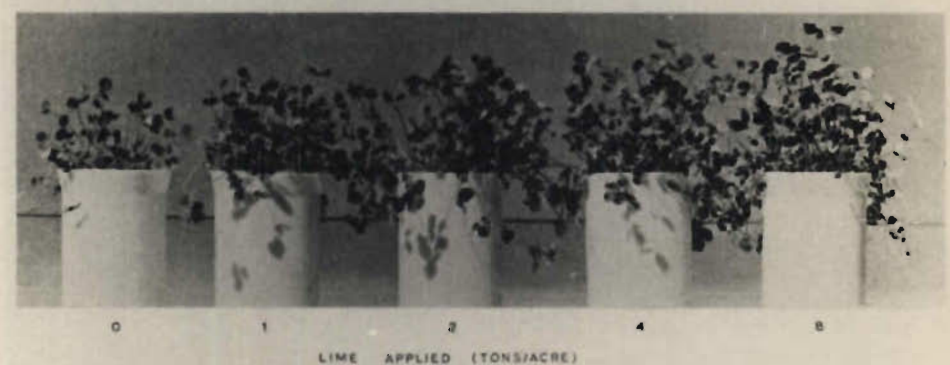

Plate 6. Response of clover to applications of lime on a humic phase soil - CLOVELLY series.

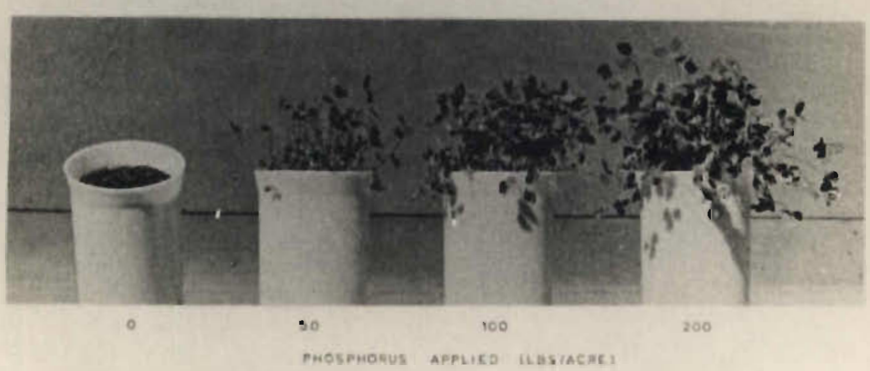

Plate 7. Response of clover to applications of phosphorus on a humic phase soil - CLOVELLY series.

of the clover and a vigorous growth over both the cuts. Graven and Theron (1969) found marked increases in yields of clover with increasing amounts of phosphorus although, in their study, the fertilizer was banded and the soil less humic.

Yields from the addendum pots showed that there was no significant difference in response to the agricultural lime used and a dolomitic lime containing 21.1 percent calcium and 14.5 percent magnesium. A response to magnesium may have become more apparent had the trial been continued. Furthermore, the need for a soluble form of P-fertilizer for the rapid establishment of clover was clearly evident from a comparison made between superphosphate and calmafos (8.8% total P) in the presence of a standard lime treatment of 3 tons/acre. The less soluble P produced very poor initial growth but improved considerably by the second cut. First and second-cut yields for the superphosphate and calmafos treatments, each equivalent to 100 lb P/acre, were 5.40 and 6.64 gm/pot and 0.3 and 5.14 gm/pot respectively.

Despite its preliminary nature, the investigation indicated that clover-based swards can be grown very successfully on humic phase soils with judicious liming and adequate phosphorus. However, the lime requirement of clover deserves more critical study. Lime and P-fertilizers are customarily broadcast and thoroughly mixed with the soil at establishment. Since the levels applied to these soils are often low, much of the phosphorus is soon rendered 'fixed' resulting in low production from the clover constituent. The results obtained in the previous study and that of Graven and Theron (1969) suggest that band seeding the clover constituent of the sward could have a decided advantage over conventional methods. A combination of broadcasting lime and rock phosphate and banding superphosphate should, from a long term point of view, prove highly successful. The granulated form of fertilizer used, although fine, probably acted in much the same way as a band treatment although Graven and Theron (1969) found that granulated superphosphate had no advantage over the powdered form.

Responses to lime and phosphorus may be considerably influenced by the current status of organic matter. Since there is usually a marked reduction in the organic carbon content following cultivation response patterns should, in fact, be related to the status of the organic fraction.

2.3 Soil moisture characteristics

Order was brought into the study of soil moisture and its availability to plants when the significance of chemical potential, or free energy, was recognized (Schofield, 1953). According to Gardner (1965), many early studies aimed at developing precise definitions and placing both plant and soil water energy concepts on a sound thermodynamic basis (Schofield, 1935; Day, 1942; Edelfsen & Anderson, 1954). These studies formed the basis for the development of recent theoretical considerations and equations (Babcock & Overstreet, 1955; Bolt & Frissel, 1960).

Soil moisture is best expressed in terms of condition, or free energy, rather than on a quantity basis (Hill, 1965). The interaction between water and the soil solid phase is the most important of several forces influencing soil water. In practice, this effect may be expressed quantitatively by evaluating matric suction which is defined as: "the negative gauge pressure relative to the external gas pressure on the soil water, to which a solution identical in composition with the soil water must be subjected in order to be in equilibrium, through a porous permeable wall, with the soil water" (Sumner, 1965d). The common units for matric suction are centimetres of water, or bars, and it is usual for the negative sign to be neglected.

Essentially similar considerations apply to soil water as to the potential measurements of ionic equilibria. A simple analogy is provided by relating soil water to the quantity-intensity relations of a particular ion. The amount of water in the soil, or the water lost by a soil if dried at 105°C, constitutes the pool or quantity (Q) of water at a common potential. Matric suction is equivalent to the intensity factor (I).

When a small amount of water is withdrawn from the soil there is a reduction in the potential of all water left in the pool. Conversely, water added loses its identity in the pool which then contains more water all at a higher potential (Schofield, 1953). Simply, the soil suction increases as the soil dries, and decreases as water is added.

The relationship between water content and matric suction was originally described by Childs (1940) as the 'soil moisture characteristic' and is generally illustrated by a curve. The relationship may be influenced by many soil characteristics such as texture, structure, nature of exchangeable ions and salt concentration and is also temperature dependent (Sumner, 1965d).

The degree of wetness of a soil is thus expressed by the amount of water it contains at a given suction. A definite equilibrium suction is exerted by the soil which is dependent on its moisture content, and also on whether it is wetting or drying. The hysteresis effect may influence soil moisture characteristics considerably, particularly in a soil exhibiting volume change with change in moisture content. All moisture characteristics described in this discussion were determined under drying conditions.

<u>Available moisture: Definition of upper and lower limits</u>: Total available moisture (TAM) is the amount held between the water content at the upper limit (field capacity) and that at the lower limit (permanent wilting). Perusal of the literature, which was summarized in an excellent review by Gardner (1965), indicates that agreement on the definition and determination of the upper and lower limits is by no means unanimous. It is generally agreed, however, that water becomes progressively less available as water content decreases. Kramer (1963) noted that it is impossible to predict at what level soil water stress will limit plant growth unless atmospheric conditions, the kind of plant and its stage of growth are also considered.

Despite many soil conditions which may alter the upper limit from prescribed definition, field capacity is accepted as the amount of water held in the soil after excess gravitational water has drained away and the rate of downward movement of water has materially decreased (Peters, 1965). Salter and Howarth (1961a) showed that direct determination in the field was the most reliable method for critical studies while Hill (1965) proved conclusively that field capacity is not a standard tension for all soils. Wilcox (1962a) suggested a somewhat different approach to the definition of field capacity which he regarded as more realistic. According to this re-definition field capacity is "the upper limit of that range in soil moisture that is available for consumptive use, including all consumptive use from the time of irrigation but excluding all loss of water by drainage below root level". Determination of field capacity on this basis was developed in a series of studies by Wilcox (1959, 1960, 1962a, 1962b) and was also adopted by Hensley and Sumner (1967) in a recent study of several sandy soils.

The lower limit is defined as the water percentage of a soil when plants growing in that soil are reduced to a wilted condition from which they cannot recover. Peters (1965) regarded the biological method as one of the 'oldest' techniques for determining the lower limit of available water and many studies have revealed that, especially in medium textured soils, the 15 bar percentage will sufficiently describe the permanent wilting point. Wilting point is not a true constant, or intrinsic soil property, since the point at which plants wilt is controlled by rate factors, both supply and demand, and not by a unique retention value. At high values of soil water retention, however, the rate of water movement becomes so slow as to give an apparent retention value controlling wilt (Peters, 1965).

In soil water-crop relationships it is necessary to consider that growth processes and transpiration are inhibited before the lower limit of availability is reached. The range of water content between the inception of wilting and the lower limit can be considerable and varies according to soil properties. Several workers have suggested that the initial, or incipient, wilting point lies between 5 bar and 9 bar percentages (Gardner, 1960b; Hensley & Sumner, 1967). On a similar basis Hill (1965) found it necessary to determine readily available moisture (RAM) which he considered to be a more realistic value for determining water duties for irrigation purposes. This is especially true for fine textured soils in climates of high evaporative demand.

The object of this study was to determine soil moisture characteristics for a wide range of soils that would aid the overall assessment of their agricultural potential. A quantitative evaluation of available moisture capacity was considered essential in view of the complete lack of information concerning this important criterion. At the time of study no data were available for any of the soil series in the Area or in the adjoining Tugela Basin. The need to study the water-holding capacity of various soil series had, however, been stressed by Phillips (1966) who considered it a valuable criterion in planning the development of rainfed and irrigation farming. The study should be viewed as a preliminary investigation, designed to afford a better understanding of the potential productivity of defined soil series. However, the results are not intended as a guide for calculating water duties in irrigation planning. A superficial investigation into the influence of land-use practice on soil moisture characteristics was also undertaken and for this purpose virgin and cultivated soil samples were included in the study. Despite recent developments in the techniques for studying soil moisture relationships, such as those suggested by Richards (1966), normal standard procedures were adopted. Sampling error is probably the most important limitation of the experimental procedure.

1) Materials and methods

Twenty-six soil series, represented by 51 profiles, were included in the study. Some of the selected profiles were sited in the Tugela Basin and in a number of cases only one modal profile per series was sampled. All samples were collected during August and included undisturbed core samples (4" x 3") and disturbed samples from depths of 6 and 18 inches. Disturbed samples were also collected from selected virgin and cultivated soils. All samples were transported in air-tight containers to the laboratory.

The undisturbed and disturbed samples were saturated for 48 and 16 hours respectively, prior to the determinations. In the case of the ESTCOURT, RENSBURG and Emmaus series it was necessary to saturate the core samples under vacuum (Richards, 1965). The undisturbed samples were used to determine the upper range of matric suction using a tension table similar in design to that described by Hosegood (1963). A cover of plastic sheeting was found to be essential for the accurate determination of the point of equilibrium. Samples were transferred to pressure plate extractors to determine the 0.33 and 1.0 bar values.

Disturbed samples were used to determine the lower range of the moisture characteristic curve using pressure membrane extractors with mercury differential regulators. The use of disturbed samples for moisture determinations is open to criticism since Hill (1965) found such samples provided an optimistic value for TAM. In the case of the lower limit, however, it can be noted that Wilcox (1960) found the 15 bar pressure membrane determination to be satisfactory. The determinations were carried out at room temperature over a period during which the mean maximum and minimum temperatures were 26^{o}C and 23.3^{o}C respectively. At the conclusion of the determinations all samples were dried to constant weight at 105^{o}C. Details of the matric suction values determined, the apparatus used and the type of sample studied are shown in Table 21.

Moisture percentage values at a standard matric suction of 0.10

Table 21 : Matric suction values, apparatus and samples used for determining soil moisture characteristics

Matric suction (bars)	Apparatus	Samples
0.01 0.04 0.10	Tension table	Undisturbed cores
0.33 1.00	Pressure plate extractor	Undisturbed cores
1.00 2.00 5.00 10.00 15.00	Pressure membrane extractor with mercury differential regulator	Disturbed samples

bars were taken as the upper limit for the calculation of TAM. The 15 bar percentages represented the lower limit. Total available moisture content per unit depth of soil and expressed on a volume basis was calculated for all samples in the following manner:

$$\text{TAM (inches/ft)} = 12(Pw)(pB)(1/pw) \quad (4)$$

where Pw = % water on an oven dry basis, pB = bulk density (gcm^{-3}) and Pw = density of water. Values for RAM were also calculated using the 5 bar percentage values as the lower limit.

The disturbed virgin and cultivated soil samples were passed through a ¼ mm mesh sieve before the 0.10 bar and 15 bar percentage values were determined on the tension table and pressure membrane extractor respectively. The organic carbon content of these samples was also determined using the Walkley Black method as described by Allison (1965). Furthermore, the moisture percentages of the undisturbed core samples at the time of sampling were calculated and, by interpolation from the moisture characteristic curves, the matric suction values obtained.

2) Results and discussion

Considerable difficulty was encountered in preparing the undisturbed samples of the claypan and margalitic soils. Preparation of a satisfactory contact surface without sealing the pore spaces proved particularly difficult. For this reason, the results of the ESTCOURT, RENSBURG and, to some extent, Cranwell series should be viewed with caution. In addition, free living nematodes and other soil micro-organisms were found in samples equilibrated for long periods of time, especially among the highly leached soils. Since these could influence moisture extraction, the fumigation of samples prior to equilibration is strongly recommended.

Large core samples are generally unsuitable for a study of this nature since the period of equilibration, particularly in the pressure plate extractors, may take four to five weeks for each determination. Hill (1965), in fact, found that equilibration time increases with the square of the height of the sample. For this reason, the use of smaller samples is recommended where large numbers of determinations are to be made. Since it is doubtful whether the contact between the samples and the porous plate is always satisfactory, the use of Tempe pressure cells developed at the U.S. Water Conservation Laboratory, Tempe, Arizona are recommended for this type of study. The use of natural soil clods coated with saran resin could also have distinct advantage over undisturbed cores since it would avoid the problems of shattering and compaction when sampling, facilitate sampling of stony soils and provide reliable bulk density values for soils of high swell-shrink potential.

(a) Series characterization

The values of TAM and RAM for topsoil and subsoil horizons of selected soils are presented in Table 22. The moisture characteristic curves for several of these are illustrated in Appendix 7.

To summarize the results and the writer's personal appreciation of the moisture characteristics of the soils studied, a general rating on a five-point scale is presented in Table 23. Combined topsoil and subsoil TAM values are used for this purpose.

The most striking feature of Tables 22 and 23 is the broad

Table 22 : Total and readily available moisture values for selected soil series*

Soil asstn.	Soil series	Profile No.	Total available moisture (TAM) inches			Readily available moisture (RAM) inches		
			Topsoil 0-12"	Subsoil 12-24"	Total	Topsoil 0-12"	Subsoil 12-24"	Total
A1	BALMORAL	1	2.06	2.49	4.55	1.78	2.28	4.06
		2	2.38	1.97	4.35	2.05	1.83	3.88
		3	2.28	2.15	4.43	2.01	1.93	3.94
A2	Broadmoor	4	2.77	2.65	5.42	2.41	2.52	4.96
	HUTTON	5	2.71	2.43	5.14	2.34	2.23	4.57
B1	FARMHILL	6	2.55	2.65	5.20	2.14	2.49	4.63
		7	2.85	2.74	5.59	2.58	2.45	5.03
	Lidgetton	8	2.21	2.30	4.51	1.76	2.00	3.76
		9	2.15	2.30	4.45	1.85	2.16	4.01
		10	2.94	2.05	4.99	2.69	1.64	4.33
	GRIFFIN	11	2.99	2.88	5.78	2.58	2.74	5.32
		12	3.55	2.61	6.16	3.32	2.39	5.71
	GRIFFIN (humic)	13	4.19	4.05	8.24	3.93	3.79	7.72
		14	1.85	1.85	3.70	1.51	1.63	3.14
	Cranwell	15	1.07	1.89	2.96	0.70	0.83	1.53
		16	2.02	0.81	2.83	1.55	0.26	1.81
	CLOVELLY	17	2.73	1.89	4.62	2.31	1.66	3.97
	CLOVELLY (humic)	18	4.02	2.82	6.84	3.63	2.46	6.09
		19	4.71	3.99	8.70	4.46	3.74	8.20
B2	CLEVELAND	20	3.67	2.89	6.56	3.38	2.71	6.09
D1	Weston	21	1.95	1.78	3.73	1.66	1.64	3.30
	SHORTLANDS	22	1.23	1.49	2.27	0.87	1.15	2.02
		23	1.85	1.42	3.27	1.51	1.12	2.63
	Bellevue	24	1.44	1.50	2.94	1.16	1.32	2.48
		25	1.36	0.67	2.03	1.13	0.26	1.39
		26	1.36	1.21	2.57	1.15	1.02	2.17
D2	Jagersdrift	27	1.43	1.17	2.60	1.34	1.07	2.41
D3	Loskop	28	2.37	2.03	4.40	1.89	1.72	3.61
		29	1.61	1.77	3.38	1.45	1.51	2.96
E1	BERGVILLE	30	1.76	1.84	3.60	1.48	1.58	3.06
		31	1.77	1.64	3.41	1.49	1.39	2.88
		32	1.56	1.74	3.30	1.32	1.41	2.73
	AVALON	33	1.77	1.78	3.55	1.55	1.54	3.09
		34	1.92	1.51	3.43	1.67	1.28	2.95
		35	1.97	1.47	3.44	1.63	1.21	2.84
	SOUTHWOLD	36	2.12	1.78	3.90	1.68	1.46	3.14
	Shendon	37	2.13	1.99	4.12	1.78	1.64	3.42
	ARROCHAR	38	2.15	1.65	3.80	1.80	1.34	3.14
		39	2.98	2.27	5.25	2.60	1.92	4.52
		40	2.23	-	(2.23)	1.92	-	1.92
E3	Melrose	41	1.35	1.57	2.92	1.24	1.41	2.65
	LEKSAND variant	42	1.52	1.56	3.08	1.37	1.41	2.78
	SPRINGFIELD	43	1.57	1.31	2.88	1.39	1.14	2.53
F1	ESTCOURT	44	1.99	1.04	3.03	1.46	0.74	2.20
		45	1.98	0.81 (0.78)	2.79 (2.76)	1.57	0.37	1.94
		46	1.93	1.29	3.22	1.66	0.89	2.55
G2	RENSBURG	47	1.88	1.80	3.68	1.26	1.17	2.43
		48	1.41 (1.35)	1.25 (1.17)	2.66 (2.52)	1.35	1.02	2.37
		49	1.20 (1.15)	1.45 (1.35)	2.65 (2.50)	0.83	0.87	1.70
C1	IVANHOE	50	3.91	4.92	8.83	3.52	4.41	7.93
H1	Emmaus	51	1.62	1.68	3.30	1.02	0.93	1.95

* Values bracketed adjusted for bulk density at 100 cm tension

Table 23 : A tentative rating of selected soils in terms of available moisture capacity (TAM)

Soil rating	Soil series
Very high (TAM > 5"/2 ft)	FARMHILL, GRIFFIN, CLOVELLY (humic), Broadmoor, HUTTON, CLEVELAND, IVANHOE
High (TAM 4-5"/2 ft)	BALMORAL, Lidgetton, CLOVELLY
Moderate (TAM 3-4"/2 ft)	Weston, Loskop, BERGVILLE, AVALON, SOUTHWOLD, Shandon, Emmaus
Low (TAM 2-3"/2 ft)	Cranwell, SHORTLANDS, Bellevue, ARROCHAR, Jagersdrift, Melrose, LEKSAND, SPRINGFIELD, ESTCOURT, RENSBURG
Very low (TAM < 2"/2 ft)	—

division of the soils coincident with the degree of leaching. In general, the highly leached soils have very favourable moisture characteristics. With the exception of the Cranwell series, all of these soils are rated high or very high. The extremely favourable characteristics of the A2- and B2-association soils are especially noteworthy.

In contrast, the considerably to moderately leached soils all fall within the moderate to low ratings. Generally, the E1-association soils have slightly higher values than soils of the D1-association although, on the basis of other criteria, the latter soils usually enjoy a higher potential rating. This is important in evaluating productive capacity of soils associated with a sub-humid climate. The 'low' rating given to the ARROCHAR series is a result of its usually shallow depth. The similarity between the topsoil samples of the SOUTHWOLD (profile 36), Shandon (profile 37) and ARROCHAR (profile 38) series, all situated in the vicinity of Mooi River, signifies uniformity in topsoil characteristic among these soils.

The marked difference between the highly and partially leached soils is attributed to two main properties viz., organic matter status and porosity. Values for both of these characteristics are highest in the former soils. TAM values for the topsoil samples are highly correlated ($r = 0.737^{***}$) with total porosity. Studies conducted by Hill (1965) endorse the view held by many workers that the geometry of the porous system is one of the main factors influencing soil water retention.

RAM values for clayey soils are between 60 - 75 percent of TAM and for loamy and sandy soils are 80 - 90 percent of TAM. Corresponding values reported by Hill (1965) were 50 percent and 75 percent although, in his case, the lower limit was taken at a matric suction of 2.0 bars. Obviously, the clayey soils will cause incipient wilting before those of lighter texture, especially in areas of high evaporative demand.

The ratings in Table 23 do not reveal other important features of the moisture characteristics. For instance, the SHORTLANDS and Jagersdrift series are both rated 'low'. Yet, because of inherent morphological properties, the moisture characteristic curves for these soils are very different (Appendix 7). Furthermore, the combined topsoil and subsoil TAM values do not reflect important differences between horizons. For example, the TAM values and characteristic curves of the BERGVILLE and Melrose series clearly indicate that the subsoil horizons have very favourable moisture characteristics. Such improved moisture conditions in lower horizons are probably related to the increase in clay content and improved porosity with depth. Hensley and Sumner (1967) reported similar results which they attributed to the increase in the clay and silt fractions. Soils such as these may thus have a higher potential for crop production than soils showing little or no improvement in moisture characteristics with depth. This is, in fact, confirmed by crop performance on soils of the AVALON form. Tillage practices that enhance intake and transmission of water to these lower horizons are thus recommended.

The favourable influence of organic matter on moisture characteristics is clearly illustrated by the high topsoil values (exceeding 4 inches/ft) of the humic phase soils of the GRIFFIN and CLOVELLY series.

The view expressed by Salter and Howarth (1961b), that the intimate association of organic matter with soil particles improves the porous structure of aggregates resulting in more pores of the right size for holding available water, offers a reasonable explanation for this finding.

Textural differences between soils in the same landscape are also reflected by the moisture characteristics. A comparison between the BALMORAL, Lidgetton and Cranwell series on the one hand and the Broadmoor, GRIFFIN and CLOVELLY series respectively on the other, shows that the moisture characteristics of the latter group are the most favourable. Although the 0.1 bar moisture percentages for both groups are similar, the 15 bar values are higher in the case of clayey soils and result in lower TAM values. Generally, the values given in Table 22 are higher than the typical values of 0.5 - 1.0 inches/ft for coarse textured soils, 1.2 - 2.0 inches/ft for fine textured clays and 1.5 - 2.5 inches/ft for intermediate textures given by Hubble, Martin, Isbell, Beckwith and Stirk (1964).

The characteristic curves for soils of the D1- and G2-association soils indicate problems with respect to rate of moisture supply. Since these soils are associated with climates of high evaporative demand, the unfavourable moisture characteristics are among their most serious limitations. This view is substantiated by Hill (1965) who found that sugar cane yields on fine textured soils showed a linear response to the amount of water applied, while for coarse textured soils, the response was curvilinear. Although the potential increase in yield over dryland production was greatest on the clayey soils, plants were found to suffer water deficits long before the wilting point had been reached. Despite the use of disturbed samples for the 15 bar determinations, the TAM values for the red, doleritic soils (e.g. SHORTLANDS) in Table 22 are similar to those obtained by Thompson and Collings (1963) and Hill (1965).

Today, irrigation practice is receiving much attention throughout the Area so that the need for intensive studies similar to those conducted by Hill (1965) is great. Grass-clover pastures, lucerne and a variety of winter fodder crops, including ryegrass, are among the most important crops requiring investigation. In the absence of more detailed information the results of this study provide a basis for assessing the irrigation potential of the various soils. When considering irrigation practice it should be noted that Stanhill (1957), in a review of soil moisture experiments, concluded that highest yields are associated with the wettest regimes. As a group, the highly leached soils are particularly favourable for irrigation although shallow, clayey soils such as the Cranwell series have obvious limitations. The loamy A2- and B2-association soils are the most suitable. Among the partially leached soils, textural characteristics are important. The clayey D1- and G2-association soils, for instance, require frequent irrigation resulting in high costs. Soils most likely to give maximum economic returns for lesser amounts of water applied are to be found among the well-drained loamy to sandy soils of the D2-, E1-, E3- and L1-associations.

Matric suction values interpolated for the time of sampling (end of winter) indicate several interesting features. For instance, the average values for topsoil and subsoil samples of the highly leached group are approximately 0.5 to 1.0 bars and 0.3 bars respectively. Excluding the claypan and margalitic soils, a similar trend is observed among the partially leached soils although the suction values are much greater i.e. between 5 - 10 bars and 1 - 2 bars respectively. Extremely dry conditions in the margalitic and claypan soils at the end of winter are indicated by suction values of between 10 and 15 bars.

These results substantiate the claims that climate, through its influence of the moisture regime, is closely related to the leaching process. They suggest conditions of water surplus and water deficiency among the highly and moderately leached soils respectively. In addition, they offer reasonable explanation for the early spring growth of natural grassland in the Highland Sourveld and Midlands Mistbelt areas.

Because the samples were collected in August prior to the spring rains the results also support the claim that veld burning should take place only after adequate rain. In no case did the suction values for topsoil samples indicate moisture conditions favourable for optimum growth.

(b) Land-use practice and soil moisture characteristics

The results for the paired virgin and cultivated samples reveal that cultivation, mainly through its influence on organic matter status and structure, can alter moisture characteristics appreciably. From the 0.1 bar and 15 bar values the available moisture percentages were calculated. The relationship between these values and organic carbon content is presented in Table 24.

Table 24 : Relationship between available moisture (%) and organic carbon content (%) for selected virgin and cultivated soils

Soil series	Virgin soils		Cultivated soils	
	Available moisture %	Organic carbon %	Available moisture %	Organic carbon %
BALMORAL	45.2	4.7	42.7	2.8
FARMHILL	32.3	5.1	25.4	4.6
CLOVELLY (humic)	53.2	7.8	51.6	5.9
Bellevue	41.3	2.5	27.7	2.0
AVALON	31.1	1.4	24.7	0.9
ARROCHAR	37.7	2.3	29.5	1.4
LEKSAND variant	24.3	1.4	12.5	0.6
Ladysmith	31.6	1.6	24.1	0.8

The reduction in both organic carbon content and available moisture percentage following cultivation is clearly reflected in the values obtained. The effect is greatest among the partially leached soils. The results also suggest that the effect of organic carbon on moisture content is particularly marked at the upper limit viz., 0.1 bar. Salter and Howarth (1961b), who attributed the failure of many studies to detect the influence of organic matter on available moisture to limitations of the techniques used, reported a significant increase in available moisture capacity following the application of farmyard manure. This increase was attributed to the improved organic matter status.

Despite the preliminary nature of this investigation the writer advocates land-use practices aimed at improving the organic matter status of arable soils. Thus, the use of well fertilized leys, manuring and the return of crop residues seem justified, especially in the drier landscapes. Notwithstanding important fertility relationships, it is suggested that the resulting yield increases could be attributed, at least partially, to improved moisture characteristics and water intake.

2.4 Other physical characteristics

Soil samples included in the study of soil moisture characteristics were used to determine several other characteristics that provide additional criteria for characterizing and assessing the soil resources. These properties, the methods used to determine them and the results obtained, are briefly discussed.

1) Bulk density and particle density

Soil bulk density is the ratio of the mass to the bulk or macroscopic volume of soil particles plus the pore spaces (Blake, 1965). It is a parameter used for several purposes including the calculation of the moisture content of soils on a volume basis. Bulk density values were determined using undisturbed core samples. Mass was obtained by drying to constant weight at 105°C. Volume was that of the sample taken in the field. Particle density, or the density of the solid particles collectively, was determined by the pycnometer method described by Blake (1965).

Results obtained for both characteristics are presented in Table 25.

Since it is generally accepted that 'moist' volumes are preferable for soils showing marked volume change with change in moisture content,

Table 25 : Bulk density and particle density values for selected soil series

Soil asstn.	Soil series	Profile No.	Bulk density				Particle density	
			(gcm^{-3})		(lbs ft^{-3})		(gcm^{-3})	
			Topsoil 6"	Subsoil 18"	Topsoil 6"	Subsoil 18"	Topsoil 6"	Subsoil 18"
A1	BALMORAL	1	1.146	1.112	71.5	69.4	2.54	2.57
		2	0.881	1.044	55.0	65.1	2.45	2.58
		3	1.184	1.275	73.9	79.6	2.52	2.53
A2	Broadmoor	4	1.020	1.102	63.6	68.8	2.45	2.56
	HUTTON	5	1.038	1.115	64.8	69.6	2.41	2.55
B1	FARMHILL	6	1.069	1.138	66.7	71.0	2.36	2.58
		7	0.697	1.030	43.5	64.3	2.30	2.48
	Lidgetton	8	1.090	1.187	68.0	74.1	2.38	2.55
		9	1.028	1.188	64.1	74.1	2.49	2.63
		10	0.955	1.250	59.6	78.0	2.39	2.64
	GRIFFIN	11	1.010	1.083	63.0	67.6	2.40	2.55
		12	0.970	0.886	60.5	55.3	2.42	2.52
	GRIFFIN (humic)	13	0.756	0.986	47.2	61.5	2.34	2.51
		14	1.305	1.330	81.4	83.0	2.43	2.58
	Cranwell	15	1.218	1.386	76.0	86.5	2.53	2.69
		16	1.161	1.355	72.4	84.6	2.43	2.55
	CLOVELLY	17	1.122	1.212	70.0	75.6	2.38	2.57
	CLOVELLY (humic)	18	0.890	1.210	55.5	75.5	2.22	2.50
		19	0.838	0.875	52.3	54.6	2.34	2.42
B2	CLEVELAND	20	1.159	1.288	72.3	80.4	2.54	2.58
D1	Weston	21	1.371	1.227	85.6	76.6	2.58	2.61
	SHORTLANDS	22	1.260	1.284	78.6	80.1	2.47	2.46
		23	1.824	1.264	80.1	78.9	2.45	2.55
	Bellevue	24	1.498	1.350	93.5	84.2	2.58	2.61
		25	1.667	1.617	104.0	100.9	2.57	2.63
		26	1.640	1.568	102.3	97.8	2.58	2.55
D2	Jagersdrift	27	1.584	1.541	98.8	96.2	2.64	2.53
D3	Loskop	28	1.283	1.283	80.7	80.1	2.45	2.44
		29	1.279	1.279	81.8	79.8	2.62	2.65
E1	BERGVILLE	30	1.494	1.349	93.2	84.2	2.59	2.62
		31	1.435	1.470	89.5	91.7	2.50	2.57
		32	1.484	1.430	92.6	89.2	2.48	2.53
	AVALON	33	1.706	1.450	106.5	90.5	2.61	2.62
		34	1.698	1.676	105.9	104.6	2.59	2.61
		35	1.348	1.406	84.1	87.7	2.51	2.59
	SOUTHWOLD	36	1.607	1.557	100.3	97.2	2.56	2.60
	Shandon	37	1.672	1.576	100.4	98.3	2.56	2.60
	ARROCHAR	38	1.688	1.663	105.3	103.8	2.61	2.65
		39	1.494	1.620	93.2	101.1	2.59	2.65
		40	1.593	-	99.4	-	2.58	-
E3	Melrose	41	1.707	1.398	106.5	87.2	2.63	2.61
	LEKSAND variant	42	1.605	1.609	100.2	100.4	2.62	2.64
	SPRINGFIELD	43	1.561	1.666	97.4	104.0	2.58	2.62
F1	ESTCOURT	44	1.485	1.581	92.7	98.7	2.65	2.47
		45	1.520	1.620 (1.561)	94.8	101.1 (97.4)	2.52	2.49
		46	1.537	1.335	95.9	95.8	2.58	2.49
G2	RENSBURG	47	1.352	1.491	84.4	93.0	2.37	2.44
		48	1.488 (1.425)	1.434 (1.352)	92.9 (88.9)	89.5 (84.4)	2.47	2.61
		49	1.[illegible]9 (1.350)	1.565 (1.452)	87.9 (84.2)	97.7 (90.6)	2.58	2.4[illegible]
C1	IVANHOE	50	0.510	0.776	31.8	48.4	2.11	2.27
H1	Emmaus	51	1.198	1.354	74.8	84.5	2.42	2.49

Values bracketed corrected to bulk density at 100 cm tension corrected bulk density values at field moisture capacity (0.10 bars) for the RENSBURG and ESTCOURT series are presented. The corrected values indicate that natural bulk density values tend to be 4 - 8% higher than the corrected values. A more precise method for correcting bulk density values to field capacity moisture has been described by Miller (1966).

The results indicate considerable variation between series and a marked difference between highly leached and partially leached soils is again obvious. The range of the former group is from 0.75 to 1.30gcm^{-3}, while values for the latter group fall between 1.20 and 1.80 gcm^{-3}. The influence of the higher organic carbon content and greater porosity of the highly leached soils is reflected in the lower values for the group; especially the humic phase soils and the IVANHOE series.

According to Baver (1956) percolation becomes slow when bulk density values exceed 1.4 - 1.5gcm^{-3}. On this basis, water movement in the majority of partially leached soils is likely to be slower than in the highly leached group. In some respects this inference is substantiated by other morphological characteristics, but does not hold for all soils.

Textural differences between series are also reflected in the values obtained. The sand fraction, as expected, increases bulk density values. For example, the subsoil value of the LEKSAND series (1.609gcm^{-3}) is considerably higher than that of the Melrose series (1.398gcm^{-3}).

Several workers have given theoretical consideration to the geometry of the porous system, stressing the importance of bulk density in affecting moisture characteristics and the derived TAM values (Hill, 1965; Box & Taylor, 1962; Taylor & Box, 1961). Practical implications were also reported by Hill (1965) who found that changing the bulk density and reducing the number of macro-pores affected moisture characteristics, infiltration and percolation. The effect on the moisture retention of sands was greatest at low suction values while with clays and clay loams an effect was exerted over the whole moisture range but especially at the 15 bar percentage. From this it is suggested that problems of compaction resulting from various farming operations will be greatest among soils of the El-, Hl- and clayey Ll-association soils.

The bulk density parameter can, however, have limited usefulness (Hubble et al., 1964). Glover (1967) also found that bulk density, as such, was not a factor controlling differential root behaviour. Rather, it was 'penetrability' of the soil that was correlated to root development. Generalized bulk density values for root impedence of sunflowers presented by Veihmeyer and Hendrickson (1948) were 1.45 - 1.65gcm^{-3} for clayey soils and 1.70 - 1.80gcm^{-3} for sandy soils. On this basis only the partially leached soils are likely to be associated with problems of this nature. Values for particle density show little variation between soils although the influence of organic carbon is evident from the topsoil values of the highly leached soils. These are generally lower than the subsoil values.

2) Soil porosity and pore-size distribution

Knowledge of the geometry of the porous system is essential for the assessment of moisture characteristics. Hubble et al. (1964) considered the total amount and distribution of soil pores as the most significant physical property for plant growth since they control the availability of water and air. Soil porosity is that percentage of the soil volume which is not occupied by solid particles. The fact that bulk density is always lower than particle density, indicates that only part of the bulk volume is occupied by solid particles, the remainder is pore space. Total porosity determinations yield the simplest partial characterization of the soil pore system but are of limited utility.

The relative distribution of pore sizes, especially the non-capillary and capillary porosity as defined by Baver (1956), is of considerable value for characterizing the structural properties of soils. Ideally the pore space should be equally divided between large and small pores. However, current use of pore-size distribution as a soil characteristic depends on the acceptance of the capillary model as representing soil pore space (Vomocil, 1965).

Essentially, pore size distribution is the determination of the value of air-filled pores at specified matric suction values. Soil moisture characteristics thus help to define soil pore-size distribution, provided the volume of the soil does not alter with change in moisture content.

Total porosity was determined for all undisturbed core samples as follows:

$$\text{Total porosity } (\%) = 100[1 - (Bd/Pd)] \qquad (5)$$

where Bd = bulk density and Pd = particle density.

The tension table method described by Vomocil (1965) was used to determine the volume percentage of air-filled pores at a suction value of 0.1 bars. This determination represents non-capillary porosity. The values for total porosity, non-capillary porosity and capillary porosity are presented in Table 26. Diagrammatic representation of these values for selected soils are also illustrated in Appendix 8.

Once again the favourable physical characteristics of the highly leached soils are indicated by relatively high total porosity values. These values, which lie mostly between 50 and 60 percent, help to explain the favourable moisture characteristics obtained for these soils. In contrast, the values of many partially leached soils are between 45 and 55 percent. The results are in general agreement with those reported by Sumner (1957) and indicate that several members of the E1-association are among the most compact soils in the Area. The results of the RENSBURG and ESTCOURT series are considerably influenced by their high swell-shrink potential. Pore-size distribution values obtained for the loamy and sandy soils of the A2-, B2-, D2 and E3-associations, though not ideal, indicate the favourable physical characteristics of these light textured soils.

The series definitions presented by van der Eyk (1965c) include

Table 26 : Total porosity and pore size distribution for selected soil series

Soil asstn.	Soil series	Profile No.	Total porosity (%)		Non-capillary porosity (% air filled pores at 100 cm)		Capillary porosity (%)		Porosity rating
			6"	18"	6"	18"	6"	18"	
A1	BALMORAL	1	54.9	56.7	12.0	10.2	42.9	46.5	
		2	64.1	59.5	25.0	22.5	39.1	37.0	H
		3	53.0	49.6	15.9	12.1	37.1	37.5	
A1	Broadmoor	4	58.4	57.0	18.0	18.9	40.4	38.1	H
	HUTTON	5	56.9	56.3	15.2	19.6	41.7	36.7	H
B1	FARMHILL	6	54.7	55.9	5.3	7.1	49.4	48.8	H
		7	69.7	58.8	24.4	9.3	45.3	49.2	
	Lidgetton	8	54.2	53.5	7.7	5.8	46.5	47.7	
		9	58.7	54.8	14.0	6.8	44.7	48.0	H
		10	60.0	52.7	6.2	5.7	53.8	47.0	
	GRIFFIN	11	57.9	57.5	13.7	15.8	44.2	41.7	
		12	59.9	64.9	9.0	26.6	50.9	38.3	H-VH
	GRIFFIN (humic)	13	66.3	60.7	8.6	8.6	57.7	52.1	
		14	46.3	48.5	12.5	15.4	33.8	33.1	
	Cranwell	15	51.9	48.5	6.8	2.7	45.1	45.8	M-H
		16	52.2	46.9	10.5	7.9	41.7	39.0	
	CLOVELLY	17	52.9	62.9	9.6	17.9	43.3	35.0	
	CLOVELLY (humic)	18	59.9	51.6	2.8	6.1	57.1	45.5	H-VH
		19	64.2	63.9	6.9	12.6	57.3	51.3	
B2	CLEVELAND	20	54.2	50.1	12.1	12.1	42.1	38.0	H
D1	Weston	21	46.9	53.0	7.3	18.4	39.6	34.6	M-L
	SHORTLANDS	22	49.0	47.8	9.6	3.8	39.4	44.0	M
		23	47.6	50.4	5.5	12.3	42.1	38.1	
	Bellevue	24	41.9	48.7	11.4	17.1	30.5	31.6	
		25	35.1	38.6	4.0	12.4	31.1	26.2	M-L
		26	35.4	38.5	7.1	9.5	29.3	29.0	
D2	Jagersdrift	27	40.0	39.1	21.5	18.0	18.5	21.1	M
D3	Loskop	28	47.2	47.4	5.7	8.0	41.5	39.4	M-H
		29	50.0	51.7	12.3	15.2	37.7	36.5	
E1	BERGVILLE	30	42.1	48.5	10.0	13.8	32.1	34.7	
		31	42.6	42.8	13.0	11.7	29.6	31.1	M
		32	40.2	43.5	4.7	9.1	35.5	34.4	
	AVALON	33	34.6	44.7	10.7	17.0	23.9	27.7	
		34	34.5	35.8	8.0	10.7	26.5	25.1	M-L
		35	46.3	45.7	14.8	14.9	31.5	30.8	
	SOUTHWOLD	36	37.3	40.1	2.1	8.2	34.7	31.9	L
	Shandon	37	34.7	39.4	6.2	13.0	28.5	26.4	L
	ARROCHAR	38	35.3	37.3	4.8	11.3	30.5	21.8	
		39	42.3	38.9	7.5	10.2	34.8	28.7	L
		40	39.7	-	4.9	-	34.8	-	
E3	Melrose	41	35.1	46.4	14.3	20.2	20.8	26.2	L-M
	LEKSAND variant	42	38.8	39.1	18.5	17.3	20.3	21.8	L-M
	SPRINGFIELD	43	39.5	36.4	18.1	15.1	21.4	21.3	L-M
F1	ESTCOURT	44	42.0	36.0	10.4	-	31.6	-	
		45	39.7	37.3*	10.5	16.5	29.2	20.8	L
		46	40.4	38.4	16.2	-	24.2	-	
G2	RENSBURG	47	42.9	38.9	1.1	-	41.8	-	
		48	42.3*	48.2*	0.2	5.6	32.1	42.6	M
		49	42.8*	39.3*	5.2	-	37.6	-	
C1	IVANHOE	50	75.8	65.8	19.1	0.6	56.7	65.2	VH
H1	Emmaus	51	50.0	51.7	12.3	15.2	37.7	36.5	M

VH - Very high, H - High, M - Moderate, L - Low, VL - Very low

* Corrected volume at 100 cm tension

Plate 8. Surface crusting of E_1 - association soils (SOUTHWOLD series). Note occurrence of pigweed (Amaranthus hybridus).

Plate 9. Cloddiness associated with E_1 - association soils (SOUTHWOLD series).

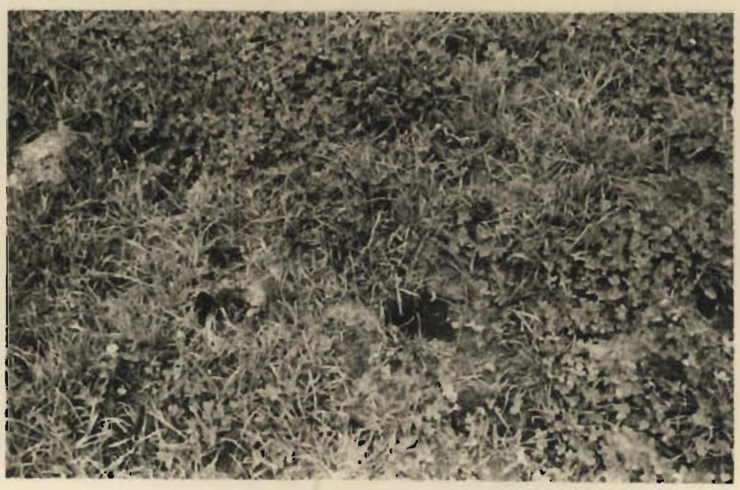

Plate 10. Puddling on E_1 - association soils as a result of grazing immediately after rain (ARROCHAR series).

an appreciation of soil porosity, estimated primarily through consideration of other physical characteristics. These estimates were found to be very similar to the ratings presented in Table 26, which are based on the following total porosity values:

Porosity rating	Total porosity (%)
Very high	Over 60
High	50 - 60
Moderate	40 - 50
Low	30 - 40
Very low	less than 30

Slight departures from the series definitions are noted among soils of the E1-association. Several of these, defined by van der Eyk (1965c) as very or moderately porous, are rated moderate to low according to the above scale. Total porosity values for the BERGVILLE and AVALON series increase very slightly with depth although, according to definition, the reverse is true.

3) Modulus of rupture

The unfavourable physical characteristics of many of the partially leached soils has previously been mentioned. Surface soil limitations such as crusting, puddling when wet and the tendency to form clods are features of many soils belonging to the E1- and F1-associations, as can be seen in Plates 8, 9 and 10. Such limitations affect tillage, seedbed preparation, germination, infiltration and run-off. An attempt was thus made to characterize those soils exhibiting cohesion or 'cementing' on drying. Modulus of rupture is a parameter used extensively for predicting the strength of materials and evaluating the cohesion of dry soils. The method described by Reeve (1965) was used in this investigation.

Eight soils each of the highly and partially leached groups were selected for evaluation. The tests were applied to sieved A1-horizon samples collected from modal test pits and five replicate samples from each soil were included. The results are presented in Table 27.

Table 27 : Mean values of modulus of rupture (millibars) for selected soil series

Highly leached soils		Partially leached soils	
Soil series	Modulus of rupture (millibars)	Soil series	Modulus of rupture (millibars)
BALMORAL	-	SHORTLANDS	362
HUTTON	-	Bellevue	454
FARMHILL	-	Jagersdrift	567
Lidgetton	-	AVALON	1044
GRIFFIN	-	SOUTHWOLD	900
GRIFFIN (humic)	-	SPRINGFIELD	390
CLOVELLY	116	ESTCOURT	6086
CLEVELAND	-	RENSBURG	5540

Marked differences in physical characteristics between the two groups of soils are clearly illustrated in Table 27. In only one instance (CLOVELLY) was it possible to make the necessary briquets from the highly leached soil samples. The high organic matter status, exceeding 2 percent organic carbon in every case, and the textural properties of these soils were the main factors preventing the evaluation. None of the highly leached soils are thus associated with the aforementioned limitations.

Values were obtained for all the partially leached soils studied. Those of the E1-association soils are considerably higher than those of the D1-association soils and are in keeping with field observations. The cohesive tendencies common to the AVALON and SOUTHWOLD series are also clearly reflected in Table 27. The low value of the SPRINGFIELD series is attributed to its sandy texture. Low organic matter content and specific sand : silt : clay ratios which permit packing of fine particles within the framework of the sand fraction are mainly responsible for the cohesiveness of the grey-brown soils. In this study the problem could not be related to exchangeable sodium since low values were obtained for all the samples studied.

The results also indicate surface soil limitations of the claypan soils (e.g. ESTCOURT series). Although high values were obtained for the RENSBURG series the physical limitations of this soil are not of the same nature as those of the other soils studied. In this case, the high swell-shrink potential and self-mulching properties prevent crusting and cementation.

Raising the organic matter status through ley cropping or the incorporation of crop residues and manure will undoubtedly improve the unfavourable characteristics. Utilization of pastures and ley crops by grazing under wet conditions is, however, likely to cause severe 'poaching' as illustrated in Plate 10. The addition of large quantities of lime or gypsum to improve the unfavourable physical conditions is not recommended for the soils studied although the latter may be important for claypan soils.

CHAPTER 3

INTERPRETATION AND ASSESSMENT OF THE SOIL RESOURCES

This chapter attempts to give meaning to the survey data in the light of current knowledge. Because most of the assessments are perforce subjective many of the views expressed are likely to alter with time. The appraisals form the basis for discussion in the remaining chapters, especially Chapter 7.

3.1 Interpretation of soil survey data

A soil survey should mean more than simply a piece of scientific research (Vink, 1963). The data and their significance, including maximum information regarding land-use potentialities, should be made clear to those who might use it. With soil survey procedures well established in South Africa a sound policy of interpretation should be developed without delay. Ideally interpretation should be initiated early and should run concurrently with the survey phase, thus keeping the delay in establishing potentialities, limitations and management needs of the soils to a minimum (Galloway, 1966).

Interpretation, though it requires co-operative consultation between the survey team and many specialists, determines the success of soil survey projects. Its purpose is primarily to organize and present soil properties, qualities and behavioural characteristics in such a manner that the survey data may be used more effectively. Interpretations are generally given in terms of suitability for a specific use (e.g. good, fair, poor), limitations (e.g. slight, moderate, severe) or special soil features affecting use (e.g. permeability, available moisture capacity, etc.). In effect, it constitutes a simplification of the survey data. Assumptions or the conditions under which the interpretation is valid and its limitations in use, should also be made clear.

It is important here to consider several important principles. For instance, numerous interpretations can be made depending upon the specific field of interest. In each case soils are usually assembled in a few easily defined groups, the design of which will depend on their objective. According to Kellog (1951) those designed for one purpose can rarely be used for another and, moreover, a grouping for one objective cannot be used for the same purpose in a different institutional environment. Thus a particular soil can seldom be ranked in the same relative position in every interpretation (Meyer, Bender, Wenner & Rinier, 1966).

The increasing complexity of agriculture has created a demand for more precise interpretations (Klingebiel, 1963). In this respect, the specificity of any prediction of input need and expected output will, to a large extent, depend on the homogeneity of the soil units. Soil maps reflecting the lowest category of a classification system are thus particularly useful for interpretation and re-interpretation. Such maps, according to Riecken (1962), permit specific evaluation of the incremental effects of vertical application of technology. This he defined as appropriate yield-increasing inputs on an homogeneous soil situation. Soil series are, therefore, regarded as the most suitable basis for assessing and interpreting the soil resources of the Area. However, although most interpretations are best displayed through interpretive soil maps, presentation in map form has not been possible in this study because of the small scale of the available map.

According to Oschwald (1966) soil survey interpretation includes both analysis and synthesis of the survey data. Analysis is the separation or 'tearing apart' of the landscape into its homogeneous component parts and the determination of all relevant information concerning each part. Synthesis on the other hand is to 'in-gather' or synthesize the component parts into contiguous soil-use areas. Synthesis of information concerning the response of vertical technology is included in this phase. Its importance lies in the fact that the farmer uses a segment of space rather than individual component parts. The need for synthesis is stressed by Oschwald's statement that "the challenge of soil survey interpretation is to more adequately synthesize the component parts of soil landscapes into segments of space that are meaningful to the soil user in relation to the soil-use decisions he faces. The degree to which the challenge is met will determine how nearly soil survey interpretation attains the objective of identifying soil-use alternatives to help people make more rational soil-use decisions". This challenge should be met by research, including quantitative studies.

Synthesis has a special role to play at the farm level where soil patterns (especially among partially leached soils) are frequently too complex to reach the goal of "using each acre according to its needs and capability". The delineation of 'soil-use areas' at this level should take account of the size and shape of the mapping units, the restrictions imposed by erosion tolerance limits and the minimum area which has sufficient regularity of shape to permit differential treatment and efficiency in machine operations. An area of 5 to 10 acres is tentatively suggested as the probable lower size limit for such areas. In general, the effect of synthesis on crop production appraisals is to lower yield estimates by comparison with those made for individual soil units. Management of soil-use areas based on the soils of highest potential holds the danger that the remaining soils will be over-intensified and subsequently damaged.

In explaining interpretation Westin (1962) noted that the farmer may expect the survey data to answer several questions, viz., 1) what crops are adapted for my soils, and 2) what yields can be expected under alternative management systems? The answers to these queries on use-suitability and yield expectancy, lie in the accurate interpretation of the data based on findings that suggest the most logical and profitable use of particular soils.

Scientific advancement and the effect of management are important considerations. Technology can, in fact, exert a more powerful effect on the use-suitability and capability of a soil than its natural characteristics. For example, over half of the increase in agricultural production in the United States between 1935 and 1950 came from regions of naturally infertile soils and, perhaps one-tenth of it, from naturally fertile soils (Wilsie, 1962). Thus, soil has less influence over production levels at the present time than it did prior to the growth of scientific knowledge. However, in a primitive society, it may remain the most important factor. It is predicted that crop production in the Area will continually shift to the large, nearly level areas favouring mechanization, to the medium textured soils and to those soils responsive to large inputs of fertilizer.

Other principles to be considered in making interpretations were noted by Klingebiel (1962). For instance, the needs and resources of those who will use the information should be well understood. The greater the skill and resources available, the more precise and sound the interpretations should be since poor management decisions can be costly. Interpretations should also aim at compromising between simplicity and loss of usefulness. A grouping of soils invariably results in a loss in precision, yet it has the advantage of simplifying the mass of recorded data. However, a simple grouping of soils according to their suitability for crop, pasture or trees has important limitations since it tells nothing of the management needs. Interpretation is a continuous process required to keep pace with developments in technology Allowance should, therefore, be made for the refinement or reinterpretation of the data. In this respect, research and farmer experience have an important role to play (Kellog, 1951; Olsen, 1966).

3.2 Assessment of the soil resources

Interpretation requires careful assessment of each soil in terms of use-suitability, productive potential and management need. Before discussing the assessments of soils in the Area, a brief account is given of several methods of assessment and the most important soil criteria.

A number of terms are also defined.

Definitions and methods: It is evident from the literature that many terms such as 'capability' and 'productivity' have been loosely used and few attempts have been made to achieve universal clarity. To avoid confusion, therefore, several terms used regularly in the text are defined.

Capability refers to the potential or undeveloped properties of a soil for a specified use. It is determined by inherent characteristics and qualities and takes account of the prevailing environmental conditions.

Productivity is regarded as the capacity of a soil to produce crops in general, or one specific kind of crop, and is the result of the qualities of natural factors plus human labour or management (Jacks, 1946; Aandahl, 1960). It is partly an economic concept since without management the productivity from most soils is of little account. It assumes that vertical technology for a high level of management can be applied as needed, and that erosion control is such that the soil will yield economically without deterioration. Productive potential is generally expressed in terms of yield per unit area but is also a function of time (e.g. kg/ha/annum).

The term use-suitability indicates the suitability of a soil for a specified use. For example, a first rate pasture soil may be fourth rate for timber.

Fertility refers to the nutrient status of a soil or its ability to supply nutrients.

Many attempts have been made to arrive at a more objective and quantitative estimate of soil productivity. According to Jacks (1946), these include both inductive (marks awarded to soil properties) and deductive (deduced from yield data) methods or both. In the writer's opinion productivity ratings can only be of real value when based on long term yield data where the system and level of management are clearly defined. In the United States productivity ratings usually include two figures. These refer to yield, expressed as a percentage of a 'standard yield' determined in areas where the crop is a principal product, under 1) common practice and 2) the best current practice. A measure of soil response to good management is thus obtained. Since predicted yield values soon become outdated the use of single values, associated with the highest possible level of management, is worthy of consideration.

An example of an inductive method of soil rating is the Storie Index (Storie, 1933, 1959). This method purports to express numerically the comparative levels of suitability or agricultural value of soil and is based on characteristics that govern the land's potential utilization and productive capacity. It was used by Phillips (1966) to rate the soils of the Tugela Basin. In his opinion it provided no more than an index to the degree of suitability or value of a soil for general, intensive agriculture and did not serve as an index of evaluation of land itself.

Inductive methods have obvious limitations. The Storie Index, for example, relies on subjective percentage values accorded to selected profile, slope and other characteristics. However, there is no moisture factor which, if included, may provide a better index (Phillips, 1966). The values for defined soil series presented by Phillips suggest that the index favours the medium to light textured soils and, although the assessment of productive capacity may be realistic, the ratings have no clear relation to important limitations such as erosion hazard. It is not generally appreciated, however, that the Storie Index was developed primarily to assess irrigation potential and to evaluate land for taxation purposes.

In considering such methods the writer is inclined to agree with Schattenfroh (quoted by Jacks, 1946) who, in discussing a German rating system, stated that "the allotment of points for separate conditions must by its very nature be so subjective that the points can be regarded only as a rough guide. Only experience can teach the assessor his job."

Furthermore, he sides with Kellog (1951) who queried whether current knowledge was sufficiently developed to permit the satisfactory use of fixed schedules or 'score cards' for appraising soils.

Clarke (1951) provided a guide to the relative productivity of certain soils by evaluating the physical characteristics of profiles in the field and then determining yields of wheat on the different soils. Overall profile values were obtained by awarding values to texture, depth and drainage. In this study the correlation between yield and profile value was good.

In a quantitative approach to 'soil-suitability' developed in the Netherlands an interesting budgeting technique was used (Vink, 1960). In this case quantitative data were combined to show practical differences between soil types and the suitability of each soil was expressed in normalized monetary units. The crops grown, their yields and the fertilizer and other costs incurred for each soil are important requisites for this method.

Blagovidov (1960) suggested that qualitative differences between soils cannot be revealed by a comparison of yield data alone. He advocated that crop yield should, in fact, be regarded as a criterion for the correctness of soil evaluation. He suggested further that soil appraisal should take account of genetic, agronomic and geologic soil data and should be corrected by practical use on the farm. By this means, satisfactory correlations between appraisal classes and crop yields were established in the Ukraine.

Yield prediction is perhaps the most useful means of expressing soil productivity. Because of its importance it has received special consideration in this chapter. Land capability classification is also an important interpretive grouping of soils but is excluded from this discussion since it is treated separately in Chapter 7.

In the writer's opinion genetic soil classification is a prerequisite for any attempt to assess the soil resources of a region. Furthermore, soil-crop relationships, established under specified management practice, provide the only sound basis for soil evaluation as indicated by Murdoch (1965, 1968). Invariably, inductive methods have appeal since they avoid soil classification and untrained men can apply them. Nevertheless, their adoption cannot be strongly recommended even in the face of considerable delays in classifying soils, establishing soil-crop relationships and training personnel. Methods awarding marks to soil properties have been purposely avoided in this study.

Criteria for assessment: Criteria to be considered in making assessments differ markedly. For instance, assessments of cropland consider properties such as drainage, texture, depth and slope while engineering application criteria may include water tables, plasticity limits and swell-shrink potential, and many others. Assessments made for recreation must take into account criteria such as flooding, slope, texture, the presence of rocks and hazard of dust since they relate to limitations for that specific use. In some cases, such as road fills and earth embankment, assessments must be made of the disturbed soil material.

Criteria for evaluating soils for intensive arable use are of particular interest in this discussion and, for this purpose, the writer has evaluated the inherent permanent soil characteristics series by series. Although the tendency is to evaluate individual soil properties it is important that the profile be considered as a whole. Over-emphasis of single factors may result in other important criteria that may sometimes dominate the assessment being overlooked. Smits and Wiggers (1959), for example, found that the clay content of a young Zuiderzee soil was the most important factor in their classification of soil-suitability. Special note is made of van der Eyk's (1965c) 'gradationalism of properties with depth' since this feature is of considerable importance in evaluating soils of the E group.

Where soil-crop data are lacking assessment must inevitably lean heavily on an appraisal of physical characteristics and qualities. Due consideration must also be given to the associated climate since this may also become restrictive. The capability of a sandy soil, for example, will be higher in a humid region than in a drier region. A reduction in either moisture or temperature generally results in a reduction in soil capability (Vincent, 1959; Klingebiel & Montgomery, 1961).

A review of literature reveals numerous criteria and other factors to be considered for the interpretation of survey data. Those consistently listed for agricultural assessments include: 1) effective depth; 2) drainage; 3) available moisture capacity; 4) erosion hazard; 5) mechanical limitations; and 6) texture (Soil Survey Staff, 1951; Clarke, 1951; Hockensmith, 1958; Vincent, 1959; Storie, 1959; Thomas, 1960; Fed. Dept. Cons. & Ext., 1960; Klingebiel & Montgomery, 1961; Loxton, 1962; Murdoch, 1968).

Drainage, as listed, is used in a general sense and is determined mainly by the permeability of individual horizons. Textural properties should include both the upper and lower horizons. Erosion hazard, often neglected despite its influence on sustained productivity, is given high priority in assessing the soils of the Area.

Slope is not included in the above list nor is it taken into account in making the assessments to be discussed. Nevertheless, it is of prime importance because of its relation to soil erodibility and mechanical limitations. The slope factor, including characteristics of steepness, length and shape is, however, dealt with in Chapter 7 since it is one of the main criteria used for classifying land in terms of capability.

The above list is by no means complete. Frequency of overflow, infiltration capacity, salinity, alkalinity, soil reaction, organic carbon content or mineral deficiencies may, in certain cases or for specific purposes, be of prime concern. Many more criteria could be listed if non-agricultural interpretations are considered. Chemical characteristics are not generally used in the evaluation of soils for rainfed, arable use. Phillips (1966), for instance, refrained from using data bearing on actual fertility. Nutrient status and organic carbon content have, however, been used in the assessment of soil capability (Cutting, 1959). In the United States, available nutrient capacity (CEC) has been listed among other criteria for classifying soils into capability classes.

A list of the main criteria used in making various assessments for the Area are presented in Appendix 9, together with the writer's evaluation of each criterion for all the main soil series.

<u>The management factor</u>: Assessments of soil productivity that ignore the management factor are virtually meaningless. For this reason, precise definition of the system and level of management is essential (Jacks, 1946). However, difficulties may arise since the farmer, through his actions, can render a soil highly productive or perhaps unfit for even the most extensive type of land use. Thus, a skilled operator may reap a higher crop yield from a soil of low potential than the average farmer does from a soil of high potential. Unfortunately, anomalies of this nature cannot be avoided. According to Murdoch (1968), ranking the farmer himself, however desirous, is not only irksome but an arduous task with many pitfalls. Its value, too, is limited since the ownership pattern in most areas is continually changing. A rating based on yield data alone also has limited value. It is better to add the favourability of the output : input ratio as a criterion and to consider the ease with which a soil can be coaxed into providing long term profits without deterioration. Where much time, effort and money must be expended to develop poor-quality soils it is clear that their true value is low (Murdoch, 1968).

The system and level of management applied to soils is often difficult to define because of the many and varied factors involved. For this reason, a standard level of 'good average' management has been assumed in assessing the soils of the Area. Murdoch (1961) described such farmers as being conscious of the need to conserve soil and maintain fertility, able to profit from opportunities and hardworking.

1) Interpretive soil rating and grouping

A number of interpretive groupings and ratings of the soils are presented despite the lack of reliable data. They are based primarily on the writer's own appreciation of selected criteria, his experience and observation in the field and, to some extent, on the knowledge gained from laboratory and field experimentation. Despite likely criticism, the attempt is made in the hope that others may be stimulated into establishing more precise evaluations.

Soil ratings should be continually re-assessed since, within a short space of time, improved technology and soil-crop research usually create a need for revision. This dynamic approach to soil assessment was clearly demonstrated by Murdoch (1968) who revised his appraisal of Swaziland soils biennially from 1960 onwards. In this way assessments are kept abreast of advances in agriculture.

(i) Rating for general agricultural use

This rating is intended to indicate the potential and suitability of individual soil series for 'general' arable use under rainfed conditions. Ratings for specific field crops are not considered because of the very wide range of crops and pastures grown in the Area. A general guide to the use-suitability of individual series is, however, given later in this chapter. Erosion hazard influences the ratings considerably since it is felt that, under current levels of farming practice, this criterion is one of the most important. For this reason, soils of high erosion hazard are generally downgraded. Characteristics of depth, drainage, available moisture capacity and texture received special emphasis especially among the partially leached soils. However, textural variations above the 35 percent clay limit did not materially influence the ratings.

The ratings do not provide a reliable basis for assessing productive capacity, or for making direct comparisons between soils in different ecological environments, and apply specifically to the upland soils. Bottomland soils are not rated since they are unique entities requiring special appraisal and treatment. They are discussed in considerable detail in Chapter 6.

The following five-point scale was used to rate the upland soils:

1 - soils with very high agricultural potential, very few limitations, the lowest erosion hazard and suitable for the widest range of crops;

2 - soils with high agricultural potential, few limitations and low erosion hazard;

3 - soils with moderate agricultural potential, limitations and erosion hazard;

4 - soils with low agricultural potential, severe limitations and high erosion hazard;

5 - soils with very low agricultural potential, very severe limitations, very high erosion hazard and suitable for a very narrow range of crops. A permanent cover of vegetation is preferable on these soils.

A positive sign is used (in addition to the numerical values) to denote further refinement within the rating classes. The same five-point scale is also used to rate the soils for afforestation, irrigation and erosion hazard. All ratings are assembled in Table 28.

The agricultural ratings in the table reflect a preference for soils derived from dolerite with their favourable characteristics of depth, drainage and erosion hazard. Since P-fixation and, in some cases, unfavourable moisture characteristics limit yield (e.g. SHORTLANDS) the ratings for these soils do not necessarily coincide with productivity.

Emphasis is given to erosion hazard as reflected in the consistent downgrading of the loamy to sandy soils of shallow depth, soils of poor drainage and those with claypans. Downgrading of the A2- and B2-association soils is possibly excessive but, in the absence

Table 28 : Soil ratings in terms of general agricultural use, afforestation, irrigation and erosion hazard for the Howick Extension Area

Soil asstn.	Soil series	Soil ratings			
		Agric. use	Afforestation	Irrigation	Erosion hazard
	(i) Highly leached soils				
A1	BALMORAL	1	1	1	1
	Tabamhlope	1	1	1	1
	FARNINGHAM	1	1	1	1
A2	Broadmoor	2	1	1	2
	HUTTON	3+	2+	1	3+
B1	FARMHILL	1	1	1	1
	Helpmekaar	1	1	1	1
	Lidgetton	2+	1	1	1
	GRIFFIN	2+	1	1	1
	Cranwell	3	2	2	2+
	CLOVELLY	3+	2	2	2+
	MISPAH (clayey)	4	4	4	4+
	Humic phase	3+	3	2	3+
B2	CLEVELAND	3	2	1	3
	OATSDALE	4+	3	3+	4
	MISPAH (loamy)	5+	5+	5+	5+
	(ii) Partially leached soils				
D1	VIMY	1	2+	1	1
	Weston	1	2+	1	1
	DOVETON	1	2	1	2
	MSINGA	3+	3	2	3
	RICHMOND	1	2	1	1
	SHORTLANDS	3	3	2	2
	Bellevue	2	3	2	2
D2	Jagersdrift	3	4	2+	3+
D3	Loskop	2+	3+	2+	2
	Rooikop	3	3	2	3
E1	NORMANDIEN	2	3+	3+	2
	BERGVILLE	2	3	3+	2
	RUSTON	3+	3+	3+	3+
	AVALON	3+	3	3+	3+
	NEWPORT	3+	4+	3	3+
	SOUTHWOLD	3	4+	3	3
	Shandon	4	5+	4	3
	ARROCHAR	4	5+	4	4+
	MISPAH (clayey)	5	5	5	4
	Majuba	4+	5+	4	3
	Frere	4	5+	4	4
E3	Melrose	3+	3	3+	4
	LEKSAND	3	4+	3	4
	SPRINGFIELD	4+	4	4	5+
	LONGLANDS	5+	4	4	5+
	MISPAH (sandy)	5	5	5	5
E5	GLENCOE	3	4+	3	3
	WESSELSNEK	4	4	4	4
	WARRICK	5+	5+	5+	5+
	WASBANK	5	5	5	5
	MISPAH (clayey)	5	5	5	5+
	KLIPFONTEIN	5	5	5	5
E6	WINTERTON	4+	4	4	3
	ALBANY	4	4	4	4+
F1	ESTCOURT	5	5	5	5
	Bluebank	5+	5	5	5
G2	RYDALVALE	4+	5	4	4+
	ARCADIA	4	5	4	4+
	UMLAAS	3	4	3	3+
	KIORA	3+	4	3+	3
	RENSBURG	4+	5	4	5+
	PHOENIX	4+	5	4	5+
	Ladysmith	5+	5	5+	5

of reliable erosion data, conservatism is favoured.

The agricultural ratings are in general agreement with those of Phillips (1966), who used both the Storie Index (Storie, 1959) and Loxton's (1962) E.C.M. capability code to assess many Natal soils. However, it is suggested that in downgrading soils such as the HUTTON, CLEVELAND, Majuba, WINTERTON, ALBANY and GLENCOE series, Phillips was unduly severe.

(ii) Rating for afforestation

No critical study on soil preference of tree species has been conducted in the Area and it is evident from the literature that few workers in the Republic have successfully related site index to soil series. In a site evaluation study in black wattle conducted mainly in the Natal Midlands, Schönau (1968) concluded that the soil series had limited value for site evaluation because of the considerable variation within the taxonomic unit. However, he found slope and depth phases to be highly significant in their effect on growth. In Swaziland, Murdoch (1968) established a reasonably good relationship between the growth of pine trees and soil series. He also reported that the effects of drought and hail-induced Diplodia damage were most severe on the shallow soils.

Ideally, interpretations for forestry use should list site indices, important management problems and suitable tree species for each soil. They should attempt to group soils that are capable of producing similar kinds of timber products, that need similar treatment and that have the same potential productivity. Since information is not yet available to permit this form of interpretation a simple rating of soils for afforestation is given in Table 28. Relevant information concerning management needs can, however, be gleaned from the assessments made for other purposes.

The ratings given in Table 28 are based primarily on soil properties such as effective depth, degree of leaching, moisture characteristics and texture. Other factors that may influence site evaluation such as hail, frost, slope, aspect and mechanical limitations (e.g. rocks) are not taken into account. Since available water is the main factor affecting the growth and vitality of trees much emphasis is given to this criterion. In this respect, Schönau (1968) found that trees grown on sandy soils required a higher rainfall to make the same growth as those on clayey soils. According to Westveld (1951), very wet or dry sites produce small volumes of inferior timber. Poorly drained and droughty soils are thus automatically downgraded.

From results obtained by commercial growers in the Area it is obvious that trees, especially conifers, are best confined to the deep, red, highly and considerably leached soils. The high potential of these soils for afforestation is also indicated in the ratings. This assessment agrees with the site index results obtained by Schönau (1968) who found that the best six soils out of thirteen series studied all belonged to this group. Obviously their favourable depth, moisture characteristics and drainage conditions render them ideal for timber production. Despite this, trees for general farm use (e.g. shelter and woodlots) can be grown extensively throughout the Area provided species are carefully selected to fit both ecological environment and soil. Hardier species of pine or gum should be selected for the shallow, droughty soils of the El-association.

Poor initial seedling growth and windthrow are two management problems worthy of note. Both are probably related to poor rooting depth caused by severe Al toxicity in the upper B-horizon, especially among the Bl-association soils. However, growth appears to improve with time and is usually normal in the ratoon crop. Windthrow is confined mostly to the very friable humic phase soils and to the shallow, light textured soils of the MISPAH form.

Although the bottomland soils are not included in the ratings, several of these are eminently suited to the production of Populus deltoides. With improved drainage, the neutral to alkaline soils such as the KILLARNEY series and the better drained alluvial soils could be used for this purpose. Others, such as the Jagersdrift series or the excessively drained alluvial soils, could also be used if carefully irrigated.

(iii) Rating for irrigation

Recent developments and interest in irrigation throughout the Area justify rating the soils for this purpose. Although Hensley (1969) stressed the need to consider the irrigation potential of land and all its components, this assessment concerns only the soil factor. The ratings (Table 28) are intended to reflect the success and ease with which the soils can be irrigated and should be viewed as a measure of the inputs required to attain a particular level of productivity. No indication is given of the system of irrigation to be applied, although sprinkler irrigation will best cater for the widest range of soil properties and conditions of slope. Soils should be capable of remaining permanently productive under intensive irrigation since the artificially transformed moisture factor can profoundly modify a soil. Caution is needed where soils have not previously been irrigated since faulty assessment may prove costly and cause permanent damage (Jacks, 1946).

The ideal soil for irrigation should be at least moderately permeable through all horizons and have unrestricted rooting depth (at least 2 feet); a good supply of available moisture (at least 3 inches in the root zone); satisfactory aeration and infiltration rate; no extremes of texture, structure or consistency; salinity levels and exchangeable sodium of less than 2 to 4 millimhos/cm and 2 me/100g soil respectively when in equilibrium with irrigation water and should be resistant to erosion (Thorne & Peterson, 1954; Thomas & Thompson, 1959; Dept. A.T.S., 1962; Murdoch, 1964, 1968; Hensley, 1969).

Texture and the predominant clay minerals play an important part in the assessments. The most favourable textural classes are those ranging from sandy loams to clay loams, or clay if kaolinite predominates. A heavy clay soil with good water stable structure is, however, also suitable for irrigation. Hill (1965) has shown that textural differences can have a profound influence on water duties.

Other criteria are also important. These include the unfavourable physical conditions of the surface soil or the tendency to 'puddle' and crust, especially among El-association soils. Claypan soils, such as the ESTCOURT series, are automatically downgraded on account of their unfavourable physical characteristics. According to Murdoch (1964) these 'two-deck' soils are problematic in irrigation planning since their poor internal drainage might not be diagnosed early enough. Problems associated with poor drainage should, therefore, be determined at the outset.

With these criteria in mind, the upland soils were rated on the five-point scale ranging from (1) very good to (5) very poor. The values presented in Table 28 generally agree with the examples given by Hensley (1969) and the views expressed by MacVicar (1962). Although they provide a guide to the suitability of the soils for irrigation purposes, they require modification where crop tolerance of specific soil conditions is considered. On this basis, Murdoch (1968) upgraded certain shallow and heavy textured soils where sugar cane was to be irrigated. Furthermore, the need to plan irrigation schemes at the phase level is stressed since minor variations in texture, depth, available moisture capacity, infiltration rate and drainage can be critical to the successful design and management of a scheme.

Bottomland soils: As a result of their impeded drainage and frequently high water tables the 'vlei' soils are rated as poor or very poor. Artificial drainage and management of high order are required if these soils are to be successfully irrigated.

The acid, hydromorphic group are generally the most favourable since their organic matter status is high and the danger of salinity low. Neutral to alkaline soils, though they are naturally drier, usually have more severe mechanical limitations, a higher erosion hazard and, in the drier parts, a potential 'brak' problem. Irrigation should, however, be regarded as a prerequisite for the 'safe-use' of this latter group.

By definition, the drainage of the clayey alluvial soils (L1-association) is never worse than 'somewhat poor' (van der Eyk, 1965c). These soils are, therefore, rated as fair (class 3) or slightly better than the 'vlei' soils. By virtue of their excessive drainage the sandy members of the L1-association are deemed 'good' irrigable soils while their loamy associates are rated as 'very good'. More often than not the alluvial soils are also conveniently situated to the main source of water.

(iv) Rating of erosion hazard

Motivation for this assessment is unnecessary. Although erosion is the net result of many factors, the main consideration here is that soils differ in erodibility through their inherent properties. These properties form the basis for this evaluation.

Erosion research and recorded experience relevant to the soils of the Area are limited to a few preliminary studies and reports. For example, Henkel et al. (1938) reported that the primary cause of sub-surface erosion among certain E1-association soils near Rosetta was the swelling and shrinking properties of the sub-surface horizons. Scott (1951) and Edwards (1961) recorded soil losses on certain Tall Grassveld soils while Sumner (1957) and Hiemstra (1965) studied the erodibility of several soil series occurring in the ESTCOURT area.

Lack of essential erosion research data forced the writer to base assessment on the combined effects of important soil properties and observation in the field. The main properties, including inferred qualities, were effective depth, texture, infiltration capacity, permeability of individual horizons, porosity, aggregation, swell-shrink potential, predominant clay minerals, and organic carbon content. It should be noted that Sumner (1957) found the relationship between single properties and erosion hazard to be unreliable. He suggested, however, that the overall effect of organic carbon was to reduce erosion. In keeping with the results presented by Hudson and Jackson (1959) soil loss was presumed to be greatest from the light textured soils. Although textural variations of the topsoil do not feature as differentiating criteria in the classification system, the need to consider these phases when assessing erosion hazard is great. Texture per se cannot be used to predict features of erodibility, permeability or infiltration capacity (Sumner, 1957).

Infiltration capacity is known to vary considerably between series. For instance, Hill (1965) established that infiltration properties of the SHORTLANDS series were better than those of the WILLIAMSON and WALDENE series which are similar to many soils of the E1-association. Infiltration capacity of the RYDALVALE series (G2-association) was rated as medium. Sumner (1957) also found that the infiltration capacity of soils derived from dolerite was higher than that of the ESTCOURT series. The permeability of the former group was 20 to 40 times better than that of the claypan soils.

Erosion hazard of the upland soils was rated on the same five-point scale. Ratings presented in Table 28 show that, in general, the hazard of erosion increases as degree of leaching decreases. The ratings also reflect favourable characteristics among all highly leached soils (excluding those of sandy texture) and greater stability among the soils derived from dolerite. There is general agreement between the ratings and the values presented by Sumner (1957).

Hiemstra (1965) showed that soil erodibility could be distinguished by pH-value, extractable Na^+ and H^+ and the content of total bases. Soils with values of pH and total bases of less than 5.1 and 5.0 me% respectively were the most stable. The light textured LEKSAND series was the most unstable of the soils studied. The order of erodibility established by Hiemstra, in terms of a dimensionless erodibility index, was:

AVALON $<$ BALMORAL $<$ CLOVELLY $<$ Bellevue $<$ RENSBURG $<$ ESTCOURT $<$ LEKSAND

The ratings shown in Table 28 do not entirely agree with this order, especially the assessment of the AVALON series. In addition to the writer's assessment MacVicar (1962) also rated the AVALON series as a moderately erodible soil, more erodible than both the BALMORAL and CLOVELLY series. These assessments are, however, subjective whereas Hiemstra (1965) used experimental techniques to establish the erodibility index.

Bottomland soils: The most serious erosion encountered in the Area, as in other parts of Natal, is associated with the highly erodible bottomland soils. Under natural conditions of permanent wetness and dense plant cover these soils are reasonably stable. However, they occupy the natural drainage ways of the landscape and are subject to periodic flooding. This feature (which is accentuated in poorly managed catchments) together with faulty drainage techniques and unfavourable soil characteristics in the bottomlands, has resulted in widespread erosion.

An interesting result reported by Hiemstra (1965) was that the KATSPRUIT series proved to be the most stable of all the soils studied. From this it can be inferred that in their natural state, the acid hydromorphic bottomland soils are relatively stable.

The following is a guide to the assessed erosion hazard of the hydromorphic bottomland soils using the usual rating scale:

Class	1	IVANHOE, KATSPRUIT, Emmaus	(C1-association)
	2	CHAMPAGNE, Dell	(" ")
	3	Emmaus (alkaline), KILLARNEY	(H1-association)
	4	Matiwane	(" ")
	5	RENSBURG and other soils of the H2-association.	

Erosion hazard of the almost level alluvial soils (L1-association) is closely related to their characteristics of texture and drainage. However, if suitably protected, these soils rarely suffer serious erosion and are more often covered by deposits of silt.

(v) Grouping in terms of the E.C.M. capability code

According to Loxton (1962a) the capability of the land to produce optimum returns in a system of long term sustained yields is governed by three main factors: erosion hazard (E), soil climate (C), or the moisture regime of the soil, and mechanical limitations (M) that hinder or prevent arable use. Assessment in terms of the E.C.M. code is thus based primarily on observable soil features and local knowledge of the environment. The capability code is designed especially for detailed pedological farm planning where features of climate and slope are included in the assessment. These two factors, however, are not considered where individual soil series are evaluated.

In order to give meaning to the E.C.M. assessments an attempt has been made to relate the capability code to the five classes of the agricultural rating. The extent to which E, C or M influence the ratings is thus indicated.

For this purpose, the E factor is simplified into three classes of erosion hazard: low (1), moderate (2) and high (3). Soil climate, or the ultimate net effect of all forces affecting soil moisture conditions, constitutes the most important factor. The five prescribed classes ranging from very wet (C1) to droughty or dry (C5) are used. Mechanical limitations are assessed in terms of the four classes presented by Loxton but exclude slope, rockiness and surface stones.

Assessment of soil climate is sometimes difficult where the moisture regime varies constantly through a single season. For instance, in soils of the AVALON and LONGLANDS forms, it may range from wet (C2), due to intermittent waterlogging, through moist (C3) to somewhat droughty (C4). Diagnostic subsoil horizons, especially those second and third in vertical sequence, provide the best indication of the soil climate. Generally, yellow apedal B-horizons and P-horizons of the grey-brown soils relate to assessments of C4 and C2 respectively.

Table 29 reflects the relationship between the agricultural ratings for upland soils and the E.C.M. capability code. It is set out according to the three main soil groups defined in Chapter 1. Factors of E, C and M become more limiting from group I to group III and, where necessary, are refined by use of decimals. Because of the wide range in soil conditions within group II, the possible range in soil climate is indicated. Assessments for individual factors series by series are given in Appendix 9.

Table 29 : Relationship between agricultural ratings for upland soils and the E.C.M. capability code (Loxton, 1962a)

Soil rating	E.C.M. capability code		
	Erosion hazard (E)	Soil climate (C)	Mechanical limitations (M)
Group I	Humid areas with highly leached soils		
1	1	3	0
2	1	3	0
3	2	3	0
4	3	3.5	0
5	3	4	1
Group II	Moist to slightly dry sub-humid areas with considerably to moderately leached soils		
1	1	3.5	0
2	1.5	2.5-3.5	0
3	2	2.5- 4	1
4	2.5	2 - 4	2
5	3	2 - 4	2
Group III	Dry to very dry sub-humid areas with moderately to slightly leached soils		
1	1	3.5	0
2	1.5	4	1
3	2.5	4.5	2.5
4	3	4.5	3
5	3	5	3

The E, C and M evaluations for each series given in Appendix 9 were checked against those presented by Phillips (1966) and several differences were established. This applies particularly to the group III soils where the writer's assessments of soil climate appear more severe.

(vi) Grouping for management purposes

At the present time all defined soil series in the Area demand individual study and treatment. Despite this, the assembly of soils into management groups could be of considerable benefit to farmers and to those engaged in extension work. For this reason two possible management groups are discussed i.e. in terms of a) agronomic and conservation practice and b) lime and fertilizer use.

(a) Agronomic and conservation practice: For this purpose soils likely to behave similarly when treated in a particular manner and with similar productive potential are grouped together. A tentative management grouping on this basis is shown in Table 30. It will be noted that the management groups are designated in terms of soil associations and soil forms, and the main differentiae for each group are clearly indicated. Calcareousness and textural classes above the 35 percent clay limit play little part in the establishment of the management groups.

It is possible that many of the Bl-association soils should be assembled in a single, more practical grouping and that the CLEVELAND and OATSDALE series should be united in a single class. This was avoided, however, because of marked differences in morphology. Although the RUSTON-AVALON and NORMANDIEN-BERGVILLE groups cover a wide range in degree of leaching, little evidence is available to indicate that further subdivision is required at this stage. The KIORA-UMLAAS grouping ignores the 35 percent clay limit but it is possible that these soils should be managed separately when intensively irrigated. This attempt has resulted in a large number of groups, several of which comprised single series. For this reason it could be argued that the grouping is of limited value. However, the grouping is tentative until further knowledge of soil response to management is available.

(b) Lime and fertilizer use: The management groups shown in Table 30 may be of little use to those concerned purely with the fertilization of soils. Yet, if each acre is to be used to its maximum

Table 30 : A tentative management grouping for soils in the Howick Extension Area

Differentiating chracteristics	Management groups: Group	Management groups: Soil series	Designation in terms of: Soil asstn	Designation in terms of: Soil form
I. Highly leached upland soils				
Red soils — Clayey	Ia	BALMORAL, Tabamhlope, FARNINGHAM	A1	H1 - HUTTON
Red soils — Loamy	Ib	Broadmoor, HUTTON	A2	H2 - "
Yellow-over-red soils — Clayey	Ic	FARMHILL, Lidgetton, Helpmekaar, GRIFFIN	B1a	GR1 - GRIFFIN
Yellow-over-red soils — Loamy	Id	CLEVELAND	B2a	GR2 - "
Yellow-brown soils — Moderate depth — Clayey	Ie	Cranwell, CLOVELLY	B1b	CL1 - CLOVELLY
Yellow-brown soils — Moderate depth — Loamy	If	OATSDALE	B2b	CL2 - "
Yellow-brown soils — Shallow depth — Clayey	Ig	MISPAH (clayey)	B1c	M1 - MISPAH
Yellow-brown soils — Shallow depth — Loamy	Ih	MISPAH (loamy)	B2c	M2 - "
Humic phase soils	Ii	Includes most B1-association soils	B1h	—
II. Considerably to moderately leached upland soils mostly with apedal structure				
Red soils — Clayey	IIa	VIMY, Weston, DOVETON, Loskop[1], RICHMOND[2]	D1a	H3 - HUTTON
Red soils — Loamy	IIb	MSINGA, Rooikop[1]	D1b	H4 - "
Grey-brown soils — Deep - mod. shallow soils — Mod. well-drained — B-horizon sedentary — Clayey	IIc	NEWPORT	E1a	CL3 - CLOVELLY
Grey-brown soils — Deep - mod. shallow soils — Mod. well-drained — B-horizon sedentary — Loamy	IId	SOUTHWOLD	E1b	CL4 - "
Grey-brown soils — Deep - mod. shallow soils — Mod. well-drained — B-horizon sedentary — Sandy	IIe	SPRINGFIELD	E3a	CL5 - "
Grey-brown soils — Deep - mod. shallow soils — Mod. well-drained — Lower B-horizon soft plinthite — Clayey	IIf	NORMANDIEN, BERGVILLE	E1c	AV1 - AVALON
Grey-brown soils — Deep - mod. shallow soils — Mod. well-drained — Lower B-horizon soft plinthite — Loamy	IIg	RUSTON, AVALON	E1d	AV2 - "
Grey-brown soils — Deep - mod. shallow soils — Mod. well-drained — Lower B-horizon soft plinthite — Sandy	IIh	Melrose, LEKSAND	E3b	AV3 - "
Grey-brown soils — Deep - mod. shallow soils — Mod. well-drained — Lower B-horizon hard plinthite — Loamy	IIi	GLENCOE	E5a	GL1 - GLENCOE
Grey-brown soils — Deep - mod. shallow soils — Mod. well-drained — Lower B-horizon hard plinthite — Sandy	IIj	WESSELSNEK	E5b	GL2 - "
Grey-brown soils — Deep - mod. shallow soils — Poorly drained — B-horizon sedentary	IIk	Shandon, ARROCHAR	E1e	CA1 - CARTREF
Grey-brown soils — Deep - mod. shallow soils — Poorly drained — Lower B-horizon soft plinthite — Clayey	IIl	WINTERTON	E6a	L1 - LONGLANDS
Grey-brown soils — Deep - mod. shallow soils — Poorly drained — Lower B-horizon soft plinthite — Loamy	IIo	ALBANY	E6b	L2 - "
Grey-brown soils — Deep - mod. shallow soils — Poorly drained — Lower B-horizon soft plinthite — Sandy	IIp	LONGLANDS	E3c	L3 - "
Grey-brown soils — Deep - mod. shallow soils — Poorly drained — Lower B-horizon hard plinthite — Loamy	IIq	WARRICK	E5c	W1 - WASBANK
Grey-brown soils — Deep - mod. shallow soils — Poorly drained — Lower B-horizon hard plinthite — Sandy	IIr	WASBANK	E5d	W2 - "
Grey-brown soils — Shallow soils — Mod. well-drained over shale — Clayey	IIs	MISPAH (clayey over shale)	E1f	M3 - MISPAH
Grey-brown soils — Shallow soils — Mod. well-drained over shale — Loamy sand	IIt	MISPAH (loamy sand over shale)	E3d	M4 - "
Grey-brown soils — Shallow soils — Poorly drained over hard plinthite — Clayey	IIu	MISPAH (poorly drained clay over hard plinthite)	E5e	M5 - "
Grey-brown soils — Shallow soils — Poorly drained over hard plinthite — Loamy sand	IIw	KLIPFONTEIN (poorly drained sand over hard plinthite)	E5f	M6 - "
III. Moderately to slightly leached upland soils mostly strongly structured				
Red soils — Structured — Clayey	IIIa	SHORTLANDS, Bellevue	D1c	S1 - SHORTLANDS
Red soils — Apedal — Sandy	IIIb	Jagersdrift	D2a	H5 - HUTTON
Grey-brown soils — Non-duplex — (see group II for plinthic horizons)	—	—	—	—
Grey-brown soils — Non-duplex — Lower B-horizon cutanic — Clayey	IIIc	Majuba	E1g	GE1 - GEMVALE
Grey-brown soils — Non-duplex — Lower B-horizon cutanic — Loamy	IIId	Frere	E1h	GE2 - "
Grey-brown soils — Duplex or claypan — Lower B-horizon prismatic textural — Clayey	IIIe	ESTCOURT	F1a	E1 - ESTCOURT
Grey-brown soils — Duplex or claypan — Lower B-horizon cutanic — Clayey	IIIf	Bluebank	F1b	KR1 - KROONSTAD
Black soils — A-horizon melanic — Clayey	IIIg	KIORA, UMLAAS	G2a	KI1 - KIORA
Black soils — A-horizon vertic — Over C or R — Clayey	IIIh	RYDALVALE, ARCADIA	G2b	AR1 - ARCADIA
Black soils — A-horizon vertic — Over firm gley — Clayey	IIIi	RENSBURG, PHOENIX, Ladysmith	G2c	R1 - RENSBURG
IV. Bottomland soils				
Hydromorphic soils — pH of upper G < 7.0 — with O-horizon — Plastic — Clayey	IVa	IVANHOE	C1a	CH1 - CHAMPAGNE
Hydromorphic soils — pH of upper G < 7.0 — with O-horizon — Friable — Loamy	IVb	CHAMPAGNE	C1b	CH2 - "
Hydromorphic soils — pH of upper G < 7.0 — with Al-horizon humic or orthic — over firm gley — Clayey	IVc	KATSPRUIT, Emmaus	C1c	KA1 - KATSPRUIT
Hydromorphic soils — pH of upper G < 7.0 — with Al-horizon humic or orthic — over friable gley — Loamy	IVd	Dell	C1d	F1 - FERNWOOD
Hydromorphic soils — pH of upper G > 7.0 — Clayey	IVe	KILLARNEY, Emmaus (alkaline), Matiwane	H1	KA2 - KATSPRUIT
Alluvial soils stratified — Clayey	IVf	Clayey alluvium	L1a	D1 - DUNDEE
Alluvial soils stratified — Loamy	IVg	Loamy "	L1b	D2 - "
Alluvial soils stratified — Sandy	IVh	Sandy "	L1c	D3 - "

[1]Soils mapped as D3-association

[2]Structured soil included in HUTTON form soils.

Textural classes : Clayey - over 35% clay
Loamy - 15-35% clay, over 50% sand
Sandy - less than 15% clay, over 65% sand

potential (an essential if the increasing cost-price squeeze is considered) the farmer must know how to fertilize correctly. In fact, lime and fertilizer guides based on selected soil groups are most necessary. Such groups could also serve to reduce the much needed calibration studies to a manageable number.

Although no positive attempt is made to group the soils for this purpose, it is suggested that a soil fertility guide would require soils to be grouped according to their suitability and productivity for each of the important crops grown in the Area. Fertilizer recommendations could then be prescribed in terms of soil test data, the crop and the soil group. The possibility of grouping the soils in terms of anticipated reaction to liming i.e. a lime response grouping, is also worthy of consideration. Although the groups in Table 30 generally separate soils of similar productive potential, a more simple grouping is probably required at this stage. Thus, it is suggested that a grouping based on similarity in degree of leaching, colour and texture will best meet the immediate needs.

2) Assessments relating to agricultural engineering

De Villiers (1962) emphasized the potential value of soil survey data for agricultural engineers and the need for soil to be treated as a genetic product of the environment and not simply as a material. Besides being familiar with the many soil properties listed by Stockstad (1958), the engineer should have a thorough understanding of the national system of classification and procedure for identifying soils.

Soil properties for engineering purposes are often related to Atterberg limits which define the moisture limits for various physical conditions and may be used to predict the potential expansiveness of soils. De Villiers (1962) determined these limits for a number of representative soil series and found that certain criteria were not sufficiently selective to prevent the highly leached soils (e.g. BALMORAL series) which, in practice tend to behave like silts, being classed among the potentially expansive soils. A further result of the study indicated that these soils could fail if saturated with water and 'loaded'. This applies especially to clayey soils overlying pre-weathered saprolite.

The 'activity' or swell-shrink potential of soils is of particular interest to the engineer and, in general, 'activity' increases as the degree of leaching decreases. Soils of the G2- and F1-associations show the highest change in volume with change in moisture content. Soils of less than 27 percent clay are usually non-plastic or have low potential expansiveness (de Villiers, 1962). Soils rich in organic matter may, however, show marked volume changes. For instance, the writer found samples of the IVANHOE series, taken at six and eighteen inch depths, to shrink by as much as 34.8 percent and 48.2 percent respectively when dried from an initial saturated condition. Tscheborioff (1952) recorded values of up to 40 percent for peat soils. For this reason, soil material with a high content of organic matter is not suitable for earth fills.

(i) Hydrological groups

In the United States interpretations for engineering uses invariably include a classification of soils into hydrological groups. These groups indicate, in general, the amount of run-off to be expected from the soil when thoroughly wetted. The grouping is based on soil properties that influence infiltration and transmission rates and ignores the influence of ground cover.

On a similar basis the soils of the Area are classified into four groups.

A. Soils of low run-off potential. These soils have a high infiltration rate and rapid permeability. They are usually well- to excessively drained. Deep soils with red and yellow apedal horizons are included.

B. Soils of moderately low run-off potential. The infiltration rates, effective depth and drainage conditions in these soils are generally moderate. Permeability is slightly restricted.

Soils with red and yellow structured B-horizons are included. B-horizons of soft plinthite are permissible if the depth to the water table is adequate (over 36 inches).

C. Soils of moderately high run-off potential. These soils have slow infiltration rates and restricted permeability. Slowly permeable, clayey subsoil layers are common and depth is often shallow. Hard plinthite or rock frequently occurs at a depth of between 20 and 36 inches. Soils with perched gley, cutanic, soft and hard plinthic B-horizons are included.

D. Soils of high run-off potential. These soils have very slow infiltration rates and severely restricted permeability. Soils with a high swelling potential, claypans, impervious layers, permanently high water tables or of very shallow depth are included. Vertic Al-horizons and firm gley or prismatic textural B-horizons are characteristic of many of these soils.

In this grouping a wide range in texture is permitted. Experience has not yet shown the need for further refinement and many additional groups would be necessary if all textural classes are to be accommodated. The classification is presented in Table 31 and should form the basis for hydrological farm planning.

Table 31 : Hydrological classification of soil series in the Howick Extension Area

Hydrological group			
A	B	C	D
BALMORAL Broadmoor CLEVELAND DOVETON FARMHILL FARNINGHAM GRIFFIN Helpmekaar HUTTON Jagersdrift Lidgetton Loskop MSINGA Rooikop Tabamhlope VIMY	AVALON Bellevue BERGVILLE CLOVELLY Cranwell KIORA LEKSAND Melrose NORMANDIEN NEWPORT OATSDALE RICHMOND RUSTON SHORTLANDS SOUTHWOLD SPRINGFIELD UMLAAS	ALBANY ARCADIA[1] ARROCHAR Frere GLENCOE LONGLANDS Majuba MISPAH (weathered shale) RYDALVALE[1] Shandon WARRICK WASBANK WESSELSNEK	BLUEBANK CHAMPAGNE Dell Emmaus ESTCOURT IVANHOE KATSPRUIT KILLARNEY Klipfontein Ladysmith Matiwane MISPAH (hard plinthite) PHOENIX RENSBURG

[1] soils tentatively upgraded

(ii) Earth fills, dams and conservation works

Several matters concerning conservation engineering are considered worthy of discussion since few attempts have previously been made to relate these aspects to defined soil series.

Earth fills: According to Knight (1952) the relation between soil type and the degree of compaction is best given by the maximum dry density and the plastic limit. Using ranges presented by Knight (1952) and data established by de Villiers (1962) the suitability of the soils of the Area for earth fills (excluding dams) was considered. It is apparent that sandy soils with sufficient binding material are the most suitable. Soils of good load-supporting ability are to be found among the E1- and E3-associations. Generally, these associations are rated good, the A2-, B2- and D1-associations as fair to good, the A1- and B1-associations as fair to poor and the F1- and G2-associations as poor.

However, the stability of soils in steeply sloped earth fills or embankments is an important consideration. In this respect, the light textured soils of the E3-association are among the least stable. Soft plinthic materials of sandy texture erode very rapidly if the embankment is left unprotected. Rate of erosion is, of course, related to slope length and steepness.

Soils of high silt content and plastic clay soils are generally unsuitable for earth fills. Data from numerous profile pits indicate that, with the exception of the bottomland soils, the soils of highest silt content are to be found among the highly leached group. Other factors such as accessibility, presence of stones and depth to water table will influence assessments for specific projects.

Earth dams: Interpretation for farm dams should include both the embankment and the basin area. In this discussion only walls of up to 15 feet in height are considered. Although few materials are totally unsuitable for the small roller-fill earth dams the following requirements should be met: a high shearing value, impermeability, good workability, high density, favourable particle size distribution and low cost of handling. Wall material inclined to dry out should have the ability to adjust itself to gradual consolidation.

Impermeability is judged from several criteria including texture, Atterberg limits, maximum dry density and compacted permeability. Dam walls failing to hold water as a result of the excessive permeability of the soil material are not common in the Area but in some cases are associated with A1-, A2- and sandy D1-association soils. This problem is more often related to faulty construction and outcrops of boulders or shale, or is the result of moles, crabs or tree roots.

The margalitic and claypan soils, though unsuitable because of their high swell-shrink potential and poor workability can prove highly effective for impounding water if properly compacted and kept moist. If used, they should be adequately covered by other suitable soil materials to prevent drying out and grassed. Heavy textured 'active' material should form the centre or upstream portion of the wall or should be used for the clay core.

Among the E1- and F1-association soils marked differences in texture, consistency and permeability between upper and lower horizons are important features affecting dam building. The most permeable material, usually from the upper horizons, should be placed on the downstream side of the wall. The highly leached soils, although the most easily worked, are associated with problems of excess pore pressure if construction takes place when the material is wet. Slightly dry construction is thus advocated for these soils and others that have high moisture limits.

Factors to be considered in assessing the basin area include those properties of undisturbed soils that affect their suitability for water impoundments, especially those affecting seepage. Permeability, depth to water table or bedrock and slope (influencing storage capacity) are important criteria. Clayey bottomland soils (C1- and H1-association) are the most favourable while severe seepage is often encountered among soils of the A1-, A2- and D1-associations. Subterranean leaks sometimes occur in soils of the CLOVELLY and MISPAH forms where the underlying shale or sandstone is fissured.

Assessments of the soil resources (association level) in terms of several engineering purposes, including dam building, are summarized in Table 33 (page 114(i)). These are based primarily on data presented by de Villiers (1962), van der Eyk _et al_. (1969) and the writer's experience in the field. Generally, the assessments for dam building are not as restrictive as those presented by van der Eyk _et al_. (1969.

Spillways and waterways: Erosion within the spillway area or waterway is a major threat to most conservation dams and layouts, and greatly affects the planning and design of these works. For this reason, a general assessment of soil limitations or hazards for spillways and waterways (association level) is also presented in Table 33 (page 114(i)).

Current procedures for designing spillways are based on permissible limits for depth and speed of flow which, in turn, are dependent on broad textural classes (Dept. A.T.S., 1963; Pazzi, 1963). However, no account is taken of other important soil characteristics. To serve as a guide for those designing spillways, the main upland soil series are related to the standard textural classes in current use. Soils requiring special treatment with respect to permissible speed and depth of flow are assembled in a special class. The grouping, based on textural properties of the B-horizon, is presented in Table 32 overleaf.

Adjustment to this grouping is necessary where hard shale or plinthite is exposed in the spillway cut. In this case, soils such as the KLIPFONTEIN, MISPAH, ARROCHAR and WASBANK series should be placed in class 5. Estimates for designing spillways or waterways should be conservative for soils in the special class, at least until more precise data are available. Problems associated with these soils have little to do with texture as such.

Important criteria for waterways include soil features that influence the establishment and successful growth of the plant cover

Table 32 : Grouping of selected soil series for spillway design

Textural class	Soil series
1. Sand - sandy loam	KLIPFONTEIN, LEKSAND, LONGLANDS, MISPAH (sandy), SPRINGFIELD, WASBANK, WESSELSNEK
2. Sandy loam - loam	Jagersdrift, Melrose, MSINGA, WARRICK
3. Loam - clay loam	ALBANY, ARROCHAR, AVALON, Broadmoor, CLEVELAND, Frere, GLENCOE, HUTTON, MISPAH (loamy), OATSDALE, Rooikop, RUSTON, Shandon, SOUTHWOLD
4. Clay loam - clay	Bellevue, BERGVILLE, CLOVELLY, DOVETON, FARNINGHAM, GRIFFIN, Helpmekaar, Loskop, KIORA[1], Majuba, NEWPORT, NORMANDIEN, Tabamhlope, Weston, WINTERTON
5. Clay	BALMORAL, Cranwell, FARMHILL, Lidgetton, MISPAH (clayey), RICHMOND, SHORTLANDS, UMLAAS[1], VIMY
Special class	ARCADIA, Bluebank, ESTCOURT, Ladysmith, RENSBURG, RYDALVALE

[1] soils purposely upgraded

and the construction of the waterway. These include depth, texture, drainage, moisture capacity, nutrient supply and erosion hazard, together with slope, stoniness and the problems of siltation and seepage.

Generally, the spillway or waterway should be established well before the major work is constructed, either by seeding suitable grass species or blanketing the area with sods. Sound fertilization is a prerequisite for successful establishment and subsequent protection of these vulnerable areas.

<u>Conservation works constructed of earth</u>: Until recently tariffs for the valuation of conservation works were specified in terms of three textural classes. This approach had serious limitations since important properties affecting the 'workability' of the soils were ignored. Furthermore, morphological differences between upper and lower horizons (e.g. ESTCOURT form) could not be accounted for unless excavation was kept to a specified depth. 'Workability' is usually a function of moisture content and cannot be defined by single measurements

(e.g. modulus of rupture or penetrability). The optimum moisture limits may also be extremely narrow in the case of some soils (e.g. RENSBURG series) and very wide in others (e.g. HUTTON series).

Although no attempt is made to rate all the soils according to 'workability' it is suggested that this criterion should be given greater attention when assessing the suitability of soils for conservation works. A reasonable approach would be to rate the soils to show their limitations (slight, moderate, severe) in 'workability' as indicated in the following example:

Slight : HUTTON, CLEVELAND

Moderate: BERGVILLE, SHORTLANDS

Severe : ESTCOURT, RENSBURG

(iii) Drainage, tillage and conservation requirements

The rational selection of land-use practices to meet the capabilities and needs of each soil is not only sound, but often produces the most economic returns. With rising land pressure it will be necessary to bring soils which, because of their poor physical characteristics, are today regarded as being 'marginal' under intensive cultivation. This discussion, therefore, provides some indication of the current needs of the soils and those issues that will become important as intensification progresses. The assessments rely mainly on physical soil criteria since little information is available from either research or recorded field experience. Consideration is not given to the specific requirements of crops. A summary of the drainage, tillage and conservation needs are presented in Table 33.

Drainage requirements: Factors to consider in assessing the drainage requirements are those soil properties affecting the installation and performance of surface and sub-surface drainage works. These include permeability, texture, structure, swell-shrink potential and depth to an impervious layer or water table. Topography, hazard of flooding, available outlets, corrosion potential and stability of ditch banks should also be considered at each site.

Table 33 : Selected engineering assessments for soils in the Howick Extension Area

Soil asstn.	Management group	Soil series	Suitability for dam walls (wall height < 15 feet)	Spillway hazards	Drainage requirements	Tillage requirements	Conservation needs
			(a) UPLAND SOILS				
			(i) Highly leached soils				
A1	A1/H1	BALMORAL Tabamhlope FARNINGHAM	Generally poor owing to rapid permeability and outcrops of rock. Easily worked. 'Slightly dry' construction advocated.	L-M	Nil	Normal, as determined by crop need.	Influenced by slope. Good husbandry and easily applied conservation practices sufficient for safe use.
A2	A2/H2	Broadmoor HUTTON	Poor owing to excessive permeability. Impervious clay core essential. Very easily worked.	M	Nil	As above. Secondary tillage should avoid pulverization and structural degradation. Rotovation for weed control and incorporation of organic residues permissible with slow rotor speed and high forward speed recommended. Avoid excessive rotovation.	Intensive biological (e.g. leys) and mechanical measures required for control of erosion by wind and water especially on sloping land. Tillage and residue management important. Avoid exposure of land during late winter and early spring.
B1	B1a/GR1	FARMHILL Lidgetton Helpmekaar GRIFFIN	Similar to A1-association, but generally less permeable.	L-M	Nil	Normal. Work deeply i.e. to lower limit of A1-horizon with tined implement or chisel plough. Avoid inversion of yellow apedal B-horizon unless adequately limed.	As for A1-association.
	B1b/CL1	Cranwell CLOVELLY	As above. Leakage through shale strata possible	L	Clayey and shallow soils subject to overflow may require surface drainage.	As above. Shallow phase soils to be subsoiled periodically.	As for A1-association but more intensive for shallow soils.
	B1c/M1	MISPAH (clayey)	Poor. Shallow depth and exposed shale hinder construction. Leakage through shale strata possible.	L-VL	Internal drainage improved by subsoiling.	Subsoiling recommended. Deep ploughing is justified under special conditions but may be costly.	Intensive conservation measures required. Careful selection of land-use including long duration leys necessary.
	B1h	Humic phase soils	A1-horizon unsuitable, otherwise generally poor.	L-M	Soils subject to overflow may require surface drainage.	Efficient tillage is dependent on moisture status. Soil material adheres to implements when wet. Roll when 'slightly dry'. Avoid pulverization. See also B1a/GR1 group.	Intensive biological control measures required. Conserve organic matter and prevent exposure to wind erosion.
B2	B2a/GR2	CLEVELAND	Similar to A2-association	M	Nil	As for A2-association.	As for A2-association. Intensity of need determined by effective depth and textural class.
	B2b/CL2	OATSDALE	Poor owing to excessive permeability. Easily worked if deep. Leakage through sandstone strata possible.	M	Nil	As for A2-association but including occasional subsoiling for shallow phases. Minimum tillage and incorporation of crop residues recommended.	Intensive biological and mechanical measures required. Long duration leys and residue management important. Increase intensity for shallow phase soils and avoid wind erosion.
	B2c/M2	MISPAH	Poor owing to excessive permeability, shallow depth and possible leakage.	M	Internal drainage improved by subsoiling.	Minimum tillage, subsoiling and rolling recommended for pasture establishment.	Very intensive conservation measures required especially on sloping land. Permanent swards recommended.
			(ii) Partially leached soils				
D1	D1a/H3	VIMY Weston DOVETON Loskop RICHMOND	Fair but permeability of subsoil rapid. Easily worked if rock outcrops absent.	L-M	Nil	Normal. Deep tillage strongly recommended.	As for A1-association.
D1	D1b/H4	MSINGA Rooikop	Fair to poor owing to excessive permeability. B-horizon most favourable. Easily worked under favourable moisture conditions.	M	Nil	Deep primary tillage, incorporation of crop residues and winter ploughing recommended. Avoid structural degradation.	Intensity dependent on slope. Mechanical control measures essential on sloping land. Conserve organic matter for long term arable use.
	D1c/S1	SHORTLANDS Bellevue	Fair but subsoil permeability fairly rapid. Firm consistence when dry increases power requirement. Rock outcrops hinder construction.	L	Nil. Subsoil when irrigated.	Deep primary tillage in early winter essential for moisture conservation. Deep ploughing and occasional subsoiling recommended.	As for A1-association. Residue management important.

Table 33 contd

Soil asstn.	Manage-ment group	Soil series	Suitability for dam walls (wall height < 15 feet)	Spillway hazards	Drainage requirements	Tillage requirements	Conservation needs
					(a) UPLAND SOILS		
		(ii)	Partially leached soils				
D2	D2a/H5	Jagersdrift	Poor owing to excessive permeability.	M	Nil. Carefully sited cut-off drains required for intensive irrigation.	As for D1b/H4 group.	Easily applied conservation measures normally sufficient. Residue management important.
E1	E1a/CL3	NEWPORT	Fairly good. Leakage through underlying strata possible. Easily worked if depth normal.	L	Internal drainage improved by subsoiling. Simple surface drainage techniques may be required on level terrain especially if irrigated. Investigate partial 'downslope' subsoiling.	Deep primary tillage, including subsoiling and possibly deep ploughing, in early winter recommended for moisture conservation. Secondary tillage needed to prevent formation of clods and should take place between critical moisture limits. Avoid tillage when soil is wet. Minimum tillage recommended to reduce compaction. Rotovation for incorporation of crop residues to be done with care. Light tined implements such as rotary weeder or weeder mulcher suitable for eliminating crusts and for weed control, but should be operated at high speed. Sod-bound pastures should be subsoiled and well fertilized.	Fairly intensive conservation required including biological and mechanical measures. Ley cropping and residue management supported by efficient agronomic practice and deep tillage will generally ensure safe use. Conservation of organic matter essential.
	E1b/CL4	SOUTHWOLD	Fair, similar to above	L-M	As above.	As for above but keep tillage to a minimum.	As for above but increased intensity required. Deep primary tillage, leys of moderate duration, residue management and mechanical measures important.
	E1c/AV1	NORMANDIEN BERGVILLE	Good, especially lower subsoil, material, seepage through soft plinthite or concretionary layers possible in basin area.	L	Some form of surface drainage and possibly underground drainage (e.g. mole) required for level land under irrigation.	As for E1a/CL3 group.	As for E1a/CL3 group.
	E1d/AV2	RUSTON AVALON	Fair improving with depth. As above.	M	As for above. Mole drainage doubtful due to light texture.	As for E1a/CL3 group but keep tillage to a minimum.	Intensive biological and mechanical measures required on sloping land. Selected crop rotations, tillage, residue management and supporting conservation structures important.
	E1e/CA1	Shandon ARROCHAR	Fair to poor. Shallow depth and exposed shale hinders construction. Leakage through shale strata possible.	L	Subsoiling improves internal drainage. Other forms of drainage not generally recommended, but may be justified on level land.	Deep tillage including subsoiling essential for optimum production. Deep ploughing may be economically justified. See also E1a/CL3 group.	As above but with increased intensity.
	E1f/M3	MISPAH (clayey)	As above.	L	As above.	As above.	As above.
	E1g/GE1	Majuba	Fair improving with depth. Working becomes more difficult with increased depth if dry.	L-M	Deep primary tillage including subsoiling will improve overall drainage. Surface drainage and possibly underground techniques justified for level, irrigated land.	Deep and timeous tillage operations including subsoiling of prime concern. See also E1a/CL3 group.	Intensive conservation measures required for safe use. Similar to E1a/CL3 group.
	E1h/GE1	Frere	Fair to poor improving with depth.	M	As above.	As above.	As above but with increased intensity. Selection of land use practices important (e.g. long term ley).
E3	E3a/CL5	SPRINGFIELD	Poor, owing to excessive permeability. Easily worked if deep. Leakage through sandstone strata possible.	H	Deep primary tillage (subsoiling and ploughing) improves internal drainage. Additional drainage may be necessary under very intensive irrigation.	Timeous deep tillage (including subsoiling and minimum tillage) and residue management recommended. Rolling usually advantageous. Select machinery to avoid excessive wear. See also E1a/CL3.	Very intensive conservation measures needed. Supporting mechanical structures required for protection since density of plant cover usually low. Keep crop period to a minimum. Prevent wind erosion by partial incorporation of crop residues and protection during early spring.
	E3b/AV3	Melrose LEKSAND	Poor to fair improving with depth. Seepage through soft plinthite or concretionary layers possible.	H	Underground drainage (e.g. tiles) may be justified with intensive irrigation. Siting of cut-off drains important.	As above. Avoid excessive tillage. Deep ploughing recommended.	As above. With suitable slopes can crop extensively provided residue management is of high order. Efficient agronomic practice essential for safe use.

Table 33 contd

Soil assn.	Management group	Soil series	Suitability for dam walls (wall height < 15 feet)	Spillway hazards	Drainage requirements	Tillage requirements	Conservation needs
(ii) Partially leached soils				(a) UPLAND SOILS			
E3	E3c/L3	LONGLANDS	Poor to fair improving with depth.	H	Surface drainage for level areas subject to overflow. Underground techniques (tiles or slotted pipe) control water table but should be economically justified.	As above but avoid tillage operation when wet.	Very intensive conservation measures required. Selected land use practices, including leys of very long duration or permanent cover, important.
	E3d/M4	MISPAH (sandy)	Poor owing to shallow depth and excessive permeability.	H	Subsoiling recommended.	Similar to E3a/CL5. Deep ploughing may be justified.	Very intensive conservation measures required. Permanent plant cover recommended.
E5	E5a/GL1	GLENCOE	Poor. Hard plinthite hinders construction. Clayey material below hardpan suitable.	L-M	Shattering of hardpan may improve drainage but is costly. Surface drainage possibly justified.	As for E1d/AV2 group. Ironpan may hinder subsoiling.	As for E1d/AV2 group but with increased intensity.
	E5b/GL2	WESSELSNEK	As above.	M	As above.	As above.	Very intensive conservation measures required including long duration leys or permanent cover.
	E5c/W1	WARRICK	Poor. Hard plinthite hinders construction. Lateral seepage above hardpan likely.	M	As for E4a/GL1 but surface drainage justified for level land.	As for E5a/GL1. Tillage should maintain the shape of ridges and incorporate crop residues.	As above.
	E5d/W2	WASBANK	As above.	H	As above.	As above.	As above but permanent cover generally favoured.
	E5e/M5	MISPAH (clayey - poorly drained)	Moderate but shallow depth and underlying hardpan hinders construction.	M	Surface drainage with narrow inter-ridge spacing recommended if soil depth sufficient.	As for E5c/W1.	Requires intensive conservation. Permanent cover preferable.
	E5f/M6	MISPAH (sandy - poorly drained)	Unsuitable.	H	As above.	Restrict tillage operations to those required for pasture establishment.	Very intensive conservation measures required. Should be established to permanent cover.
E6	E6a/L1	WINTERTON	Good, especially lower subsoil. Ease of working dependent on moisture status.	L-M	Surface drainage and subsoiling recommended.	Deep, timeous tillage including subsoiling recommended. Avoid tillage when wet. See also E1a/CL3.	Intensive conservation on sloping land. Ridge and furrow provides adequate protection of level phase. Land use practices to include long term leys.
	E6b/2	ALBANY	Fair, improving with depth.	M	As above.	As above	As above but with increased intensity.
F1	F1a/E1	ESTCOURT	A1- and P-horizons fair if concretionary layer absent. B- and G-horizons good if covered by material of low swell-shrink potential. Difficult to work.	VH	Under exceptional circumstances surface drainage may be required viz. if land level and irrigated.	Arable use not generally recommended but tillage required for pasture establishment. Avoid interference and exposure of claypan (e.g. subsoiling). Primary tillage dependent on depth of claypan. Secondary tillage similar to E1-association soils. (See E1e/CL3.)	Previously cultivated land requires very intensive conservation especially biological practices. Long term or permanent leys important. Mechanical measures of limited value but required during establishment period.
	F1b/KR1	Bluebank	As above.	VH	As above.	As above. Primary and secondary tillage should ensure maximum moisture conservation and erosion control.	As above but slightly less intensive.
G2	G2a/KI1	KIORA UMLAAS	Fair to good. Lower subsoil moderately permeable. Easily worked if moisture conditions favourable.	L	Nil	Normal, as determined by crop need. Deep primary tillage and periodic subsoiling strongly recommended. Subsoil when dry. Periodic deep ploughing beneficial but should be economically justified.	Requires moderately intensive conservation measures but depends on slope. Good husbandry and easily applied conservation practices normally sufficient for safe use.
	G2b/AR1	RYDALVALE ARCADIA	Fair to poor owing to high swell-shrink potential. Should be kept moist. Difficult to work under extremes of moisture.	H	Under special conditions may require some surface drainage.	Heavy equipment including subsoiler or tined implement required initially. Leave in rough state to weather. Avoid excessive secondary tillage which which should be shallow so as to prevent rapid drying out of surface. Periodic subsoiling with 2 or 3 tined implement when slightly dry recommended. Cultivate to reduce moisture loss from deep cracks.	Intensive conservation measures required but depends on slope. Design of mechanical structures should take account of high swell-shrink potential.

Table 33 contd

Soil asstn.	Management group	Soil series	Suitability for dam walls (wall height < 15 feet)	Spillway hazards	Drainage requirements	Tillage requirements	Conservation needs
				(a) UPLAND SOILS			
		(ii)	Partially leached soils				
G2	G2c/R1	RENSBURG PHOENIX Ladysmith	Poor, owing to high swell-shrink potential but may be suitable if kept adequately moist. Difficult to work. G-horizon suitable for core.	VH	In bottomland position and with irrigation, surface and underground drainage recommended. Inter-ridge space should be narrow (20-30 feet). Deep tillage and subsoiling necessary.	As above if cultivation permitted.	Very intensive conservation required for soils in bottomland position. Ridge and furrow provides adequate mechanical protection and safe disposal of overflow. Long term leys or permanent cover recommended.
				(b) BOTTOMLAND SOILS			
C1	Cla/CH1	IVANHOE	Good excluding organic horizons. Suitable for clay core. Usually difficult to work.	N/A	Surface drainage recommended. Open ditches should be carefully designed to avoid scour. Mole drains may be effective for draining O-horizons. Drainage system should provide 'absolute' control over water table.	Tillage required for pasture establishment. Initial deep ploughing, rotovation and rolling when 'slightly dry' recommended. Initially shape of beds to be maintained by annual tillage (e.g. 3 years).	Very intensive conservation required for bottomland as a whole. Ridge and furrow provides adequate mechanical protection and safe disposal of overflow. Restrict utilization to permanent pasture, preferably under irrigation. Establish pasture section by section.
	Clb/CH2	CHAMPAGNE	As above.	N/A	As above.	As above.	As above but with increased intensity due to higher erosion hazard. Preferably left in natural state.
	Clc/KA1	KATSPRUIT Emmaus	Good, especially suitable for clay core. Difficult to work.	N/A	Surface drainage recommended for safe disposal of overflow. Deep tillage improves internal drainage. Underground techniques not recommended though mole drainage may be considered. See also Cla/CH1 group.	Allow time to moulder down after initial tillage. Deep secondary tillage with tined implements recommended. Rotovation and rolling important for seed bed preparation. Tillage should maintain shape of beds. Avoid use when wet.	As for Cla/CH1 group.
	Cld/F1	Dell	Cg-horizon suitable. Difficult to work.	N/A	As for Cla/CH1 group. Underground drainage (e.g. tile) may prove suitable. Success of mole drainage doubtful.	As for Cla/CH1 group.	As for Cla/CH1 group but with increased intensity. If safe use in doubt leave under natural vegetation.
H1	H1a/KA2	KILLARNEY Emmaus (alkaline) Matiwane	Cg-horizons suitable, especially for clay core. Difficult to work.	N/A	As for Clc/KA1 group.	Primary tillage should be as deep as possible and includes subsoiling when dry. See also Clc/KA1 group.	Conservation primarily concerned with selection of land use practice. Long term or permanent pasture, preferably under irrigation, recommended. See also Clc/KA1 group.
L1	L1a/D1	ALLUVIUM (clayey)	N/A	N/A	Surface drainage and deep tillage strongly recommended.	As above.	Conservation practice to prevent scouring during floods. Ridge and furrow provides safe disposal of flood water. Provide protective cover.
	L1b/D2	ALLUVIUM (loamy)	N/A	N/A	As above but consider mole drainage as possible alternative.	As above.	As above. Residue management important with intensive cropping.
	L1c/D3	ALLUVIUM (sandy)	N/A	N/A	Surface drainage may be necessary with intensive irrigation or for safe disposal of flood water. Underground drainage (e.g. tiles) suitable if economically justified.	Deep primary tillage and incorporation of crop residues recommended.	As above.

Hazard rating: VH - very high, H - high, M - moderate, L - low, VL - very low.

A surprisingly high proportion of the soils in the Area require some form of improved drainage, especially the sandy soils overlying sub-surface horizons of impervious clay. Poor drainage is frequently associated with landscape position, especially with slope gradients of less than 5 percent. Alternative forms of land-use should first be considered before initiating elaborate and costly systems of drainage.

The recommended drainage systems discussed include both surface and underground methods. However, surface drainage, coupled with carefully selected tillage operations, will generally suffice for the majority of poorly drained soils. The high capital requirements of underground methods can hardly be justified under the systems of cropping currently applied in the Area. Despite this, it has been claimed that underground drainage can, in the long run, be a better economic proposition, is also cheaper to maintain and avoids wastage of land (S.A. Sugar Asstn., 1968). Nevertheless, it is doubtful whether underground techniques alone could handle the large volumes of water so often experienced during heavy rainfall. Many poorly drained soils overlie ferruginous hardpans or claypans at varying depths and are, therefore, unsuited to underground drainage techniques. They are also associated with a high run-off potential and erosion hazard. For these reasons, it is suggested that surface drainage, capable of handling large volumes of water and providing adequate erosion control, would be of greatest value over a wide range of soils.

The broadland or modified 'ridge and furrow' technique advocated by Hill (1961) offers many advantages. It has already proved highly satisfactory in many parts of the Area on both heavy bottomland soils and in shallow, poorly drained upland soils. Improvement in the drainage conditions of some tropical black earths in Ghana was also achieved by this method (Brammer, 1959). The 'ridge and furrow' layout has the advantage that between crests the capacity for flood water is large, providing a wide margin of safety, especially where abrupt changes in gradient occur. Furthermore, the improved drainage conditions permit the use of machinery soon after wetting. Because, after several seasons, a hardpan tends to develop at the base of the regular plough layer, lateral internal drainage is also encouraged.

The success of this system depends on careful layout, construction and maintenance. Correct shaping of the beds usually takes several seasons, after which the system should function efficiently with normal tillage. Although precise data relating to width of beds and permissible gradients have yet to be established for the various soils, much relevant information has been given by Hill (1961). Many hand-dug interception ditches are to be found in the cultivated bottomlands. The spoil from these (often incorrectly sited and poorly maintained ditches) is usually dumped along one edge of the ditch and impedes the movement of surface water. The resulting conditions are frequently worse than those experienced prior to drainage. 'Ridge and furrow' avoids problems of this nature.

To date, underground drainage has received little attention in the Area. Mole drainage and 'improvised' underground drains using a variety of available materials have been tried on some bottomland soils with varying success. Mole drainage, which can be done at relatively low cost, can be used to advantage on the clayey bottomland soils if closely spaced (2 to 3 metres). Undulating surface conditions, sandy textures and sub-surface obstructions should, however, be avoided. 'Improvised' drains can be used on a limited scale to improve local wet patches or to control the seepage from 'eyes' of springs within a bottomland. Tile or plastic drains may prove successful in some loamy, sandy and humic phase soils but would first have to be economically justified. The use of plastic pipes has the advantage of saving labour. In addition to the lack of spacing and depth specifications, the limited scope for producing highly remunerative crops on soils drained by underground methods is a deterrent to the use of this technique in the Area.

Tillage requirements: The basic tillage requirements of the soils are assessed by considering morphological features. Correct tillage is important in soil drainage, moisture conservation, the prevention of structural degradation and erosion control. The advantage of timeous tillage operations in promoting moisture conservation (e.g. winter ploughing) is not widely appreciated. This practice remains one of the most neglected aspects of crop production throughout the Area. Furthermore, few realize that with some soils there is a potential danger in the continued use of a particular operation or machine. With others there is a need to avoid certain operations between critical soil moisture limits. Hill[1], for example, has observed the unexpected occurrence of a ploughpan in the HUTTON series which he attributed solely to the use of a rotavator over long periods. Similar problems in soils of the HUTTON form have been noted elsewhere in Natal.

Two groups of tillage operations are considered viz., primary tillage, including the initial ploughing or subsoiling, and secondary tillage including discing, harrowing, rotavating, cultivating and rolling. Extra deep ploughing (e.g. Nardi system) is receiving considerable attention at the present time but little critical information for the Area is available. On the basis of characteristics, such ploughing should be recommended mainly for shallow soils, especially in the drier parts where an increase in effective depth and volume of soil will improve infiltration, moisture conservation and rooting depth. Despite this, farmers have recorded substantial yield increases even on soils such as the DOVETON series. Power requirements and costs are, however, likely to be considerably higher than those of conventional methods (e.g. subsoiling).

Subsoiling is recommended for soils of limited effective depth, firm consistence and strongly developed structure. The shallow El-association soils are particularly responsive to subsoiling. It has

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1 P.R. Hill - personal communication

been established that yields of maize on these soils can be substantially increased by subsoiling[1]. Furthermore, Hill (1965) reported a reduction in run-off and soil loss following subsoiling of the WINDERMERE series. Research is needed to establish yield responses and specifications relating to spacing, gradients, frequency and the power requirements for subsoiling each soil series. Subsoiling cannot, however, be recommended for all soils. For instance, Sumner (1957) and Jamison, Smith and Thornton (1968), warned against subsoiling claypan soils (e.g. ESTCOURT series) because of the likely sub-surface erosion and poor yield responses. Although 'downslope' subsoiling for improved drainage may be justified in some cases, its widespread application cannot be recommended without further investigation.

Deep tillage is strongly recommended for many partially leached soils where improved moisture conservation is needed. Deep ploughing of some light textured soils (e.g. LEKSAND series) could also have the added advantage of bringing illuviated clay and nutrients from lower horizons to the surface. However, the advantage of deep tillage on the highly leached soils is not so clear. Analysis of data for numerous profiles indicates that the sub-surface horizons of these soils are highly infertile (Chapter 1) and it has been shown that the most favourable conditions for growth are confined to the relatively shallow, organic rich surface horizons (Graven & Theron, 1969). Problems may also result from bringing infertile soil material, rich in exchangeable Al, to the surface. Although lime could be incorporated to greater depths by deep ploughing the advantages have yet to be proved by field experimentation. For these reasons, the use of tined implements for incorporating lime and fertilizer as deeply as possible, without the actual inversion of soil material, is prescribed until more is known.

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[1] Department Agric. Tech. Services, Natal Region, Res. rep. N-Ko 2/2

Certain surface characteristics may require special treatment. Among E1-association soils, for instance, there is the tendency to crust and form clods. Because these clods do not break down rapidly once they have formed, the moisture status at which tillage takes place is critical. In this case, primary and secondary tillage should be completed in rapid succession.

Margalitic or 'black turf' soils of the G2-association have special tillage requirements. Initial tillage is often costly since heavy implements are required. Furthermore, the soils are either too plastic when wet or too hard and compact when dry. The aim in cultivating these soils should be to maintain a granular structure throughout the plough layer. The structure is stable as long as the soils are not 'poached' by cultivation or trampling when wet (Brammer, 1959). Following primary tillage, including subsoiling to a depth of approximately two feet, the soils should be left to weather and moulder down to a coarse, granular structure. This may take considerable time. Repeated discing and harrowing to produce a very fine tilth should be avoided since the soil material is then extremely difficult to work after rain. Despite the high swell-shrink potential and self-mulching properties of these soils, periodic subsoiling is recommended. Overall drainage and infiltration capacity are also enhanced by the deep cracks that develop when these soils dry, at least until the lower subsoil has again become fully saturated and the cracks closed. In the BONHEIM series this was found to occur after midsummer and resulted in a marked reduction in infiltration capacity (Burney, 1968). Some form of surface drainage is also recommended for margalitic soils exhibiting gleyed conditions in the subsoil (e.g. RENSBURG series).

Conventional tillage may compact a soil to a condition worse than before the initial ploughing (Cook, 1962). For this and other reasons, much attention is being given to 'minimum tillage' i.e. the least amount required to promote germination and provide optimum plant stands. This technique, which is tantamount to wheel track planting, could possibly be of considerable benefit if applied to the E group soils.

Important soil criteria for assessing the tillage requirements (Table 33) are effective depth, nature of limiting material, texture, consistence, surface soil characteristics, swell-shrink potential and the gradation of properties down the profile. Recommendations concerning the type of implement or machine to be used are not made since these depend on many other factors including personal choice. There is, however, a need for further information on the influence that soils may have on the choice of machine. Sandy soils, for instance, cause excessive damage to implements with many wearing parts.

Conservation needs: The assessment of erosion hazard (Table 28) forms the basis for considering the conservation needs of the various soils. Wind erosion is not of particular significance in the Area but may be of importance locally where land form influences wind direction and velocity. Within the Highland Sourveld light textured, humic and single-grained soils will erode as a result of strong winds if left unprotected during early spring.

Conservation should begin with the careful selection and application of correct land-use practices. Apart from the choice of suitable crops these include all the important agronomic, tillage and drainage practices and the management of crop residues required to improve and conserve organic matter. Adequate and correct fertilization is also viewed as one of the chief aids to effective soil conservation. It is impossible in this discussion to enumerate the many possible biological and mechanical erosion control measures but an indication of the degree of intensity with which conservation practices should be applied is given in Table 33.

Conservation needs depend on many factors and may change at different times of the year. For example, many arable fields are particularly vulnerable to erosion in early summer when plant cover is usually inadequate. On the other hand, run-off from high swell-shrink potential soils is greatest late in the season when subsoil horizons have become fully saturated. Furthermore, poorly drained soils (often given a high erosion hazard rating) usually have weak gradients in their favour. Factors such as these were considered in assessing the general conservation needs of the soil resources.

3) Yield prediction

Soil survey reports should predict the potentialities of each soil in terms of long term average yields of adapted crops under alternative sets of management practice (Soil Survey Staff, 1951). Within specified climatic situations yield predictions, which express soil productivity, constitute basic information essential to land-use planners. Their importance lies in developing economic cropping systems. They do not suggest what should be done with the soil, but what may be expected from it. Predictions are statements using numbers not words (Aandahl, 1962; Riecken, 1962).

Yield prediction requires the assembly of all relevant data at the time of the survey. Such procedure has not, however, been standard practice in recent surveys conducted in the Republic. This has led to a delay in the interpretation of soils data. For this reason, it is strongly recommended that timeous fact collection should be seriously considered in planning soil surveys.

Yield is the result of many interacting factors including climate, soil properties, crop characteristics, management and the skill of the operator. Yield prediction requires consideration of all these factors. Skill of the operator has a marked influence on ultimate yield but is often difficult to assess. Despite this, it can be assumed that a farmer who applies several good practices is also likely to do other essential operations efficiently and timeously. The combined influence of all practices applied by him will determine the final success and attainment of a maximum yield. In this connection, Odell (1958) found that yields of maize under farm conditions were approximately 25 percent less than those established by experimentation.

Management level often provides the ceiling to expected yield.

Clear definition of both management level and the combination of practices applied to the soils is essential if predicted yield values are to be meaningful. Yield prediction tables usually reflect two levels of management but even this number may be excessive where technological advancement is so rapid that the predicted values soon become outdated. Because of the wide range in farming standards within the Area three levels were used in presenting the expected yields in Table 34. These are defined as follows:

Level A: Management practised by the majority of farmers in the Area. Here, the soils are usually inadequately fertilized and/or drained and cultural practices are mostly poor.

Level B: Management practised by the top 20 percent of the farmers i.e. the most successful and progressive conservation farmers. Cultural practices are of a high order and the soils are generally adequately fertilized and/or drained. Suitable rotations using the best available varieties are applied and cultural practices are good.

Level C: Management assumed to be the best in the present state of the agricultural arts i.e. developed by the most up-to-date research. This level is consistent with that required to exploit the <u>economic</u> potential of the soil to its maximum.

In considering practices to be applied at each level, it should be noted that as they become more costly so they must fit the kind of soil more precisely. Furthermore, the greater the homogeneity of the soil unit, the better the prediction is likely to be. Although the predictions in this discussion apply to soil series, the phase level is more meaningful for detailed farm planning. Steep slopes, for instance, have the effect of reducing yields although in most cases the reduction is slight.

<u>Yield predictions for selected crops</u>: Here the object is to indicate the relative productivity of selected soils in the Area by predicting the yields of two widely grown crops viz., maize and <u>Eragrostis curvula</u>. The predictions are intended to serve as a guide for planning

production schedules and to encourage farmers to adopt a more quantitative approach in their cropping efforts. It is also hoped that others will be stimulated to compile yield expectancy tables for a wide spectrum of crops, pastures and trees for all the important soils. The predictions are based on meagre information gathered through interviews with farmers and extension workers, research projects, co-operative trials, study group reports and several surveys conducted in the Area.

Climatic variations, because of their influence on yield, were also taken into account. However, the difference in temperature conditions between the Highland Sourveld and Midlands Mistbelt did not influence the predictions. As a guide to yield expectancy for highly leached soils in the Highland Sourveld, the yields presented should be reduced by approximately 10 percent. For obvious reasons abnormal conditions (e.g. droughts) were ignored. On a short term basis, yields can be expected to vary by approximately 25 percent although on shallow and sandy soils variation can be very much greater.

Management levels and practices for the two crops concerned are briefly described on the basis of the defined A-B-C levels. Since fertilizer application is the main factor affecting yield, a guide is given to the rate of application for each level of management. Details concerning the numerous types of fertilizer and methods of application are of necessity omitted. The indicated nutrient levels refer specifically to those applied to highly leached soils and are approximately 20 to 30 percent higher than those for the partially leached soils. Efficiency in all agronomic and conservation practices increases from level A to level C.

Level A: At this level soils planted to maize receive infrequent application of ½ to 1 ton of lime per acre followed by 20 to 30 lbs each of N, P and K per acre. Side-dressing with N is not a common practice or, if applied, the level is low. Plant populations are generally between 8,000 and 10,000 plants per acre and local varieties are commonly planted. Agronomic and conservation practices are generally unsatisfactory.

For *E.curvula* the fertilizer applied is less than 100 lbs N, 50 lbs P and 50 lbs K per acre. The rates given for P and K apply to establishment. The nitrogen is generally applied in several dressings and the amount of lime is similar to that indicated for maize.

Level B: Lime is usually applied at a rate of 1 to 2 tons per acre every 3 to 5 years. Fertilizer rates approximate 70 to 80 lbs N, 30 to 40 lbs P and 30 to 50 lbs K per acre although the levels of P and K may be considerably higher. Side-dressing with nitrogen is common practice and plant populations are between 12,000 and 15,000 plants per acre. Hybrid varieties are usually planted and sound conservation and cultural practices, including pest and weed control, are applied.

E.curvula is established with approximately 1 to 2 tons lime and 80 to 100 lbs P per acre. Annual applications of 200 to 250 lbs N and 80 to 100 lbs K per acre are usually applied.

Level C: Lime and fertilizer rates are based on soil analyses with threshold values established by research. As a general guide the lime requirement of the highly leached soils is usually between 2 and 4 tons lime per acre. Fertilization rates are based on target yields and are not less than 120 lbs N, 80 lbs P and 100 lbs K per acre. Refined fertilizer and tillage techniques, such as band placement and subsoiling, are automatically applied where needed. Cultural, drainage and conservation practices are designed to meet the needs of individual soil series, maintain a high level of fertility and reduce soil loss to a minimum. Hybrid varieties are planted at populations exceeding 15,000 plants per acre. The return of all stover is common practice.

As a general guide, the fertilizer rates for *E.curvula* are upward of 250 lbs N, 100 lbs P and 100 lbs K per acre with most of the phosphorus applied at establishment.

Yields of maize and *E.curvula* under the defined levels of management for a number of important upland soils are presented in Table 34.

The predicted yields under C-level management may appear unduly optimistic but, if the recent advances in soil and crop technology continue, even these could be outdated well within a decade. Already new yield horizons have been established that were once considered

Table 34 : Predicted yields of maize and *Eragrostis curvula* for selected soils in the Howick Extension Area

Soil series	Maize bags/acre			*E.curvula* (hay) tons/acre		
	Management level					
	A	B	C	A	B	C
1) Highly leached soils						
BALMORAL, FARNINHAM	12	25	over 40	3	5	8
HUTTON	12	25	35	3	4	7
FARMHILL, GRIFFIN	15	30	40	3	6	8
CLOVELLY, Cranwell	12	25	35	3	5	7
MISPAH (clayey)	10	18	25	3	4	5
CLEVELAND	12	20	30	3	4	6
OATSDALE	10	15	25	3	4	5
MISPAH (loamy)	10	15	20	2.5	3.5	4.5
2) Considerably to moderately leached soils						
VIMY, DOVETON	12	22	over 35	3	4.5	6
MSINGA	10	20	30	2.5	4	5
BERGVILLE	15	25	35	2.5	4	6
AVALON	12	25	30	2.5	3.5	5
LEKSAND	10	20	30	2	3	4.5
WINTERTON	8	15	25	1.5	2.5	4
ALBANY	8	15	22	1.5	2.5	3.5
LONGLANDS	6	12	20	1	2	3
ARROCHAR	8	18	25	2	3	4.5
MISPAH (clayey)	8	12	20	2	2.5	3.5
KLIPFONTEIN*	6	12	15	1	2	3
3) Moderately to slightly leached soils						
SHORTLANDS, GLENDALE	12	18	over 25	2	3	4
ESTCOURT*	6	12	20	1.5	2.5	3.5
UMLAAS	10	18	25	2	3	4
ARCADIA	8	14	20	1.5	2.5	3.5
RENSBURG*	10	16	22	1.5	2.5	4

* Not generally recommended for arable use

unrealistic. In fact, experimental data for some soils show that very much higher yields than those indicated can be achieved in a favourable season. It will be noted that the more stable highly leached soils have been favoured in the predictions. It is possible, however, that yields from the loamy HUTTON and CLEVELAND series should be similar to, or, on a short term basis, even higher than those of the clayey soils.

According to popular opinion the grey-brown, considerably leached soils (e.g. BERGVILLE) have a higher yield potential than the associated red soils (e.g. VIMY) by virtue of their more favourable moisture characteristics at depth, their less complex fertility problems (especially P-fixation) and the less likely occurrence of witch weed. The similar yields presented for these two groups are based on the assumption that agronomic practice at the C-level will be such that the main effects of inherent soil properties will be reduced.

Response of maize to 'inputs' is likely to be greatest among the highly leached soils. With low levels of management, it can, however, be argued that the partially leached soils hold economic advantage over the former group since costs of corrective lime and fertilizer treatment are relatively low. Nevertheless, there is little doubt that with the highest level of management the highly leached soils will produce substantial and consistent economic returns.

Table 34 includes several soils (e.g. ESTCOURT) that are not generally recommended for arable use. Their inclusion is merely to indicate their assessed productivity for comparative purposes. Yields of E. curvula refer specifically to the peak production period of the ley.

4) Use-suitability, limitations and management needs

This discussion serves to summarize the information on use-suitability, limitations and management for each soil series. The information lacks specificity for planning soil and crop management programmes in detail but is intended as a general guide and a basis for accumulating additional knowledge of soil behaviour.

If the development of a pedological approach to land-use planning is to follow American experience, it is predicted that the farmer will eventually fit a combination of management practices to each soil on his farm to meet the objectives of the enterprize. In this way he will tend to reap the same yield from a given crop on many kinds of soil. However, the amount, kind and combination of practices used to achieve this will, of course, differ from one soil to another. This concept is very different from that in which a limited number of practices are applied to all soils and differences in yield are attributed to differences in soil productivity (U.S.D.A., 1965).

Generally, the highest agricultural potential for a wide range of crop, pasture and tree species lies with the highly leached soils despite their low inherent fertility. Although many problems relating to phosphate fixation, exchangeable Al and trace element deficiencies have been noted, experience shows that with judicious corrective treatment these soils are potentially highly productive. Among the partially leached soils physical limitations relating to moisture stress, erosion hazard, drainage and unfavourable surface soil characteristics are more important and influence recommendations for use and management. On these soils the choice of crop, especially under rainfed conditions, is more restricted. Where possible, crops tolerant of moisture stress and poor drainage, and those providing an effective protective cover should be chosen above all others. Furthermore, the adoption of practices inclined to improve the organic matter status of these soils is strongly recommended.

Claypan soils are problem soils. At present it is widely accepted that these should be treated as 'non-arable' soils and should be carefully protected. While agreeing with this, the writer is of the opinion that there exists a certain potential for increasing intensity of use on these soils, albeit limited to pasture production. Management of the highest order would, however, be required. Jamison et al. (1968) have demonstrated how well claypan soils respond to good management and how they can be brought to a level of production approaching that of the best soils.

Assessments of use-suitability, main limitations and special management needs for all the main soil series in the Area are presented in Table 35. Since it is impossible to list all alternative crops that can be grown on each soil, the assessments should be considered together with the discussion presented in Chapter 6. Additional information concerning the bottomland soils is also given in Chapter 6.

5) Interpretations for non-agricultural uses

Attention is drawn to these interpretations because the demand for them in the near future will be considerable. With the rapid urbanization and industrial expansion taking place in the Area careful planning is needed to avoid costly development and environmental hazards. It is necessary, therefore, that the soil survey be systematically expanded to include many interpretations for uses other than agriculture.

No attempt has been made to interpret the soil resources for non-agricultural purposes in this study since many of the necessary criteria have still to be established. These include soil properties that affect such items as road construction and maintenance, building foundations, water storage projects, sewage disposal systems and even the corrosivity of metal and concrete conduits. Interpretations are needed especially for the development of residential areas, building sites for light industry and commerce and the location of highways, railways and even airports.

Interpretations for aesthetic and recreational purposes are also important. These are required to conserve existing resources of land and water, promote beauty, protect wildlife and develop recreational facilities. Recreational projects may include, amongst

Table 35 : Use-suitability, limitations and management needs of soils in the Howick Extension Area

Soil asstn.	Management group	Soil series	Use-suitability	Main limitations	Management needs	Remarks
			(a) UPLAND SOILS			
		(i)	Highly leached soils			
A1	A1/H1	BALMORAL - Tabamhlope FARNINGHAM-	Stable soils of very high potential for intensive arable use. Suitable for a very wide range of cash and fodder crops, vegetables and pastures. Excellent for afforestation. Well suited to intensive supplementary irrigation.	Very low plant nutrient status and extreme acidity. Intense P-fixation. Prolonged cultivation may lead to deficiencies of K and trace elements. Associated with steep slopes and outcrops of rock. Red colour adheres to root crops e.g. potatoes.	Judicious lime and fertilizer practice. Ordinary good farming and organic matter conservation usually ensures safe use. Steep slopes require fairly intensive protection.	Corrective lime and fertilizer needs to be established by research. Shallow phases overlying shale fairly common. Afforestation preferable on steeper slopes.
A2	A2/H2	Broadmoor HUTTON -	With rigid conservation and efficient husbandry suitable for intensive arable use including a wide range of crops, pastures and trees. Leys of moderate duration should be included in the rotation. Well suited to supplementary irrigation.	As for A1-association but higher erosion hazard (wind and water) on steep slopes and following prolonged cultivation. Generally associated with lower aerial temperatures in the Area.	Corrective lime and fertilizer need more exacting but less complex than for A1-association. Organic matter conservation. Intensive conservation practice on steep slopes. Avoid pulverizing tillage operations and exposure to wind erosion in early spring.	Water holding capacity and productive potential generally underrated. Erosion control and corrective fertilizer treatment require further study.
	B1a/GR1	FARMHILL - Helpmekaar Lidgetton GRIFFIN -	Stable soils of very high potential for intensive arable use. Suitable for wide range of crops (especially roots) and grass-clover pastures. Very suitable for afforestation and supplementary irrigation. Maize-clover based pasture or potato-*E.curvula* rotations recommended.	Very low plant nutrient status, Al-toxicity and severe P-fixation. Zn deficiency causing 'yellowing' in maize common. Initial growth of trees sometimes poor.	Corrective lime and fertilizer treatment essential for high production. Organic matter conservation. Unless steep simple conservation practice will ensure safe use.	First crop on virgin land often poor.
	B1b/CL1	Cranwell CLOVELLY -	Stable soils of high potential for intensive arable use. Suitability as above.	As above with added possibility of depth variation. Shallow soils overlying weathered shale common.	As above but with more intensive conservation measures for shallow or steep phases.	Among the most extensive B1-association soils.
B1	B1c/M1	MISPAH - (clayey)	With intensive conservation and deep tillage level areas have low-moderate potential for arable use. Rotation to include leys of long duration. Second rate for trees.	Low plant nutrient status, shallow depth, moderate to high erosion hazard and low available moisture capacity. Underlying rock may hinder cultivation. Trees subject to windthrow.	Adequate lime and fertilizer application and especially deep primary tillage and subsoiling can render this soil productive. Intensive conservation practice required on steeper slopes.	Occurrence on level terrain not extensive. Confined mainly to steep slopes.
	B1h	Humic phase soils of B-association	High potential for arable use. Best suited to rotation of potatoes, roots and pasture including grasses such as *E.curvula*, cocksfoot and ryegrass. Clover production requires high levels of lime and phosphorus. Periods of cropping should be short. Suitable for cold resistant tree species.	Very low plant nutrient status and intense P-fixation. Subject to erosion by wind after relatively short periods of cropping. Build-up of important potato diseases (e.g. *Rhizoctonia sp.*) possible. Soils associated with low aerial and soil temperatures. Trees subject to windthrow.	Corrective lime and fertilizer treatment (lime and P requirement very high). Conservation needs fairly intensive especially where subject to overflow and erosion by wind.	Advantage of reducing high organic content for disease control and improved fertilizer response to be investigated. This should be related to specific crop rotations.
B2	B2a/GR2	CLEVELAND -	With adequate protection and corrective fertilizer treatment moderate-high potential for arable use. Suitable for fairly wide range of crops. Short term crop (roots and fodder) - long term ley (e.g. *E.curvula*) rotation recommended. Suitable for afforestation and supplementary irrigation.	As for B1-association but greater erosion hazard (wind and water) especially on steep slopes and shallow phases. Rapid structural degradation and loss of organic matter results from continued arable use.	Corrective fertilizer treatment more exacting but less complex than B1-association soils. Minimum tillage and intensive conservation practice required for safe use. Organic matter conservation. Avoid pulverizing tillage operations and exposure to wind erosion.	Moisture characteristics and productive potential generally underrated. Erosion control requires special study.

Table 35 contd

Soil asstn.	Manage-ment group	Soil series	Use-suitability	Main limitations	Management needs	Remarks
			(a) UPLAND SOILS			
		(i)	Highly leached soils			
B2	B2b/CL2	OATSDALE	Low to moderate potential for arable use provided protection and corrective fertilizer treatment adequate. Leys of long duration and short periods of cropping recommended. Steeper slopes require permanent cover. Suitable for trees and limited supplementary irrigation.	As for CLEVELAND series but shallow depth results in higher erosion hazard and lower available moisture capacity. Single grain condition will result from intensive cropping. Shallow phases tend to be sandier than normal. Trees subject to windthrow on shallow phases.	As for CLEVELAND series but intensity of conservation practice to be increased. Deep tillage and subsoiling may aid erosion control.	Erosion control research required.
	B2c/M2	MISPAH (loamy)	Low potential for arable use. Best suited to production of permanent pasture or left under natural veld. Hardier tree species can be grown.	Very low nutrient status, very shallow effective depth and mechanical limitation due to underlying rock. Trees subject to windthrow.	Corrective lime and fertilizer treatment and very intensive conservation practice required. Subsoiling and deep ploughing advantageous.	Usually associated with steep slopes.
		(ii)	Partially leached soils			
D1	D1a/H3	VIMY Weston DOVETON Loskop* RICHMOND	Stable soils of high potential for intensive arable use. Similar to A1-association but with fractionally lower yield potential. Suitable for wide range of crops, pastures and trees. Very suitable for intensive supplementary irrigation.	As for A1-association soils with added limitation of periodic moisture stress. Witch weed frequently associated with these soils. Trace element deficiencies e.g. Zn may be severe.	As for A1-association soils. Timeous deep tillage (e.g. ploughing and sometimes subsoiling) recommended for moisture conservation.	Fertility problems of D1-association soils not generally of same magnitude as those of A1-association.
	D1b/H4	MSINGA Rooikop*	Moderate to high potential for intensive arable use under rainfed conditions. Maize, sorghums and fodder crops in rotation with grass leys recommended. Second rate for afforestation. Very suitable for supplementary irrigation.	Low plant nutrient and organic matter status, moisture stress and moderate erosion hazard on sloping land.	In addition to corrective lime and fertilizer treatment and protection against erosion the conservation of moisture and organic matter are especially important.	Not widespread in Area.
	D1c/S1	SHORTLANDS Bellevue Mone	Stable soils of high potential for intensive arable use. Under rainfed conditions crops tolerant of moisture stress recommended (e.g. sorghums, maize, soyabeans, lucerne and <u>E.curvula</u>). Suitable for intensive irrigation. Many crops including lucerne, vegetables, citrus, wheat and grass-clover pastures can be grown under irrigation. Commercial afforestation not recommended. Poplar could be grown under irrigation.	Droughty soil climate, steep slopes and outcrops of rock. Low nutrient status especially P. Witch weed associated with these soils.	Effective moisture conservation most needed. Deep tillage and organic matter conservation recommended. Occasional deep ploughing or subsoiling, especially where irrigated, and incorporation of crop residues of benefit. Simple conservation measures generally ensure safe use.	Further study of irrigation requirements and moisture conservation needed.
D2	D2a/H5	Jageredrift	Low to moderate potential under rainfed conditions. Very suitable for intensive irrigation which will permit intensive production of vegetables, lucerne, citrus, wheat and high quality pasture.	Low available moisture capacity and plant nutrient status (e.g. P).	Moisture and organic matter conservation.	Occurs mainly on level sites adjacent to the Mooi river. Erosion hazard generally low.

Table 35 contd

Soil assn.	Management group	Soil series	Use-suitability	Main limitations	Management needs	Remarks
			(a) UPLAND SOILS			
		(ii)	Partially leached soils			
E1	E1a/CL3	NEWPORT	High potential for intensive arable use. Rotation to include crops such as maize, sorghums, soyabeans and leys (e.g. E.curvula and lucerne) of moderate duration. Second rate for afforestation. May be sprinkler irrigated.	Fairly low plant nutrient and organic matter status and physical limitations such as shallow effective depth, moderate moisture capacity, moderate erosion hazard and tendency to crust, form clods and puddle. Compaction likely under intensive grazing. Drainage slightly impeded.	Judicious fertilization (especially N) moisture and organic matter conservation. Deep timeous tillage including subsoiling and fairly intensive conservation practice. Avoid tillage or grazing when wet. Incorporate crop residues.	Marked responses to N and farm manure. Pig weed (Amaranthus spp.) often troublesome.
	E1b/CL4	SOUTHWOLD	As for NEWPORT series but including leys of longer duration.	As for NEWPORT series but with higher erosion hazard and moisture stress.	As for NEWPORT series with increased intensity of conservation practice. Deep tillage (e.g. subsoiling) recommended.	
	E1c/AV1	NORMANDIEN BERGVILLE	Fairly stable soils of high potential for intensive arable use. Especially suited to production of maize. Sorghums, soyabeans, cowpeas, wheat and short term leys of E.curvula also recommended. Second rate for afforestation. Can be sprinkler irrigated with care.	Similar to NEWPORT series but with slightly more favourable moisture characteristics. Impeded drainage in lower subsoil may affect deep rooted crops.	Similar to NEWPORT series. Emphasis should be given to correct fertilization (especially N) and improvement of organic matter status.	Safe rotation of crops should be established.
	E1d/AV2	RUSTON AVALON	Similar to above with leys of longer duration on sloping land.	Similar to above with slightly increased erosion hazard and moisture stress.	Similar to above but requiring intensive conservation especially on sloping land.	
	E1e/CA1	Shandon ARROCHAR	Low to moderate potential for intensive arable use. Short term crop (e.g. Maize, soyabeans and sorghum) - long term ley (E.curvula, Rhodesgrass or lucerne) rotation recommended. Not suited to afforestation or intensive irrigation.	Shallow depth, impeded drainage, droughty soil climate, moderate erosion hazard and unfavourable surface soil characteristics. Underlying rock may hinder tillage. Mounds of snouted termite sometimes prevent mowing	Similar to other E1-association soils with emphasis on deep, timeous tillage (including ploughing and subsoiling) and organic matter conservation. Intensive biological and mechanical erosion control measures required on sloping land. Avoid tillage or grazing when wet.	Tillage, drainage and crop rotation requirements should be established.
	E1f/M3	MISPAH (clayey)	Low potential for intensive arable use. Suited to leys of long duration or permanent cover (e.g. natural veld).	Very shallow depth, droughty soil climate and moderately high erosion hazard. Underlying rock hinders deep tillage. Termite mounds may be common.	Similar to ARROCHAR but requiring more intensive conservation practice.	In moist regions and with efficient agronomic practice potential generally underrated.
	E1g/GE1	Majuba	Low to moderate potential for intensive arable use. Crops and pastures tolerant of moisture stress recommended e.g. Sorghums and soyabeans. Leys should be of long duration. Under special conditions may be sprinkler irrigated.	Physical limitations including moisture stress, periodic waterlogging, moderate erosion hazard and unfavourable surface soil characteristics most important.	Moisture conservation and deep tillage to effect improved drainage and moisture retention. Intensive conservation practice.	Not widespread in the Area.
	E1h/GE2	Frere	As for Majuba series.	As for Majuba series but with increased erosion hazard.	As for Majuba series but with increased intensity of conservation practice.	
E3	E3a/CL5	SPRINGFIELD	Low potential for intensive arable use. Rotations to include leys (e.g. E.curvula) of long duration and crops tolerant of moisture stress. Permanent cover recommended for sloping land. Careful irrigation permitted.	Shallow depth, low available moisture capacity, high erosion hazard and low plant nutrient and organic matter status.	Judicious fertilization (especially N). Deep timeous tillage, organic matter conservation and very intensive conservation practice needed. Subsoil shallow phases.	Plant density frequently too low for effective erosion control.

Table 35 contd

Soil assn.	Management group	Soil series	Use-suitability	Main limitations	Management needs	Remarks
			(a) UPLAND SOILS			
		(ii)	Partially leached soils			
E3	E3b/AV3	Melrose LEKSAND	Moderate potential for intensive arable use. On favourable slopes suitable for maize, sorghums, soyabeans, groundnuts, wheat, etc. Rotations should include leys of moderately long duration. Can be sprinkler irrigated to advantage.	Low plant nutrient and organic matter status, high erosion hazard (wind and water), low available moisture capacity and impeded drainage at depth. Trace element deficiencies and Al-toxicity may occur.	As above with emphasis on erosion control, organic matter conservation and tillage. Corrective fertilizer needs more exacting but less complex than E1-association series.	Potential and moisture characteristics generally under-estimated. Fertilizer needs, safe rotations and optimum irrigation practice should be stablished.
	E3c/L3	LONGLANDS	Very low potential for intensive arable use. Suitable for leys of very long duration (e.g. *Paspalum spp.*) especially for silage or hay production. Unsuitable for irrigation without effective drainage.	Poor drainage, low plant nutrient and and organic matter status, high erosion hazard and low available moisture. Water-logged conditions alternate with drought. Tillage delayed when wet.	Judicious fertilization (especially N), effective surface and/or underground drainage, very intensive conservation practice and organic matter conservation. Avoid tillage and grazing when wet.	Usually associated with lower slope position and weak gradients.
	E3d/M4	MISPAH (sandy)	Very low potential for intensive arable use. Should be sown to permanent cover or left under natural veld.	Similar to SPRINGFIELD but with increased erosion hazard and moisture stress. Underlying rock hinders deep primary tillage.	Similar to SPRINGFIELD but requires very intensive conservation practice.	
E5	E5a/GL1	GLENCOE	Fairly stable soil of moderate to high potential for arable use. Recommended use similar to AVALON series for deep phases although yield potential fractionally lower.	As for AVALON series but iron hardpan may restrict deep primary tillage.	As for AVALON series. If subsoiling impractical or too costly surface drainage may be necessary.	Potential related to depth. Ironpan suitable for road metal
	E5b/GL2	WESSELSNEK	As for GLENCOE series but with lower potential and intensity of use. Rotation should be based on leys of long duration.	As for GLENCOE series but with lower available moisture capacity and higher erosion hazard.	As for GLENCOE series but with increased conservation of soil moisture and organic matter. Protective measures should be intensified.	
	E5c/W1	WARRICK	Low potential for intensive arable use. Suited to leys (hay or silage) of very long duration or permanent pasture swards tolerant of poor drainage. Unsuitable for irrigation unless effectively drained.	Poor drainage and moderately high erosion hazard if subject to overflow. Alternative periods of waterlogging and moisture stress. Difficult tilling and grazing when wet. Unfavourable surface soil characteristics and obstruction of deep primary tillage by ironpan.	Effective surface and/or underground drainage. Deep, timeous tillage including subsoiling. Organic matter conservation and intensive protective measures. High N requirement related to temporary waterlogging. Avoid tillage and grazing when wet.	Usually associated with weak gradients.
	E5d/W2	WASBANK	Very low potential for intensive arable use. Should be left under natural veld or planted to permanent pasture (hay or silage).	As for WARRICK series but with severe limitations of poor drainage, low moisture availability and high erosion hazard.	As for WARRICK series but including conservation practice of greater intensity.	
	E5e/M5	MISPAH (clayey - poorly drained)	Very low potential for arable use. Should be sown to permanent pasture or left under natural veld.	Very shallow depth, poor drainage, low available moisture capacity and ironpan obstruction.	Effective surface drainage depending on depth. Protection during establishment period.	
	E5f/M6	MISPAH (KLIPFONTEIN) (sandy-poorly drained.	Extremely low potential for arable use. Should be left under natural veld.	As above but with increased severity of moisture stress, poor drainage and erosion hazard.		

Table 35 contd

Soil assn.	Management group	Soil series	Use-suitability	Main limitations	Management needs	Remarks
			(a) UPLAND SOILS			
		(ii)	Partially leached soils			
E6	E6a/L1	WINTERTON*	Low potential for intensive arable use. Eminently suited to mixed pasture swards for hay or silage (e.g. Paspalum spp.). With effective drainage limited cropping of maize, silage crops and Poplar possible. Careful sprinkler irrigation recommended if effectively drained. Pastures of Fescue and Ryegrass suitable under irrigation.	Poor drainage, unfavourable soil characteristics, compaction if grazed intensively and tillage delayed when wet	Effective surface drainage. Deep timeous tillage (e.g. subsoiling) and organic matter conservation. Avoid tillage and grazing when wet.	Usually associated with lower slope position and weak gradients. Drainage techniques require investigation.
	E6b/L2	ALBANY*	Similar to WINTERTON series.	As for WINTERTON series but mechanical limitations not as severe. Higher erosion hazard if subject to overflow.	As for WINTERTON series but may require more intensive conservation practice.	
F1	F1a/E1	ESTCOURT*	Very low potential for intensive arable use. Generally regarded as non arable; to be sown to permanent well fertilized swards (e.g. Rhodesgrass or E.curvula) or left under natural veld. With efficient management and protection short (1 year) period of drought-resistant crops could be permitted in rotation. Not generally suited to irrigation although careful sprinkler irrigation will increase crop yield but is generally uneconomic. Highly remunerative shallow rooted crops may justify the expense if better soils unavailable.	Very high erosion hazard (especially subsoil), severe moisture stress, periodic waterlogging, unfavourable surface soil characteristics, low plant nutrient status, high swell-shrink potential and difficulty working when wet.	Very intensive conservation practice including adequate plant cover (well fertilized) during summer and careful layout of mechanical structures (e.g. waterways). Organic matter conservation. Avoid disturbing subsoil and working when wet. Maintain grass sward around farm buildings to prevent deep drying out of subsoil and subsequent cracking.	Erosion control research and optimum land-use practice to be established. Run-off increases when subsoil is saturated i.e. late in season.
	F1b/KR1	Bluebank	Similar to ESTCOURT series but land-use practice not as restrictive. Best suited to leys of long duration or permanent cover. Generally unsuitable for irrigation.	High erosion hazard, poor drainage and unfavourable moisture characteristics.	Very intensive conservation of soil and organic matter, and judicious fertilization.	Not extensive in the Area.
G2	G2a/KI1	KIORA* UMLAAS*	Moderate potential for intensive arable use under rainfed conditions. Intensive grain and fodder production sometimes hazardous but depend on seasonal rainfall. Well suited to intensive irrigation. Wide range of crops including lucerne, vegetables, grass-clover pastures and possibly poplars, can be grown under irrigation.	Droughty soil climate, slight swell-shrink potential and moderate erosion hazard on steep slopes. Satisfactory tillage only possible between critical moisture limites.	Effective moisture conservation through deep timeous tillage. Conservation practice required on steep slopes.	Not widespread in Area.
	G2b/AR1	RYDALVALE* ARCADIA*	Low potential for intensive arable use under rainfed conditions. Suitable for short periods of drought-resistant crops and leys of long duration or left under natural veld. Suitable for careful sprinkler irrigation under which fairly wide range of crops and pastures can be grown (e.g. cotton). Lucerne and pastures recommended.	Droughty soil climate and severe moisture stress at times of high evaporature demand,	Moisture conservation judicious fertilization (N and P) and intensive protection against erosion. Avoid working when wet.	No allowance made for calcareousness of ARCADIA series. Rate of K supply may be too slow for high demanding crops.
	G2c/R1	RENSBURG PHOENIX Ladysmith	Low potential for intensive arable use under rainfed conditions. Permanent cover crops (e.g. lucerne or pasture) advocated. Limited period of drought-resistant crops permitted if adequately protected. In narrow bottomlands subject to overflow should remain under natural vegetation. Can be irrigated to advantage (sprinkler) but requires high level of management. Lucerne and pasture recommended if irrigated.	Very high erosion hazard in the bottomland position, very droughty soil climate, poor drainage in lower subsoil, high swell-shrink potential and unfavourable physical characteristics. Tillage delayed when wet.	Very intensive conservation practice, careful tillage, judicious fertilization and moisture conservation. With very level topography requires drainage (e.g. surface).	RENSBURG series in bottomland position usually severely eroded.

* Soils mapped in D3-association

Table 35 contd

Soil asstn.	Management group	Soil series	Use-suitability	Main limitations	Management needs	Remarks
				(b) BOTTOMLAND SOILS		
C1	C1a/CH1	IVANHOE	Unsuitable for arable use. With special land improvement and conservation techniques can be used for production of permanent pasture (e.g. Paspalum spp., Fescue, rye-grass and clover) preferably under sprinkler irrigation.	Very poor drainage (waterlogging). Occasional overflow, potentially high erosion hazard and difficult to work when wet. Parasites a danger to grazing live-stock.	Effective safe drainage (surface and underground) to afford 'complete' control over watertable. Conservation practices to protect vlei as a whole. Judicious lime and fertilizer application and establishment of pasture in sections. 'Key' area to be totally protected. Roll heavily for pasture establishment.	Utilization to be considered with overall planning of catchment area especially with regard to water conservation.
C1	C1b/CH2	CHAMPAGNE	Similar to IVANHOE series but preferably left in natural state.	As for IVANHOE series.	As for IVANHOE series but with increased intensity of conservation practice.	Not extensive in the Area.
C1	C1c/KA1	KATSPRUIT Emmaus	Unsuitable for arable use but may be used for the production of permanent pastures preferably under sprinkler irrigation. Requires special land improvement techniques and conservation practice to ensure safe use.	Very poor drainage and occasional overflow, potential erosion hazard, unfavourable physical characteristics and compaction under intensive grazing.	As for IVANHOE series although value of underground drainage doubtful. Preferable to cut for silage during summer and to graze during winter. Avoid compaction.	
C1	C1d/F1	Dell	Preferably left in natural state. Under special conditions could be established to permanent pasture.	Very poor drainage and potentially very high erosion hazard. (See IVANHOE series.)	As for IVANHOE series but greater intensity of conservation practice.	Not extensive in the Area.
H1	H1a/KA2	KILLARNEY Emmaus (alkaline) Matiwane	Where development is justified well suited to production of high producing pasture swards. May be irrigated (sprinkler) to advantage. Irrigation permits wide choice of pasture species. Under special conditions of drainage and conservation fodder (silage and hay) crops and poplar may be considered.	Very poor drainage and occasional overflow, intermittent moisture stress, mechanical limitations (including consistence and tendency to puddle and compact). Difficult to work when wet. Potential erosion hazard and occurrence of poisonous weeds Matricaria spp. and Moraea spp.	Similar to KATSPRUIT series.	
L1	L1a/D1	ALLUVIUM - (clayey)	Limited potential for intensive arable use but potential for pasture production with effective drainage and sprinkler is high. Poplar production suitable if adequately drained.	Poor drainage, periodic flooding, mechanical limitations (consistence and compaction) silt deposition on fodder crops, presence of Moraea spp. and difficult to work when wet.	Effective surface drainage and protection against flooding, requires rapid removal of flood waters and protection against scouring. Avoid working or grazing when wet and conserve organic matter.	
L1	L1b/D2	ALLUVIUM - (loamy)	High potential for intensive arable use. Well suited to wide range of crops and pastures. Intensive vegetable production, lucerne, pastures and poplars recommended. Well suited to irrigation.	Periodic flooding and occurrence of Moraea spp.	Adequate and safe disposal of flood water, judicious fertilization and organic matter conservation.	
L1	L1c/D3	ALLUVIUM - (sandy)	Moderately high potential for arable use. Lucerne, high producing pastures, vegetables and poplars most suitable especially if irrigated. Irrigation essential for maximum productivity.	Excessive drainage, low available moisture capacity, occasional flooding and occurrence of weeds.	Adequate and safe disposal of flood water, protection against scouring, judicious fertilization and organic matter conservation.	Successful production of poplar dependent on height of water table.

others, intensive (e.g. athletic fields) and extensive (e.g. parks and picnic areas) play areas, camping sites and golf courses. Interpretations could also aid the development of a variety of wildlife habitats.

Although much research and experience is required before interpretations such as these can be made with confidence, the need for them is great. Many projects within the Area have been planned and completed without any regard to the suitability or limitations of the soils.

3.3 Bench mark soils and agricultural research needs

The need for further study of the soils of the Tugela Basin was described by Phillips (1966) as imperative, because the poor farming conducted on them was conducive neither to soil conservation nor to the economic advancement of the farmer. In the Howick Extension Area this need is just as great and there are now obvious advantages to be gained from the completed soil survey.

Soil classification should be tested and refined, through research. In this way refinement of existing soil series on a basis of productivity and soil behaviour is permitted. For example, Riecken (1962) showed how the Grundy series was eventually refined to have a much narrower range in morphology and productivity than was formerly accepted. Studies of this nature, especially of the upper clay percentage limits (55 percent) of the highly leached soils and refinement of the orthic A1-horizons, are strongly recommended.

The soil survey provides the basis for a sound research programme. It requires, however, that each project should be clearly related to defined soil series, or phases thereof, by accurate soil identification at each site. This need is great since qualifying analytical data and descriptions do not always accompany present day research reports.

The research worker should also appreciate that soil is so intimately associated with its environment that it cannot be taken 'wholly' into a laboratory - only samples of its many parts can be subjected to scientific investigation. For most studies he must, therefore, return to the field and integrate his results with all other unsampled properties and processes (Kellog, 1966).

Olsen (1966) drew attention to another important principle i.e. the inter-disciplinary approach to soil research. Pedologists should join forces with planners, engineers and others in order to correlate all available information. Correlating the soil map and the mapping units with other available data, no matter what the source, often brings to light information of great value.

The following discussion refers to 'vertical' research and not to the broader 'blanket' or 'horizontal' research (Riecken, 1962; Oschwald, 1966; van der Eyk et al., 1969). Reference is made only to those aspects of particular importance to the Area.

1) The philosophy of bench mark soils

It is not practical to study in detail all defined soil series. To meet this problem a philosophy of 'bench mark' soils was developed in the United States whereby only special soils were selected for intensive study. Thus, 'bench mark' soils represent a small number of soils selected to bracket a wide range of soil conditions. By knowing their characteristics, qualities and behaviour, good predictions for other soils having similar properties can be made (Aandahl, 1962; Klingebiel, 1962).

Using this approach, a number of 'bench mark' soils were selected for the Area. Due consideration was also given to the specific ecological areas in which the soils occurred. A list of the 'bench mark' soils, together with their major research needs is presented in Table 36. The alluvial soils (Ll-association) were not included because of their extreme variability.

2) Agricultural research needs

Table 36 is intended as a guide for specialists and is by no

Table 36 : 'Bench mark' soils in the Howick Extension Area and their main agricultural research needs

Bench mark soils		Main agricultural research needs																			
Soil asstn.	Soil series	Production potential	Rainfall erosion losses	Response calibration and use 1) Lime	Response calibration and use 2) Fertilizer	Moisture characteristics	Improve rooting depth by 1) Amelioration	Improve rooting depth by 2) Tillage	Tillage requirement	Drainage technique (Surface and underground)	Moisture conservation	Surface soil limitations	Irrigation need and technique	Investigate condition and control of "brak"	Crop sequence	Residue management	Improved pasture	Veld reinforcement or replacement	Disease control	Control of erosion 1) Water	Control of erosion 2) Wind
A1	BALMORAL and/or FARNINGHAM	x	x	x	x	x	x		x				x		x	x					
A2	HUTTON	x	x	x	x	x	x		x				x		x	x				x	x
B1	FARMHILL and/or GRIFFIN	x	x	x	x	x	x		x				x		x	x					
	CLOVELLY and/or Cranwell	x	x	x	x	x	x								x	x		x			
	MISPAH (clayey)	x	x				x	x	x								x	x		x	
	Humic phase soils	x	x	x	x	x	x		x			x	x		x	x	x		x	x	x
B2	CLEVELAND	x	x	x	x	x	x		x				x		x	x				x	x
	OATSDALE	x	x	x	x		x										x	x		x	x
	MISPAH (loamy)	x	x				x	x	x		x						x	x		x	
C1	IVANHOE and KATSPRUIT	x		x	x	x			x	x			x	x		(x)	x	x			
D1	VIMY and/or DOVETON	x	x	x	x	x	x	x	x		x		x		x	x					
	MSINGA	x	x	x	x	x			x		x		x							x	x
	SHORTLANDS and/or Bellevue	x	x	x	x	x	x	x	x		x		x	x[2]	x	x					
D2	Jagersdrift	x			x	x					x		x							x	
E1	BERGVILLE	x	x	x	x	x			x	x[1]	x	x	x	x	x	x					
	AVALON	x	x	x	x	x			x	x[1]	x	x	x		x	x				x	
	SOUTHWOLD	x	x		x	x		x			x	x					x	x		x	
	ARROCHAR	x	x		x			x		x[1]	x	x				x	x	x		x	
	MISPAH (clayey)	x	x					x	x		x			x			x	x		x	
E3	SPRINGFIELD	x	x	x	x	x		x	x		x	x	x				x	x		x	x
	LEKSAND	x	x	x	x	x			x	x[1]	x	x	x		x	x				x	x
	LONGLANDS	x	x		x	x			x	x		x			x	x	x	x		x	
	MISPAH (sandy)	x	x					x	x		x						x	x		x	x
E5	GLENCOE	x	x					x	x	x		x		x			x			x	
	WARRICK	x	x					x	x	x		x					x	x		x	
E6	WINTERTON and/or ALBANY	x	x		x				x	x		x		x	x	x	x	x		x	
F1	ESTCOURT	x	x		x	x	x	x	x	x	x	x		x	(x)		x	x		x	
G2	UMLAAS	x	x		x	x			x		x		x	x		x				x	
	ARCADIA	x	x		x	x			x		x	x	x	x	x	x	x	x		x	
	RENSBURG	x	x		x	x			x	x	x	x	x	x	(x)		x	x		x	
H1	KILLARNEY	x			x	x			x	x		x	x	x	(x)		x	x			

1 - If irrigated
2 - Depending on situation in landscape
(X) - Special investigation

means a complete list of the many possible avenues for future research. Alternative soil series are listed where the need to separate soils for land-use purposes is not clearly warranted (e.g. 55 percent clay limit). Reference to 'crop rotation' includes all studies relating to organic matter conservation, residue management, fertility status and soil loss.

The following, not necessarily in order of priority, are the main fields requiring intensive study:

(i) Since the majority of soils in the Area are highly leached, fertility studies are among the most important. The extremely low plant nutrient status has led to poor conservation and limited economic achievement. The chief need is, therefore, to establish the lime and fertilizer requirements for a selected number of crops on the 'bench mark' soils. The best form of fertlizer and method of application (placement) should also be established and the role of rock phosphates and the economics of P-fertilization require thorough investigation. Amongst the partially leached soils, especially the E1-association soils, calibration of optimum nitrogen levels as suggested by Mallett (1961) is important. Although the G2-association soils are able to supply more potassium at a particular energy level than most other soils, the rate of supply may be insufficient to meet the needs of high K-demanding crops. Further study in this direction is also needed. Graven and Croft (1968) have already established widespread sulphur deficiencies in many Natal soils and investigations of this nature are required on a more intensive scale for the Area. Since a sound fertilizer advisory service is of immense value as a 'tool' for extension, the need to calibrate soil analytical data with yields of all the important crops and to establish critical threshold values is easily motivated. This is a top priority.

A special appeal is made for investigation into the effects of organic matter on both chemical and physical soil properties and its influence on soil moisture and erosion. From observation in the field it is clear that not only do soils differ markedly in organic matter status but their behaviour and management needs are greatly influenced by this property.

The potential for 'fertilizer injury' on specific soils, especially those of light texture, low CEC and unfavourable moisture characteristics, is also important. On some soils, even small quantities of dissolved fertilizer salts contribute to the 'injury' potential. Upper limits to fertilizer rates, especially when banded, should be established.

(ii) Physical characteristics influencing erosion control, irrigation, tillage and drainage provide an important field for study, especially among the partially leached soils. Additional physical data such as permeability, coefficients of liner expansion (COLE) and 'workability' are needed for engineering interpretations and other non-agricultural purposes. Studies of this nature should not be restricted to single-value criteria but should also include the profile as a whole.

Aspects relating to soil moisture, its entry into, movement within and improved storage of the profile, have an important bearing on recommended land-use practices for nearly every soil. Sub-surface barriers to promote improved moisture regimes and improved tillage and fertilizer treatment to ensure deep root penetration are also matters to be investigated. The influence of factors such as consistence and texture on depth, frequency, gradients, power requirements and economics of various tillage operations (e.g. subsoiling) are also worthy of intensive study. No attempt has yet been made to establish the power requirements for various tillage operations on individual soils. The establishment of optimum gradients for flood irrigation beds on each soil series provides a further example of fields yet to be studied. In addition, the drainage requirements and hydrological characteristics of the bottomland and other poorly drained soils should be investigated, since not only must recommended land-use ensure optimum production from these soils, but it must also ensure their safety. Leaching requirements of the 'vlei' soils should also be studied since irrigation is a prerequisite for their safe use.

(iii) Soil-crop relationships, under both rainfed conditions and irrigation, are of specific interest to the land-use planner. For his purposes the yield level attainable under different soil-crop management practices is of special value. These studies form the basis for soil evaluation and establishing yield potentials important to the planning of economic cropping systems. According to Riecken (1962), the development of precise yield estimates and crop production functions and to add quantitative information for as many practices as possible, is a challenge for future research. Murdoch (1965) regarded the answer to the deceptively naîve query of what harvest can be expected from a given crop on a particular soil series to be among the ultimate goals of applied pedology. From a number of alternative methods designed to meet this goal, including 'maximum yield' trials, Murdoch (1968) chose to concentrate on a selected number of crops. Stands of these, wholly or largely floored by a single series, were selected and thoroughly studied. Odell (1958), in a yield prediction study, found that although records from 50 to 150 farm fields presented a reliable guide, small plot trials were more precise. Since the sheer organization of sufficient trials of this nature is likely to thwart such attempts in the Area, Murdoch's approach warrants serious consideration. For this purpose, farmer study groups with their economic bias could be used to good advantage. Possible refinement of primary correlations between crop yield and soil series, obtained through 'single-value' studies (Ball, 1964) and 'edaphic trials' (Butler, 1964), is worthy of further consideration by those seriously attempting to study this field.

In addition to accepted farming practice, the suitability of many of the soils in the Area for high producing pasture swards of long duration has reduced the emphasis on crop rotation. Despite this, rotations should remain an important field for study especially on the partially leached soils. The establishment of profitable rotations that fit not only local farming practice but contain soil loss to within specified limits, is urgently required. Cook (1962) showed that cropping systems resulting in effective conservation and economic production, can be selected on the basis of productivity indices determined by the percentage loss of nitrogen and organic matter following cropping. The arithmetic approach to the rise and fall in the productive capacity of land does, however, require years of research and, according to Vincent and Hack (1960), includes many imponderables. The writer supports Nathanson (1962) who urged that properly designed ley rotation experiments should be planned with the proviso that data pertaining to organic matter status and soil loss on different soils are obtained.

The prevalence of certain diseases and weeds on specific soils should also be noted. For example, the occurrence of Rhizoctonia rot of potatoes on the humic phase soils of the B1-association Amaranthus spp. (pig weed) on the E1-association soils and witch weed on the D1-association soils warrant further study.

(iv) Improved pastures and the natural veld play a vital role in ensuring the conservation of most soils in the Area. Veld reinforcement and methods of replacement with minimum tillage are aspects requiring further study especially on the steep, low potential soils. Progress in this direction has already been made but more is needed in the drier parts. Grouping soils into 'vegetative groups' or 'range sites', on the basis of their similarity in characteristics affecting their capability for producing veld and pasture plants, also requires attention. This would encourage a more intensive investigation of soils within the 'non-arable' areas and inextensive farming regions.

(v) Erosion control research is urgently needed and is related to most of the fields already mentioned. The dearth of erosion control data, despite so much emphasis given to soil conservation since the passing of legislation in 1946, is inexplicable. A summary of results up to 1963 (Greyvenstein, 1963) indicates a meagre research effort in this field and since then, apart from isolated projects, little of practical value has been forthcoming. Elsewhere in the world, especially in the United States, much emphasis is placed on permissible soil loss values in formulating recommended conservation practices (U.S.D.A., 1965). The writer agrees wholeheartedly with Burney (1969) who stated that "it is of vital importance to the future of this country to determine scientifically what the allowable soil erosion rates are on the various soil series". Such information should be the prime objective of erosion control research, since it could serve to plan essential conservation practices and be used to advantage by extension personnel to activate the complacent farmer. The value of agronomic practices in erosion control should also be studied simultaneously. In this respect, Vincent and Hack (1960) reported that efficient agronomic practice could be as effective as crop rotations and mechanical control measures in reducing soil loss.

'No-tillage' and 'minimum tillage' techniques in some systems of arable production warrant special investigation since they benefit soil and moisture conservation. No-tillage planting after pasture or broadcast crops is suggested for the highly and considerably leached soils. In the drier parts the use of mulch systems is preferred. This field has not yet received the attention it deserves.

The beneficial effect of high fertility on soil and water loss has already been stressed but bears repetition. In fact, it is strongly recommended that research and extension should promote, above all else, the idea that judicious fertilization is, in itself, an essential means of combating soil erosion.

A particularly important field requiring intensive study is that concerning conservation engineering specifications for individual soils. This includes permissible gradients, spacing and speed of flow for various conservation works. Those in current use take little account of the characteristics of individual soil series. Specifications should thus be determined for individual series or management groups and should include effects of slope.

Soils of highest erosion hazard such as those of the F1-, G2- and E3-associations should receive priority. For the claypan soils studies such as those reported by Jamison et al. (1968) will be invaluable. An interesting feature of the study reported by these workers is that measurements of changes in soil surface elevation did not give reliable estimates of soil erosion losses, since large decreases in elevation of the surface can be caused by moisture losses in the subsoil. Greater attention should also be given to the use of well-fertilized Cynodon dactylon in the reclamation of eroded areas. Although donga control has received considerable attention in Natal, the fertility needs of highly erodible subsoil materials to permit the rapid establishment of a vigorous grass sward, have not been established. Protection and seeding of exposed areas by means of various emulsions, the use of grass sods established elsewhere for blanketing the eroded area and testing the effectiveness of various grass varieties against scour, are also aspects requiring immediate attention.

Erosion by water is most important but there is also a need to establish the seriousness and extent of wind erosion in the Area and, where necessary, the control measures. At present the problem is probably confined to the light textured soils of the A2-, B2 and E3-associations and to the humic phase soils.

(vi) Despite the results obtained by Shönau (1968) research should attempt to establish 'site indices' as a basis for interpreting soil data for forestry purposes. Soil limitations causing seedling mortality, erosion, windthrow and droughtiness, and the ordination of soils into suitability groups for timber production offer a wide field for study.

3.4 Application of interpreted data

A programme of education to encourage the widespread application of interpreted data should be given high priority in the overall extension programme for the Area. The aim should be to ensure that maximum use is made of all the existing soils information. The educational programme should describe the soil survey and explain how best it can be put to use. It must enlighten the public about soils, their capabilities and management needs and should explain how a soil will respond to treatment and manipulation. Ideally, the programme should stimulate demands for more detail, better interpretation and perhaps, new and more detailed surveys.

The programme should acknowledge that the audience for soils information is becoming broader and that many groups of people with many different interests, needs and goals are involved. It should, therefore, extend to both rural and urban communities (non-agricultural interpretations). Despite many benefits the programme may have for reaching the masses, it will not replace the need for individual consultation between farmer and soil scientist regarding specific problems.

In finalizing the procedures and methods for such a programme much can be learnt from American experience. Bidwell (1966) reported that the best method of reaching the public is via community educational meetings provided a suitable programme is arranged and attendances are large. The success of such meetings depends on careful planning involving the various institutions, holding the meetings at the correct time, good publicity and visual aids, careful selection of speakers, drawcards and the support of all local people including those of influential standing in the urban areas. Community meetings within the Area should involve the local soil conservation committees, farmers' associations, farmer study groups, programme planning committees, schools and other bodies. The venues selected should also cater for all sections of the community. It is suggested that meetings should be held during the winter or early spring and be of $1\frac{1}{2}$ to 2 hours duration. Well-planned and timeous publicity via local press, circulars, posters, radio and personal contact should ensure good attendances (20 to 50). Speakers should be selected from those concerned with recent advances in the field of pedology, including extension, research and university personnel. Maximum use should be made of visual aids including monoliths, slides, maps and field exhibits.

The Area lends itself to short tours and excursions to view soils and related land-use practices in the field since a wide range of soils can be observed over short distances. The possibility of introducing community rivalry through soil judging or crop yield competitions should also be considered.

The use of drawcards generally ensures successful meetings. Distributing copies of the soil survey report and other relevant literature on the soils could suffice for this purpose. American experience also shows that the supply of free refreshments is one of the most successful drawcards. The local Extension Officer should involve all people who could and should assist in the educational programme, including formal and informal leaders and influential business personalities.

Spectacular but ineffective publicity should be avoided. A subtle approach is thus advocated whereby the entire community is 'forced' into planning agricultural and other development on the basis of soil knowledge. For instance, all relevant extension media such as reports and publications (especially fertilizer guides) should be designed so that information on soils is constantly in the limelight.

PART II

NATURAL CHARACTERISTICS AND AGRICULTURE

CHAPTER 4

OTHER NATURAL CHARACTERISTICS AND AGRICULTURE IN THE AREA

Natural characteristics, other than soil, are described in this chapter. A summary is also given of the general agricultural conditions in the Area and the main problems associated with current farming practice. All of these features influence land classification and land-use planning. Classification of land in terms of inherent characteristics provides the foundation upon which all other types should be superimposed. A thorough inventory of these characteristics is thus essential.

4.1 Climate

Besides its influence on the nature and distribution of the soils, climate is the most important single factor affecting land-use and determining agricultural potential. It also controls the development and distribution of many plant communities. Graham (1944), in considering the climatic climax concept, suggested that life and climate are so inextricably associated that their relationship cannot be ignored. Jacks (1946) also regarded climate as being most useful in demarcating broad agricultural regions for classification purposes. Local changes in climate assume greater importance as the intensity of land use increases. Such variations, brought about by frequent changes in altitude and aspect, are typical of the Area.

In addition to a description of the most important climatic factors, several climatic sub-regions identified in the Area are defined.

1) Climatic factors

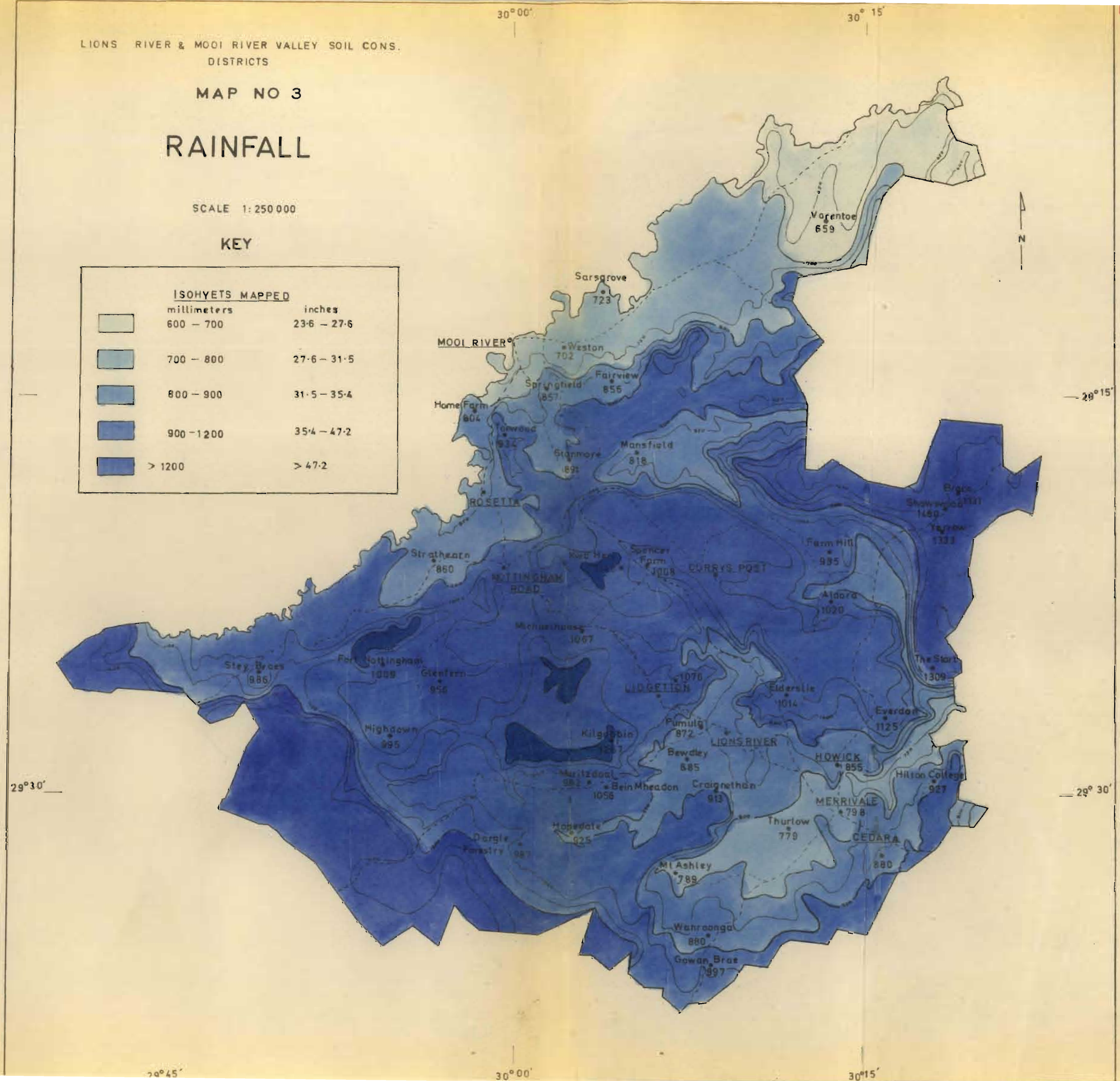
Unfortunately, elements of precipitation and temperature do not define climate. Many interacting factors, some of which are difficult to assess, should be considered in evaluating climate. However, in this discussion only the main factors are considered. All available data including official records and those kept by farmers within and in close proximity to the Area, were collected and analyzed to provide a general appraisal of the climate. Reference is also made to the 'water balance' as defined by Thornthwaite (1948) since, as already indicated, it is clearly related to the soil resources.

(i) Precipitation

Rainfall: The available rainfall data for all relevant stations are presented in Appendix 10. From this information a rainfall map (Map 3) for the Area, at a scale of 1:250,000, was compiled.

The mean annual rainfall varies between 600 mm and 1,500 mm and is distributed mainly between October and April. December and January are the wettest months. A constant summer : winter ratio of approximately 0.24 typifies many of the stations. Total rainfall values provide no indication of other important features such as variability, extremes and intensity. The coefficient of variation and mean deviation at a number of stations were thus calculated. Despite the wide range of climatic conditions covered by these stations, the values were surprisingly constant, approximately 20 and 15 percent respectively. Lowest values of 15.4 percent and 12.8 percent respectively were recorded for Nottingham Road. Unfortunately, no data on rainfall intensities were available for the Area.

Highest (1271 mm) and lowest (516 mm) annual rainfall extremes for Nottingham Road serve as an example of the erratic nature of the rainfall. Moll (1965) stressed the importance of this by suggesting that periodic low rainfall years could, in fact, determine vegetation type. The mean annual number of days with rain are also shown in


LIONS RIVER & MOOI RIVER VALLEY SOIL CONS. DISTRICTS
MAP NO 3
RAINFALL
SCALE 1: 250 000
KEY
ISOHYETS MAPPED
millimeters
inches
600 – 700
23·6 – 27·6
700 – 800
27·6 – 31·5
800 – 900
31·5 – 35·4
900 – 1200
35·4 – 47·2
> 1200
> 47·2
30° 00'
30° 15'
29° 15'
29° 30'
29° 45'
N
MOOI RIVER
Sarsgrove
723
Weston
702
Vorentoe
659
Fairview
856
Springfield
857
Home Farm
804
Mansfield
818
Stanmore
891
ROSETTA
Strathearn
860
NOTTINGHAM ROAD
Spencer Farm
1008
CORRYS POST
Farm Hill
935
Aldora
1020
Michaelhouse
1067
Fort Nottingham
1009
Glenfern
956
Stey Braes
986
LIDGETTON
1070
Eldersile
1014
The Start
1309
Everdon
1125
Highdown
995
Kilgobbin
Pumula
872
LIONS RIVER
Bewdley
885
HOWICK
855
Hilton College
927
Bein Mheadon
1056
Craignethan
913
MERRIVALE
798
Thurlow
779
CEDARA
880
Hopedale
925
Dargle Forestry
Mt Ashley
789
Wanroonga
880
Gowan Brae
897
Yarrow
1133
Showwood
1460

Appendix 10. Mean values for areas of high (>900 mm), moderate (700 to 900 mm) and low (< 700 mm) rainfall are 114, 101 and 65 days respectively. The relationship between rainfall, aspect and altitude is illustrated in Appendix 11a and 11b. The importance of elevated barriers in creating local rain shadows is clearly demonstrated by these illustrations.

Mist: Much of the Area lies within the so-called "mist belt" of Natal where the physiography encourages the formation of mist, especially at altitudes above 1220m (4,000 ft). Mist frequently covers the high-lying areas in summer while, in winter, the drainage of cold air often causes mist in the valleys. Besides providing an important source of moisture, mist also has the effect of reducing evaporation and increasing humidity. The climax Podocarpus forests which characterize many southern-aspect slopes bear testimony to the moist conditions.

Hail and snow: Hail and snow are important limitations within the Area. Thunderstorms, often accompanied by hail, are particularly common in early summer. The incidence of hail, though fairly similar throughout the high rainfall areas, increases in the drier parts. For example, the average number of days with hail for Nottingham Road and Cedara are 3.4 and 3.5 days per annum respectively, while for Estcourt, an outside station representing the drier areas, the value is 4.9 days per annum. Although November experiences most hail, it also occurs fairly regularly during December and January (S.A. Weather Bureau, 1954). Hail not only causes damage to crops and trees but is also a constant threat to natural fauna and flora. A severe hailstorm which struck the Dargle Valley in 1963, took heavy toll of many forms of wildlife, including bushbuck, and caused serious damage to the indigenous forest trees. Secondary infection by Diplodia pinea causes serious losses in pine plantations following injury.

Snowfalls have been recorded in all but the driest parts of the Area. The regular snowline is, however, at approximately 1524m (6,000 ft) above sea level. One or more falls can be expected above this altitude during the winter months. Mechanical damage to trees is sometimes serious and 'out of season' snowfalls, generally occurring in early summer and accompanied by severe cold and frost, are particularly harmful to crops and livestock.

(ii) Temperature

Temperature data are assembled in Appendix 12a although very few official or farm records were available. The data indicate that mean annual temperatures of less than 15^{o}C typify the coolest parts of the Area while in the warmest parts they exceed 18^{o}C. Temperature extremes for selected stations are given in Appendix 12b. These have an important influence on agriculture since they affect the distribution and suitability of many plants.

Frost is experienced throughout the Area but is most severe at altitudes above 1524m (5,000 ft). At Nottingham Road, one of the coldest stations, temperatures below zero can be expected on at least 75 days per annum. The drainage of cold air also has a marked influence on the occurrence of frost. Diurnal fluctuations in temperature are pronounced in the warm areas where cold air movement at night gives rise to large temperature differences between day and night.

Three main factors affect temperature conditions in the Area. These are oceanic influences, altitude and topography. The thermal lapse-rate calculated for several stations is similar to the 1.6^{o}C per 305m (1,000 ft) established by de Villiers (1962) for other Natal stations.

To compare climatic sub-regions within the area, heat units were calculated for a number of stations. These were obtained by multiplying the mean monthly temperatures above a base of 5^{o}C by the number of days in each month. Yearly and half-yearly values for selected stations are shown in Table 37.

Table 37 : Yearly and half-yearly heat units (degree-days) for selected weather stations

Station	Heat units (degree-days)		
	Oct-March	April-Sept	Yearly Total
Nottingham Road*	2170	1000	3170
Lidgetton	2733	1770	4503
Hopedale	2250	1392	3642
Cedara*	2479	1654	4133
Howick*	2627	1708	4335
Bewdley	2836	1646	4482
Weston	2394	1329	3723
Estcourt*	2734	1564	4298
Weenen*	3141	1732	4873
Uitgedacht	3001	1720	4721

(* Official weather stations)

(iii) Wind

The most important sector from which the wind blows is south-east (S.A. Weather Bureau, 1960). These are the main rain-bearing winds. During July, August and September, however, the wind blows mainly from the west and north-west sectors. These winds are locally termed 'berg winds' and, being hot and dry, have a marked desiccating effect. Besides being critical for forest regeneration (Rycroft, 1942) they give rise to a severe fire hazard in spring and may cause erosion. They are often followed by precipitation and a sudden drop in temperature.

The wind factor also influences recommended land-use practice. For example, Hubbard (1964) was of the opinion that the potential of the Highlands for timber production, especially pine, was limited by severe winds occurring during the cold months.

(iv) Sunshine and cloudiness

The proportion of sunshine in relation to the total possible amount is very high (McCrystal, 1963). Official records indicate little difference in the average daily amount of cloud per annum between several stations. For instance, the values (Beaufort scale) for Nottingham Road, Cedara and Estcourt are 4.4, 4.4 and 4.1 respectively.

The slightly higher values for the two first named stations reflect higher rainfall conditions. November and December experience the highest percentage of overcast and misty days. These conditions seriously affect farm operations, such as haymaking, and encourage the development of plant diseases such as late blight of potatoes (Phytophtera infestans).

The Area lies between latitudes $29^{o}00'$ and $29^{o}40'$ south so that the sun is always to the north. For this reason, Moll (1965) noted that the angle of elevation at midday in mid-summer and mid-winter would be 82^{o} and 52^{o}, respectively. North and north-west facing slopes thus receive the most insolation and are hot and dry.

(iv) The water balance

No attempt has been made to relate the climate of the Area to any standard classification. Information is, however, given by de Villiers (1962) in his discussion on the classification of climate in Natal. The 'water balance' concept (Thornthwaite, 1948), despite certain weaknesses indicated by Phillips (1959), provides a suitable means for understanding the qualities of climate in the Area and provides a reasonable basis for explaining the most recent moisture regime under which the soils have formed.

Water balance is the relationship between precipitation and water need, or, potential evapotranspiration. The latter constitutes the moisture lost to the atmosphere from a vegetation covered soil if it were constantly available in optimum quantity. It provides an index of thermal efficiency and is also an expression of day length and temperature. Given in the same units as precipitation it relates thermal efficiency to precipitation effectiveness.

Thornthwaite (1948) used water availability, expressed as a Moisture Index (Im), as an important criterion in classifying climate. Values of water surplus and deficiency are obtained from a simple bookkeeping procedure where precipitation and potential evapotranspiration provide the income and outgo respectively. Available soil moisture provides a reserve that may be drawn on as long as it lasts. A mean reserve value equivalent to 100 mm rainfall was used by Thornthwaite to calculate the water balance. The results of the soil moisture studies previously discussed indicate, however, that this gross simplication may have serious limitations.

The moisture index for any locality is derived from the relationship between water need (n) and precipitation. It represents the balance between monthly water surplus (s) and deficiency (d) taken over the year and is calculated from the relation: $Im = \frac{100s - 60d}{n}$, where moist and dry climates have positive and negative values respectively.

This basis was used for defining each climatic sub-region (Map 4). Calculated moisture indices and water need values for a number of stations are presented in Appendix 13. The annual water balance for moist, dry and intermediate climates is also illustrated in Appendix 11c. A close relationship between water balance and soil characteristics was indicated in defining the degrees of leaching in Chapter 1.

It is of interest to note that the annual evapotranspiration at Cedara, as measured by the Class A pan, is approximately 1580 mm (62.2 inches). No other reliable data are available for the Area although a number of farmers have recently installed the necessary equipment.

(vi) The period of active growth

In assessing the potential of the Area for agricultural production the 'period of active growth', or that period during which conditions of moisture and temperature favour maximum plant growth, has been considered. The length of this period is important in planning crop programmes to yield maximum returns, since, the shorter the period the more severe the limitation. According to Wilsie (1962), extremely short periods constitute the greatest deterrent to the future extension of agriculture into the colder regions of the world. The length of the period is usually determined by first and last frost dates but limits can be set by defining specific temperature or moisture values.

Maximum and minimum temperatures beyond which growth does not occur, are generally accepted as 40°C and 0°C respectively. Landsberg (1958) considered 5°C as the threshold for growth with temperatures above 30°C being inhibitory rather than growth promoting. According to Thornthwaite (1948) the temperature at which growth is most rapid is always near 30°C. The optimum temperature for most crops generally lies between 24°C and 30°C and for maize is between 30°C and 35°C (Wilsie, 1962). Available data indicate that only Estcourt, Weenen (situated outside the Area) and Howick experience mean daily maximum temperatures exceeding 25°C during the period November to March. It is suggested, therefore, that the temperature conditions over much of the Area, especially at the higher altitudes, are not suitable for optimum growth of crops such as maize.

Temperature conditions influence many aspects of crop production including seed germination. For instance, the number of days required for the germination of maize seed at temperatures of 12.2°C, 15.5°C and 18.8°C were found to be 11.25, 3.55 and 3.0 days respectively (Wilsie, 1962). These values illustrate the importance of temperature in determining growth rate.

The available climatic data were studied with a view to determining the active growth period for the main climatic sub-regions. Ignoring extreme frost dates, the optimum period for active growth in most of the Area is between the beginning of October and the end of April. Excluding the colder areas (represented by Nottingham Road), the length of the period is similar for most parts although the limiting factors may differ. In the drier parts, where temperature conditions are favourable, the length is usually limited by moisture deficiency. Here the period is fractionally shorter than for most other areas. In the high-lying areas temperature curtails the growth period. At Nottingham Road, for instance, the period is from four to six weeks shorter than in most other parts. Here, incidence of frost is a major factor limiting the growth period. The duration of the frost period, as determined by average first and last dates, is 135 days. This is considerably longer than that for Howick which has an average of 80 days of frost. The average duration in the warmer areas is approximately 60 days.

Average first frost dates are noticeably constant but the last frost dates show considerable variability and, in the cool regions, may range from mid-August to the end of October. The frost-free period is reduced at all stations if extreme frost dates are considered. Such extremes are important when planning crop rotations including crops susceptible to frost (e.g. potatoes).

Conditions relating to annual rainfall and temperature and the period between first and last frost dates for a number of selected stations are presented in Appendix 11d. The extent to which these criteria may limit the period of active growth is well illustrated.

2) Climatic sub-regions

Phillips (1959) defined a bioclimatic sub-region as a natural area created and maintained by the interplay of climatic factors and biotic phenomena, so integrated as to permit the development of natural vegetation to a stage where this is in dynamic equilibrium with the climate. With this in mind and after considering all relevant data eight climatic sub-regions within the Area were defined. These include several that are somewhat transitional but have been demarcated to aid detailed farm planning. The sub-regions are closely related to physiography and vegetation type.

Special terms and criteria have been used in defining the climatic sub-regions and are summarized in Table 38.

Table 38 : Terms and criteria for defining climatic sub-regions in the Howick Extension Area

Descriptive terms	Criteria		
(a) Assessment of moisture conditions			
	Mean annual rainfall (mm)	Moisture index	
Humid	> 900	> 20	
Moist sub-humid	800 - 900	5 to 20	
Slightly dry sub-humid	750 - 800	-5 to 5	
Dry sub-humid	700 - 750	-10 to -5	
Very dry sub-humid	< 700	< -10	
(b) Assessment of temperature conditions			
	Mean annual Temperature (°C)	Heat units (degree/days)	
		Yearly	Oct-March
Cool	< 15	< 3500	< 2500
Mild	15 - 18	> 3500	> 2500
Warm	> 18	> 4500	> 3500

The location of the eight defined climatic sub-regions is shown on Map 4. A brief description of each follows.

<u>Climate sub-region 1</u>: This is the largest and coolest sub-region occupying the north, west and south-western sectors in the Area. It is represented by Nottingham Road although this is one of the driest stations within the sub-region. The altitude varies between 1463m (4,800 ft) and 1890m (6,200 ft). The climate is <u>humid and cool</u>. The mean annual rainfall varies from 850 mm to more than 1,500 mm, and the moisture index exceeds 20, indicating a large water surplus. The low water need is the result of the generally cool conditions. Low cloud and mists are common and afternoon thunderstorms may occur frequently in mid-summer. The mean annual temperature and yearly heat sum are below 15°C and 3,500 degree days respectively and mean daily maximum temperatures rarely exceed 25°C. The mean daily minimum temperatures between April and November are less than 10°C. Frosts occur regularly during the winter months and are particularly severe during June and July. Snow occurs annually in the high-lying areas. The period of active growth is short. Further subdivision could be made to separate the very humid parts experiencing more than 1,300 mm of rainfall from the remainder. These lie above an altitude of 1677m

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LIONS RIVER & MOOI RIVER VALLEY SOIL CONS. DISTRICTS

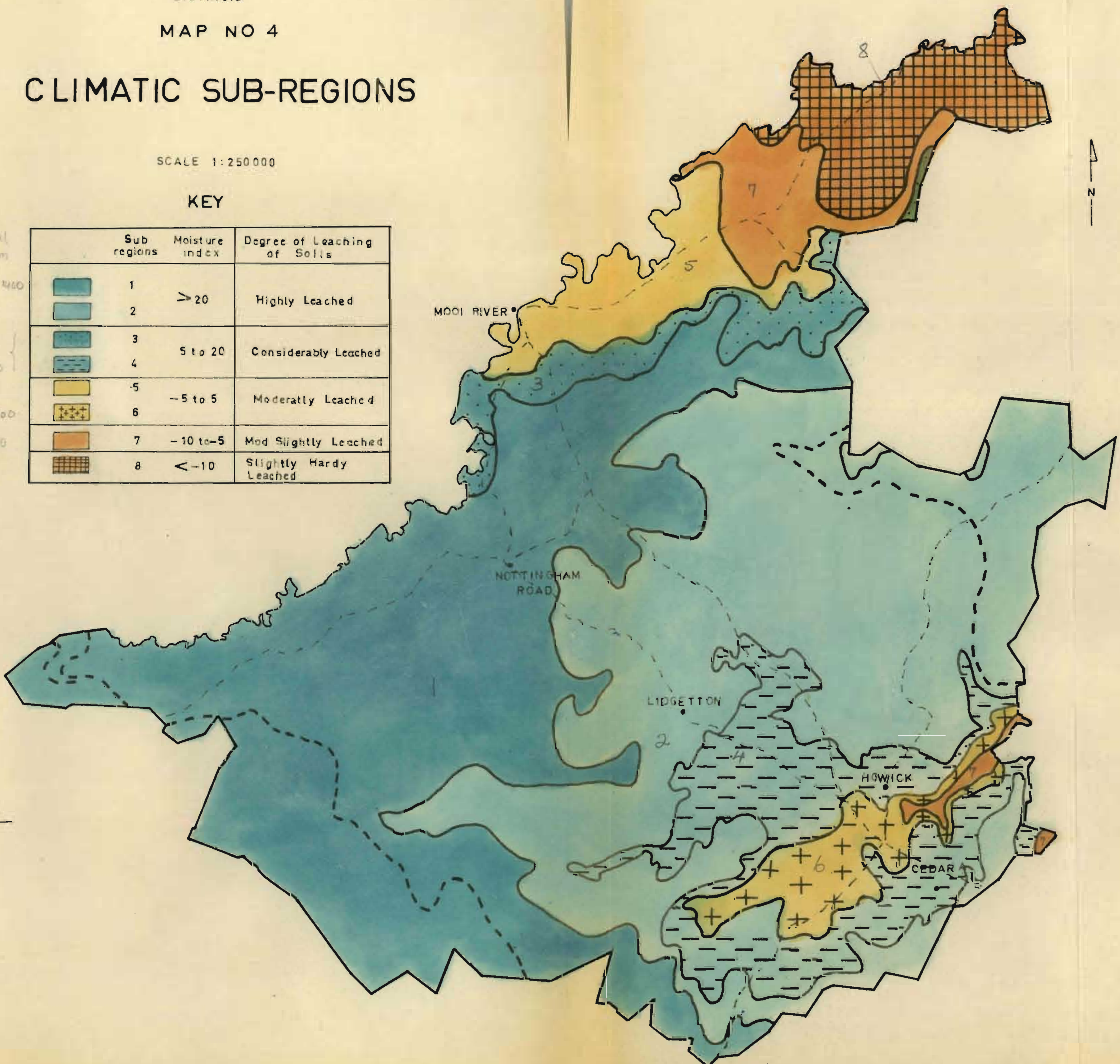
MAP NO 4

CLIMATIC SUB-REGIONS

SCALE 1:250000

KEY

	Sub regions	Moisture index	Degree of Leaching of Soils
	1	> 20	Highly Leached
	2		
	3	5 to 20	Considerably Leached
	4		
	5	−5 to 5	Moderatly Leached
	6		
	7	−10 to −5	Mod Slightly Leached
	8	< −10	Slightly Hardy Leached



(5,500 ft) and experience sub-alpine conditions.

Climatic sub-region 2: Physiography plays an important role in determining the climatic conditions experienced in this sub-region which lies to the south-east of sub-region 1. The altitude is between 1067m (3,500 ft) to 1524m (5,000 ft). The general south-easterly aspect, lower altitude and broken topography distinguish this sub-region from sub-region 1. Lidgetton is the representative station. The climate is mostly humid and mild with a mean annual rainfall of between 900 mm and 1,500 mm. The moisture index exceeds 20. Although precipitation may fall below water need at the end of the season there is never a deficiency. Soil moisture is soon recharged in spring. There is also an abundance of low cloud and mist, and temperature conditions lie between 15°C and 18°C. The broken topography favours cold air drainage so that most of the upland areas experience only light frosts during June, July and August. Further subdivision within this sub-region could also be made to separate the eastern sector of the Karkloof range which experiences a mean annual rainfall exceeding 1,300 mm from the remainder.

Climatic sub-region 3: This sub-region forms a narrow, northern extension to sub-region 1. The climate is moist sub-humid and cool. A mean annual rainfall of between 800 mm and 900 mm, but mostly below 850 mm, is experienced. The moisture index lies between 5 and 20. Although the mean annual temperature is less than 15°C, the temperature conditions are fractionally milder than those in sub-region 1. The altitude varies between 1372 (4,500 ft) and 1463m (4,800 ft).

Climatic sub-region 4: This sub-region is transitional to sub-region 2. It occurs at an altitude of between 1067m (3,500 ft) and 1220m (4,000 ft), and includes the Cedara, Tweedie and Howick areas and extends for several miles up the valleys of the Umgeni and Lions rivers. It surrounds the dry Merrivale valley. Howick and Cedara are representative weather stations for this sub-region. The climate is moist sub-humid and mild. The mean annual rainfall varies between 800 mm and 900 mm but is mostly above 850 mm. The moisture index lies between 5 and 20 but is mostly between 10 and 15. The temperature conditions are similar to those of sub-region 2 but may be fractionally warmer. At Howick, the mean daily maximum temperature for the period November to March exceeds 25°C.

Climatic sub-region 5: This sub-region occurs to the north of the Mt. West range and although it is in close proximity to sub-regions 1 and 3 it is decidedly drier. It extends from Mooi River to Joubertsvlei and lies between 1220m (4,000 ft) and 1372m (4,500 ft) above sea level. Weston is the representative station. The climate is slightly dry to dry sub-humid and mostly cool. The mean annual rainfall varies between 700 mm and 800 mm but is mostly less than 750 mm. The moisture index varies between 5 and -5 but is frequently negative. Water need exceeds rainfall for most of the year and mists are uncommon. With the lack of accurate temperature data the mean annual temperature is estimated to be approximately 15^{o}C.

Climatic sub-region 6: This sub-region is confined to the well-defined lower basin of the Merrivale valley and is surrounded by sub-region 4. The rain-shadow effect of the Swartkop range strongly influences the prevailing climate. The altitude varies from 975m (3,200 ft) to 1068m (3,500 ft). The climate is slightly dry sub-humid and mild. The mean annual rainfall is between 750 mm and 800 mm and the moisture index, which lies between 5 and -5, is mostly positive. The sub-region is situated below the mist line. The mean annual temperature and yearly heat units exceed 15^{o}C and 3,500 degree days respectively. Frosts occur between May and September and, as a result of cold air drainage, may be severe on the bottomlands.

Climatic sub-region 7: The northern part of the Area lies within the rain-shadow of the Mt.West-Proudfoot range and has a northerly aspect. The altitude falls rapidly from 1372m (4,500 ft) to 1220m (4,000 ft). Within this sector lies sub-region 7 which experiences a dry sub-humid and mild to warm climate. Estcourt, although outside the sub-region, is regarded as the representative station. The mean annual rainfall is between 700 mm and 750 mm and the water balance indicates a definite period of deficiency between July and November. There is no water surplus. The meagre recharge of soil moisture during summer is rapdily exhausted during the dry season. The moisture index is between -5 and -10. The mean annual temperature lies between 16^{o}C and 18^{o}C and absolute maximum temperatures between October and March exceed 25^{o}C. The absolute minimum temperatures between May and September are generally less than 10^{o}C. Frosts occur during this period and are most severe in June and July.

Climatic sub-region 8: This sub-region lies north-east of sub-region 7 and drops rapidly from 1280m (4,200 ft) to 1067m (3,500 ft). The climate is very dry sub-humid and very warm. It is characterized by high maximum summer temperatures and, because of strong, nocturnal temperature inversions, low minimum night temperatures in winter. The mean annual temperature and yearly heat sum exceed 18°C and 4,500 degree days respectively. For the period December to February the absolute maximum temperature exceeds 30°C and is over 25°C for as many as eight months of the year. Weenen, though outside the Area and somewhat atypical, has been taken as the representative station. The mean annual rainfall is less than 700 mm resulting in a strongly negative moisture index of below -10. Annual rainfall is seldom able to meet the water need and causes a deficiency throughout the year. For this reason, vegetation and dryland crops are dependent almost entirely on current rainfall.

4.2 Vegetation

Since vegetation is a product of the conditions under which is has developed it is a measure of the environment. It has been claimed that, if correctly interpreted, the growth of natural vegetation will indicate the biological potential of that environment (Weaver & Clements, 1938; Albrecht, 1940; Pentz, 1949; Edwards, 1963). Because of this, the vegetation of the Area was carefully studied. In defining and mapping the vegetation types, a number of relevant works were consulted (Rycroft, 1942; Pentz, 1945; Acocks, 1953; Edwards, 1963; Moll, 1965).

In this discussion the fire factor warrants special mention since it has influenced the development and structure of most of the vegetation over long periods of time. Veld fires, from the pre-Bantu period to the present day, have occurred mainly between autumn and early spring and little, if any, vegetation has escaped the ravages of annual burning. Soil moisture and temperature conditions also influence the development of local communities. Mismanagement, too, has caused many changes. The secondary nature of much of the vegetation, the encroachment of undesirable species and the shrinking forests bear witness to these changes.

1) Vegetation types

The diversified nature of the vegetation is reflected in the thirteen different types that were defined. These fall within four major groups: grasslands and savanna (76 percent of the Area); ecotonal grasslands (16 percent); valley vegetation (5 percent) and forests (3 percent). Small bottomland communities occur throughout the Area and are discussed separately. Each vegetation type, falling within the broader grouping, is briefly described and their location is indicated in Map 5. Boundaries between types rarely occur as abruptly as those indicated on the map; rather they occur as transitional zones gradually passing from one type to the next.

(i) Grasslands and savanna

Several well defined types fall within this group.

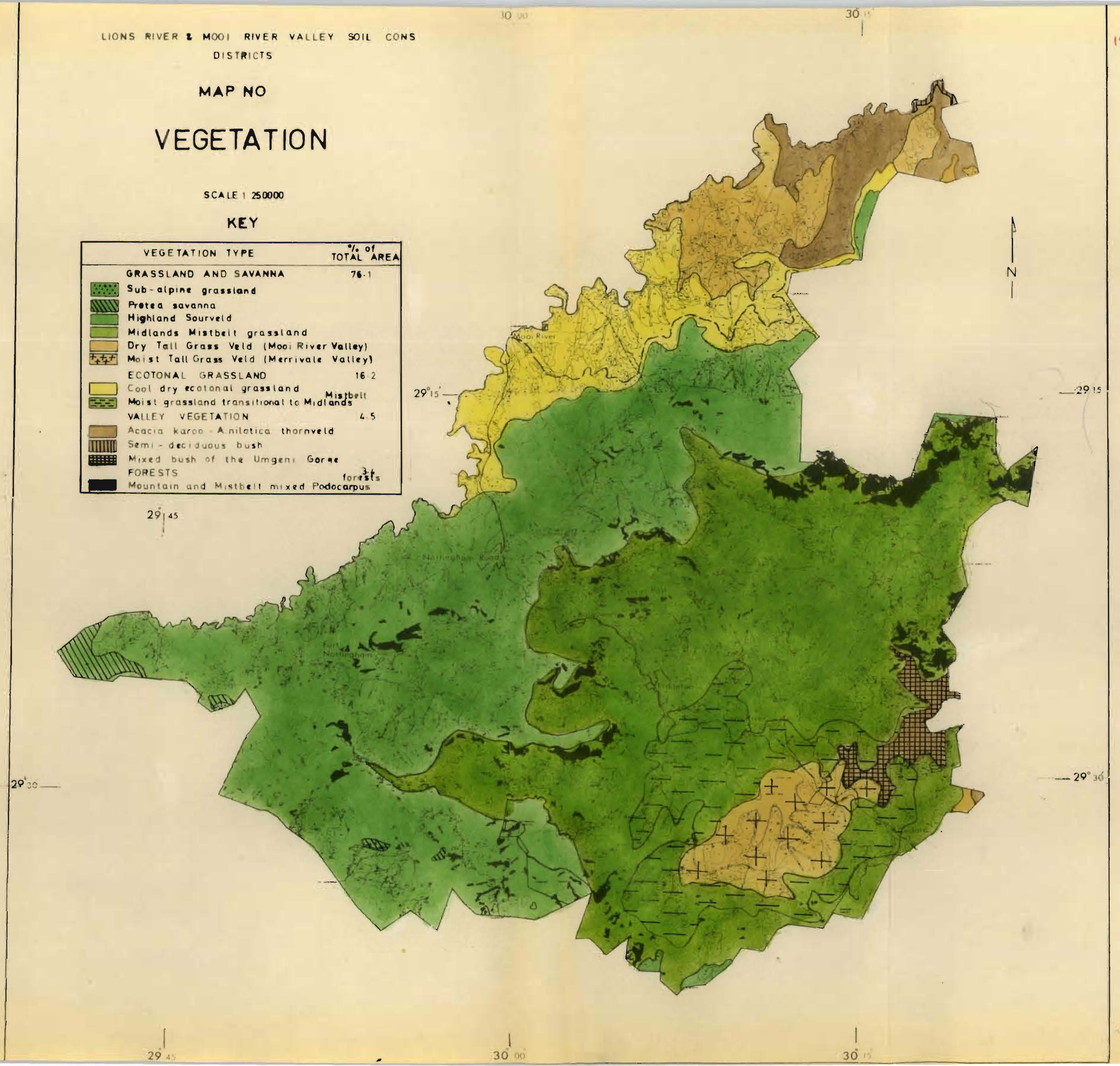
(a) Sub-alpine grassland: This vegetation is not extensive and is usually confined to areas above an altitude of 1829m (6,000 ft). The mean annual rainfall exceeds 1,500 mm and conditions are generally temperate. Edwards (1963) noted an outlier occurring in the vicinity of Mt. Gilboa in the Karkloof range. Fire is believed to be responsible for maintaining this grassland which, except for a short period in summer, provides low quality grazing.

The index species for this type include Themeda triandra, Festuca costata, Koelaria cristata, Stiburus alopecuroides and Andropogon filifolius. Pentaschistis tysonii may also occur on the steep, moist slopes.

(b) Highland Sourveld: This is the most extensive grassland in the Area and occurs between 1463m (4,800 ft) and 1829m (6,000 ft) above sea level. It experiences a mean annual rainfall of 850 mm to 1,500 mm and a mean annual temperature of below 15^{o}C. Severe frosts are regular.

Two sub-types occur within the Highland Sourveld:

(1) Protea savanna: Small isolated patches of Protea savanna,



LIONS RIVER & MOOI RIVER VALLEY SOIL CONS DISTRICTS
MAP NO
VEGETATION
SCALE 1 250000
KEY
VEGETATION TYPE
% of TOTAL AREA
GRASSLAND AND SAVANNA 76·1
Sub-alpine grassland
Protea savanna
Highland Sourveld
Midlands Mistbelt grassland
Dry Tall Grass Veld (Mooi River Valley)
Moist Tall Grass Veld (Merrivale Valley)
ECOTONAL GRASSLAND 16·2
Cool dry ecotonal grassland
Moist grassland transitional to Midlands Mistbelt
VALLEY VEGETATION 4·5
Acacia karoo - A. nilotica thornveld
Semi - deciduous bush
Mixed bush of the Umgeni Gorge
FORESTS 3·4 forests
Mountain and Mistbelt mixed Podocarpus
N
Mooi River
29° 15'
29° 15
29° 30
29° 30
29 45
30 00
30 15
151(1)

believed to be remnants of a once extensive community, occur above an altitude of 1677m (5,500 ft) along the western mountain range (Plate 11). This savanna is usually confined to the steep debris slopes beneath the outcrops of cave sandstone or is associated with shallow soils. It is not of great agricultural importance.

The important tree species include Protea multibracteata and P. roupelliae. The former, usually occurring on deeper soils, is best able to withstand damage by fire (Edwards, 1963). Where soils are shallow many trees may be windthrown. The grass stratum is typically Themeda-Trachypogon grassland with temperate species becoming common at the higher elevations.

(2) Grassland: This sub-type is characterized by relatively short bunch grasses and is dominated by the mid-grass stratum species, Themeda triandra and Tristachya hispida. In addition to these, the index plants include Trachypogon spicatus, Monocymbium ceresiiforme, Andropogon filifolius and Alloteropsis semialata. Eragrostis racemosa, Michrochloa caffra and Rendlia altera characterize the lower stratum. The woody species Buddleia salviifolia and Leucosidia sericea constitute index plants in protected areas. Non-grass plants, many of them listed by Moll (1965), are particularly common in this grassland. The Compositae family, for example, is well represented by several Helichrysum species.

Several faciations, which are the result of local variations in climate, altitude, soil and aspect, occur within this grassland. These were not mapped separately. A dry faciation occurs in the upper reaches of the Karkloof river valley and on north facing slopes in the vicinity of Nottingham Road and Rosetta. Likewise, at an altitude of approximately 1829m (6,000 ft) there is a zone transitional to the sub-alpine grassland which can be considered as a separate faciation. Here, temperate species such as Festuca costata and Danthonia stricta are common.

Throughout the Highland Sourveld there is evidence of invasion of undesirable species. With continuous grazing, species such as Eragrostis spp. and Sporobolus spp. tend to increase while some, such as Trachypogon spicatus, may become less common. The dominance of Elyonurus argenteus and Festuca costata, together with the shrub Athanasia acerosa (Curry's Post weed), in certain parts of the Area, is attributed mainly to continuous grazing by sheep. A small consociation of Festuca costata at Curry's Post suggests that invasion of this species throughout the Highland Sourveld is likely if the grassland is mismanaged. The grass is easily recognized by its tussock character and bright, green colour in winter. The problem of invasion also concerns Aristida junciformis which has already spread to many parts of the Highland Sourveld. Furthermore, Hyparrhenia hirta is among the first to invade the grassland and may soon become dominant where the original plant cover is disturbed.

Mismanagement also tends to favour an increase in abundance of Helichrysum aureo-nitens and, in places, Pteridium aquilenum, although precise reasons for this are not clear. The well-known weed Rubus cuneifolius (American bramble) is widespread throughout the Area and Ulex europeaus (gorse) might prove a serious problem if left unchecked (Edwards, 1963). Sarothamnus scoparius (broom) occurs on disturbed grassland areas in the vicinity of Nottingham Road. The most important poisonous weed occurring within this grassland, especially at higher altitudes, is Moraea spp. (tulip) which may cause heavy stock losses in early spring (Plate 12).

(c) Midlands Mistbelt grassland: This is the second most extensive vegetation type and lies between 1067m (3,500 ft) and 1463m (4,800 ft) above sea level. It experiences a mean annual rainfall of 900 mm and 1,500 mm and mists are very common. Temperature conditions are milder than those of the Highland Sourveld.

In the absence of fire the grassland develops to a climax community of mixed Podocarpus forest in which Combretum kraussii and

Plate 11. Protea savanna community within the Highland Sourveld (photo: E. J. Moll).

Plate 12. Early spring growth of Moraea spp (tulip) occurring within the Highland Sourveld (photo: E. J. Moll).

Plate 13. Cyathea dregei as it occurrs in the Midlands Mistbelt (photo: E. J. Moll).

Plate 14. Themeda grassland (right) and Secondary Aristida grassland (left) occurring within the Midlands Mistbelt. (Note occurrence of <u>Indigofera</u> spp and <u>Tephrosia</u> spp in Themeda grassland

Xymalos monospora are important. At one time these forests were very extensive. Cyathea dregei, also listed as an index plant for the coast hinterland (Edwards, 1963), occurs frequently along streams or where underground subsistence affords adequate protection (Plate 13).

The Midlands Mistbelt grassland is subdivided on the basis of the primary and secondary nature of the vegetation. Plate 14 illustrates the difference between these two types.

(1) Mistbelt Themeda grassland: This, once extensive primary grassland, is today observed only where adequate protection is afforded. Physiognomically and floristically it resembles the Highland Sourveld grassland (Edwards, 1963). The upper and lower strata have been described by Moll (1965) in considerable detail. Mismanagement has led to the widespread replacement of many species by Aristida junciformis so that occurrence of this grassland is now rare. A notable feature is the abundance of indigenous legume species of which Indigofera spp. and Tephrosia spp. are particularly common (Plate 14). This grassland was mapped together with the secondary Aristida grassland.

(2) Secondary Aristida grassland: The invasion of Aristida junciformis into the Themeda grassland was first recorded by early ecologists. Edwards (1963) regarded the invasion as being of considerable economic importance. Many consider selective grazing of the primary grasses, trampling by stock and winter or 'early' burning to be the prime causes of this invasion. The grassland is characterized by a complete dominance of the strongly rooted, densely tufted and unpalatable invader Aristida junciformis. Edwards (1963) described several distinct phenological phases within this vegetation and associated numerous non-grass plants, including many prevernal geophytes, with the grasses.

On moist, southern aspect slopes forest margin and precursor scrub communities are particularly common. Buddleia salviifolia, Leucosidea sericea and the grass, Miscanthidium capense, typify these communities. A faciation, dominated by tall growing grass species such as Hyparrhenia spp. and Cymbopogon spp., has been found to occur in several of the major valleys. Examples of this are to be found near Balgowan and in the Dargle valley.

Rubus cuneifolius is the most serious weed occurring in this grassland and important poisonous weeds include Senecio spp., Urginea spp., Ornithogolum spp. and Cestrum laevigatum (Inkberry).

(d) Tall Grass Veld: The Tall Grass Veld is sandwiched between the moist grasslands and the valley vegetation. It experiences warm temperatures and a mean annual rainfall of 700 mm to 850 mm.

A characteristic feature of this grassland is the dominance of Themeda triandra, Tristachya hispida and Hyparrhenia hirta resulting in marked seasonal aspects. Moll (1965) suggested that H.hirta may not always have been important. Themeda triandra and Tristachya hispida comprise 66 percent of the living rooted basal cover of the Tall Grass Veld (Edwards, 1961). Other Hyparrhenia species may form local communities while Cymbopogon plurinodis becomes more abundant in the drier parts.

Acacia sieberiana is an important index plant although temperature appears to influence its occurrence. In the drier parts Acacia karroo and A.nilotica become more frequent. Edwards (1963) noted that the grassland may be reduced, or completely invaded, by A.karroo-A.nilotica scrub.

Generally, this three-layered grassland has a lower basal cover and less prominent forbs than the grasslands already described. Two climatically determined faciations were recognized and mapped.

(1) Dry Tall Grass Veld: This occurs in the lower reaches of the Mooi river valley and experiences a mean annual rainfall of 700 mm to 750 mm. The altitude varies between 1067m (3,500 ft) and 1372m (4,500 ft).

In this faciation A.sieberiana is scarce which is possibly the result of temperatures being lower than those in the typical Tall Grass Veld (Pentz, 1949). However, many trees may have been removed by Bantu for firewood and other uses.

A continuous middle grass layer is recognized and includes Themeda triandra, Tristachya hispida, Eragrostis capensis and Heteropogon contortis. The short stratum includes E.racemosa, Michrochloa caffra, Cynodon dactylon and Brachiara serrata. E.superba and Cymbopogon plurinodis become dominant in dry situations.

Overgrazing usually results in an increase of species such as Eragrostis spp., Sporobolus spp., Aristida spp., Cynodon dactylon and Elyonurus argenteus. The last named increases where there has been overgrazing by sheep. E.plana, S.capensis and S.pyramidalis are generally indicative of past cultivation or soil disturbance.

In moist, protected areas a woody scrub community, including A.sieberiana, Zizyphus mucronata and Maytenus cymosus, frequently develops.

(2) Moist Tall Grass Veld: This grassland is situated in the driest part of the Merrivale valley where it experiences a mean annual rainfall of 750 mm to 800 mm and lies between 975m (3,200 ft) and 1067m (3,500 ft) above sea level. Moll (1965) classified this vegetation as Themeda-Hyparrhenia grassland but in the writer's opinion it is most similar to the moist transitional Themeda-Hyparrhenia grassland defined by Edwards (1963).

In many respects it resembles the dry Tall Grass Veld of the Mooi river valley. However, there is a greater abundance of A.sieberiana which is apparently due to the milder climate. The three strata of the grass sward have been discussed by Moll (1965).

Today, very little of the natural grassland remains. The favourable topographic features and suitability of the Area for intensive farming have led to widespread cultivation. Very little of the grassland that does remain is in a primary condition.

(ii) Ecotonal grasslands

Ecotonal grasslands are recognized where the climax vegetation is ill-defined. For example, to the south and east of Mooi River, grasslands transitional in nature and lying between the Highland Sourveld and dry Tall Grass Veld are to be found and are deemed ecotonal. Two types were provisionally mapped.

(a) Cool, dry ecotonal grassland: For the most part this grassland is similar to Edwards's moist transitional Themeda-Hyparrhenia grassland. It occupies the area immediately south and to the east of Mooi River and experiences a mean annual rainfall of between 700 mm and 800 mm. The mean annual temperature is mostly below 15°C. Cooler conditions are indicated by the short nature of the sward, the absence of A.sieberiana and the presence of Leucosidea sericea.

In the moister parts this grassland is likened to a dry faciation of the Highland Sourveld. The boundary between the ecotonal vegetation and the Highland Sourveld is shown on Map 5. The transition to the Tall Grass Veld is extemely gradual. Grass species are similar to those of the Tall Grass Veld although there is a lower abundance of H.hirta.

A common feature of this grassland is the abundance of scattered antheaps. The multi-coloured weed, Cosmos bipinnatus, abounds where there has been soil disturbance.

(b) Moist grassland transitional to the Midlands Mistbelt: This grassland occupies the ecotone between the Tall Grass Veld of the Merrivale valley and the Midlands Mistbelt grassland and experiences a mean annual rainfall of 800 mm to 900 mm. Moll (1965) classified this area as moist transitional Themeda-Hyparrhenia grassland although in the writer's opinion it is not typical of the grassland similarly named by Edwards (1963).

The transitional nature of the grassland is reflected in the mixed composition of the sward in which Hyparrhenia hirta, Themeda triandra and Aristida junciformis are commonest. Two local facies within this grassland were defined by Moll (1965). These include the Aloe candelabra savanna and the Cussonia spicatus savanna, neither of which is extensive. In the absence of fire, a scrub-forest community develops which is thought to be the climax vegetation.

(iii) Valley vegetation

This vegetation occurs in the rugged valleys experiencing a dry and warm climate. The mean annual rainfall rarely exceeds 700 mm.

Communities serving as indicators for this type include the Acacia karroo-A.nilotica thornveld in the drier parts and the A.sieberiana tree veld in the moister parts. Much of the vegetation is secondary in nature and severe erosion is a common feature. Three communities have been recognized and are indicated on Map 5.

(a) Acacia karroo-A.nilotica thornveld: This community is confined to the lower reaches of the Mooi river valley and occurs below an altitude of 1280m (4,200 ft). It does, however, extend to greater heights on the steep north-facing slopes. The boundary generally coincides with an abrupt change in topography and is clearly defined. The mean annual rainfall is approximately 650 mm.

The most important index plants include A.karroo, A.nilotica and the grasses, Hyparrhenia hirta and Eragrostis superba. The grass field layer below the characteristic short tree stratum is similar to that of the Tall Grass Veld. Its composition, however, is influenced by the tree layer itself, the soil and the applied managemement practices. The principle grasses include Themeda triandra, H.hirta, Bothriochloa insculpta, Chloris gayana, Cymbopogon plurinodis, Heteropogon contortus and Setaria sphacelata. Important grasses of the secondary succession include Digitaria pentzii, D.tricholaenoides, Elyonurus argenteus, Eragrostis chloromelas and E.curvula. With severe disturbance Cynodon dactylon, E.plana, Aristida spp. and Sporobolus spp. become dominant. Beneath the trees Panicum maximum and Melinis minutiflora are common. Edwards (1963) listed many additional shade-tolerant herbs and climbers which occur in this vegetation type.

(b) Semi-deciduous bush: The semi-deciduous bush is not extensive and occurs below the main waterfall on the Mooi river. The important tree and shrub species include Acacia tortilis, A.nilotica, Schotia brachypetala, Olea africanna, Boscia albitrunca and Euclea spp.

(c) Mixed bush of the Umgeni gorge: Included in the valley vegetation is a small area occurring as a narrow strip along the Umgeni river and extending eastwards from below the Howick falls. Here, the climatic conditions are moister and milder than in the case of the Acacia karroo-A.nilotica thornveld.

Aspect has a marked effect on the ecology of this area. The steep north-facing slopes are heavily wooded with A.karroo and A.nilotica being particularly common. Aloe spp. may become locally dominant. An open savanna occupies the moister south-facing slopes in which Acacia sieberiana, together with Hyparrhenia hirta and Aristida junciformis, is abundant. In protected kloofs the bush is very mixed and contains elements that suggest a close relationship between this vegetation type and the semi-coast forest described by Edwards (1963). Cestrum laevigatum (Inkberry) is an important poisonous plant occurring in this vegetation type.

(iv) Forests

Evergreen Podocarpus forests are climax communities for both the Highland Sourveld and Midlands Mistbelt. Mere relics of what were once extensive forests are seen today (Plate 15). Much has already been written of these forests including their history, structure, composition, exploitation and need for protection (Fourcade, 1889; Rycroft, 1942; Taylor, 1961; Edwards, 1963; Scotney, 1964; Moll, 1965). It has been suggested that the forests were subjected to severe exploitation and, at times, faced total destruction. Chief threat to their existence is fire although over-exploitation by both European and Bantu and grazing by livestock are also important (Plate 16). The remnants seen today are confined to the steep, moist slopes and deep kloofs which afford protection from fire and the hot 'berg' winds. The total extent of the forests which are shown on the soil map is 26.3 square miles.

Two distinct forest types have been recognized and, since they are

Plate 15. Relics of once extensive forests in the Howick Extension Area (photo: E. J. Moll).

Plate 16. Forest margin severely damaged by fire (photo: E. J. Moll).

Plate 17. The most extensive Podocarpus forest occurs along the Karkloof range (photo: E. J. Moll).

not of much agricultural importance, are described very briefly.

(a) Mistbelt mixed Podocarpus forests: These forests occur between an altitude of 1067m (3,500 ft) and 1372m (4,500 ft) and experience frequent mists and a mean annual rainfall exceeding 1,000 mm. The most extensive of these occurs along the Karkloof range (Plate 17). The structure and composition of these forests and their associated seral communities have been described in detail by Rycroft (1942), Taylor (1961), Edwards (1963) and Moll (1965). The last named also presented a diagrammatic illustration of the forest layers. Edwards (1963) regarded *Combretium kraussii* and *Xymalos monospora* as important index plants.

(b) Mountain Podocarpus forests: These forests differ from the former in that the trees are generally shorter and the forest itself is structurally simpler and floristically poorer. They are not as extensive as the mixed Podocarpus forests and occur above an altitude of 1372m (4,500 ft). Mean annual temperatures are low. The main index plants include *Podocarpus latifolius*, *Rapanea melanophloeos*, *Olinia emarginata* and *Halleria lucida* (Edwards, 1963).

(v) Bottomland communities

Bottomlands include level, poorly drained and often submerged 'vleis' and the narrow alluvial strips. In addition to hydromorphic soil conditions they are subject to frosts of greater severity than the surrounding uplands. Although several workers have described the communities associated with these bottomlands, no attempt has yet been made to differentiate between the several types of bottomlands on the basis of soils. For this discussion the bottomlands are separated as follows:

(a) Acid, hydromorphic bottomland communities: Downing (1966) presented a detailed account of the ecology of a typical acid vlei and Moll (1965) has described the vleis of the upper Umgeni catchment. The most striking features of these communities is the distinct zonation determined by soil moisture conditions. With decreasing moisture the following communities are recognized:

(1) Aquatic communities where free water occurs at all times.

(2) Reedswamp communities in which Phragmites communis and Typha capensis are dominant.

(3) Sedge meadow communities subject to periodic flooding in summer. These are probably the most extensive and are characterized by perennial sedges such as Cyperus spp., Scleria spp. and Pycreus spp., and grasses such as Fingerhuthia sesleriaeformis, Hemarrthria altissima and Pennisetum spp. Agapanthus natalensis, Satyrium spp. and Gladiolus papilio are flowering species frequently seen. A conspicuous hummock formation, caused by ant activity and trampling by livestock, is a characteristic feature of this community (see Plate 23).

(4) Hygrophilous grassland communities form the outermost zone but may be absent where the topography is steep. The water table fluctuates considerably. Downing (1966) recorded fluctuations from 0 to 63.5 cm (25 inches) in summer to 152 to 178 cm (60 to 75 inches) in winter. Commonest grasses include Tristachya hispida, Poa binata, Koelaria cristata, Festuca caprina, Monocymbium ceresiiforme, Eragrostis capensis, Themeda triandra and Harpechloa falx. Forbs such as Helichrysum spp. and Hypoxis spp. and geophytes may be abundant. Agrostis tenuis occurs on bottomlands near Nottingham Road and at higher elevations.

(b) Neutral to alkaline bottomland communities: These occur within the Tall Grass Veld and associated ecotonal grasslands. Many of the bottomlands have been cultivated and, in most cases, erosion of the main drainage channel has lowered the water table. By comparison with the acid 'vleis', the aquatic and reedswamp communities are very much smaller or may be absent. The sedge meadow and hygrophilous grassland communities are extensive but these, too, may be replaced where soil moisture conditions become too dry. Under these conditions concocies and associes of Pycreus macranthus, Fimbristylis complanata and Fuirena pubescens may develop (Edwards, 1963).

In addition to many of the species found in the acid 'vleis', the sedge meadow community includes grasses such as Beckeropsis uniseta, Miscanthidium erectum and Setaria sphacelata. Verbena bonariensis, Polygonum pulchrum and Kniphofia buchanii may also occur.

The hygrophilous grassland communities include such species as Bulbostylis spp., Hemarthria altissima, Imperata cylindrica, Agrostis spp., Eragrostis spp., Andropogon spp. and Cynodon dactylon. Introduced Paspalum spp. are common especially in the Merrivale valley. In the drier parts Imperata cylindrica and Andropogon eucomis become more frequent on the margalitic soils. Matricaria nigellaefolia is an important poisonous weed in this community and wild clover (Trifolium africanum) is fairly abundant.

(c) Stream hydrosere and riverine communities: Sedge meadow and hygrophilous grassland communities, similar to those already described, frequently occur on the alluvial deposits. However, in rocky and rugged terrain these communities give way to a narrow strip of woody vegetation, the composition of which depends upon the locality. Examples of this include Leucosidea sericea and associated plants in the Highland Sourveld; Combretum erythrophyllum and associated plants in the Tall Grass Veld and Acacia karroo, Spirostachys africana and Ficus spp. in the valley vegetation. Salix woodii is common throughout the Area.

Tulip (Moraea spp.) is a common weed on the alluvial deposits, particularly along the Mooi and Karkloof rivers.

2) Extent and distribution of the vegetation types

The extent and distribution of the vegetation types in relation to the Area as a whole are summarized in Table 39. The extent of the bottomland communities is not indicated.

Table 39 : Extent and distribution of vegetation types in the Howick Extension Area

Vegetation type	Extent and distribution	
	(sq. miles)	% of area
Grasslands and savanna		
1. Sub-alpine grassland	0.4	
2. Highland Sourveld		
(a) Protea savanna	5.6	
(b) Grassland	264.4	
3. Midlands Mistbelt grassland	231.7	
4. Tall Grass Veld		
(a) Dry Tall Grass Veld	30.3	
(b) Moist Tall Grass Veld	27.4	
	Total 559.8	75.8
Ecotonal grasslands		
1. Cool, dry ecotonal grassland	60.6	
2. Moist grassland transitional to the Midlands Mistbelt	59.7	
	Total 120.3	16.3
Valley vegetation		
1. *Acacia karroo-A. nilotica* thornveld	22.4	
2. Semi-deciduous bush	0.4	
3. Mixed bush of the Umgeni gorge	9.8	
	Total 32.6	4.5
Forests		
1. Mistbelt mixed Podocarpus forests	20.0	
2. Mountain Podocarpus forests	6.3	
	Total 26.3	3.4

4.3 Physiographic features

1) Physiography

The predominant physiographic features of the Area are illustrated by means of the simplified block diagram with river profiles presented in Fig.7. Generally, the land falls rapidly in stepwise descent from a maximum altitude of 2134m (7,000 ft) in the west to 762m (2,500 ft) at the confluence of the Umgeni and Karkloof rivers. A prominent 'main divide' which forms the watershed between the catchments of the Mooi and

163(i)

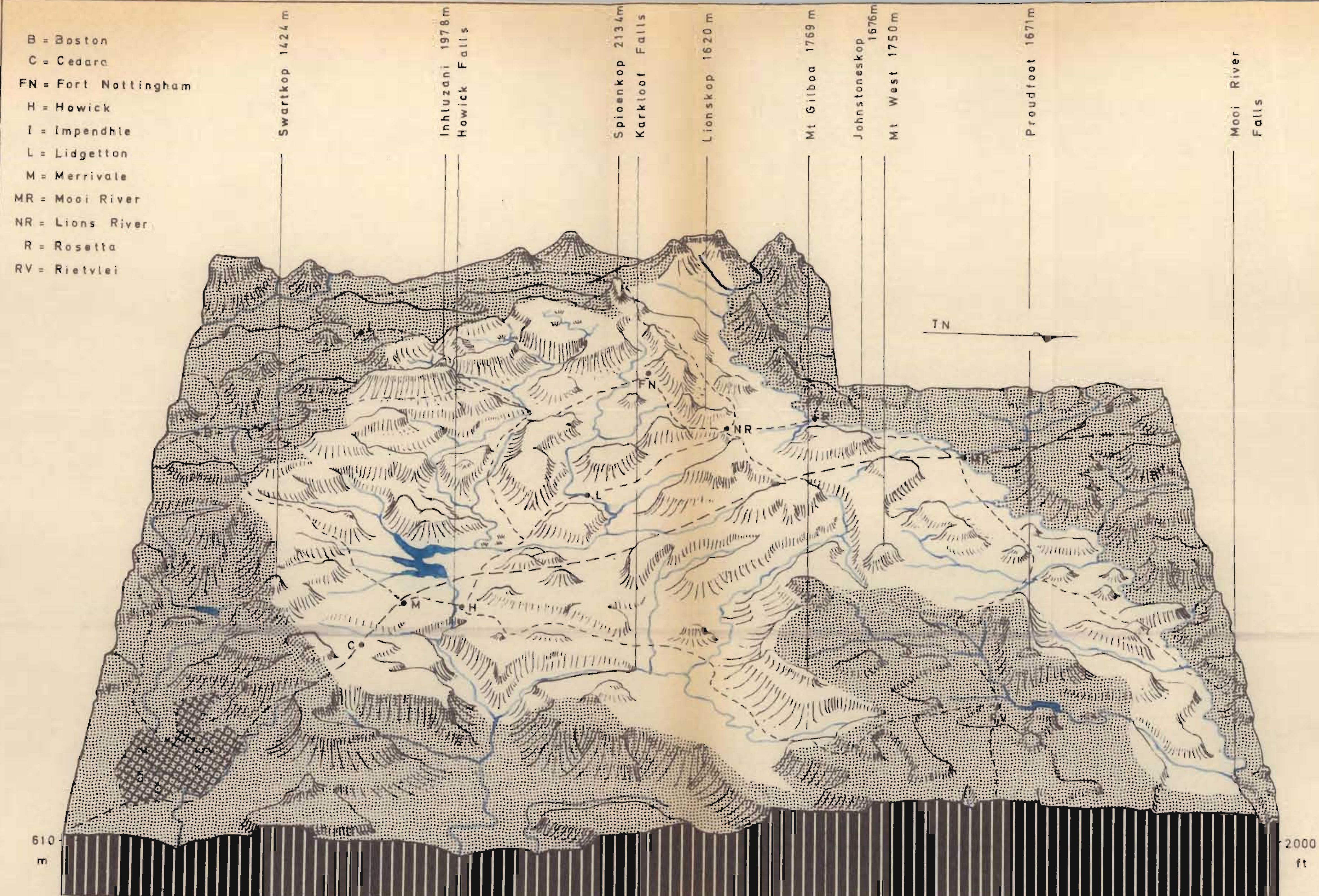


Fig 7 (a) Physiographic block diagram of the Howick Extension Area.

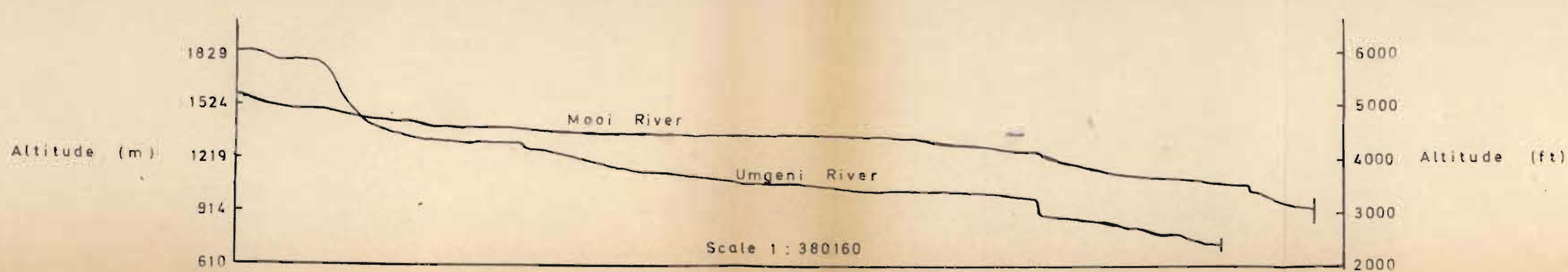


Fig 7 (b) Selected river profiles in the Howick Extension Area.

Plate 18. The western barrier extending south of Inhluzane peak (photo: E. J. Moll).

Plate 19 Inhluzane peak (6488 ft) - prominent landmark in the Howick Extension Area (photo: E. J. Moll).

Umgeni rivers is created by the Spioenkop (2146m - 7,040 ft) - Lionskop (1620m - 5,315 ft) - Johnstoneskop (1670m - 5,479 ft) - Mt. West (1750m - 5,739 ft) - Proudfoot (1671m - 5,482 ft) range. A massive off-shoot of dolerite extending south to Swartkop (1424m - 4,672 ft) forms a natural barrier in the west (Plate 18). The outstanding landmark in this range is the Inhluzane Peak (1978m - 6,488 ft) (Plate 19).

A south-east extension of the 'main divide' reaching to Mt. Gilboa (1769m - 5,803 ft) forms the eastern boundary and well-known Karkloof range. North of the 'main divide' the land falls consistently and fairly rapidly to the Mooi river which forms the northern boundary.

The percentage of the Area falling between certain altitude limits is presented in Table 40. From this it can be seen that approximately 75 percent of the Area is over 1220m (4,000 ft) above sea level.

Table 40 : Altitude ranges in the Howick Extension Area

Altitude range (meters)	Percentage of Area (%)
less than 915 (3,000 ft)	1
915 (3,000 ft) - 1220 (4,000 ft)	24
1220 (4,000 ft) - 1524 (5,000 ft)	47
1524 (5,000 ft) - 1825 (6,000 ft)	25
over 1825 (6,000 ft)	

In general, the topography is hilly and steep. Notable exceptions occur to the south-west and north-east of Nottingham Road, in the lower reaches of the Karkloof valley, in the Merrivale valley and above the major scarps. In these parts the topography is gently sloping to undulating and here the bottomlands are most extensive.

Four main river catchments drain the Area namely: Umgeni river (264 square miles), Lions river (134 square miles, Karkloof river (135 square miles) and Mooi river (southern sector only - 205 square miles). The Mooi river, which forms an important tributary of the Tugela river, drains the area north of the 'main divide'. South of the 'main divide' the rivers and their numerous tributaries tend to flow in a south-easterly direction. This area forms the upper reaches of the important Umgeni river catchment. Each of the major rivers boasts at least one spectacular waterfall.

The physiography of the Area has a marked influence on other natural features, especially climate and soils, and land-use practice. There is a general increase in precipitation and decrease in temperature with rising altitude, and note has already been made of the rain-shadow effect of the prominent ridges. The broken topography is also one of the main features limiting the agricultural potential of the Area, especially in preventing intensive arable use. Steep topography limits the use of farm machinery and is closely related to erosion hazard.

2) Geological formations

The geology of the Area is relatively simple. Details of the formations and their chronological sequence have been described in detail by King (1951) and du Toit (1954). With the exception of the Dwyka series all groups of the Karroo system are represented. In ascending order these include:

Ecca series: The Ecca shales and sandstones, excluding the lower beds, occupy approximately 55 percent of the Area. Their distribution is confined to areas below an altitude of 1372m (4,500 ft). The lowest strata, which occur at Hilton Road and in the lower reaches of the Mooi river valley, comprise the light coloured, fine to coarse grained sandstones of the middle Ecca beds.

Beaufort series: The triple Beaufort series follows conformably on the Ecca series and lies between 1372m (4,500 ft) and 1829m (6,000 ft) above sea level. It covers approximately 43 percent of the Area. The lower group comprises yellowish, fine to medium grained felspathic sandstones while bright red, maroon and purple mudstones are characteristic of the middle and upper divisions.

Stormberg sediments: These occupy only two percent of the Area and are confined to the highest peaks which form part of the great spurs extending from the little Drakensberg. Outliers of these sediments cap Spioenkop and occur on the farm 'Allandale'. These consist of pale coloured, coarse grained felspathic sandstone.

Karroo dolerite: A striking feature of the Area is the abundance of dolerite which is intrusive into both the Ecca and Beaufort series. It occurs as horizontal or inclined sills, often many feet thick, or as narrow vertical dykes. The latter may run in sinuous or straight lines for considerable distances and are particularly common to the west of Nottingham Road. The natural resistance of dolerite to landscape development is evidenced by numerous elevated hills and ridges and many waterfalls (e.g. Howick falls). Dolerite dykes often form the all-important 'key' areas that give rise to the hydromorphic bottomlands or 'vleis'.

Although kaolinite of low quality is mined at several places in the Area there are no formations of economic consequence.

3) Geomorphology

Study of the geomorphology of an area provides an understanding of the formation and distribution of soils and may elucidate many problems of a pedological nature (Maud, 1965; Sparrow, 1965). The standard cycle of river incision, scarp retreat and pediplanation and its influence on soil formation is clearly reflected in the landform and soil resources of the Area.

Past tectonic upheavals and the subsequent erosion cycles reduced the ancient land surfaces to their present day form. Remnants of the early tertiary 'African surface' are today represented by the table-topped ridges and hills of the main divide (e.g. Mt. West, Johnstoneskop and Mt. Gilboa). The 'post African surface' is represented by the plains that surround Nottingham Road.

Two major erosion scarps running parallel to the coast and moving in a westerly direction were generated by late Pliocene and early Quaternary upheavals. The first of these, at approximately 1220m

(4,000 ft) above sea level, has traversed to just beyond Balgowan. The other lies immediately to the south of the Area at Hilton Road. The inland limits to erosion of the Quaternary cycle which was rejuvenated by uplift and tilting, are marked by several of the well-known waterfalls in the Area.

The relative hardness of the constituent rock formations have largely determined the landform. In addition to this, the gentle westerly dip of the Karroo system has given rise to the typical 'cuesta-type' topography observed in the higher regions. Here the frequent occurrence of steep southern-aspect slopes, although below 6,000 feet above sea level, is probably due to Pleistocene periglacial erosion (Sparrow, 1964).

Terracetes and slip-scars are frequently observed at the higher elevations. These are the signs of a natural erosion phenomenon aided by features such as frost action, wind and livestock movement. Their occurrence has drawn the attention of several workers (du Toit, 1954; de Villiers, 1962; MacVicar, 1962; Moll, 1965).

4.4 Other characteristics and features affecting land use

There are several other characteristics and features of the Area that not only affect present land-use practice, but deserve recognition in land-use planning.

1) Water resources

The Area must rate as one of the best watered farming areas in the Republic. A copious water supply is provided by numerous strong-flowing perennial streams which feed the four main rivers. The abundance of water was stressed by McCrystal (1963), who calculated that the Lions River magisterial district alone contributed almost 40 percent of the total number of perennial streams of eight adjoining districts. Considerable information is also available concerning the river flow and sustained draught of the Umgeni river (Natal Town and

Regional Planning Commission, 1961; Thorrington-Smith, 1960; Kokot, 1963). Official gauging weirs sited in the Area provide information on the water resources of the other main rivers.

Available data[1] show that the mean monthly flow of all the rivers increases and decreases markedly during November and March respectively. The difference between summer and winter flow is greatest for the Mooi and Karkloof rivers. The latter also has the highest annual run-off (407 mm) of all the main river catchments. Relevant information is summarized in Appendix 14.

Large volumes of water are impounded in the numerous farm dams scattered throughout the Area. In the Lions River magisterial district alone there are well over 400 dams (S.A. Bureau of Statistics, 1964). The largest project, however, is the Midmar dam near Howick with a capacity of 143,636 acre feet.

The resources of the Umgeni river system are vital to industrial development and the expected urban expansion in the Durban - Pietermaritzburg complex. The expected increase in population for the entire catchment area is from 1.7 million in 1980 to 2.9 million by the turn of the century (Natal Town and Regional Planning Commission, 1961). Recently, the latter estimate has been placed at 3.1 million with a total water requirement in 2000 AD of 360 million gallons per day (Kinmont, 1970).

The water resources of the Mooi river were regarded as more than adequate for future industrial development and irrigation (Thorrington-Smith, 1960). The total estimated requirements were only one third of the calculated sustained draught of the river. Recent study, however, has shown that the water resources of the Mooi river could be used elsewhere in the Tugela Basin or diverted via the Karkloof river into the Umgeni system (Matthews, 1969; Pegram, 1970).

In comparison with industrial and urban demand the water

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[1] Hydrological Research Division, Dept. Water Affairs - personal communication

requirements for irrigation are considered by many to be negligible. Although there are no major irrigation projects in the Area, the writer records the phenomenal increase in the number of farm-scale projects and general interest afforded to this type of production in recent years. Analyses of water collected from each of the major rivers indicate that the quality of water is, in all cases, suitable for irrigation. Although there are no major projects planned for generating hydro-electric power it can be noted that the S.A. Rubber Co. (Pty) Ltd., at Howick produces power for its own needs.

Two additional aspects related to water resources are worthy of mention. Firstly, the management and use of the 'vleis' within the Highland Sourveld have led to much controversy over the past twenty years. Although little scientific evidence is to hand on which to base recommendations, it is imperative that a suitable policy for ensuring their safe-use be formulated without delay. This aspect is discussed further in Chapter 6.

Secondly, there is the effect of tree planting on water supplies. Since afforestation is one of the main forms of land use in the Area its demands on the water resources is undoubtedly high. Although Nänni (1970) has established beyond doubt that tree planting has an adverse affect on stream flow, no critical study has yet been conducted in the Area. The serious light in which this problem is viewed has led to the recent proclamation of the Karkloof river catchment as a Water Catchment Control Area.

2) <u>Soil erosion</u>

Reference has already been made to the lack of data relating to run-off and soil loss. In assessing the state of soil erosion in the Area, therefore, the writer has relied almost entirely on visual observation and the reports by Henkel *et al.* (1938), Scott (1951), Midgeley (1952), Sherry (1954, 1964), Hiemstra (1965) and Hiemstra and Edwards (1965).

The fundamental causes of erosion listed by Pentz (1949) are as valid today as they were more than two decades ago. One of these, "the mental attitude of the individual towards the land" deserves special mention. It is unfortunately true that, despite considerable effort on the part of the local soil conservation committees and the extension service, there is a general attitude of complacency among the farming community. These remarks, however, should not detract from the splendid achievements of those who have heeded the many timely warnings. The relatively stable soils and dense natural sward over most of the Area have no doubt contributed much to the complacent attitude.

In the lower reaches of the Mooi river valley there is an abundance of severe donga erosion. The seriousness of the erosion, especially in the bottomlands, has been adequately stressed in Chapter 1. Over the remainder of the Area, endowed with relatively stable soils, insidious sheet erosion is common and is more serious than most believe. Run-off data presented by Midgeley (1952) indicate the potential danger of soil loss from the high rainfall areas. Added to this is the danger of wind erosion, particularly on the light textured soils of the A2- and B2-associations. The low plant nutrient status of the highly leached soils and related poor crop growth contribute significantly to the erosion problem on many arable lands.

To assess the situation in the Area, data[1] relating to the silt loads of three of the main rivers were studied. A summary of this information is presented in Appendix 15. Despite the short duration of the records several interesting features are worthy of note.

The annual soil loss per unit area of catchment is very much higher in the case of the Mooi river catchment (79.6 tons/sq.mile) than in either the Umgeni (29.9 tons/sq.mile) or Lions river (29.5 tons/sq. mile) catchments. This is attributed to the fact that the Mooi river rises in the precipitous terrain of the Drakensberg range which

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1 Hydrological Research Division, Dept. of Water Affairs - personal communication

experiences very high rainfall of considerable intensity. Furthermore, the low basal grass cover of the steep debris slopes associated with Stormberg sediments and of the Tall Grass Veld and the high erosion hazard of the B2-association soils in the upper reaches of the catchment, add to the problem. A relatively high (30%) percentage of the catchment also comprises moderately to slightly leached soils of high erosion hazard and there are many dry and steep north-facing slopes along the southern flank of the river. Edwards (1961) showed conclusively that soil loss is positively correlated with dry soils.

The marked increase in the silt content of all the rivers between October and December coincides with the period during which most arable areas are vulnerable to erosion. It is also the time when much of the natural veld, having been burnt early, provides the least protective cover.

3) Markets, industries, communications and labour

Enterprize location is an important aspect to consider in land-use planning. Since land resources are located at varying distances from the centres of economic activity, costs are involved in bringing capital and labour to the land and products to the markets. Transport costs are thus a key factor in determining land-use patterns. Sites near the market enjoy an element of comparative advantage over sites located further away (Barlowe, 1958). The importance of location factors in determining land-use patterns within the Area has been noted by McCrystal (1963) and Yates (1966).

Markets and industries: The Area is favourably situated with respect to markets and industrial activity. Pietermaritzburg lies immediately to the south and there is direct road and rail link with the port of Durban situated some sixty miles away. These cities offer excellent opportunity for the marketing of all farm products. Timber is generally sold to industries in these centres although much pulpwood and mining timber is shipped to Mandini and the Reef respectively.

The vast Tugela Basin with its great potential for industrial development lies immediately north of the Area and ensures alternative markets. Estcourt, situated only seventeen miles from Mooi River, already draws most of the pork produced and a limited amount of wattle timber. Mooi River itself boasts a creamery, bacon factory and textile industry. The rubber manufacturing factory and the small textile and plastic concerns at Howick are the only other industries worthy of note.

Communications: The extent and distribution of communications are particularly favourable. The main national highway and the rail link between Johannesburg and Durban pass through the Area. A network of district and private roads permits easy access to the main highways. Furthermore, it has been estimated that over 70 percent of the Area lies within a zone extending ten miles on either side of the main national highway. Communications are, however, somewhat inadequate for some of the mountainous areas within the Highveld Sourveld. As a result, intensification has been delayed in these parts.

Labour: Most of the regular and casual labour is resident on farms in the Area. In 1961-62, for example, less than 3 percent of the regular labour was born outside the Lions River magisterial district (S.A. Bureau of Statistics, 1965). At that time, the number of regular and casual labourers per holding was 13.4 and 6.8 respectively, and 82 percent of the casual labour was female.

In addition to resident farm labour there are the Montrose Bantu location near Merrivale and the Swartkop and Impendhle locations adjoining the western boundary. These sources ensure that the labour requirements for the Area as a whole are adequate.

Recent economic studies in the Lions River and Mooi River districts show that the average annual wage expense for regular farm labour is approximately R3040 and R1865 respectively. The respective values for casual labour are R255 and R225. Over the past decade these wages have shown a steady increase and, in the Lions River district, have been influenced by competition from industry and large farming companies.

On most of the larger farms it has been common practice for the regular labourers to own approximately 10 percent of the total livestock on the farm and to be allotted a section of the arable land. At present this practice is being curtailed in lieu of higher wages.

4) Diseases, pests and weeds

Notwithstanding the widespread use of modern control measures, diseases, pests and weeds demand constant vigil and are of considerable economic importance. The most important of these are listed.

(i) Livestock diseases

Besides the obvious consequences of direct stock losses, livestock diseases cause untold damage through reduced yield and reproductive capacity. In the writer's opinion the indirect losses from the so-called erosion diseases (e.g. low calving and lambing percentages) are far more important than is generally realized. The most important diseases in the Area are given below and have been described by Henning (1949) and Monning and Veldman (1956).

Cattle: Today, diseases such as lung diseases, rinderpest and East coast fever which, at one time, caused severe losses are rare. The extent to which veterinary practice has controlled diseases in the Lions River district can be judged from data in the agricultural census. During 1959-60, for instance, total losses of white-owned cattle amounted to 2,016 head out of a total of 34,259. Of this number only 1,435, or 4.2 percent, were caused by disease (S.A. Bureau of Statistics, 1962).

Redwater and gallsickness constitute the main tickborne diseases while quarter-evil is one of the most serious bacterial diseases. Less common diseases include lumpy skin and three-day stiff sickness. State control schemes have almost completely eliminated the incidence of anthrax and, to a lesser extent, tuberculosis.

Mastitis and brucellosis are constant problems in dairy cattle. Verminosis, including liver flukes, tapeworms and many roundworms, is a serious hazard in young animals. High rainfall conditions and intensive pasture usage promote infestation by parasites unless rigid control is applied. Since a low plane of nutrition is a predisposing condition, verminosis takes its heaviest toll during late autumn and winter. Paratyphoid and white scours are important calf diseases.

Although not a disease, the fairly high incidence of bloat on established pastures deserves mention. Individual farmers have on occasions experienced heavy losses from this cause.

Sheep: In 1959-60 the total sheep losses in the Lions River district amounted to 6.7 percent of the total number and, of this amount, 3.3 percent were due to disease (S.A. Bureau of Statistics, 1962). Blue tongue and pulpy kidney (enterotoxaemia) are the most serious diseases although verminosis is a major problem on most sheep farms.

Horses, pigs and poultry: Horse sickness can take heavy toll during late summer but is generally effectively controlled by immunization. Intensive pig and poultry husbandry has led to a general decline in the incidence of infectious diseases amongst these classes of livestock.

(ii) Crop diseases and pests

The most important diseases and pests for selected crops grown in the Area are listed.

Maize: Leaf blight (Helminthosporium turcicum) is particularly prevalent among local varieties. Other diseases usually regarded as unimportant but which warrant more attention include the root, stalk and ear rots (Gibberella spp. and Diplodia zeae), tassel and head smut (Sorosporium reilianum), boil smut (Ustilago zeae) and streak disease (Virus storey). The most prevalent insect pests include cutworm (Euxoa spp.) and stalk borer (Busseola fusca).

Potatoes: The most important potato diseases include late blight (Phytophthora infestans), early blight (Alternaria solani) and leaf roll caused by the potato leaf roll virus. Rhizoctonia (Rhizoctonia solani), often associated with humic phase soils, is becoming increasingly important and very occasional infestations of common scab (Actinomyces scabies) have been reported. Eelworm (Meloidogyne spp.) is a danger throughout the Area, especially on old wattle land. Aphids are particularly common and are important in transmitting virus diseases.

Root crops: Black rot (Xanthomonas campestris), downy mildew (Peronospora parasitica) and leaf spot (Cercospora sp.) cause considerable damage to crops of radishes and turnips. Aphids may completely destroy newly planted crops.

Cabbages: The most serious diseases affecting the production of cabbages and other Brassica crops include black rot (Xanthomonas campestris), black leg (Phoma lingam) and downy mildew (Perenospora parasitica). The cabbage moth (Crocidalomia binotalis), cutworm (Euxoa sp.) and aphids are the most important pests.

Cereals, grasses, clover and lucerne: Rust and smut diseases frequently attack crops of oats and ryegrass under warm, moist conditions. Ergot (Claviceps sp.) is commonly found on the seed heads of Paspalum spp. but although it may cause livestock poisoning it is not associated with abortion (Mönning & Veldman, 1956). Leaf spot (Pseudopeziza sp.) is common on lucerne and sometimes clover. The lucerne caterpillar (Colias electo), which often occurs in clover swards, is widespread throughout the Area. Occasional outbreaks of army worm (Laphygma exempta) may also occur. Recently, ghost worm (Gorgopis libania) has been found in natural veld, pastures and lawns.

Trees: Die-back (Diplodia pinea) causes considerable damage to pine plantations following injury by hail. Rodent damage to newly planted pines may also reach serious proportions. Bagworm (Kotochalia junodi) is one of the most serious pests in wattle plantations.

The Natal fruit fly (Pterandus rosa) is by far the most important hazard affecting the production of plums and peaches, and large quantities of these fruits are destroyed during December and January.

(iii) Weeds

The following is a list of the main proclaimed, poisonous and other important weeds in the Area.

Proclaimed weeds: The common weeds proclaimed under the Weeds Act, No. 42 of 1937, as amended, include bramble (Rubus cuneifolius), bugtree (Solanum mauritianum), scotch thistle (Cirsium lanceolatum) and cocklebur (Xanthium strumanium). Burweed (Xanthium spinosum) occurs along the lower reaches of the Mooi river and isolated patches of lantana (Lantana camara) are found in the Merrivale valley. Dodder (Cuscuta campestria) is restricted to areas along the lower reaches of the Lions and Umgeni rivers. The water weeds, Kariba weed (Salvinia auriculata) and water hyacinth (Eichornia crassipes), have been identified in several farm dams situated in the catchment area of the Midmar dam but active steps have already been taken to bring these under control.

Poisonous weeds: 'Tulip' (Moraea spp. and Homeria spp.) is the most troublesome poisonous weed causing cattle and small stock losses in the early spring. Moraea spp. occur in the Highland Sourveld, Midlands Mistbelt and Tall Grass Veld. The weed is particularly widespread in the Karkloof area where it often occurs on the moist, alluvial strips and in the grassland. Ragwort (Senecio sp.), slangkop (Urginea macrocentra), chinkerinchee (Ornitholagum spp.) and inkberry (Cestrum laevigatum) cause occasional losses in cattle, particularly in the Midlands Mistbelt. Staggers weed (Matricaria nigellaefolia) is common along streams and on bottomlands in the Midlands Mistbelt and adjoining areas.

Other important weeds: A number of other important or potentially troublesome weeds occur in the Area. These include the silver wattle (Acacia dealbata), ouhout (Leucosidea sericea), Curry's post weed (Anthanasia acerosa) and broom (Sarothamnus scoparius). Witchweed (Striga asiatica) is not widespread but is a potential hazard to maize production. It is confined mainly to the Howick and Merrivale areas where it is associated with partially leached, red soils.

5) Recreation and wildlife

From a recreational point of view the Area is not only popular but has immense potential. This is due to many natural attractions, such as the Podocarpus forests, numerous waterfalls and dams, scenic beauty and wildlife resources, together with its close proximity to Pietermaritzburg and Durban. The Midmar dam alone is a most popular attraction.

History reveals that the wildlife, as in all other parts of the country, has succumbed to pressures resulting from the increased intensity of land use. Stories of lions roaming the Dargle area, buffalo being shot near Fort Nottingham and game pits dug by early Bantu inhabitants (in the Karkloof area), speak for themselves. Despite this, the Area still supports a rich variety of smaller farm game species, birdlife and fishes.

Commonest ruminants include the grey duiker (Sylvicapra grimmia), reedbuck (Redunca arundinum), bushbuck (Tragelaphus scriptus) and oribi (Ourebia ourebi). Blesbuck (Damaliscus dorcas) have been introduced to several farms within the Highland Sourveld.

The vervet monkey (Cercopithecus aethiops cloetei) occurs throughout the Midlands Mistbelt in both natural forests and exotic plantations. The black or silver backed jackal (Thos mesomelas mesomelas) is the only carnivorous mammal of any consequence.

A very wide variety of birdlife, including waterfowl, abounds in all parts of the Area. The occurrence of the crested guinea fowl (Guttera lividicollis lividicollis) in the Karkloof forest is worthy of note.

Earliest attempts to propagate fresh water fish in Natal took place in the Area (Crass, 1964). From hatcheries near Balgowan and in the Karkloof area fish were distributed to many rivers, streams and dams. Brown trout (Salmo trutta) occur mainly in the Mooi, Lions, Umgeni and Yarrow rivers. Their presence in the last-named river at an altitude of approximately 1148m (3,800 ft) marks the lower limit of their distribution. Rainbow trout (S. gairdneri) have been introduced into many dams in the Highland Sourveld.

Largemouth bass (Micropterus salmoides) occur in the majority of dams below an altitude of 1524m (5,000 ft) and are often associated with bluegill (Lepomis mairochirus). The occurrence of smallmouth bass (M. dolomieui) in Natal is confined almost entirely to the Umgeni river near Howick and the Mooi river for some miles downstream from Rosetta (Crass, 1964). Spotted bass (M. punctulatus), also confined to the Area, occur mainly in the Umgeni, Lions, and Karkloof rivers. The red-chested tilapia (Tilapia melanopleura) was also introduced into several dams near Howick and has persisted. Carp (Cyprinus carpio) introduced into the Midmar dam are reported to be doing well.

A fairly wide range of indigenous fish species occur throughout the Area. The most important of these include the scaly (Barbus natalensis), barbel, (Clarias gariepinus), Natal catlet (Amphilius natalensis) and the eel (Anguilla mossambica). These species are most plentiful in the lower reaches of the main rivers.

4.5 Agriculture

Details of present land use and natural characteristics of an area provide information required to assess its capabilities. The intensity of the current land-use practices, considered against the assessed capabilities, provides a basis for identifying important problems in agricultural development. Present land use is, however, largely influenced by economic factors and, as such, may provide little indication of the real capabilities of the land (Kellog, 1951). The information should, therefore, be used with caution.

1) Early development and settlement

This discussion concerns the period up to 1900 AD.

(i) Settlement

Following a period of sparse population during the Shaka era, settlement took place under the influence of the Voortrekkers and the British who arrived at Port Natal. Annexation of Natal in 1843, however, saw many of the Trekkers who had arrived in the late thirties withdraw to lands across the Drakensberg, although some remained in the lower region of the Mooi river valley.

By 1858 the population had increased considerably and the area was one of the principally settled regions in Natal, with farm boundaries fixed (Moll, 1965). Undoubtedly, communications and the availability of water contributed most to the siting of the present day towns and villages. Howick, however, was among a number of towns selected for settlement as early as 1846. Between 1850 and 1870 public pounds were established at Howick and Lidgetton as an aid to the administration of the area north of Pietermaritzburg.

Development of the main centres was determined by social and commercial functions, especially educational and trading needs (McCrystal, 1963). The first railway line through the Area also did much to stimulate economic growth.

(ii) Agriculture

Initially, extensive cattle farming was the main farming activity. Gradually the pattern changed to more intensive systems and mixed farming became common practice. The change to a more intensive system of agriculture coincided with the arrival of the British settlers (McCrystal, 1963).

Dairying soon became one of the main lines. Mann (1859) quoted by McCrystal (1963), suggested that dairy farming in the Midlands was capable of being made a source of high remuneration. Lidgetton, in fact, became one of the important dairy centres with the production of butter the main line. Milk yields were generally low being of the order of 0.5 to 1.0 gallons per cow per day (McCrystal, 1963). Markets and communications were the main factors influencing the development of this industry.

Extensive cattle farming was confined to the Highland Sourveld where land could be purchased at very low cost. The hardy Afrikander, initially introduced by the Trekkers, was the most popular breed. In 1855 an epidemic of lung sickness (pleuro-pneumonia) swept through Natal and did much to reduce the numbers of cattle and effect a general change from cattle to sheep farming. This disease was one of the most destructive up to 1896 (Henning, 1949). Cattle numbers were further reduced by rinderpest and later by East Coast fever.

Sheep farming, mainly Merino, became important after 1855. The early development of the Merino industry was described by Sellers (1946) and from this, it can be deduced that the Area was widely acclaimed as being suitable for sheep. The main problems confronting the farmers included poor acclimatization of imported sheep, little knowledge of sheep husbandry and diseases such as scab, blue tongue and geelsiekte. Early reports make no reference to problems of winter feeding and internal parasites.

One of the earliest sheep experiments in Natal was carried out by Edwin Parkinson at Shafton Grange in the Karkloof district, and showed that wool yields could be increased from 2 lb to 4½ lb per sheep. Serious attempts to promote the importation of sheep into Natal resulted in 1,000 sheep being offered for sale in Howick on the 19th April, 1859. Prices ranged from £1-3-6 to £1-4-6 per ewe.

In 1862 John S. Dobie arrived in Natal and set about demonstrating the art of sheep rearing to farmers within the Area. In September 1862 he returned from a visit to the Eastern Cape with a flock of 2,500 sheep. These he took to his farm, 'Cotswold', near Fort Nottingham. Dobie, however, did not share the general view that most of the Area was suitable for sheep since he stated that he "had misgivings as to the propriety of making any attempt at sheep farming".

Despite a setback during the mid-sixties sheep farming continued and by 1877 was one of the best paying pursuits (Sellers, 1946). It should be noted, however, that the early attempts at sheep farming did much damage to the vegetation through excessive numbers, grazing habits and related malpractices such as early burning and continuous grazing (Edwards, 1963). Today, such damage is evidenced by infestations of _Athanasia acerosa_ and the secondary nature of much of the grassland.

The early settlers were quick to realize the potential of the Area for the production of wattle and timber. The black wattle (Acacia mearnsii) was introduced by van der Plank in 1864 and was soon established near Howick inducing much economic growth. By 1900 the Lions River district was producing over 500 tons of dry stick bark per annum and a pattern of land use had been established that was to persist to the present day (McCrystal, 1963).

The exploitation of timber, mainly yellowwood (Podocarpus spp.), from the indigenous forests was an important activity. Many saw pits, still to be seen, indicate the intensity with which the forests were 'worked'. The timber was brought to Pietermaritzburg for industries and building, and provided a valuable source of income. The widespread destruction of these natural forests led to the appointment of a commission of inquiry and to many subsequent pleas for their preservation.

Maize was the most important crop grown in these early times. Its main use was for livestock although considerable quantities were used by the settlers and their labourers. Average yields were low being of the order of 4.5 bags per acre (McCrystal, 1963). Kaffir corn, potatoes, oats and vegetables were also grown fairly extensively.

2) Present land use

This discussion deals primarily with the agricultural conditions prevailing over the past twenty years. It relies heavily on data obtained from the agricultural census which, in many instances, are available only for the Lions River magisterial district.

(i) Agricultural production

(a) Intensity of land use: The following discussion indicates the intensity of land use within the Area and the main farming lines practised.

Farming systems: A similar basis to that used by Pentz (1949) was chosen to reflect the degree of intensification on each farm within the Area. The three categories used are defined as follows:

Intensive farming systems: Those relying heavily on production from arable land. The soils have a high potential for intensive arable use and the ratio of veld to arable land is small (less than 5:1). The main lines include afforestation, cash cropping (rainfed and irrigated), fresh milk production, pigs, poultry and the breeding of pedigree livestock. Generally, these lines provide the best economic possibilities.

Semi-intensive farming systems: Those relying mainly on the natural grassland but supplemented by production from arable land. The soils have moderate potential for intensive arable use and the ratio of veld to arable land is fairly high (5:1 to 10:1). The main lines are less remunerative than those of the intensive farming systems and include the production of industrial milk or cream, beef and/or sheep. However, a limited amount of fresh milk may be produced on some farms.

Extensive farming systems: Those relying almost entirely on production from the natural grassveld. The soils have a low potential for intensive arable use and the ratio of veld to arable land is very high (more than 10:1). The main lines include beef and/or sheep.

The degree of intensification for the Area, based on the above definitions, is presented in Map 6 which also shows the main lines of farming practised on each farm. Although the above definitions do not reflect the efficiency of each farming enterprize this aspect was, to some extent, taken into account in compiling the map.

The influence of the favourable climate, especially rainfall and temperature, and communications on the intensity of use is clearly reflected on Map 6. Afforestation, for instance, is confined to the Midlands Mistbelt while fresh milk production, though somewhat more scattered, is strongly influenced by communications. Topographic features and poor communications in the western and eastern sectors of the Lions River district have obviously prevented intensification in these climatically suitable areas.

The move to intensification within the Area has been slow. In fact, it has not yet reached a maximum on most farms. A feature also borne out by several economic surveys is that intensification on any one farm is frequently restricted to the arable areas. A large proportion of the available resources is thus used very extensively or not at all.

Main farming lines: Map 6 shows that a high degree of diversification

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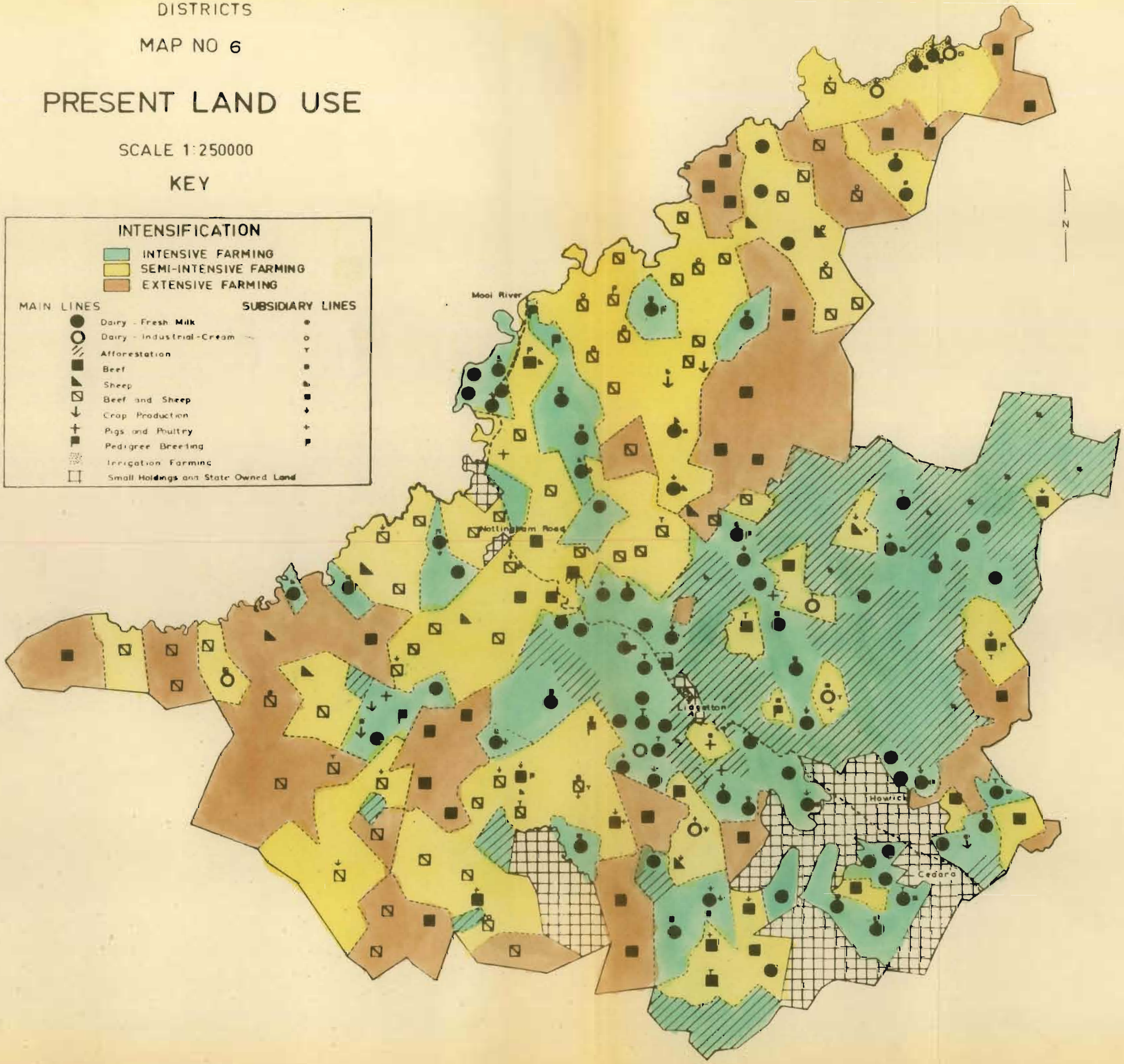
LIONS RIVER & MOOI RIVER VALLEY SOIL CONS DISTRICTS

MAP NO 6

PRESENT LAND USE

SCALE 1:250000



is characteristic for the Area. For this reason, only those lines of considerable economic importance are discussed. Special lines such as pigs, poultry and the breeding of pedigree stock usually form subsidiary lines or are confined to smallholdings. These are not discussed.

Dairying: Dairy production, not being an export-orientated industry, has followed rather than preceded economic development (McCrystal, 1963). Nevertheless, it dominates the agricultural economy of the Area. In 1962, for example, the value of milk sold was almost three times as much as that of all timber and bark produced. Approximately 80 percent of the milk was sold as fresh milk. Five percent was retailed to consumers and approximately 4 percent was used on the farms.

Despite suggestions that much dairying has been replaced by beef or afforestation, the total amount of milk produced has risen steadily since 1950. This is due to an increase in both production per cow and in the total number of cows. Data presented by McCrystal (1963) for the period 1950 to 1959 show an increase in production per cow of approximately 12 percent. Today, many progressive farmers are averaging more than 2.5 gallons per cow per day. Thus, the rate of increase noted by McCrystal has been far surpassed during the last decade.

Beef and sheep: Beef and/or sheep form the main lines of production in the remote parts of the Highland Sourveld and in the Thornveld area. They also play a subsidiary role to dairying on many farms where they utilize the natural grazing in summer. Although breeding remains the main type of production, intensive fattening and speculating have recently become popular.

Available data show a steady decline in the number of oxen in the Lions River district from 1950 to 1962. During the same period the number of wheeled tractors increased from 210 to 352. Although the decline in oxen is attributed partly to the replacement of draught animals the greater attention afforded to the production of sheep and dairy cattle is a contributory cause.

Today, the production of sheep, including wool and fat lamb, is one of the main lines of farming in the semi-intensive areas. The initial sheep population in the Area was considerably reduced by economic influence, disease (blue tongue and internal parasites) and the low plane of nutrition experienced in winter. Sheep numbers increased by over 100 percent from 1950 to 1962. This trend has continued.

Afforestation: For many years afforestation formed the main line of farming in the Midlands Mistbelt, and today there are large tracts of land planted to trees. The present day spatial distribution is also reflected on Map 6. From 1950 to 1962 the area under timber increased by 94 percent and since then the area has been considerably boosted by the activities of several large tree-growing companies. Table 41 shows the increase in total area under trees during the period 1950-1962 and the position regarding the various types of trees in the Lions River district.

Table 41 : Area under afforestation during the period 1950-1962 in the Lions River district (S.A. Bureau of Statistics, 1952-1964)

Tree species	Year				
	1949-1950	1954-1955	1957-1958	1958-1959	1961-1962
Conifer hectare	1372	2320	4197	5545	6530
%	17.5	22.7	31.4	37.2	42.9
Eucalypt ha	632	1770	2404	2469	2072
%	8.1	17.4	17.9	16.6	13.6
Wattle ha	5703	6029	6388	6640	5942
%	72.7	58.9	47.8	44.6	39.2
Poplar ha	140	99	188	242	379
%	1.7	1.0	1.4	1.6	2.5
Other ha	-	-	194	-	274
%			1.5		1.8
Total ha	7447	10228	13371	14896	15198
%	100.0	100.0	100.0	100.0	100.0

In 1950 and 1962 afforestation covered approximately 5.4 percent and 10 percent of the district respectively. The marked extent to which the area under wattle has decreased and that of conifers has increased is clearly reflected. The area of Eucalypts has increased considerably subsequent to 1962.

The return from the sale of wet wattle bark (R117,641) in 1962 was by far the highest of any of the timber products. In order of value the other main products were saw timber (R68,403 - mainly conifers), pulpwood (R17,288 - from wattle (42%), eucalypts (36%) and conifers (22%)), mining timber (R16,560 - contributed equally by wattle and eucalypts) and firewood (R15,790 - almost entirely from wattle).

Utilization of farm land and farm size: A number of surveys conducted by the writer established that the average farm size (excluding smallholdings) was approximately 1,500 acres. Of this area 20.5 percent was existing arable land, 71.6 percent natural grassland, 5.6 percent afforestation and 2.3 percent wasteland. Approximately 12 percent of the arable area was irrigated and 3 to 5 percent was cultivated by Bantu. Over 70 percent of the farmers included in the survey practised irrigation. On an average, 6 percent of the natural grassland was mown for hay.

In a separate survey conducted in the Thornveld area the average farm size was also found to be approximately 1,500 acres, less than half the recommended size as suitable for extensive farming systems (Scott, 1954).

A most disturbing feature concerning farm size, especially in the Lions River district, is the widespread subdivision of farmland into uneconomic units. Agricultural census returns for the district reveal that the average farm size decreased from 1,300 acres in 1951 to 1,100 acres in 1962. During the same period the number of holdings of less than 100 acres in size increased from 17 percent to 32 percent. This trend has accelerated phenomenally in recent times and can be attibuted to the steep rise in land prices and the desire of the average farmer to take advantage of this. Also, it was stated that legislation to prevent uneconomic subdivision of land was pending and this led to a demand for smallholdings before the legislation was introduced.

Table 42 reflects the trends in the Lions River district.

In addition to the increase in smallholdings there was a marked decrease in the number of holdings exceeding 2,000 acres. This trend

Table 42 : Trends in the size of farm holdings from 1951 to 1961 in the Lions River district (S.A. Bureau of Statistics 1952-1964)

Size of holding (acres)	Percentage distribution		
	1951	1956	1961
0 - 100	16.9	17.8	31.9
101 - 500	17.3	19.8	15.9
501 - 1000	17.3	16.7	32.5
1001 - 2000	28.2	24.6	14.9
2001 - 300	10.0	10.2	3.2
over 3001	10.3	10.9	1.6

will, however, be influenced by the recent activities of several organizations that have purchased and consolidated adjoining farms.

(b) Crops, pastures, fodder and agronomic practices: Most of the crop production provides fodder for livestock. A feature of many of the cropping programmes is the large acreage of winter fodder crops grown under rainfed conditions. Considerable effort and capital are expended, often without success, to produce these crops when conditions of moisture and temperature are limiting. This practice has important economic implications.

The main crops and pastures grown include the following:

Fodder crops: Maize is the most extensively grown crop and occupies approximately 25 percent of the total arable acreage. About 70 percent is reaped as grain and the remainder as silage. Over 80 percent of the grain produced is used locally. Yellow maize, which comprises 65 percent of the total, is grown primarily for dairy cattle and pigs. White maize is used mainly for labour.

Yields have increased sharply with improved technology. A survey conducted in 1961 showed that the average grain yield at 11 sites was 19 bags/acre (Mallett & Scotney, 1961). A more recent survey of 22 farm fields, conducted in 1967, showed that the average yield was 30.3 bags/acre. The highest yield was in excess of 40 bags/acre (Scotney & Wiseman, 1968).

In 1962 over 70 percent of the maize grown consisted of locally selected varieties but today wide use is made of hybrid varieties, especially for grain production. In the second survey mentioned only one field was not planted to a hybrid variety.

Japanese millet is grown fairly extensively for ensilge but today is less popular than it was. In 1960 a total of 17 percent of the area cultivated by whites was sown to millet. This crop is favoured in the colder parts since it can be followed by a winter fodder crop. Yields of 7 to 8 tons green material per acre are usual although yields of up to 15 tons have been recorded under favourable conditions.

The very limited acreage of annual legume crops, such as soyabeans, is striking. In 1960 only 1.5 percent of the total area cultivated comprised leguminous field crops. This is probably due to the low yields frequently attained, the problem of curing and the increased popularity of E. curvula as a source of hay. Dolichos beans are grown on a limited scale in the drier parts of the Mooi River district. Beans are sometimes sown with maize for ensilage.

Annual grazing crops for dairy cattle and sheep are grown extensively. Oats and ryegrass are the most widely planted although initially the former was favoured. In 1960, approximately 9 percent of the cultivated area was sown to oats. This crop has, however, gradually given way to smaller acreages of highly fertilized fodder crops, mainly ryegrass, produced under irrigation (Wiseman & Scotney, 1968).

Root crops are widely grown for winter feed, especially for sheep. Japanese radishes and turnips are most popular although the former are generally regarded as having the highest yield potential. Chou moellier was once extensively grown on all dairy farms but is no longer of importance because of variable yields, susceptibility to insect damage and high labour demands.

Cash crops: Excluding maize, cash crops to date have played a relatively minor role in the farming systems. In 1960, for example, potatoes and vegetables comprised only 3 percent of the total acreage cultivated. The acreage under potatoes, however, doubled between 1951 and 1962 and a steady increase has continued to this day. The production of seed potatoes provides the main source of income on a number of farms, especially within the Highland Sourveld. Cabbages and other vegetables are next in importance to potatoes. Vegetables are produced under irrigation along the lower reaches of the Mooi river and at Lidgetton. Phormium tenax, pyrethrum and kenaf have been grown in the Midlands Mistbelt but have not assumed importance.

Pasture production and ley crops: Much of the Area is eminently suited to the production of high quality pastures and ley crops. Maize has, in fact, lost its supremacy as the most widely grown crop and by 1960 the area under pasture had exceeded that under maize. In the five years prior to 1962 the area of pasture increased by over 70 percent and in 1962, 56 percent of the pastures consisted of mixed grass-clover swards. The demand for grazing of high quality and the improved establishment, fertilizer and management techniques have led to the increased acreage.

A survey in 1963 revealed that approximately 34 percent of the arable land was under permanent pasture or leys rotated with annual fodder or cash crops (Scotney, 1963). Almost half the area of ley crop consisted of E.curvula.

The most important summer producing grasses include kikuyu (Pennisetum clandestinum), Paspalum spp. and E.curvula. Cool season varieties, usually grown under irrigation, include ryegrass (Lolium spp.), cocksfoot (Dactylis glomerata) and tall fescue (Festuca elatior - Kentucky 31). Rhodes grass (Chloris gayana) was initially included in most pasture mixtures but, although it has persisted on some fields in the Merrivale valley, it has proved disappointing. As already indicated clovers are extensively grown throughout the Area. Their success outside the Highland Sourveld and Midlands Mistbelt is largely dependent on the availability of irrigation. Ladino clover (Trifolium repens) is the most widely grown variety.

Successful lucerne production is confined almost entirely to the lower regions of the Mooi river valley where irrigation is practised. Observation trials and experience indicate that lucerne production under rainfed conditions, especially on the highly leached soils, has not proved highly successful. This failure is undoubtedly the result of poor fertilization and inadequate lime.

Horticultural crops: In addition to the vegetable production previously noted, a very limited amount of fruit is produced. The prevalence of hail and the fruit fly, together with late frosts in spring, are the main factors preventing large-scale production. The successful production of plums (Methley variety) in the Balgowan area is, however, noteworthy. The bulk of the fruit produced is for home use. In 1960 there was a total of 35,115 deciduous trees and 3,000 citrus trees on farms in the Lions River district.

Conserved feeds: Silage production remains the basis for meeting the 'summer surplus - winter scarcity' problem. Recently, however, there has been a tendency for dairy farmers to dispense with silage and to rely entirely on the production of heavily fertilized ryegrass under irrigation. The economic advantage of this practice over the conventional systems has yet to be clearly established. The exceptionally high yield potential of ryegrass was revealed in a local survey, which showed that yields of over 40 tons of green material (or 7 tons dry matter) per acre and over 12,500 lb crude protein per acre, were being obtained by some farmers (Wiseman & Scotney, 1968). Irrigated ryegrass yielded twice as much as that grown under dryland conditions. Handling excess growth under adverse weather conditions in early summer is a problem associated with this crop.

A survey conducted in 1963 showed that maize (47 percent) and millet (36 percent) were the main silage crops grown although yields were exceptionally low as a result of poor fertilization (Scotney, 1963). Most farmers commenced feeding silage late in the season (May or June) and the quality of more than half the number of silage samples collected, mostly millet, was rated as poor.

The main sources of hay are E. curvula, teff and the natural veld. Lucerne hay is imported into the Area. In the 1963 survey the average yields of hay from the veld and E. curvula were approximately 1 and 3 tons/acre respectively although much higher yields of E. curvula were achieved by some farmers. The lack of a high quality, locally produced, legume hay and the difficulty of curing good quality hay in the field are aspects worthy of special emphasis.

Agronomic practices: The standard of agronomic practice in the Area is moderate. The most important single factor preventing the attainment of high yields is poor fertilization. Although reference has already been made to the main problems (Chapter 2), it is suggested that nitrogenous fertilizer and lime are the most poorly supplied materials. In 1962 the average amount of nutrients applied to maize was 35 lb nitrogen, 26 lb phosphorus and 36 lb potassium per acre (Scotney, 1963). This amount of nitrogen is sufficient only to meet the needs of a crop yielding 7 bags per acre. It is standard practice for farmers to apply ½ to 1 ton lime per acre irrespective of soil, crop or nutrient status.

Several features, including optimum plant populations, improved varieties, efficient weed and pest control and correct tillage methods, are frequently neglected. Recently, however, there has been a marked improvement. For example, a maize survey conducted in 1961 revealed an average plant population of 9,850 plants per acre (Mallett & Scotney, 1961). In 1967 the average value for high rainfall areas was approximately 16,000 plants per acre (Scotney & Wiseman, 1968). A problem associated with the large-scale production of winter fodder crops is that early winter ploughing, especially recommended for the partially leached soils, is not permitted. Although crops are generally rotated there is seldom any clearly defined objectives in selecting the cropping sequence.

(c) Livestock: In 1962 the livestock population in the Lions River district, excluding horses, consisted of 71 percent white-owned cattle, 18 percent sheep and 11 percent Bantu-owned cattle. Most noticeable changes after 1951 were the 100 percent increase in sheep and the 39 percent reduction in Bantu-owned cattle. On the basis of data presented by Edwards (1963) the approximate carrying capacity of the Lions River district during the 1951-62 period was 9.8 acres per mature livestock unit. Corresponding values for the Umvoti, Bergville, Estcourt and Weenen magisterial districts were 13.0, 11.3, 9.8 and 7.4 acres respectively. Although the total number of white-owned cattle remained almost constant from 1951 to 1962 the number of cows over two years of age increased from 54 percent to 67 percent of the total number. Sixty three percent of this number were kept for milk production.

The main breeds of cows in 1962 were, in numerical order, Friesland, Jersey, Afrikander, Ayrshire, Aberdeen Angus and Hereford. Compared to the situation in 1951, there is a marked increase in both the Jersey and Hereford while the Friesland and Afrikander showed a slight increase and decrease respectively. In recent years the Sussex has increased in popularity.

Sheep: Sheep largely compensated for the reduction in oxen and Bantu-owned cattle. Woolled sheep, including the Merino and Corriedale, are commonest. The use of certain 'Down' breeds for the production of fat lamb, has increased considerably in recent years.

Pigs, poultry and other classes: During 1951 to 1962 the number of pigs in the Lions River district declined by as much 140 percent. Recently, however, there has been renewed interest in pigs. Large-white and Landrace are the most popular breeds.

The number of fowls in the Area fluctuates continuously. The total number in 1951, 1958 and 1962, for instance, was 51,980, 88,921 and 42,802 respectively. Other classes of poultry are not important.

Horses are widely distributed and although the total in 1960 was given as 2,204, the number was probably underestimated since many horses are migrant from, and to, the adjoining Bantu locations.

Goats are common in the Thornveld area but numbers have not been satisfactorily ascertained. According to Edwards (1963), numbers are usually highest where erosion is worst.

(ii) Economics

Agriculture in the Area contributes much to the economy of the Umgeni Region which Horwood (in McCrystal, 1963) described as diversified and vigorous. Although many economic aspects of land use in the Lions River district were studied by McCrystal (1963) very little reference was made to the situation at farm level.

In 1960, a study of the economics of dairy farming in Natal was initiated by the Department of Economics and Markets and co-operation of a number of farmers in the Lions River district was solicited. These were the nucleus of a Howick Farmers Study Group which the writer formed in 1964. In 1966 a second group came into being in the Mooi River district. Detailed records kept by the participating farmers and analyzed annually by the Department of Economics at the University of Natal, provided some of the economic standards for the Natal Region (Dept. of Agric. Economics, 1968). These standards and the annual business summaries for both study groups form the basis for this discussion. It is acknowledged, however, that there are deficiencies due to the limited number of participants. Furthermore, the study does not include the economics of forestry production.

(a) Capital investment: The average size of farms studied in the Howick and Mooi River districts is 1,531 acres and 1,382 acres respectively. Table 43 shows the average capital investment for both study groups.

The total capital investment (on Howick farms) is among the highest in Natal. This is due mainly to the high values for land, fixed improvements (mainly buildings) and dairy stock. Over-capitalization is thus a problem in the Lions River district. Values for the Mooi River group compare favourably with those in other parts of Natal.

(b) Total farm expenditure and income: A summary of the total farm expenditure and income for Howick and Mooi River farms is presented in Table 44.

The most important fixed costs include wages, repairs and

Table 43 : Capital investment (R) on farms in the Howick and Mooi River districts (Dept. Agric. Economics, 1968)

Item	Capital investment (R)	
	Howick farms (1,531 acres)	Mooi River farms (1,382 acres)
1. Fixed capital		
Land	52,531	38,906
Fixed improvements	26,592	10,029
Total fixed capital	79,123	48,935
Fixed capital per acre	51.7	35.4
2. Movable capital		
Mechanical power and equipment	9,511	6,086
Livestock:		
Dairy	21,806	12,041
Beef	6,984	1,317
Sheep	5,716	2,598
Pigs	1,488	118
Other	-	8
Total livestock	35,994	16,082
Crop on hand	777	109
Total movable capital	46,282	22,277
Movable capital per acre	30.2	16.1
3. Total capital investment	125,405	71,212
Total capital per acre	81.9	51.5
Movable capital as % of total capital	36.9	31.3

Table 44 : Total farm expenditure (R) and income (R) for farms in the Howick and Mooi River districts (Dept. Agric. Economics, 1968)

Item	Howick farms	Mooi River farms
1. Total expenditure		
Fixed costs	18,886	8,766
Variable costs		
a) Livestock	8,567	6,089
b) Crops	6,947	3,256
Total variable costs	15,514	9,345
Total costs	34,400	18,111
2. Total income		
Dairy	26,916	16,758
Beef	2,535	369
Sheep	1,935	1,697
Pigs	2,743	910
Crops (trading)	4,647	1,874
Other	1,767	633
Total farm income	40,543	22,241
3. Net farm income	6,143	4,160
Net farm income per acre	4.01	3.01
Net farm income per R100 capital invested	4.90	5.84

maintenance, miscellaneous costs and depreciation. Of the variable costs, purchased feeds and fertilizer are by far the most important. The high value of the latter for the Howick farms is in keeping with the fertilizer requirements of the soils. The ratio of fixed to variable costs for the Howick farms again indicates high capital requirements for would-be farmers.

Although the net farm income per R100 capital invested for both groups does not appear to be particularly attractive they compare favourably with the averages determined for other study groups in the Natal Midlands. Values for net farm income indirectly reflect a low intensity of land use although both districts are particularly suited to intensive farming systems. Crop trading income for both groups is second in importance to the main dairy income and is largely derived from the production of potatoes.

The economic analyses also reveal a high degree of indebtedness on many farms. In 1966, the indebtedness for the Howick and Mooi River groups, expressed as a percentage of the total capital, was 12 and 28 percent respectively.

(c) Enterprize results: Although detailed accounts of the main enterprizes are not given, special note is made of those aspects most affecting the overall financial results. The average yield of milk per cow for the Howick and Mooi River groups was 607 and 657 gallons respectively. Since these yields should be at least 30 percent higher there is considerable scope for improvement in this direction. An important factor in this respect is feeding, especially the relationship between purchased feeds and farm produced forage crops. Although the quality of livestock is generally good, rigid culling and a general upgrading of herds would raise the level of production and improve the financial results.

For the few beef farmers in the Howick group the direct gross margin per animal unit was R21. In the case of sheep it was R27 and R37 for the Howick and Mooi River groups respectively. Today, however, the economic advantage of sheep over beef is not so obvious. Continued improvement in the profitability of beef farming is anticipated. Both enterprizes would benefit from improved feeding and management. Calving and lambing percentages are often too low for optimum economic returns. The enterprize results suggest that, under the existing economic conditions, fresh milk production and intensive cash cropping should contribute most to farm income.

3) Application of the Soil Conservation Act

Following proclamation of the Lions River and Mooi River Valley soil conservation districts in the early 1950's progress in soil conservation was sporadic. Response from the farming community was particularly satisfactory in the former district. Although progress, as measured by the number of farm plans, amendments and works, either passed or approved, was most encouraging (at least up to 1960), a general apathetic attitude towards the erosion problem persisted. Few seemed to appreciate that 'planned farming' was the prelude to sound conservation. Perhaps those advising farmers focussed insufficient attention on the economic benefits or profitability of conservation farming.

By 1962 many so-called 'physical farm plans' had been served and in the Lions River and Mooi River Valley districts the total area covered by planned farms was 55 percent and 58 percent respectively. The situation in the Umgeni, Lions and Karkloof river catchments was 47 percent, 72 percent and 52 percent respectively. The extent to which the subsidy scheme contributed to the initial progress is difficult to assess. Undoubtedly, it did much to attract the attention of farmers although the rapid change in land ownership was also a feature that influenced planning activities appreciably.

Fencing is by far the most important of the soil conservation works constructed in the Area. In 1964 over 80 percent of the conservation works completed were fences. Stock-watering schemes are next in importance. Although the majority of arable lands are laid out on the contour, the construction and maintenance of the actual structures are generally poor. This and the poor agronomic practices already referred to, have resulted in accelerated run-off and much soil loss.

Several provisions of the original district schemes were not rigidly applied. These include the regulation or prohibition of veld burning, grazing management, the restriction of the numbers and kinds of livestock and the protection of springs and sponges.

The cool, moist conditions experienced over much of the Area leads to much veld burning before the end of July, especially on the steep mountainous slopes where run-off is high (Scott, 1951; Edwards, 1961). Damage to early growth following the burn is caused by frost. Soil moisture conditions are, however, adequate for growth at this time (Chapter 2). Specified dates after which burning may take place do not cater for the very wide range in ecological conditions prevailing in both soil conservation districts. Although the majority of farms are adequately fenced, as yet few farmers have applied satisfactory systems of veld management.

The provision that "no spring or water sponge shall be harmfully drained" has remained one of the most controversial. Despite many pleas for total protection, the majority of vleis have been subjected to some form of drainage and, in most instances, are established to pastures.

4) Problems indicated by present land use

In addition to limitations brought about by the natural features of the Area, notably climate and soils, present land use indicates several problems of an economic and managerial nature. These include problems related to intensity of land use, the production of livestock and crops and those affecting conservation.

(i) For most of the Area the intensity of land use has not yet reached a maximum. However, in the Thornveld area the application of incorrect farming systems (e.g. dairying) and the small size of farms have led to over-intensification with unfortunate results. The degree to which economic reward, markets and communication have influenced land-use pattern is reflected in the scattered occurrence of dairy farms throughout the Area, irrespective of prevailing ecological and pedological conditions. Intensive systems rely heavily on arable land and, as such, cognisance should be taken of the available soils and their potential for arable use. The highly leached soils offer the best possibilities for this purpose.

Two problems related to the increased afforestation are 1) the direct competition between timber and crop production for the relatively limited amount of land of very high potential for arable use, and 2) the possible detrimental effect of afforestation on vital water resources. Such problems stress the need for the rational selection of land for each particular enterprize. Although much of the Area is suitable for timber the small farmer seldom has sufficient capital to establish an economic enterprize.

The constant reduction in farm size poses important economic problems. At present the current average size in the high rainfall areas is more than adequate, but it is essential that a lower limit be established as a guide to future subdivision. In a production function study of marginal returns and optimum intensity, Kassier (1966) found the optimum farm size in East Griqualand to be approximately 400 acres. In this area net farm income was found to be highest on farms under 1,400 acres (Dept. Agric. Economics, 1964). The optimum farm size is determined, to a large extent, by the area of available arable land. In this respect, much of the Highland Sourveld is particularly favourable for intensive farming and as a result, farms can be expected to become smaller in the future.

At present, beef farming cannot compete economically with other lines, yet, natural features are such that beef production should play an important role in the Area. With improved economic conditions the prospects for intensive beef production are good.

(ii) Economic studies indicate over-capitilization, high fixed and variable costs, and mediocre managerial ability. The high costs of purchased feeds are noteworthy and greater effort should be made to produce high yielding crops of suitable quality for use on the farm. Added attention should also be given to planning the farmers financial resources since, in many cases, there is a high degree of indebtedness. Readily available short term production loans would do much to increase the rate of development.

(iii) Most of the crop and livestock production problems are related to the low plant nutrient status of the soils and the cold dry winters. Provision must be made for the relatively long winter feeding period. It is essential that the yield potential of a wide variety of suitable crops be established for each of the major soil series, preferably under both rainfed conditions and irrigation. Optimum economic levels of fertilizer and seeding rates for different crops should also be determined. For example, Kassier and Mallett (1966) established that for a predicted yield of 21 bags maize per acre on the Loskop series the most economic inputs of fertilizer were approximately 69 lb N, 20 lb P and 61 lb K per acre if the price of maize was R2.87 per bag.

Livestock yields must be increased through better feeding and the raising of the herd or flock standard. The search for a suitable legume hay and improved curing methods should also be continued. For this purpose, the production of dryland lucerne on partially leached soils should be investigated.

(iv) Conservation of the natural resources should be ensured through the widespread adoption of sound land-use practices in which the profit motive is stressed. Codes of practices for ensuring the safe use of arable land, natural veld and water resources should be formulated with special regard given to the soil factor. The time has also arrived for positive action to be taken in conserving and utilizing wildlife on the farm and to develop more areas for recreation.

CHAPTER 5

THE INTERRELATIONSHIP OF NATURAL CHARACTERISTICS AND LAND USE

Preparatory and continuing studies of <u>all</u> natural characteristics and their complex interrelationships, based on ecological principles and viewed holistically, are the essence of sound agricultural development. The object of this chapter is, therefore, to review the interplay between the main natural characteristics and to suggest how these might be related to the agricultural potential and needs of the Area. The natural features previously described form the basis of the discussion and the establishment of defined ecological areas. These, in turn, provide the foundation for classifying land in terms of use-capabilities (Chapter 6). Pratt, Greenway and Gwynne (1966) adopted a similar approach in their classification of East African rangeland.

With the emphasis on ecological principles little regard is given to the influence that man may exert on the environment. This can, however, be so great as to change or re-direct the normal functioning of the ecosystem. Odum (1959) went so far as to suggest that 'tinkering' with basic ecosystems could result in a glorious future or complete destruction. It is important, therefore, to appreciate that man, through management or mismanagement, can radically change the environment.

5.1 Interplay between physical and biotic factors

All interactions of natural features, some of them extremely complex, influence the natural setting and agricultural potential of the Area. The significance of individual factors, and just how far the influence of one may supersede that of another, is often difficult to assess. In Snowdonia, however, Hughes and Milner (1964) found that local variations in geology and rainfall affected soils and vegetation markedly which, in turn, influenced human settlement, sheep population densities, growth of sheep and the production of dry matter. Despite the difficulties in determining such relationships an attempt is made to identify the most important factors and correlations.

The overriding influence of climate is particularly noteworthy. Through its master elements it has controlled the pattern of distribution of both soils and vegetation. Its dominance as an active factor in soil formation is adequately expressed in the chemical and physical characteristics of the soils. Because of this, a guide to the 'effective' moisture conditions is obtained by considering the degree of leaching (Chapter 1). On this basis, a moist, warm climate is equated to a slightly dry, cool climate since both result in the same degree of leaching. Climate has also dominated the development and distribution of vegetation and the climatic climax concept is adequately demonstrated by the presence of the Podocarpus forests in the humid regions. Jacks (1946) rated climate as the most important factor influencing the distribution and adaptability of crops to be grown. He regarded soils as the important factor controlling crop productivity.

1) Interplay between climate, soils and vegetation

There is a definite and repeated world pattern of climates all associated with general and repeated patterns of native vegetation and soils (Trewartha, 1954). Similar patterns, though more detailed, have been established in the Area. By considering the independent studies and surveys previously reported distinct correlation between the environmental factors become evident. Comparison of the various maps shows these clearly. The soil map (1:50,000) was reduced specifically for this purpose (Map 2). A short account of the most striking correlations follows.

(i) Climate and soils: There is a close relationship between the climatic sub-regions and the landscape groups. Since the latter are defined in terms of degree of leaching there exists a gross correlation between climate and soils. Climatic sub-regions 1 and 2 shown on Map 4, each with a moisture index exceeding 20, are associated with highly leached soils. These two sub-regions are, however, separated on the basis of temperature. The cooler conditions in sub-region 1 are clearly reflected in the higher organic matter status of the soils (e.g. humic phase soils), although this is not always a reliable criterion for separating these sub-regions. In contrast, the very dry sub-humid regions with a moisture index of -10 or less are generally associated with slightly leached soils. Between these two extremes the correlation holds equally well although local variations in climate may give rise to soils not in keeping with the general pattern.

(ii) Climate and vegetation: The relationship between climatic factors and vegetation is explained by Phillips (1959), who states that "the form, structure and development stages of plant communities are a faithful reflection of the integration of the master climatic factors, modified in varying degree by local characteristics of soil". A strong correlation exists between the defined climatic sub-regions and the vegetation types. Many vegetation type boundaries shown on Map 5 are verified by the independent studies of Edwards (1963) and Moll (1965). Although the cool, dry, ecotonal grasslands coincide with climatic sub-regions 3 and 5 a more detailed investigation is necessary to place this correlation beyond doubt. The Highland Sourveld and Midlands Mistbelt correspond exactly with climatic sub-regions 1 and 2. The different form and structure of the vegetation in each of these types reflect important temperature differences between the sub-regions.

Vegetation types reflect the integrated factors of climate. As climate changes from the humid, through moist, to dry sub-regions so the vegetation alters in form, structure, floristic composition and basal cover. The change from Podocarpus forest and sour grassland through ecotonal grasslands and Tall Grass Veld to typical Thornveld is a "faithful reflection" of the master factors of climate.

(iii) Soils and vegetation: It follows that soils are grossly correlated with vegetation. This discussion is, however, confined to the more detailed plant-soil relationships. Frequent examples of edaphic climaxes are seen throughout the Area, perhaps more so in the slightly drier parts. Specific correlations are less clear in landscapes where the leaching process has reached to the highest limit. Miller (1966), working in a sample of Highland Sourveld at the Tabamhlope research station near Estcourt, found no obvious correlation between plant distribution, altitude, aspect or soil. Correlations of this nature would, however, require detailed investigation at the phase level.

Individual soil properties may exert a profound influence over the development of a plant community. For example, different drainage conditions are reflected in the typical zonation of the 'vlei' communities. At high altitudes, grasses such as Arundinella spp., Danthonia macowanii and Pennisetum spp. and the sedges Junceae spp., Eleocharis spp. and Rhyncospora spp. indicate impeded drainage. In drier habitats Imperata cylindrica and Andropogon eucomis are the indicators for similar conditions. Seasonal waterlogging is frequently indicated by sedges such as Ascolepsis sp., Bulbostya sp., Carex sp. and Fuirena sp., together with grasses such as Agrostis sp., Andropogon sp., Festuca sp. and Stiburus sp.

Soil depth is often reflected in the characteristics of plant communities. Xerosere communities including Digitaria monodactyla, Microchloa caffra, Rendlia altera, Eragrostis racemosa and E.capensis often occur on shallow, rocky and eroded areas. Within the Highland Sourveld, Protea roupelliae and grasses such as Andropogon filifolius, Alloteropsis semi-alata, Loudetia simplex and Danthonia stricta frequently reflect shallow soils. Moll (1965) also noted a considerable variation in the height of trees within the Podocarpus forests which he attributed to differences in soil depth.

Correlations with soil texture are not very apparent except on sandy soils of the E3- and L1-associations. Cynodon dactylon and Aristida spp. are common on these 'light' soils especially in the lower reaches of the Mooi River Valley district. Edwards (1963) also related Acacia robusta to outcrops of middle Ecca sandstone.

There is a close relationship between the Acacia karroo-A.nilotica communities and the margalitic and claypan bottomland soils, especially where severe gully erosion has drastically lowered the ground water table. Dominance of Bothriochloa insculpta on margalitic soils was also noted by Edwards (1963).

The examples quoted serve to illustrate how soils, or soil properties, may influence the development of plant communities or the dominance of individual species. Moreover, vegetation is an important factor in soil formation. The effect of the Podocarpus forests on soil properties illustrates this natural process (Chapter 1).

Several other less important relationships can be noted. Parent materials through their influence on plant nutrient status of soils often influence species composition and palatability. Using the soil survey data Channon (1962) found a close correlation between parent material and percentage base saturation. Soils derived from dolerite had the highest values. Parent material may even influence systems of grazing management (Scott, 1947). Soils derived from dolerite are generally associated with a high basal cover, palatable grass species and a dominance of Themeda triandra. Many other species commonly found on outcrops of dolerite have been listed by Edwards (1963) and Moll (1965). In contrast, basal cover, density and height of vegetation are often lower for soils derived from sedimentary rocks.

2) Interplay between other natural factors

Special note is made of a number of other natural interactions since they are important to land use. Soil erosion, for instance, is related to many interacting natural factors such as soil, slope, plant cover, rainfall intensity and wind velocity. Reference has previously been made to the erosion hazard of individual soils and the criteria contributing most to this quality (Chapter 3). However, slope is directly related to soil loss and, as gradients increase, the danger of erosion becomes greater, land use becomes less intensive and mechanization more restricted. Soil loss values with different gradients stress the importance of slope. Vincent and Hack (1960) found that the natural erosion in tons per acre per annum from undisturbed sandveld was of the order of percentage slope multiplied by one.

Although few reliable measurements of percentage basal cover have been made for each of the main vegetation types the tendency is for cover to increase with rainfall. This factor is obviously related to natural erosion and probably contributes much to the stability of soils within the high rainfall areas.

Physiography, through altitude and local topography, affects climate markedly. High altitudes are associated with high rainfall, low aerial and soil temperatures, windiness and severe winters. The rain-shadow effect of the 'main divide' is demonstrated by the differences in climate between the Midlands Mistbelt (sub-region 2) lying to the south and the Thornveld (sub-region 8) lying to the north, both of which are between 3,500 feet and 4,000 feet above sea level. The influence of altitude on soil properties is demonstrated by the positive correlation between altitude and organic carbon content established by Channon (1962).

Gently undulating topography is often associated with greater uniformity of vegetation type especially in the Highveld Sourveld. Furthermore, local areas of level topography invariably influence both vegetation and soil properties (e.g. drainage). This is best illustrated by a comparison of upland and bottomland soils and their associated plant communities.

Aspect, through its influence on the moisture regime, has a profound effect on vegetation and soils throughout the Area. The occurrence of Cymbopogon-Hyparrhenia communities on southern aspect slopes and the more palatable grasses on northern aspect slopes, are examples of these effects. Thus, aspect should determine the subdivision and management of the natural grassland and the selection of sites for forestry.

In summary it can be said that:-

a) climate, mainly the water balance, has an overriding influence on both the edaphic and biotic features of the Area. Accurate appraisal of the climate provides the basis for determining agricultural potential;

b) positive but gross correlations exist between climate, soils, vegetation and the other natural features;

c) vegetation reflects the conditions of climate and is modified, to some extent, by edaphic features. Soil characteristics, singly or collectively, may control the occurrence of plant communities or single species. Vegetation, in turn, can modify characteristics of the soil; and

d) all major natural features of the Area are related to the important problem of soil erosion.

5.2 Influence of natural features on assessment of agricultural potential

This discussion concerns the assessment and significance of the natural features and their relation to agricultural potential. It purposely excludes the soil factor since much has already been said of the soil resources. Nevertheless, this information (read together with the soils data) provides a realistic appreciation of the potentialities of the Area for agriculture. On this basis land use can be planned so as to avoid over-exploitation of the natural resources, fruitless endeavour and erosion.

1) Assessment of climate in relation to agricultural potential

Methods of expressing the relationship between environmental conditions, mainly climate, and crop production have been the object of numerous studies. Many of these have been reviewed by Landsberg (1958) and Wilsie (1962). Accurate evaluation of pluviometric and thermic situations is often made difficult by the complex interactions between factors of the environment and between these factors and the crop.

Haude and Moese (according to Landsberg, 1958), for instance, developed an agricultural climatic index based on temperature and the effectiveness and variability of precipitation. Many different approaches, however, have been adopted in the attempts to assess the environment for land use purposes.

(i) <u>Environmental potential index (EPI)</u>: A numerial index reflecting environmental potential, even if solely in terms of the elements of climate, can be of considerable value in planning agricultural development. With this in mind, Scotney and de Jager (1969), developed an environmental potential index (EPI) for general use. Development of the index was based on climatic data of some 30 stations throughout Natal and Transkei.

Although details of the method and procedure adopted in developing and testing the EPI are not given here it can be noted that the variables included a moisture factor based on potential evapotranspiration (Thornthwaite, 1948), a heat factor comprising yearly heat units, and a rainfall variability factor calculated from the coefficient of variation of annual rainfall. An arbitrary scale of 0 to 5 was used where 0 represented the most favourable and 5 the most unfavourable conditions for rainfed crop production.

The EPI which assumes a linear relationship between environmental potential and the selected variables was calculated using the equation:

$$EPI = 3.388\left[\frac{250 - (R-PE)}{500}\right] + 2.401\left[1 - \frac{H}{6000}\right] + 0.367\left[\frac{C - 15}{15}\right] \qquad (6)$$

where, EPI is the environmental potential index, R the mean annual rainfall, PE the potential evapotranspiration, H the yearly heat units and C, the coefficienct of annual rainfall (Scotney & de Jager, 1969).

In order to characterize the most important climatic sub-regions in terms of environmental potential, EPI values were calculated for a number of representative stations, including Estcourt and Weenen. The results are presented in Table 45.

Clearly, the Midlands Mistbelt (sub-region 2) has the most

Table 45 : Environmental potential indices (EPI) for representative stations in the Howick Extension Area

Climatic sub-region	Representative station	Environmental potential index (EPI)
1	Nottingham Road	1.82
2	Lidgetton*	0.80
3†	-	-
4	Cedara	1.87
5	Weston*	3.15
6†	-	-
7	Estcourt	3.15
8	Weenen	3.84

† data unavailable
* unofficial temperature data used

favourable climatic conditions for crop production and the Thornveld (sub-region 8) the most unfavourable. Although the EPI values for Nottingham Road and Cedara are very similar the chief factors contributing to the respective indices are not the same. It is of interest that the value for Howick, also representing sub-region 4, was 2.12. A general value of approximately 2.0 for sub-region 4 is thus a realistic assessment.

As a general guide to the assessed potential of the climatic sub-regions, five potential rating classes were established, each corresponding to a range of EPI values. Because of the limited number of stations for which EPI values could be calculated, some climatic sub-regions had to be assessed on a subjective basis. Since the five-point scale tends to oversimplify a wide range in climatic conditions it will be noted that, in some instances, the representative stations do not fit the rating classes exactly. General ratings of each climatic sub-region, together with the recommended intensity of use for each class, is shown in Table 46.

It now remains for environmental potential to be related to agricultural production. Scotney and de Jager (1969) achieved this by presenting potential yields of several widely grown crops (rainfed) for each of the rating classes. The relationship is shown in Table 47.

Table 46 : Potential rating classes of climatic sub-regions in the Howick Extension Area

Potential rating classes		Climatic sub-regions	Intensity of land-use
Class	EPI value		
1 - Very high	0 - 0.9	2	Very intensive
2 - High	1 - 1.9	1,3,4	Intensive
3 - Moderate	2 - 2.9	5,6	Semi-intensive
4 - Low	3 - 3.9	7	Extensive
5 - Very low	4 - 4.9	8	Very extensive

Table 47 : Relationship between environmental potential and the estimated yield of selected crops in the Howick Extension Area (Scotney & de Jager, 1969)

Selected crops (rainfed)	Potential rating class				
	1	2	3	4	5
Maize (bags/acre)	> 25	20-25	15-20	< 15	-
Potatoes (bags/acre)	> 200	150-200	100-150	50-100	-
<u>Eragrostis curvula</u> (ton/acre/annum)	> 4	3-4	2-3	1-2	-
Wattle (ton/acre) 1) Bark 2) Timber	 > 10 > 43	 8-10 32-42	 6-8 20-32	 < 6 < 20	 - -
Natural veld (acre/m/u)	< 4	4-5	5-8	6-10	10-12

The indicated yields are related to an assumed 'good average' level of management and are generally conservative. A rating class of 3 or better is needed for the economic production of most crops under rainfed conditions. A class of 2 or better is required for the production of timber on a commercial scale.

(ii) <u>Concept of ecological optimum</u>: A somewhat different but sound approach was developed by Klages (cited by Wilsie, 1962). Considering the whole range of adaption of a given crop, it is assumed that there are areas that give consistently high yields with low variability from year to year. In simple terms, the crop is in harmony with the environment.

With the lack of sufficient yield data this concept could not be applied specifically to the Area. However, data presented by Scotney and de Jager (1969), indicate areas of 'ecological optimum' for maize in Natal. Ten year (1951-1960) average yields of maize and the coefficients of variation were calculated for 14 magisterial districts. The results, together with the EPI values for selected stations, are summarized in Table 48.

Table 48 : Average yields of maize for selected magisterial districts and their relation to computed EPI values (Scotney & de Jager, 1969)

Magisterial district	Average maize yield 1951-1960 (bags/morgen)	Coefficient of variation %	Computed EPI value
Richmond	13.23	13.15	*
New Hanover	12.50	8.24	1.81
Umvoti	11.96	15.81	1.32
Lions River	11.95	13.50	1.87
Ixopo	11.93	17.15	1.98
Bergville	10.72	16.95	*
Pietermaritzburg	10.29	8.94	1.81
Estcourt	9.29	13.48	3.01
Paulpietersburg	7.02	16.08	2.32
Dundee	6.74	13.22	2.22
Matatiele	6.63	13.42	3.04
Mt. Currie	6.42	13.19	2.82
Vryheid	6.40	12.45	2.27
Umtata†	6.27	23.71	4.02

EPI data not available
† Acreage reaped less than 2,000 acres

Despite limitations arising from the variation in climate within a single magisterial district the concept of ecological optimum is well illustrated by Table 48. The districts generally fall into two broad groups, one associated with high potential (rating class 2), the other with moderate potential (rating class 3). The relative position of the Lions River and Estcourt districts should be noted. On the basis of this concept it is reasonable to conclude that the potential of most of the Area for maize production is high, or at least, moderate. The assessment should, of course, be refined by the introduction of a soil factor.

2) <u>Indicator significance of vegetation</u>

A climax community provides the ultimate biotic expression of the potentialities of the environment (Phillips, 1959). On this basis, the indicator significance of vegetation has been used by many to assess the suitability and potential of land for agriculture. Communities are generally more reliable than single species. As an example, Graham (1944) suggested that "land once forested proves best for growing trees while the cultivation of cereal grasses is most profitable in regions once occupied by native grasslands". Albrecht (1940) was of the opinion that vegetation reflected the degree of soil development. Its record, when properly read, ought to be an excellent help in land classifications as premised in soil productivity. Much of the value of indicators lies in a detailed analysis of all the facts and the acute and synoptic interpretation of them (Phillips, 1966).

The principle of indicator significance was adopted by Pentz (1949) in his widely acclaimed agro-ecological survey of Natal and was also used by Edwards (1963). Most studies of this nature lay emphasis on the presence of species since, according to Bellings (cited by Wilsie, 1962), it is dangerous to evaluate an environment on the absence of species. Despite this, the writer made note of the absence of *Acacia sieberiana* in distinguishing between certain of the ecotonal grassland.

Single plants, however, are valuable as indicators of environmental conditions and land quality if they are carefully interpreted. Woods and Moll (1967), for instance, used multivariate techniques to show how the frequency of certain species could be used to deliminate different grasslands and to expose the effects of major environmental factors. Tingle (1966) suggested that the heavy growth of *Paspalum dilatatum* and *Phragmites communis* were indicative of good sites for *Poplus deltoides*. *Aristida junciformis*, *Cyprerus sp*. and *Helichrysum sp*. were considered indicators of poor sites.

Management has a profound influence on the composition, structure and development of plant communities. The secondary nature of much of the vegetation in the Area verifies these changes. For this reason, Jacks (1946) favoured soil as an indicator of land quality in preference to vegetation. With these principles in mind the indicator significance of the defined vegetation types is summarized.

(i) Forests and moist grasslands: The presence of climax forest vegetation within the Highland Sourveld suggests a high potential for intensive agriculture. However, the short, floristically poor forests and the characteristic nature of the grassland indicate low temperatures and severe winters. Thus, the season for optimum growth is short and the choice of crop, pasture and tree species is restricted. Although a suitability for afforestation is indicated, only the hardier species can be recommended. Obviously, pastures comprising temperate species should play a major role in the development of this Area. Although the natural grass sward is 'sour' it provides excellent quality grazing for 4 to 5 months during summer.

The tall, floristically rich Podocarpus forests of the Midlands Mistbelt indicate a very high potential for intensive use. No other farming line would be more suited, ecologically, than afforestation. However, the long term effects on water supplies, and the need for rational selection of land, together with economics, are important considerations for making land use decisions. The vegetation indicates the suitability of the Area for a very wide range of plants including crops such as tea, pyrethrum, Phormium tenax and the pecan (Phillips, 1964). The spring growth of grasses and forbs following the rise in soil temperatures, is 3 to 4 weeks earlier than that of the Highland Sourveld. Not only is the overall growth potential higher but management practices such as veld burning are also affected. Although the grassland provides suitable grazing for 5 to 6 months, much will depend on the conditions of the sward. Its value is reduced considerably where Aristida junciformis has become dominant.

(ii) Ecotonal grasslands: By virtue of their mixed composition the ecotonal grasslands indicate a variable potential determined by the severity of moisture deficiency and temperature conditions. Because of the 'sweeter' nature of the grassland semi-intensive systems of farming are indicated. Grassland transitional to the Midlands Mistbelt with its apparent scrub-forest climax community, indicates a high potential. The slightly lower effective rainfall is a limitation of importance to forestry projects in these parts. On the other hand, the cool, dry ecotonal grasslands reflect moisture deficiency, low temperatures and unfavourable soil characteristics such as shallow depth. Consequently, a moderate potential for intensive agriculture is indicated. The relatively low basal cover and unfavourable soil features point to a moderately high erosion hazard.

(iii) Tall Grass Veld: The Tall Grass Veld, characterized by a late season aspect of Hyparrhenia hirta and the presence of Acacia sieberiana, is indicative of distinct periods of moisture deficiency and warm conditions. Since the rainfall is low and erratic, and the soils generally erodible, the agricultural potential is rated as moderate to low. The tall nature of the sward suggests a preference for cattle farming although Phillips (1964) claimed that sheep may do more good than harm provided all tenets of pastoral management are rigidly applied. The natural sward provides palatable grazing for as much as 9 months of the year but is frequently overgrazed and less productive. The predominance of other Acacia spp. within this vegetation type indicates over-exploitation and abuse. In many instances they are associated with highly erodible soils (e.g. ESTCOURT series) and a low basal plant cover.

The moist Tall Grass Veld of the Merrivale valley indicates a moderate potential and a suitability for semi-intensive farming systems. However, the moisture conditions and favourable topography allow a greater degree of intensification than is normally to be expected.

The dry Tall Grass Veld indicates a low potential for intensive agriculture. It is best suited to semi-intensive or extensive systems of farming since crop production is generally hazardous. The high erosion hazard of most soils demands rigid application of conservation practices and the rational selection of soils for arable use.

(iv) Valley vegetation (Thornveld): The valley vegetation indicates serious limitations imposed by acute moisture deficiency. Because of this, the agricultural potential is low. Except for small areas under irrigation, agricultural production is dependent almost entirely on the natural vegetation. Fortunately, the majority of grass species remain palatable throughout the year. Extensive systems of farming, based on cattle ranching, are thus indicated. The secondary nature of much of the vegetation and the severe encroahment of Acacia karroo-A.nilotica communities reflect the severe deterioration that has taken place. They also reflect an abundance of claypan, margalitic and calcareous soils, many of which have been seriously eroded. In most instance, the object of agricultural planning should include the needs for reclamation.

3) Influence of physiography

Physiographic features have a profound influence on the agricultural potential of an area. Jacks (1946) listed topography as one of the important physical land characteristics significant in plant production. McCrystal (1963) used physiographic features as the basis for a physical classification of land in the Umgeni catchment. Generally, the importance of topography lies in the extent to which it permits intensification through regular arable use. At the farm level, features of mechanization, cropping programme and conservation practice are all directly related to characteristics of slope. From a conservation point of view, the principle effect of slope is to influence water movement.

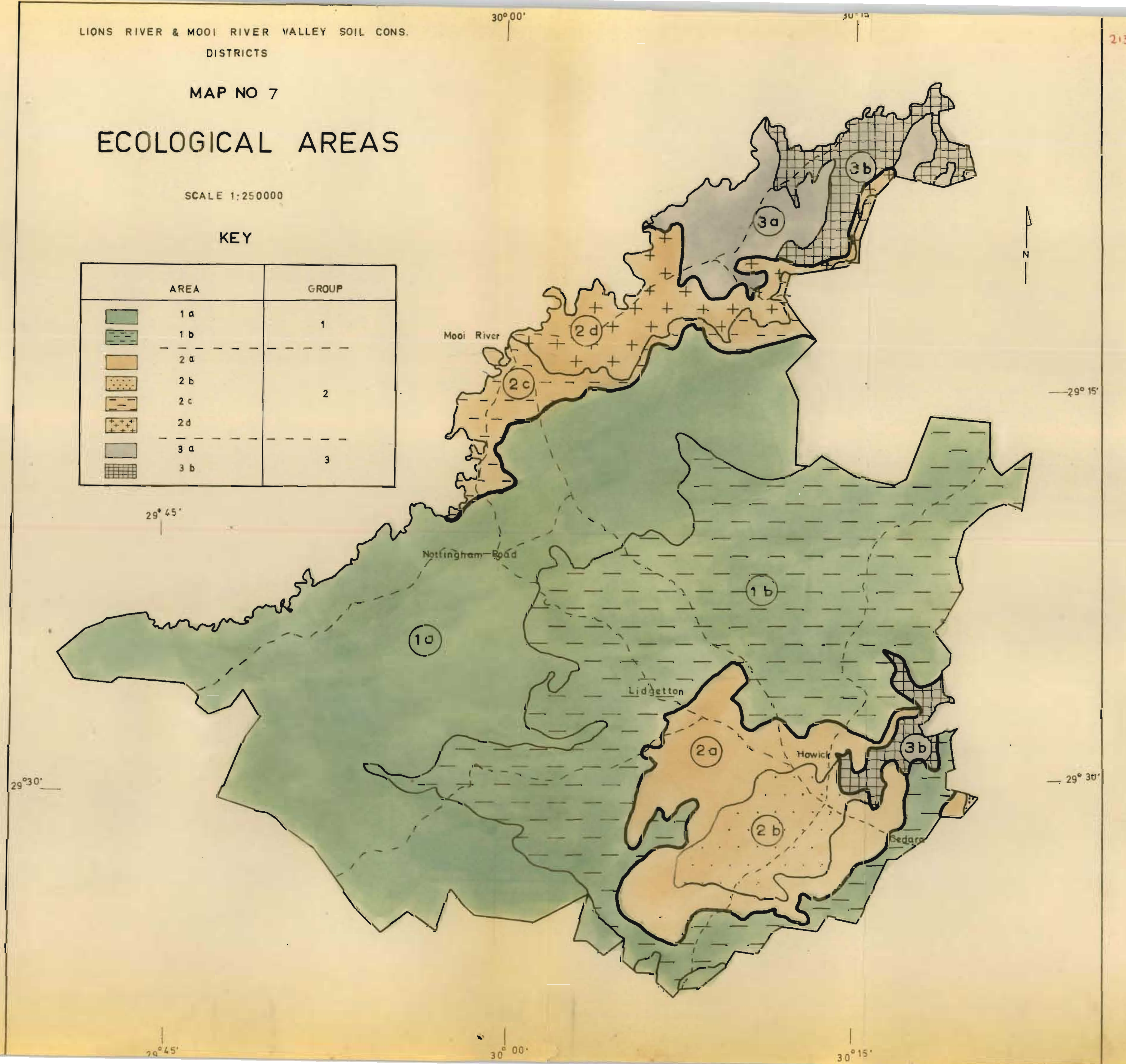
Approximately 55 percent of the Area has slopes exceeding 15 percent and is thus non-arable. Slopes exceeding this limit restrict land use to pasture production, forestry or the natural veld. In the humid parts, however, limited cropping may be permitted provided very intensive conservation practices are applied. In 75 percent of the Lions River district slopes exceed 8 percent although the variation between landscape groups is considerable. In the Highland Sourveld, the older land surface gives rise to a large area of gently sloping land which is suited to intensive crop production. Along the 'main divide', and to the west, steep slopes predominate. A hilly topography characterizes the Midlands Mistbelt where less than 20 percent of the area has slopes under 8 percent. In such areas, afforestation should be restricted to the steeper sites, since the small areas of favourable topography have exceptionally high potential for arable use. Undulating topography characterizes the ecotonal grasslands and, although it favours arable use, the low rainfall and poor edaphic features reduce the potential for intensive agriculture. The topography of the Thornveld areas is mostly steep and broken and, together with other natural limitations, renders this area unsuited to arable use.

5.3 Definition of ecological areas

Definition of ecological areas serves to crystallize the many interrelations already discussed. In effect, they summarize the information on natural characteristics and form the basis for the important task of classifying land according to its use-capabilities. They are used to discuss the potential, limitations and prospects of the Area in Chapter 6. Definition of the areas relies heavily on the survey and study of the natural features, especially climate and soils. The boundaries were established by inspection of soil profiles and plant communities. Soil data proved particularly effective where transition was so gradual as to prevent precise delineation. In such instances B-horizon samples were used to establish the degree of leaching. The defined ecological areas are listed and briefly described and are shown on Map 7. For the sake of simplicity they are assembled into three main groups.

GROUP I

The outstanding feature common to these ecological areas is the substantial moisture surplus. As a result the upland soils are highly leached, of low plant nutrient status and, generally, of low erosion hazard. Podocarpus forest is the climax plant community. Two ecological areas are recognized within this group. Temperature, vegetation type,


LIONS RIVER & MOOI RIVER VALLEY SOIL CONS. DISTRICTS
MAP NO 7
ECOLOGICAL AREAS
SCALE 1:250000
KEY
AREA
GROUP
1 a
1 b
1
2 a
2 b
2 c
2 d
2
3 a
3 b
3
30° 00'
29° 15'
29° 30'
29° 45'
30° 15'
N
Mooi River
Nottingham Road
Lidgetton
Howick
Cedara
1a
1b
2a
2b
2c
2d
3a
3b

altitude and some soil properties form the basis for their separation.

Ecological area 1a: This area is the most extensive and occupies 38 percent of the Area. It includes almost all land above an altitude of 1463m (4,800 ft). The climate coincides with that described for climatic sub-region 1. The highly leached upland soils belong to major groups A and B with the BALMORAL, FARNINGHAM, HUTTON, GRIFFIN, CLEVELAND, CLOVELLY, OATSDALE and MISPAH series dominant. Humic phase soils are common. The bottomlands are occupied by C1-association soils of which IVANHOE and KATSPRUIT series are important. The vegetation is typically Highland Sourveld with isolated patches of mountain Podocarpus forest and communities of sub-alpine grassland and Protea savanna. Approximately 57 percent of the Area is unfit for intensive arable use owing to excessive slopes and/or rockiness. The remainder is gently undulating.

Vegetation, especially the climax forest, is the main criterion for delineating the area. Buddleia salviifolia and Leucosidea sericea in protected areas are used as index plants.

Ecological area 1b: This area occupies 34 percent of the Area, lies between 1066m (3,500 ft) and 1463m (4,800 ft) above sea level and extends south from the 'main divide'. The generally humid and mild climate coincides with that described for climatic sub-region 2. The soils are similar to those in area 1a except that there is a predominance of heavy textured soils such as the FARMHILL, Lidgetton and Cranwell series. Loamy and sandy soils are confined to the area immediately above the Umgeni-Karkloof river gorge where middle Ecca sandstone is exposed. The topsoils usually show greater structural development and contain less organic matter than those of area 1a. Stoneliness and fossil concretions are also commoner and hydromorphic soils less frequent. Mistbelt mixed Podocarpus forest is the climax vegetation and secondary Aristida junciformis grassland the main vegetation type. Except for small level areas in the Karkloof district, the topography is hilly to steep with as much as 63 percent of the area unsuitable for intensive arable use.

GROUP 2

Group 2 includes four ecological areas in which the water balance has influenced the characteristic features of vegetation and soils to a marked degree. There is usually a two-month period of moisture deficiency. The interrupted leaching process is reflected in the high base status, presence of ferruginous mottles, concretions and hardpans, and a strong structural development of many of the soils. Organic carbon content of the topsoil is generally low and most soils have a moderate erosion hazard. Ecotonal grasslands and moist faciations of the Tall Grass Veld typify the vegetation.

Ecological area 2a: Ecological area 2a is transitional to the Midlands Mistbelt and surrounds the lower Merrivale valley. It occupies 9 percent of the Area and lies between 1066m (3,500 ft) and 1219m (4,000 ft) above sea level. The climate coincides with that of climatic sub-region 4. The upland soils are considerably leached with the D3-, E1- and D1-associations occupying 42, 32 and 23 percent of the arable upland area respectively. The VIMY, DOVETON, Loskop, NEWPORT and NORMANDIEN series are the most widespread.

Soil features reflecting the slightly restricted leaching process, such as the moderate to strong structural development in the A1-horizon of the VIMY series, serve as a guide to this area. The occurrence of hard plinthite in the B-horizons of many red soils (e.g. Loskop series) is also a feature of special note. The KILLARNEY and Emmaus series occupy the hydromorphic bottomlands. The vegetation includes a scrub-forest climax community and the moist grasslands transitional to the Midlands Mistbelt. Elements of both the Midlands Mistbelt and the moist Tall Grass Veld vegetation types are to be found. The rare occurrence of Acacia sieberiana is also a diagnostic feature for this area. The topography is mostly undulating to hilly with 44 percent of the area considered unsuitable for intensive arable use.

Ecological area 2b: This area is confined to the Merrivale basin proper and occupies 5 percent of the Area. It lies between 975m

(3,200 ft) and 1066m (3,500 ft) above sea level and experiences a climate similar to that described for climatic sub-region 6. The upland soils are generally moderately leached and are predominated by the E1-association which covers 52 percent of the arable area. The D1- and D3-associations occupy 23 and 11 percent respectively. Small patches of E5- and E6-association soils also occur. The SHORTLANDS, Bellevue, BERGVILLE, ARROCHAR, WINTERTON, ALBANY, WARRICK, KLIPFONTEIN and MISPAH series are well represented. Poor drainage, ferruginous hardpans and a moderate erosion hazard are notable soil features of the upland soils. The KILLARNEY series is the most important bottomland soil. The vegetation type is moist Tall Grass Veld with Acacia sieberiana sparsely distributed throughout. The topography is gently undulating but occasionally hilly. Slightly more than 40 percent is considered non-arable.

Ecological area 2c: This area is perhaps not as clearly defined as the others and is transitional in character. It occupies 3 percent of the Area and lies between 1371m (4,500 ft) and 1463m (4,800 ft) above sea level. The climate coincides with that of climatic sub-region 3. The uplands soils are considerably leached and mostly light in texture. The E1-association is well represented. The Weston, DOVETON, RUSTON, AVALON and SOUTHWOLD series are the most important. H1-association soils occupy the bottomlands. The vegetation constitutes a dry faciation of the Highland Sourveld but is included in the cool, dry ecotonal grasslands. The undulating topography favours intensive arable use.

Ecological area 2d: This area, lying east of Mooi River, occupies 4 percent of the Area. The altitude is between 1219m (4,000 ft) and 1371m (4,500 ft) and the climate is similar to that of climatic sub-region 5. The upland soils, of which the E1-association is most widespread, are mostly moderately leached. The Bellevue, Rooikop, ARROCHAR, SOUTHWOLD and MISPAH series are the most important although small areas of E3- and E5-association soils also occur. Rubble or gravel horizons comprising fragments of shale, laterite and fossil wood, together with abundant small fossil iron concretions, are found in many profiles. Termite mounds are a characteristic feature of the landscape. Bottomlands are fairly extensive and are occupied by the KILLARNEY and Matiwane series.

The cool, dry ecotonal grassland is uniform throughout this area and there is a rare occurrence of Leucosidea sericeae. The topography is undulating with only 33 percent of the area unfit for arable use on this basis.

GROUP 3

This group includes the dry, warm areas experiencing a distinct period of water deficiency, usually commencing in autumn and lasting for 5 to 7 months. The most important single criterion separating these areas from Group 2 is the presence of claypan and margalitic soils. Most soils are associated with a high erosion hazard.

Ecological area 3a: This area comprises 5 percent of the Area and lies between 1219m (4,000 ft) and 1371m (4,500 ft) above sea level. The climate is similar to that of climatic sub-region 7. The upland soils are moderately to slightly leached and are represented by members of the F1-, E1, E5- and D1-associations. The ESTCOURT, SHORTLANDS and Bellevue series and the shallow members of the E1-association are most important soils. Small areas of sandy soils (E3-association) are also found. The RENSBURG series occupies most of the bottomlands and in most cases has been severely eroded. The vegetation is dry Tall Grass Veld in which Acacia sieberiana is common. The grassland shows a marked seasonal aspect as a result of the dominance of Themeda triandra, Tristachya hispida and Hyparrhenia hirta. Owing to the hilly topography and high percentage of erodible soils most of the area is deemed non-arable.

Ecological area 3b: Ecological area 3b occupies 4 percent of the Area and is confined mainly to the lower reaches of the Mooi river valley. A small area occupies the Umgeni gorge. The altitude is between 1066m

(3,500 ft) and 1280m (4,200 ft) and the climate is similar to that of climatic sub-region 8. The upland soils are generally slightly leached and are represented mainly by Fl-association soils which occupy up to 50 percent of the uplands. The bottomlands occupy as much as 20 percent of area 3b. Nearly all of these are severely eroded and comprise the ESTCOURT and RENSBURG series. Calcareousness is a feature of many of the soils. The vegetation comprises Acacia karroo-A. nilotica thornveld and encroachment of these species is a serious problem. The topography is hilly to steep which, together with many rock outcrops, renders over 50 percent of the area unsuitable for intensification, irrespective of climatic limitations. There is ample evidence to indicate that man, through injudicious farming practice, has upset the natural equilibrium with disastrous results.

CHAPTER 6

RECOMMENDATIONS FOR AGRICULTURAL DEVELOPMENT WITHIN THE AREA

The term 'land-use' implies interrelationships between land, crops and man (Hills, 1961). Recommendations for land-use planning within the Area should, therefore, cover a very wide field including long term objectives, economics and a programme for development. However, for the purpose of this discussion the writer has restricted himself to those aspects influenced by land characteristics, notably soils. It is hoped that the indicated development will ensure the allocation of appropriate ecological sites and soils to specific aspects of agriculture and forestry (Phillips, 1966).

A number of important principles selected from the literature are listed since they are particularly relevant to the discussion (Graham, 1944; Jacks, 1946; Lewis, 1952; Phillips, 1959, 1966; Hills, 1961). These include:

1) the utilization of land for its greatest value; with the best use for each 'parcel' of land being determined by its potential for long-time productiveness;
2) the necessity for intimate knowledge of all land characteristics and ecological interrelationships;
3) the development of a classification of land in accordance with its capacity to produce which may serve as a basis for presenting procedures for each 'parcel';
4) the initial exclusion of man and his changing economics as criterion in land characterization;
5) the amount of land required for producing food (this is of prime concern in planning for development since it is expedient for any nation to set aside sufficient land for this purpose;
6) the need for recommended use to be optimum in the light of existing knowledge and the labelling of recommendations based on

value judgements as 'speculative';

7) a dynamic land-use plan changes as it progresses;

8) a desire for people to solve community problems and their active participation in the execution of the plan should be established; and

9) the consideration of the land-use plan at national and local level and, in the same way, relating individual farm plans to a master plan for a particular area.

6.1 Selected criteria applicable to the study of agricultural development

Many failures of projects in Africa have been caused by lack of formulation and definition of criteria known to be important in the examination of regions and propositions for development. A number of these have been selected from a comprehensive list presented by Phillips (1966) for consideration in determining a master plan for each ecological area. A brief account of each is given.

(i) Holistic conception and study of the Area: A synoptic investigation of the biological, economic and human phenomena of the Area was made in order to meet the requirement of complete examination. Although a general account of many of the relevant factors of the physical environment has been given, exhaustive study in some fields was prevented by the lack of reliable data. Nevertheless, careful consideration has been given to the siting of the Area and its relationship to other propositions and regions, viz., the Tugela Basin and the Umgeni catchment, in considering its development.

(ii) Precise formulation of objectives: In this case clear definition of the objectives is made difficult by the general nature of the land-use plan. Varied potentialities of land within an area and the many possible avenues for development inevitably leads to a lack of precision. The overall objective is, however, to promote optimum exploitation of the available potential that is not only economically sound, but which results in the maximum conservation of all the natural resources.

(iii) Natural and economic setting: The Area has considerable economic potential in view of its setting. The Tugela Basin with its prospects for immense industrial development lies immediately north. The Durban - Pietermaritzburg metropolitan complex, with its economic influence, adjoins the southern boundary. In general, the Area is very favourably situated in relation to declared growth points.

(iv) Adequate preparatory and continuing investigations:

(a) Save for certain climatological and hydrological data the physical features have been carefully studied and reported. Hydro-electric power is of little consequence in the Area and has not been seriously considered. The physical infrastructure is particularly favourable and existing road and rail facilities provide adequate communication with the markets. There are, however, certain areas of high agricultural potential which cannot be intensively farmed until communications are improved viz., areas near Impendhle, Kamberg, Fort Nottingham, Karkloof and Curry's Post.

(b) Many of the biological features listed by Phillips have also been discussed. However, recommendations made for certain crops have relied on value judgements and as such are speculative. The favourable state of mechanization, high standard of the livestock industry and efficient diseases and pest control suggest progressiveness amongst the farming community. Public health does not warrant special mention in this study. However, with regard to the Midmar dam, reference is made to the potential danger of schistosomiasis and pollution because of the siting of a Bantu location within the catchment area.

(c) Of the human features, the existence of several small communities is worthy of note (e.g. Karkloof, Dargle, Nottingham Road, etc.). The importance of these lies in their influence on any extension programme formulated for the Area. The existence of farmers associations, study groups and co-operatives is, however, evidence of the willingness of the farmers to work together and, to some extent, indicates the acceptance of the 'self help' principle. Considerable influx of people into the Howick - Hilton Road area, if not because of industrial development then for residential purposes, is anticipated. The same applies to the Mooi River area, where much will depend on development within the Tugela Basin.

(d) Study of economic features at farm level was hampered by the lack of long term records. Valuable but limited information from study group records indicates a wide range in farming efficiency, economic advantage from cash cropping and a high degree of indebtedness. Limited credit facilities available to farmers, also noted by Phillips, has clearly restricted rapid development of the available potential. The need for short term loan facilities is thus considerable. Reference has already been made to the problem of excessive subdivision of agricultural land into uneconomic units.

(e) The prospective impact of agricultural development in the Area upon economy elsewhere in Natal is likely to be considerable, particularly within the Umgeni catchment. Favourable conditions of labour, water and communications suggest that development of light industries will be substantial, although the nearby city of Pietermaritzburg is likely to attract the major share of new industries. Such development would, however, affect the supply of farm labour and influence ruling conditions of employment, including wages.

Several other criteria listed by Phillips should be considered. The Area is fortunate in having the Cedara College of Agriculture within its boundaries since the results of local research are directly applicable to most of the Midlands Mistbelt and transitional areas. However, the remaining ecological areas must rely on research and pilot trials conducted elsewhere in Natal. It will also be necessary to take into account problems of siltation and pollution as the Area develops, although these are not yet serious. It is also possible that certain practices such as timber production may become obsolete as species become unacceptable or economically less valuable. In this respect, the writer contends that afforestation in the Area is likely to experience radical changes within the foreseeable future. Furthermore, agricultural development will be subjected to constant pressure from peri-urban settlement, inflated land prices and the subdivision of land into uneconomic units. The last-named is soon to be restricted by legislation.

6.2 Use-capability of land within the Area and general recommendations

Principles of land classification are not discussed here since they are dealt with more fully in Chapter 7. Nevertheless, the classification or rating of agricultural and forestry land according to its capability for assumed uses, provides a ready basis for making recommendations. Classifications of this nature indicate the probable results of land use in terms of crop productivity (e.g. farm crops, forestry and wildlife). The capability of the land to produce living organisms of several kinds under different conditions, referred to by Hills (1961) as 'biological productivity', is a basic feature of land use. This principle is important since what is now regarded as the most suitable use for the land will change whenever there is a change in economic and social conditions.

Use-capability determinations at a regional level often ignore the influence of soil patterns or local topography on land capability. A complex soil pattern comprising the AVALON-WASBANK-MISPAH series, for example, should result in a general downgrading of capability because of the presence of the shallow and poorly drained soils. The same applies where local topography is hilly and steep despite all other natural features being favourable for intensive agriculture.

A simple five-point scale of rating is used to indicate the capability of the land for general use and for specific crops. However, single class designations are not entirely satisfactory where a wide range in capability occurs. Hills (1961) evolved a practical means of overcoming this problem that is particularly useful for detailed classifications. This course was not followed in classifying land within the Area.

1) Classification of use-capability

A number of uses were assumed in presenting the use-capability classifications for the Area although several of the crops have still to prove themselves. The assessments of agricultural potential presented in Chapter 5 are particularly relevant to this discussion.

(i) Use-capability for intensive agriculture

The 'assumed use' in this instance, though somewhat vague, implies the capability of the land for intensive systems of farming as defined in Chapter 4. Capability is rated in terms of five classes:-

Class 1 (1st rate potential) - land of very high potential for intensive agriculture based on the production of a wide range of crops. Non-arable land is suitable for afforestation or permanent cultivated pastures. Limitations are few but may include the low plant nutrient status of the soils.

Class 2 (2nd rate potential) - land of high potential for intensive agriculture based primarily on arable production. Non-arable areas are suitable for afforestation or veld replacement but sites require careful selection. Limitations are slight but may include unfavourable conditions of climate (temperature and moisture), topography and low plant nutrient status of the soils.

Class 3 (3rd rate potential) - land of moderate potential for intensive use. Semi-intensive systems of farming based on arable production and the natural veld are recommended. Arable areas permit a moderate degree of intensification and the natural grassland may be reinforced. Limitations are moderate and include moisture deficiency and unfavourable physical characteristics of the soils.

Class 4 (4th rate potential) - land of low potential for intensive use. Semi-intensive systems of farming based mainly on the natural veld are recommended. Arable areas are capable of providing supplementary fodder. Limitations are severe and include unfavourable climatic conditions, mainly moisture deficiency and poor physical characteristics and high erosion hazard of the soils.

Class 5 (5th rate potential) - land of very low potential for intensive use and suitable only for extensive systems of farming based on the natural veld. Limitations are very severe and include unfavourable conditions of climate (severe moisture deficiency), soil characteristics (very high erosion hazard) and topography.

The use-capability classification for the Area, based on the five-point rating scale, is presented in Map 8 (page 232(i)). Boundaries of each class were established by considering the previously defined ecological areas. Major limitations of each class are also indicated on the map.

(ii) Use-capability for selected field crops and pastures

Widely grown crops, and those considered to be of potential importance, are considered in this classification. Ratings refer primarily to production under rainfed conditions and assume the application of 'good average' management, the rational selection of suitable soils and the application of corrective fertilizer treatment. Economic implications resulting from the corrective fertilizer treatment of some soils can be considerable. The importance of adjusting land-use practice on the basis of individual soils is greatest within the drier landscapes.

Maize: The relative importance of factors such as moisture, temperature and radiation in determining yield is of consequence in assessing the use-capability of the Area for maize. The problem of determining such relationships in each ecological area without data led to a very general assessment of the climatic conditions. Factors that promote optimum growth up to the critical flowering period, and provide favourable conditions thereafter, were rated highest. Efficient agronomic practices such as correct plant densities were assumed.

A five-point rating scale ranging from very high (Class 1) to very low (Class 5) was applied to each area. These classes are not related directly to yield potential but, in general, Classes 1 and 5 are associated with yields of over 25 bags and less than 10 bags per acre respectively. The use-capability classification for maize is shown in Table 49.

Table 49 : Use-capability classification for maize in the Howick Extension Area

Use-capability rating	Ecological area
1 - Very high	1b, 2a
2 - High	1a
3 - Moderate	2b, 2c, 2d
4 - Low	3a
5 - Very low	3b

This classification holds only if problems such as Al toxicity and P-fixation associated with the soils of areas 1a and 1b are eliminated by corrective treatment.

Clearly, favourable moisture conditions influenced the classification. Low temperatures and radiation are important limitations in area 1a since they retard initial growth. Competition from weeds such as watergrass (Cyperus esculentis) and a high moisture content of the grain at harvesting are thus important problems in this area. The moisture percentage of maize grain 190 days after planting was, in fact, found to be as high as 40 percent in a trial conducted by Cuthbert (1962).

Root Crops: The use-capability classification for root crops is essentially similar to that for maize except that Class 1 includes areas 1a and 1b and area 2a is downgraded to Class 2. Area 1a is upgraded because the soils are eminently suited to the production of roots. However, the use of modern disease control measures is essential. Without these, area 1b would have slight advantage over area 1a since the earlier planting permitted by the milder climatic conditions would, in the case of potatoes, reduce damage by late blight.

Cultivated pastures: For the purpose of this discussion 'pastures' refer to grass-clover swards including exotic species such as Festuca spp., Lolium spp., Dactylis glomerata and Trifolium repens (ladino clover) grown under rainfed conditions. Summer-producing grasses such as Paspalum dilatatum, Eragrostis curvula and Pennisetum clandestinum yield best in the humid parts and have a wider range of suitability than the former group.

Use-capability of the Area for these high-producing grass-clover swards is essentially similar to that for maize (Table 49) except that Class 1 includes only area 1b and Class 2 includes areas 1a and 2a. Clover production is limited to capability Classes 1 and 2 since elsewhere moisture deficiencies are too severe for successful production under rainfed conditions. In all other ecological areas supplementary irrigation is a prerequisite for successful clover production.

Lucerne: At this stage lucerne is regarded as 'unproven' for the Area. However, its future in those areas predominated by partially leached soils, especially D1- and E1-association soils, is viewed with optimism. In considering the capability of the Area for the production of lucerne (rainfed) rating classes are not used since areas 1a and 1b are, for the time being, excluded from the assessment owing to the problems of curing and soil fertility. In these areas the production of clover is more attractive and best suited to the existing lines of farming. Ecological areas 2b, 2c and 2d are, however, considered most favourable. Selected sites in areas 3a and 3b may also be suitable although moisture deficiency is a serious limitation. Nevertheless, the potential for irrigated lucerne in these parts is very high.

Horticultural crops: These include both deciduous fruits and vegetables. On the whole, the use-capability of the Area for deciduous fruits is low since hazards of early and late frosts, hail, high humidity, diseases and pests prevent large-scale commercial production. Fruit culture is thus unlikely to offer serious competition to the main fruit growing areas, although production for home use is worthwhile. Nevertheless, ecological area 1b offers the best possibilities for the production of fruit. In this area the culture of plums (e.g. Santa Rosa and Methley), for local markets and canning, is feasible. 'Unproven' crops such as avocados, berries and tea may also prove successful on frost-free sites.

The close proximity of suitable markets provides an incentive for vegetable production in most ecological areas. Irrigation is, however, essential for optimum production. With the exception of area 3b, production is confined mainly to the summer months. The development of effective disease and pest control measures permits the production of many vegetables, including tomatoes. Ecological area 1b is considered to be the most suitable for general purposes although the capability of area 3b for intensive year-round vegetable production under irrigation is highest. The establishment of a local processing plant would do much to stimulate interest in vegetable production but more would have to be done by way of extension and credit facilities to the farmer.

(iii) Use-capability for timber

The capability of much of the Area for the production of many timber products is high. Land bearing forest growth or which shows evidence of past forest occupancy, indicates a high suitability for timber. Consideration must, however, be given to those factors that 1) determine the use and quality of the products and 2) to those affecting the establishment, management and harvesting of the plantations (Hills, 1961). It is necessary, therefore, to evaluate combinations of all significant physiographic features. Criteria for determining use-capability for timber may, in fact, be very different from those for field crops. A general use-capability rating for timber, using the previously defined five-point scale, is presented in Table 50. The classification is identical to that for cultivated pastures.

Table 50 : Use-capability for timber in the Howick Extension Area

Land capability class	Ecological area
1 - Very high	1b
2 - High	1a, 2a
3 - Moderate	2b, 2c, 2d
4 - Low	3a
5 - Very low	3b

Commercial projects should be confined to Classes 1 and 2, although even in these areas further investigation of site quality is necessary. Ecological area 1b is particularly suitable for wattle, pine and gum species and may yield timber products of many kinds. Second quality sites are common in areas 1a and 2a. In the former area, low temperatures restrict the choice of species to Pinus spp. Moisture deficiency and unfavourable soil conditions in the remaining areas prevent production for commercial purposes. Hardier species of pine and gum can, however, be grown for farm woodlots or firewood but the rate of growth is slow.

NOTE: Use-capability of the Area for Populus deltoides deserves special mention since it can be grown on all bottomlands. According to Tingle (1966, 1968) the future prospects and demand for match poplar are good and the climate of the Midlands Mistbelt is particularly favourable. It is important, however, to consider the fastidious soil requirements. Broadfoot (1960) developed two field methods for evaluating the tree-growing (poplar) potential of sites. The first requires identification of physical soil criteria, including texture, internal drainage and inherent moisture conditions, which are then related to tree height. The second is based on identification of the soil series and local phases for which growth potential (site index) has already been established. Site selection has also been discussed in considerable detail by Peace (1952), McKnight (1962) and Tingle (1966). According to McKnight poplar grows best in well-drained, moist soils of medium texture and containing sufficient montmorillinite to cause deep fissuring. Soil pH is also important. Peace (1952) put the lower limit for satisfactory growth at pH 5.0 while the average value for sites in Natal was found to be approximately pH 6.5 (Tingle, 1966). Site selection thus depends on the careful investigation of soils. In most bottomlands these occur in complex patterns.

The well-drained alluvial soils appear to be eminently suited to poplar although growth will be slowest in ecological area 1a. The sandy, alluvial strips in area 3b are also suitable but in this case the depth to the water table should not exceed six feet. Flood waters trapped in 'backswamp' areas of the alluvial strips should be removed by breaching the levee if it can be done safely (Tingle, 1966).

The neutral to alkaline H1-association soils in areas 2a, 2b, 2c and 2d are the best of the 'vlei' soils for poplar provided drainage, at least within the top two feet, is adequate. Surface drainage techniques (e.g. ridge and furrow) and deep tillage are thus considered beneficial for poplar production on these soils. Consideration should also be given to underground drainage where the soil texture is favourable (e.g. mole drainage).

Tingle (1966) advocated a thinning regime that would promote the establishment of a protective cover beneath the trees, since he had found soils with the top layer removed by erosion unsuitable for poplar. According to van Laar and Tingle (1965) the financial optimum for poplar production on 'best sites' is reached at 13 to 14 years of age.

(iv) Use-capability for wildlife

The need for this classification was stressed by Graham (1944) who stated that it was no more desirable to expend primary effort raising wildlife on land best adapted to maize, than it was profitable growing maize on poor land suited to wildlife. All biologically productive land is, however, suitable for wildlife even if the main use is agriculture or forestry.

Capability classifications at the farm level will invariably reveal areas unsuitable for any form of use other than for wildlife (Chapter 7). These, usually small areas, generally provide the necessary cover for various forms of wildlife. They are areas that can often be improved and made into suitable habitat elements with little effort. More favourable classes of land, though primarily suited to production, provide another important factor, food.
In this respect, the writer records an apparent increase in birdlife, notably water fowl, in parts of ecological area 1a, that he attributes

to the increased cultivation within this area. Recent interest in cereal crops and construction of many dams for both irrigation and recreation provide the necessary food and habitat for this birdlife. For these reasons, attempts to establish 'refuge' or 'sanctuary' areas should be considered in conjunction with the use of all adjoining land.

Use-capability ratings for wildlife constitute ratings of the potential of the land to produce a variety of vegetative cover types. Actual production of wildlife depends upon the degree to which it is able to utilize that potential (Hills, 1961). The potential of the ecological areas to produce wildlife as a primary crop differs markedly from one area to another. Using the five-point scale of rating previously employed, and relying entirely on value judgement, the use-capability of the Area for wildlife was considered. The results are identical to those for timber viz., highest and lowest capability is to be found in areas 1b and 3b respectively. However, the assessment would be different if the purpose was to be limited to farming with game species.

Since much of the Area is suitable for intensive or semi-intensive agriculture there is little likelihood that 'game farming' animals will become important. Emphasis should rather be placed on 'farm game' species which, together with game birds, could be integrated with other land-use practices. Thorough investigations and much research is required to establish precise criteria for determining the use-capability of the Area for wildlife and to establish the management needs. Study of the influence of land-use practice on wildlife habitats and, in turn, on the species, would do much to assist the planner.

Many capability studies attempt to classify fresh-water bodies for the production of fish. Although no attempt is made to treat this separately fish production, primarily for recreation, plays a significant role throughout the Area and is likely to remain an important aspect of wildlife conservation. In this respect ecological areas 1a and 1b appear to have most to offer.

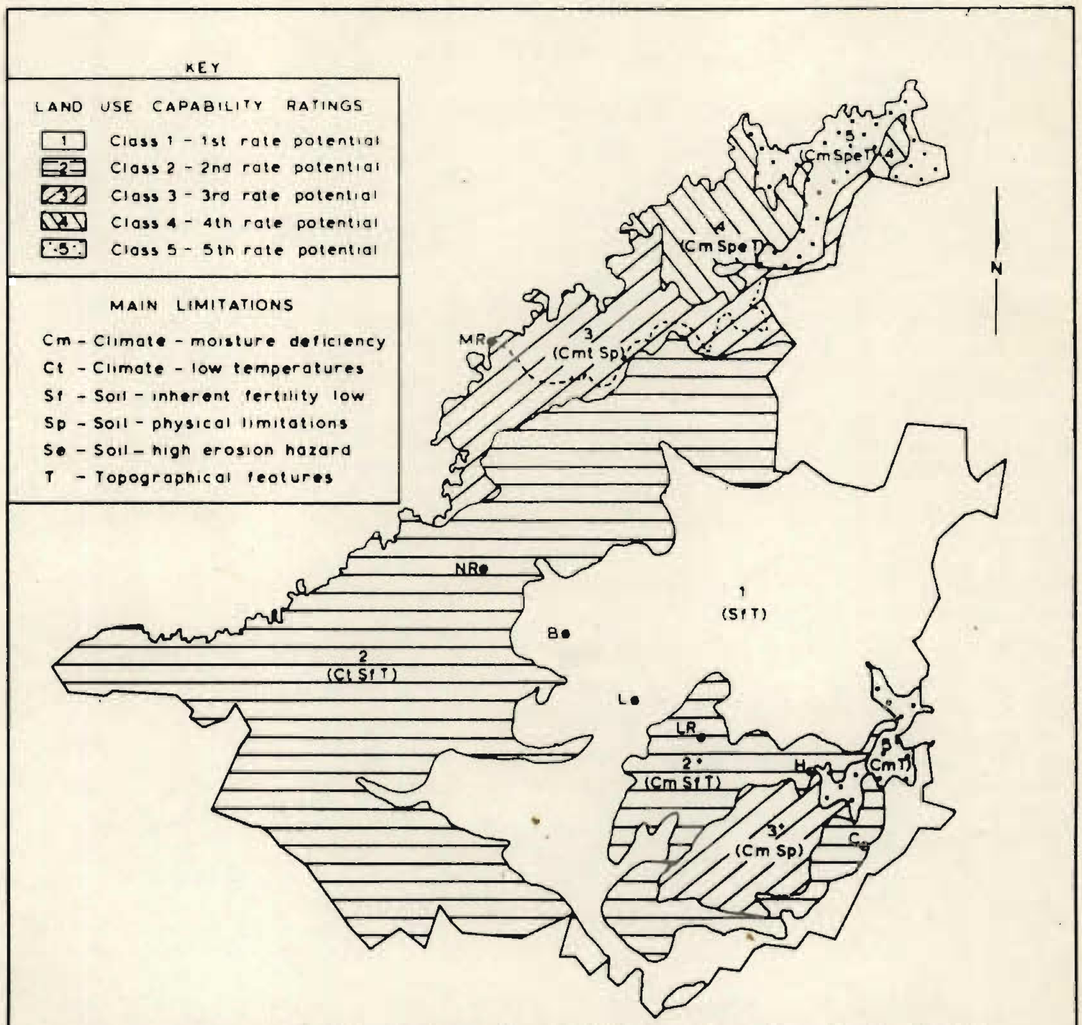
(v) Use-capability for recreation

According to Hills (1961), recreation is the pleasurable and constructive expenditure of leisure time and includes all rural out-of-door, land-based activities that revitalize the body and mind. Its definition should be narrowed to those activities that are dependent upon physiographic and ecological characteristics of land. Recreational activity does not, however, always involve harvesting a crop (game or fish), sometimes it is merely the obtaining of sensory impressions. The latter was referred to by Hills as 'copping'. There are many complexities in rating the capability of land for recreation but, in doing so, value judgements of its 'copping' value should be made and these superimposed upon the value of the crops harvested by recreational activity.

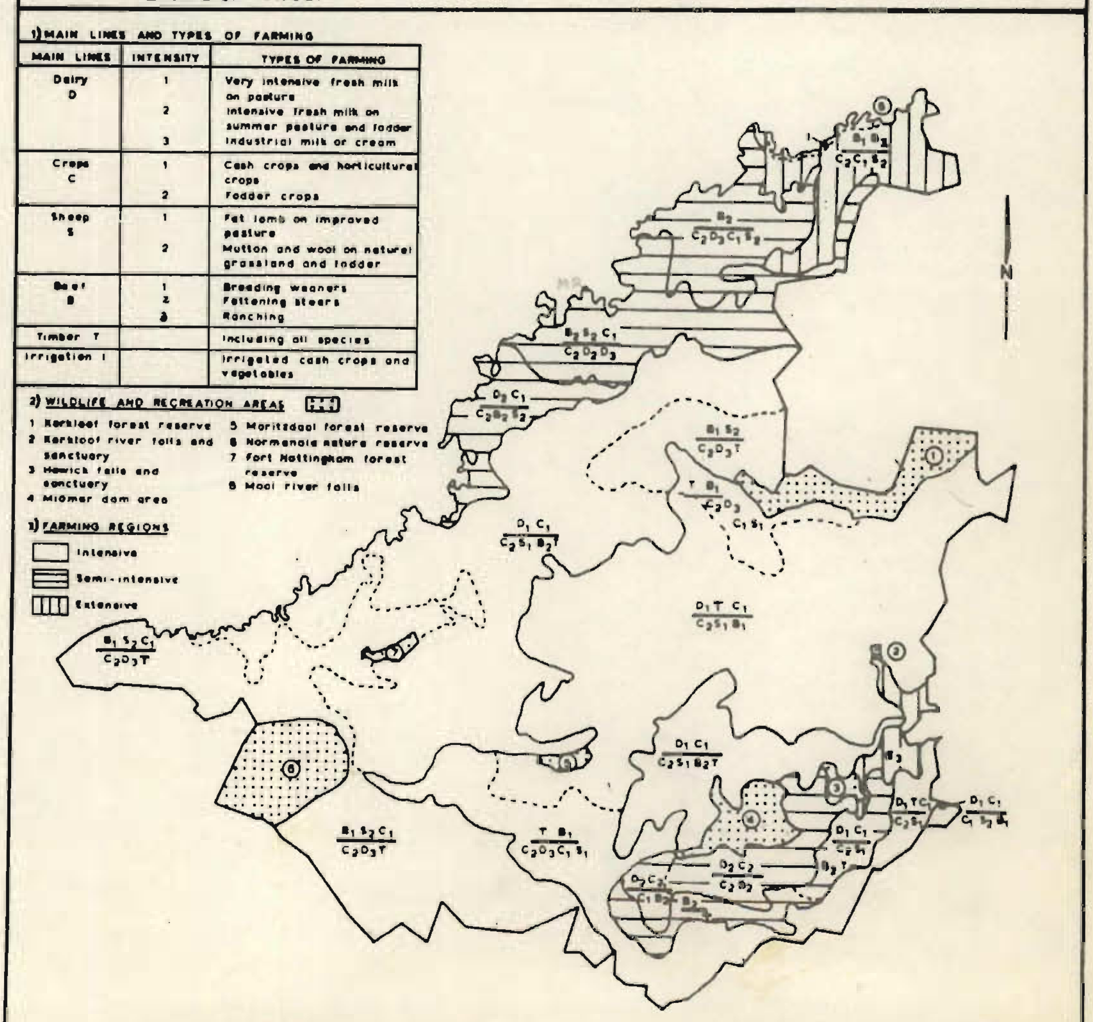
The close proximity of the densely populated Durban - Pietermaritzburg complex places a heavy demand on the Area to provide recreational facilities. In rating the use-capability for this purpose, a similar basis to the previous assessments is used, though the criteria are very different. Ecological areas are again of special value since they are largely determined by climate which, in turn, contributes much to the suitability of an area for recreation.

Contrast and uniqueness of the landscape are important criteria. Landscapes with contrasting features usually have the highest recreational value. Furthermore, biological productivity is related to activities such as hunting and fishing since 'richer' habitats provide an abundance of interesting fauna and flora. Points of interest that can be reached in a one-day return trip are particularly valuable for recreational purposes (Hills, 1961).

The use-capability of the Area as a whole is high. In assessing individual ecological areas, natural features such as waterfalls forests, and existing man-made features (e.g. the Midmar dam) are also taken into account. On the five-point scale, ecological area 2b is rated very high (Class 1) since it has a focal centre (Midmar dam) and



Map 8. Land-use capability classification for intensive agriculture in the Howick Extension Area.



Map 9 Recommended use classification for the Howick Extension Area

an attractive hinterland. Area 1b is placed in Class 2 since it is an area of high contrasts, much available space, many points of interest and high biological productivity. Areas 1a and 2a are grouped in Class 3 although the former is perhaps excessively downgraded. Class 4 includes area 3b and areas 2c, 2d and 3a are rated very low (Class 5).

Several sites are chosen as being suitable as '<u>sanctuary</u>' or '<u>refuge</u>' areas for recreation or wildlife or both. However, with the exception of the Midmar dam area and the forestry reserve at Fort Nottingham, all the land is privately owned. These areas, which could be developed and used in a number of alternative ways, are shown on Map 9. Other smaller areas, including various waterfalls, are not shown but are also of considerable value for recreational purposes viz., falls on the Umgeni river in the Dargle area, Shelter falls in the Karkloof, falls at Lidgetton and the falls on the Mooi river at Inchbrakie and Harlestone.

2) <u>Recommended development of land within the Area</u>

Use-capability classifications are not necessarily recommendations for land use. Many other principles and objectives should be considered in making such recommendations. Chief among these is that the recommendations should indicate uses that offer the best opportunities. The aim should also be to ensure production of essential goods and services on a high and sustained level. Recommended use classes should specify those uses, selected from the gamut of potential uses, that will meet the economic and social needs of the community. In defining these classes, therefore, consideration should be given to the natural and cultural characteristics of the Area and its relation to the entire economic region. Use-recommendations must ensure that the farmer can earn a living and accumulate capital. An indication should also be given of the intensity of use including 1) the comparative degree of development of different land uses in the area, and 2) the relative degree of intensity of the same land use on different areas (Lewis, 1952; Hills, 1961).

Bearing these objects in mind an attempt was made to classify the

Area in terms of recommended use. The classification is intended to serve as a multiple or master plan, and guide for detailed land-use planning. All natural and economic features of the Area are considered and the ecological areas again provide the basis for the classification. Minor variations within the areas are neglected. For example, soil differences that influence recommended use are best treated at the farm level. Recommendations for afforestation assume the rational selection of land thus leaving arable classes available for crop production and vital water resources unaffected.

An indication is given of the main lines of farming that will provide the chief source of income. Alternative types of farming within these lines are also presented to indicate the permissible intensity of land use. For this purpose, the types are arranged in special order starting with the most intensive form of land use. An indication is also given of the lines that are to play a subsidiary role in the farming enterprize. With these, too, the degree of intensity is indicated. Minor subsidiary lines such as pigs, poultry or the rearing of stud animals are not included in the classification. Although irrigation farming is one of the alternative main lines, the practice of supplementary irrigation is recommended throughout the Area wherever soil, water and economic conditions are favourable. Best responses to irrigation can, however, be expected in ecological area 3b although the extent of suitable soils is limited. A limited amount of low-intensity dairying is prescribed for areas 3a and 3b which is in conflict with ecological principles. This recommendation is made in view of the available transport facilities and possibilities for intensification with irrigation. In this instance, a realistic approach has been favoured.

Map 9 shows the recommended use-classification and reflects how alternative uses are integrated in the multi-use plan for each ecological area. In the fraction used the numerator and denominator represent the main and subsidiary lines respectively. The order, from left to right, indicates the relative importance attached to each use. Numbers in the index position indicate the relative degree of intensity of each main or subsidiary line in each ecological area. The Area is also classified into intensive, semi-intensive and extensive farming regions as defined by Pentz (1949).

6.3 Summary of the agricultural potential, limitations and prospects of defined ecological areas

In this discussion an evaluation of the potential, the main limitations confronting agricultural development and the general prospects of each area is given. An outline of the recommended master plan for each area and the most important issues to be considered in drawing up an extension programme for each area is also presented.

1) Ecological area 1a

The potential for intensive agricultural production is high. An era of considerable intensification is anticipated demanding that greater attention be paid to conservation. The master plan envisages intensive livestock production on high quality pasturage as the main line, to be supported by limited cash cropping and fodder production. Timber provides an alternative form of use on non-arable land. Economic considerations, topography and communications will determine the final choice of enterprizes.

The production of fresh milk, supported by cash crops, fat lamb and pigs is seen as the most favourable combination for the area surrounding Nottingham Road up to a radius of at least 8 to 10 miles. The breeding of beef and the production of mutton and wool off the natural veld in summer is advocated for the more rugged terrain. At present, wool production is not highly remunerative but the scope for this type of farming is considerable. The Hereford, Sussex and Aberdeen Angus are likely to remain the chief beef breeds while for sheep, the Corriedale, pure or crossed with Down breeds, will probably remain popular for some time. There is, however, little demand for their wool. The Merino and similar fine-woolled breeds could become important if the economic situation improves.

The basis to the recommended cropping system is semi-permanent, high-quality pastures of exotic grass and clover species. The need in this area is for high quality grazing, adequate fodder for winter and a limited amount of cash cropping. Grasses such as ryegrass, cocksfoot and fescue, alone or with ladino clover will provide high quality grazing if correctly managed. Kikuyu and E.curvula (for hay) produce well in summer. A rotation of E.curvula and potatoes (seed and table) is considered well-suited to the area, since respective yields of up to 10 tons of hay and 300 bags per acre for these crops are not unduly optimistic. Grass-clover pastures and maize can also be conveniently rotated. However in view of the short growing season and the problems related to soil fertility, large-scale maize production cannot be strongly recommended. Detailed studies of growth and new varieties could alter this, since already yields of over 40 bags per acre have been achieved under experimental conditions. Japanese millet and radish together with rape are suitable as supplementary winter feeds. Wheat has been grown fairly successfully in the area but until the problems of soil fertility, diseases, varieties, grass weeds and the harvesting and drying techniques are overcome it is unlikely to become important, at least on the smaller farms. In addition to potatoes, vegetable crops such as cabbages and peas may be extensively grown especially with the recent interest in the freeze-drying process. Supplementary sprinkler irrigation for pasture and winter fodder is likely to increase considerably.

Afforestation is recommended for selected non-arable sites although the profitability will be influenced by extraction and transport costs. Pinus patula and Pinus taeda are suitable species, the latter being more resistant to infection by Diplodea pinea following hail damage (Hubbard, 1965).

The natural veld, although it provides excellent grazing in summer for cattle and sheep (at a carrying capacity of 1.5 to 2 acres/mlu for the grazing period) faces widespread replacement or reinforcement (sod-seeding) by pastures and/or afforestation. Current problems include those associated with early burning and poor grazing management. On the northern slopes along the 'main divide' there are signs of much soil loss. Phillips (1964) has already made a plea for new traditions of pastoral management within the Highland Sourveld areas.

The potential of the area for recreation and wildlife, especially fish culture, is high. Several sites considered suitable for refuge areas or sanctuaries have already been noted (Map 9).

The main limitations are related to soils, climate and topography. Morphologically the upland soils are ideal for intensive cultivation although the HUTTON, CLEVELAND, OATSDALE and humic phase soils require special conservation treatment. The extremely low plant nutrient status, aluminium toxicity and severe P-fixation of most soils are important hazards with economic implication. The bottomland soils, if used at all, require very special treatment (see 6.4) for safe-use. Low temperatures and hail are the main climatic limitations while the steep and rugged terrain along the 'main divide' and western barrier prevent a high degree of agricultural intensification. Additional limitations include the prevalence of internal parasites and the occurrence of poisonous weeds, such as tulip (Moraea spp.), and other weeds including the American bramble (Rubus cuneifolius), Athanasia acerosa, gorse (Ulex europeaus) and broom (Sarothamnus scoparius). Lack of communications in the western sector have, to some extent, hindered agricultural development.

Prospects for livestock production and some cash cropping are particularly good since markets in the Durban - Pietermaritzburg complex and the Tugela Basin are close to hand. The arable areas can, with careful planning, be intensified to a maximum degree and much natural veld can be replaced. Complete replacement of the veld within the Highland Sourveld was considered by Fisher (1955) to be no figment of the imagination. Fertilization of the veld could also become important. Owing to the need for high quality hay and the problems of field curing, artificial drying may become widely adopted.

The extension programme for the area should first strive for improved land-use planning and the widespread adoption of modern farming practice. The provision of high quality farm produced feeds through the selection of suitable crops and pastures and the application of sound agronomic practices are particularly necessary. The widespread adoption of correct lime and fertilizer treatment for each soil series should be among the main objectives. Matters pertaining to livestock husbandry should include feeding and veterinary aspects. Judicious veld and pasture management and the replacement or reinforcement of the veld are additional avenues to be considered. Part of the programme should ensure the safe-use of the hydromorphic bottomlands.

2) Ecological area 1b

This area has the highest potential for intensification and is suited to farming of a very diversified nature. The Karkloof area is singled out as having exceptionally high potential. The master plan envisages mixed farming based on fresh milk production off high quality pastures and afforestation confined to selected sites. Cash crops, including vegetables, beef breeding and fattening, fat lamb, pigs and poultry are suitable subsidiary lines. A wide range of crop, pasture and tree species can be grown.

The arable land should produce maize, potatoes, cabbages, soyabeans and a wide variety of fodder crops. Temperate grass species, similar to those prescribed for area 1a, and oats are suitable for the cool season. In view of their high yield potential in summer, kikuyu. *Paspalum dilatatum* and *E. curvula* are recommended for inclusion in the pasture programme. Ladino clover is one of the best all-purpose clovers for the area. Rotations should be planned to meet the livestock needs and, where possible, should include a cash crop. Some crops, as yet 'unproven', have shown promise in small trial plantings and could become important. These include tea, pyrethrum and Phormium tenax. Pecans, avocados, wheat and cane fruits should also be tested. Vegetable production is likely to expand considerably in the near future and there is scope for limited production of plums.

Supplementary irrigation is recommended especially for the production of quality fodder for dairy livestock. Highly fertilized ryegrass and similar crops are particularly suitable for this purpose. The artificial drying of these and other hay grasses, grain and seeds of various sorts is likely to receive much attention in the future.

This area is eminently suited to afforestation. Gum, pine, wattle and poplar species can all be grown commercially. Rational selection of land for this purpose should, however, receive immediate attention. Recommendations for afforestation should be made on the basis of individual catchments. Pine could be limited to the steep and/or rocky sites, gum to the steep but ploughable sites and wattle, on a limited scale, to selected sites within the Karkloof area. Despite the suitability of the area for afforestation the writer suggests that the future might well see the replacement of some of the already extensive plantings by cultivated pastures or, on favourable sites, by crops.

Since the secondary Aristida junciformis grassland does not provide quality grazing, it is recommended that the replacement of veld by pasture and/or afforestation should reach a maximum in this area.

The extensive areas of indigenous forest, the fishable rivers, scenic drives and several waterfalls are all attractions within easy reach of the cities and towns. Thus, the area has high potential for recreation and wildlife. Several sites are recommended for these purposes and should receive special attention (Map 9).

The soil limitations are similar to those noted for area la. The same applies to climate and topography except that temperature conditions are not as restrictive. Weeds of importance include the American bramble (Rubus cuneifolius) and the poisonous weeds tulip (Moraea spp.), ragwort (Senecio spp.), slangkop (Urginea macrocentra), inkberry (Cestrum laevigatum), chinkerinchee (Ornithogalum spp.) and staggers weed (Matricaria nigellaefolia). Problems related to sub-economic farm units and the likely influence of rural and industrial expansion on farm labour have already been stressed.

The prospects for increased intensity of all facets related to land use are exceptionally good. For this reason, the extension programme should not only direct attention to the careful selection of appropriate land uses, but should also create an awareness among the farming community of the exceptional possibilities for development. It should then ensure optimum exploitation of the potential by setting yield horizons and guiding development along technologically sound avenues. Thus, the programme should strive for greater productivity and refinement in crop, livestock and forest husbandry.

3) Ecological area 2a

The potential of this area is fractionally lower than that of area 1b, owing to the slight moisture deficiency. This limitation is of particular importance to afforestation and the choice of suitable crops. The master plan is essentially the same as that for area 1b except that the production of timber products should become a subsidiary line of farming. The suitability of certain bottomland soils in the vicinity of Lions River for poplar is noteworthy. In all other respects the remarks concerning area 1b apply. The area is also well served by the Cedara College of Agriculture.

4) Ecological area 2b

The potential of this area for intensive agriculture is moderate, limited by low rainfall and many shallow, poorly drained soils of moderate erosion hazard. Despite these limitations intensive land use is encouraged by favourable topography and the close proximity of fresh milk markets. The master plan envisages a fairly intensive system of farming with dairying and crop production as the main lines. Dairy production should rely on summer producing grasses and conserved winter feeds.

The cropping system should include leys of fairly long duration and should aim at meeting the livestock requirements and the needs of the soils. Suitable summer grasses include kikuyu, E.curvula and Paspalum dilatatum. Maize is considered a principle crop for the area but should be restricted to the D1-association soils and the better drained members of the E1-association. The shallow, poorly drained soils often with ferruginous hardpans should be eliminated from regular use and planted to leys of long duration. Certain of these may be improved by surface drainage and tillage. Sorghums are well suited to the area. The production of winter fodder crops under rainfed conditions, especially on E1-association soils, should be kept to an absolute minimum. Marked responses to applications of nitrogen to these soils are noteworthy. Current cropping practice has failed to establish a suitable legume crop for the area although the production of lucerne on selected soils may well prove successful.

The extensive bottomlands are suitable for the production of permanent summer pastures of Paspalum spp. and clover for silage and grazing. Pastures of fescue and ryegrass, alone or with clover, grown under irrigation, will provide valuable green grazing for the winter period. Surface drainage techniques are generally essential for successful pasture production on these soils. In view of its limited extent the natural veld has a very minor role to play in the overall land-use plan.

Afforestation should be limited to farm woodlots with hardy species such as Pinus roxburghii, Eucalyptus fastigata, E.viminalis and E.maideni most suitable. P.elliotii and P.patula can be successfully grown on selected sites. Although poplar will do well in the area, pasture production on the bottomlands should enjoy preference. The potential of the area for recreation and wildlife is greatly enhanced by the presence of the Midmar dam. The Howick falls also provide an added attraction.

The main limitations concern the adverse physical characteristics of many of the soils and moisture deficiency. Poisonous weeds such as

Matricaria nigellaefolia may prove serious on the bottomlands.

Prospects for improving agricultural production in all spheres are good although the ultimate levels of production will be determined by inherent limitations of soil and climate. Agricultural development is bound to be influenced by nearby urbanization. Biologically, the area is suited to semi-intensive systems of farming yet a fairly intensive system is recommended. For this reason, the extension programme should pay particular attention to matters of conservation and so avoid over-exploitation. It should endeavour to direct production to the most suitable soils and to encourage the adoption of sound cropping programmes and agronomic practice.

5) Ecological areas 2c and 2d

These areas are discussed jointly since their potentials and limitations are similar. They are best suited to semi-intensive farming systems although the possibilities for intensification are considerable. The *master plan* envisages livestock and crop production as the main lines of farming although the degree of intensity is less than in the adjoining moist areas. Fresh milk production should form the main line near Mooi River and Rosetta while beef fattening, fat lamb and wool production are more suited to the drier and more remote sectors. Pigs could form a subsidiary line.

Maize and sorghums are particularly suitable but should be grown in strict rotation with leys of *E.curvula* and Rhodes grass. This programme is recommended for the D1- and E1-association soils of high potential. Long duration leys including *Paspalum dilatatum* should be selected for the poorly drained soils. Kikuyu is probably the most suitable permanent pasture grass despite the generally dry soil climate. Pastures of exotic grass and clover species are not recommended unless irrigated. Similarly, winter fodder crops grown under rainfed conditions should be avoided or kept to an absolute minimum. Lucerne could well become an important crop in these areas and it is tentatively suggested that improved strains of *Cynodon dactylon* will prove eminently suitable as permanent swards on soils of high erosion hazard.

The bottomlands, by virtue of their high erosion hazard require special treatment. Their use should be limited to permanent pasturage provided supplementary irrigation is available. The alluvial strips along the Mooi river should preferably be used for irrigated pastures and lucerne although poplars could be an alternative with careful selection of soils.

The natural veld, with an annual carrying capacity of roughly 5 acres/mlu, will play a greater role than in the areas previously discussed. Utilization of the veld by beef, sheep and replacement dairy livestock is envisaged. Veld reinforcement and fertilization may be rewarding but will require further experimentation. Afforestation should be restricted to farm woodlots. The potential for wildlife and recreation is low except for a narrow strip adjacent to the Mooi river. Although game farming species could be run on the natural grassland they are unlikely to compete seriously with domesticated livestock.

The main limitations include those related to soils (mainly physical), moisture deficiency, low temperatures in winter and, to some extent, topography.

In view of the overall potential, favourable communication and available markets, the prospects for agricultural development are good. The extension programme should be directed primarily at the soils, including their potentialities, limitations and management needs. Correct fertilization, especially with nitrogen, and tillage methods are important. Soil and water conservation are matters deserving priority while veld management and crop and livestock husbandry should form part of the programme. Full use should be made of the Mooi River Agricultural High School for co-operative extension work.

6) <u>Ecological area 3a</u>

The potential for agricultural development in this area is moderate to low. A semi-intensive system of farming is recommended although the role to be played by the arable area is limited. The proposed master plan is based mainly on the production of beef and sheep supplemented by limited fodder production on carefully selected and protected soils. Dairying of low intensity is permitted but should be considered only with special conservation practice and efficient management. The ratio of beef cattle to sheep is likely to be a critical factor in the safe-use of the land. Crops of maize, sorghums, sunflowers, cowpeas and dolichos beans can be grown on suitable soils. Much emphasis should, however, be given to leys of long duration and for this purpose *E.curvula* and Rhodes grass are well-suited. *Cynodon dactylon* and rainfed lucerne, both as yet unproved, are likely to become important. Supplementary irrigation is most desirable and permits the production of several crops and intensive grass-clover swards, kikuyu and lucerne. The bottomland soils, especially river alluvium, are particularly suited to irrigation.

Tree planting should be limited to the provision of shade and shelter. *Eucalyptus melliodora* and *E.sideroxylon* are suitable for this purpose.

The natural veld with an annual carrying capacity of 6 - 8 acres/mlu will play a major role in the master plan. Thus, emphasis should be given to veld management. Some reinforcement may be possible with selected legumes. The potential of the area for recreation and wildlife is low.

The main limitations include a low and erratic rainfall and the unfavourable soils, including the highly erodible claypan soils. Tulip (*Moraea spp.*) may occur extensively on the bottomlands.

The extension programme should aim at restricting agricultural development and intensity of use to within the limits imposed by climate and soils. It should ensure that correct forms of land use and conservation practices of the highest order are rigidly applied. The restoration of eroded areas and correct veld management should receive special attention.

7) Ecological area 3b

The potential of the Thornveld area (which is suitable for extensive systems of farming) is generally low. The master plan envisages beef breeding and ranching as the main lines. Under special conditions small stock may also be permitted. Fodder production should be limited to the most favourable soils. The claypan and bottomland soils must be excluded from regular arable use. The potential for irrigation on the alluvial soils and Jagersdrift series is very high, especially for vegetables, lucerne, citrus, intensive pastures and, in some cases, poplar. Wheat and cotton may play a role in the future. With the possibilities for intensive pasturage and the direct link with Mooi River a very limited amount of low-intensity dairying (industrial milk) can be considered. This practice, however, has already led to much deterioration of the natural resources and would require management of the highest order.

Under rainfed conditions maize, sorghums, cowpeas and dolichos beans can be grown on the limited areas of suitable soils. Many of the existing arable areas should be withdrawn from cultivation and established to permanent grass swards of E.curvula, Rhodes grass or Cynodon dactylon.

In most cases the natural veld, with an annual carrying capacity of 8 - 10 acres/mlu or more, requires improvement through careful management. The encroachment or 'intensification' of Acacia spp. is a problem of special note in this area (Phillips, 1966). Veld reinforcement is not likely to be of much importance although the use of sub-tropical legumes requires further investigation. The potential of the area for wildlife and recreation is generally low except for areas adjacent to the Mooi river including the waterfall. Farm game is usually abundant if afforded adequate protection.

Widespread erosion, especially on the bottomlands, is a special feature of the area and reflects the high erosion hazard and vulnerability of most soils. This aspect demands immediate attention.

Additional limitations within the area are the small farm size, severe moisture deficiency, wide temperature fluctuations, rugged topography, thorn tree encroachment and the occurrence of tulip (Moraea spp.) on the bottomlands.

The extension programme should aim at eliminating the main causes of erosion and reclaiming the eroded areas. Incorrect land-use practices and the small size of many of the holdings are important problems to be faced. Careful selection of soils for arable use and the application of correct veld management, plus improved crop and livestock husbandry and irrigation practice, are matters of prime concern.

6.4 Special features related to agricultural development

1) Utilization of vleis

This discussion refers specifically to bottomlands characterized by hydromorphic soils and aquatic reedswamp, sedge-meadow and hygrophilous grassland communities. The writer advocates the term 'vlei' to describe these bottomlands in preference to the many other terms frequently used (e.g. sponge, marsh, morass, swamp, etc.)

Vleis are unique in their characteristics and management needs. Their safe use is regarded as one of the prime requirements demanded of land-use planning in the Area. Many denuded vleis, especially in the drier landscapes, bear witness of poor land-use decisions of the past and the failure to recognize their need for special treatment (Plate 20). These ill-advised and ill-fated attempts to utilize vleis are, however, insufficient to justify the sweeping denunciations often heard and the demands for total protection. Kokot (1963), discussing the 'Umgeni sponge', stated that to protect land from the plough merely because that would result in erosion would be a policy of despair. Nevertheless, it is true that regular cultivation will reduce the content of organic matter in the surface soil and increase erosion hazard. A further problem is that the entire vlei is seldom under single ownership thus complicating planning and management.

Plate 20. A denuded vlei - erosion has destroyed much of the vlei (left) and downstream the donga has reached considerable depth (right).

Plate 21. Vlei development in the Howick Extension Area - vlei in process of development (left) and established to pasture with 'ridge and furrow' technique (right).

Plate 22. Vleis [redacted] have high potential for specified uses. Note high carrying capacity of pastures on developed portion of vlei (left). Poplars are an alternative form of use on certain types of vleis (right).

The soil survey provides the basic information for making recommendations for vlei utilization in the Area, yet the attempt to formulate a definite policy is thwarted by a lack of hydrological data. For instance, it is unknown whether high yielding pastures use more water than the vlei vegetation or if poplars use more than pastures.

Many of the vleis in the humid areas have already been 'worked' for long periods, some for over 40 years, and more are in the process of development. No concrete evidence is available to show what effect this development has had on water supplies. The attention given to this class of land has increased markedly in recent times and farmers are now aware of the high potential of these vleis for pasture production and poplars (Plates 21 and 22).

The views reflected here are the result of field observation and a knowledge of the soils. In the absence of research data, an attempt is made to provide a '<u>modus operandi</u>' which is urgently needed by planners in the field. Although principles are discussed, no details of design or specifications for drainage systems such as those found in various handbooks, are given (U.S.D.A., 1954; Roe & Ayres, 1954; Luthin, 1957). Bottomlands characterized by alluvial soils (Ll-association), pans with no natural outlet and the narrow, usually steep, drainage ways of the landscape are exluded from this discussion. The last-named, or 'valley vleis' (Downing, 1968), are generally subject to overflow and flooding of considerable magnitude and should be carefully protected.

(i) <u>Types of vleis and their distribution</u>

Characteristic soil features are used to distinguish three types of vleis (Scotney, 1970). In the absence of more critical data little regard is given to mode of formation or geological features in defining the types. A common feature of most vleis is the presence of a dyke or horizontal formation of hard rock forming a nick point (key) in the river valley (Turner, 1970). Downing (1968) has defined several types of vleis in the Highland Sourveld. These definitions are based mainly on phsyiographic and plant ecological features.

Three main categories, based on soils, are recognized in the Area:

Type 1 - Vleis comprising acid hydromorphic soils (Cl-association).

Type 2 - Vleis comprising neutral to alkaline hydromorphic soils (H1-association).

Type 3 - Vleis comprising margalitic and claypan soils (H2-association).

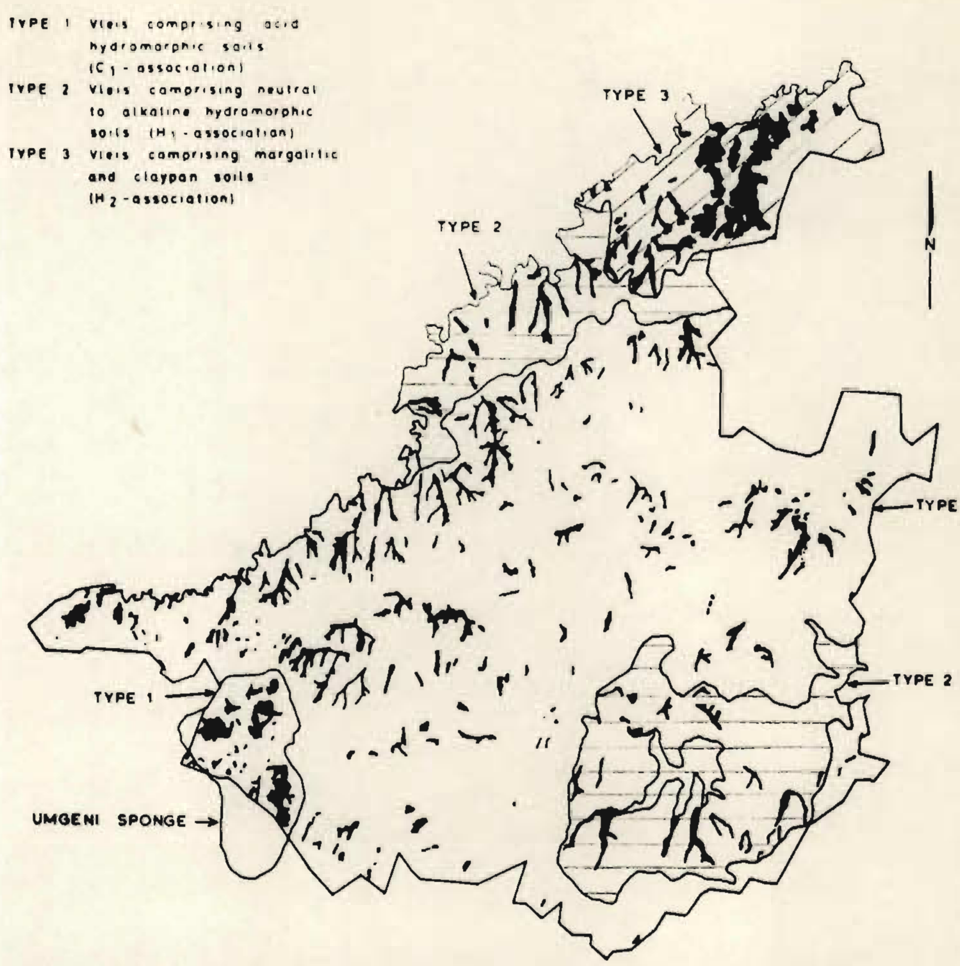
Map 10 shows the location of these types and a summary of their distribution in the ecological areas is given in Table 51.

Table 51 : Distribution of types of vleis in defined ecological areas in the Howick Extension Area

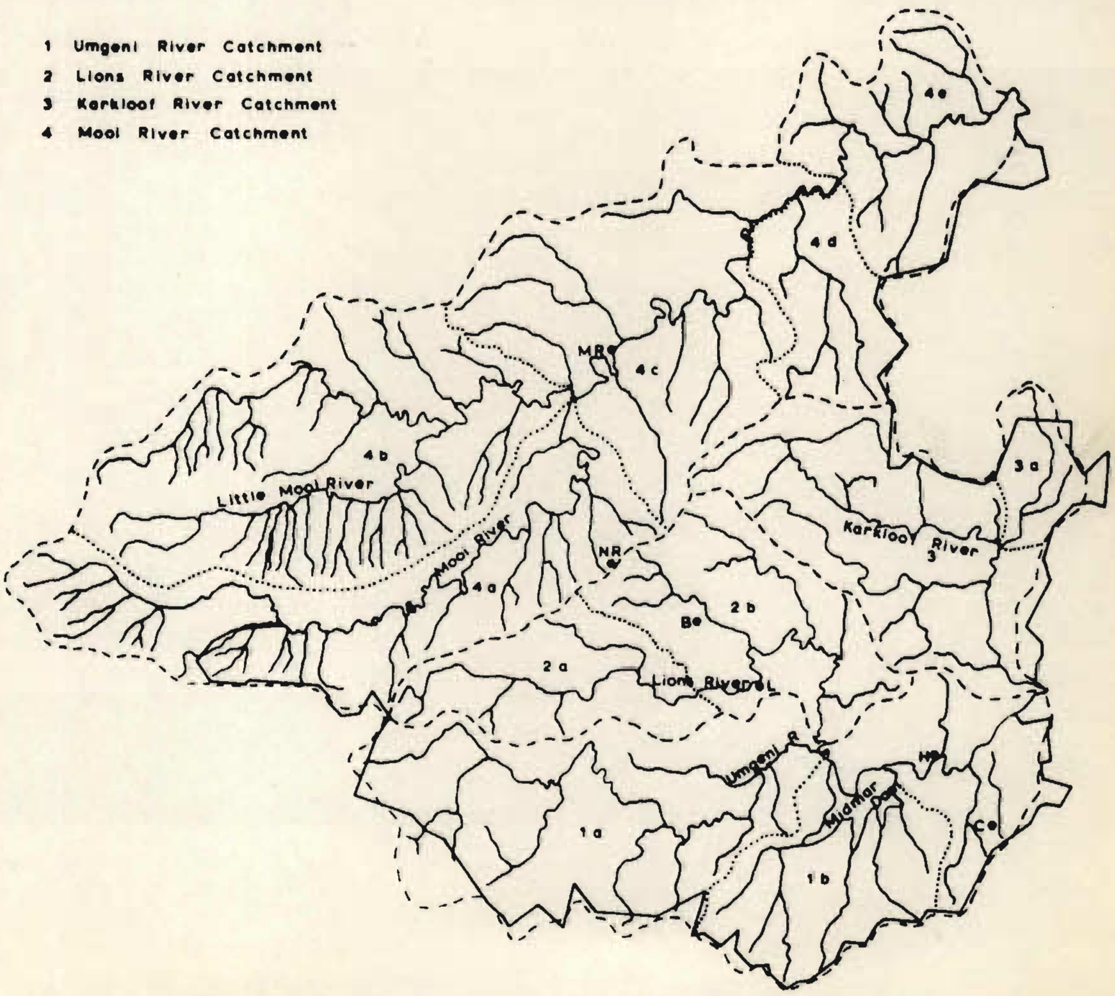
Type	Ecological area	Distribution (% of area)
1	1a 1b	7.5 2.5
2	2a 2b 2c and 2d	5.2 7.0* 7.0
3	3a and 3b	18.1

* excluding area inundated by Midmar Dam

Hazard of use of the bottomland soils increases from Type 1 to Type 3. Hiemstra (1965a) demonstrated the relative stability of the KATSPRUIT series (Type 1) and the high erosion hazard of the ESTCOURT and RENSBURG series (Type 3), which supports field observation. The common occurrence of these highly erodible soils, as shown in Table 51, is extremely important. The stability of all vlei soils is, however, enhanced with saturation. Although soil conservation is of prime concern with Type 3 vleis, hydrological matters are most important with Type 1. These two aspects have a marked influence on the recommendations to be made for each type. Before considering these it is necessary first to discuss some important principles concerning 'vlei' development, especially for Type 1.



Map 10. Distribution of hydromorphic bottomlands in the Howick Extension Area.



Map 11. Selected catchments in the Howick Extension Area.

(ii) Planning vlei development

Vlei development should first meet the requirements of the Soil Conservation Act and the planner should also acknowledge basic principles and follow set procedures. Development in the sense used here, means improvement of the vlei, primarily for the production of permanent pasturage, preferably under irrigation, but does not necessarily preclude other forms of usage. The term vlei drainage is often heard yet loose usage of the term and the inference resulting therefrom have done much harm (Hill, 1968). It is suggested, therefore, that emphasis should rather be given to development or land improvement. According to Roe and Ayres (1954) land improvement should mean more than simply the removal of free water from the land surface and the soil of the root zone. Rather, it is the 'complete' control of the elevation of the ground water table within the root zone. The object should be to lower the water table just enough to permit the successful establishment and growth of the crop. 'Complete' control of the water table implies that the moisture condition of the vlei could be returned to its original state at any time. Over-drainage and under-drainage are equally detrimental and should be avoided.

In planning for land improvement each vlei should be treated on its own merits. Some may, in fact, require total protection. The relationship between the vlei and the farm, neighbouring farms or the entire catchment area should be well understood. Planning must include the entire vlei and the whole catchment area, both above and below the vlei itself. Erosion control within the vlei, the influence of development on water yield and pollution, and the effect on natural fauna and flora, are all important aspects to be considered.

Benefits accruing from bottomland improvement include:

1) additional land of high productive potential for specific use is made available,

2) improved crop yield through better root development, earlier and timely cultivation and improved physical conditions of

the soils, e.g. better aeration and microbial activity and higher temperatures (wet soils are cold soils),

3) control or reduction of flood damage,

4) improved economy of the farm enterprize,

5) reduction in frost damage, and

6) improved access over the farm.

Procedures and techniques: Two phases are recognized viz., survey and planning.

1) A systematic and thorough survey of all relevant features should be made. Factors that affect the design of the project include a) the purpose of the drainage system, b) the outlet depth and capacity, c) ruling gradients, d) topsoil and subsoil characteristics, e) rainfall and sources of seepage, f) size, shape, topography and vegetal cover of the catchment, g) crop to be grown, and h) land values (Roe & Ayres, 1954). The topographic and soil data and the possible outlets and location of drains should be recorded in map form. Drainage problems should be identified before the layout of drains is finalized.

Detailed soil investigation is essential during the survey phase. Not only does it permit 'typing' of the vlei but soil characteristics that invariably influence the decisions to be made in the planning phase can be studied. For instance, surface features such as the hummock formation of Type 1 vleis (Plate 23) may influence the 'breaking up' procedures. Soils also influence the selection of underground drainage techniques. In H1-association soils the tendency to crack on drying is in itself an aid to sub-surface drainage (Plate 25).

The high organic status of many vlei soils gives rise to several problems. The shrinkage factor in the 'peaty' vleis (e.g. IVANHOE series) may cause appreciable subsidence if development permits excessive drying out of the O-horizon. Shrinkage of up to 40 percent on drying was reported in Chapter 2 and is clearly illustrated in Plate 25. Furthermore, problems associated with frost are often greater in

Plate 23. Hummock formation in hydromorphic acid vleis (Type 1) (Photo: E. J. Moll)

Plate 24 Shrinkage of O-horizon on drying - IVANHOE series.

Plate 25. Sub-surface cracking aids internal drainage. Note seepage from cracks above water table.

Plate 26. A typical 'key' (dolerite dyke) and 'vlei'.

Plate 27. A view of the 'key' area from within the 'vlei'.

Plate 28. An example of interference of the 'key' area which may endanger the entire 'vlei' above.

Plate 29. Steep sided outlet drain correctly made (note absence of spoil bank).

Plate 30 Old-type cut-off drain inclined to erode.

Plate 31. Old-type drain with spoil bank impeding lateral drainage.

Plate 32. Broad V-type drain under construction (note absence of spoil bank).

Plate 33. Shallow U-type drain with large capacity. Can be crossed by machinery and livestock.

Plate 34. Outlet of drain should be protected to avoid erosion.

peat soils than in mineral soils although this can be alleviated by drainage (Roe & Ayres, 1954). Good compaction by rolling is necessary for successful establishment of pastures on these soils.

2) The planning phase should commence with the catchment itself. Since the bottomland is to cater for all discharge from the catchment area, maximum conservation of water and soil in the uplands is required. Planning should establish the optimum usage for the land and should include the siting of flood control and storage dams where these are necessary. It may, for example, be necessary to control or eliminate the planting of trees, or intensive crop or pasture production where water resources are of prime concern.

Within the vlei proper the first essential is to afford complete protection of the 'key area' in its natural state. This usually comprises a dolerite dyke (Plates 26 and 27) but may take the form of alluvial deposits where feeder streams join a main river. Under no circumstances can interference (deepening) of this natural outlet be tolerated since attempts to do so are likely to end in disaster (Plate 28). Provision of a protected area of natural vegetation, or preferably a dam, immediately above the 'key' is also recommended. The plan should ensure that the vlei is developed systematically in alternate 'strips' at right angles to the direction of flow. It is suggested that no more than 20 to 25 percent of the total area should be bared at any one time. The same applies to the re-establishment period.

One of the first tasks is to control the perennial flow through the vlei and the lateral seepage water. Outlet and cut-off drains, sited exactly on the periphery of the vlei, and occasional drains across the vlei are often all that is needed for this purpose. Time should be allowed for such drains to take effect before development is continued. This is one of the few instances where steep-sided drains should be used although they are generally wasteful of land, hazardous to livestock, difficult to cross with machinery and subject to continual erosion of the banks (Plate 29). A further disadvantage is that the spoil banks often prevent lateral surface drainage thus aggravating the drainage problem. Many attempts at land improvement to date have experienced these problems (Plates 30 and 31). Broad U-type drains are preferred for their greater capacity, reduced erosion hazard, easier crossing by livestock and machinery, and better weed control (Plates 32 and 33). The W-type drain is suitable for providing a raised roadway where spoil is placed between two parallel drains (U.S.D.A., 1954). Where perennial flow is to be handled, erosion within the drain itself, must be avoided at all costs. Suitable gradients should be used or grade reducers installed. The latter should be designed so that the water table can be raised to any required level and, if need be, to provide irrigation. Flumes, drop spillways and pipe outlets are additional aids and should be used where necessary. Protection of the drain outlet is frequently neglected (Plate 34). Water from 'eyes' of springs within the vlei should be led into the main drainage system. Improvised underground drains have been used for this purpose and have proved successful in a number of vleis. Their longevity is, however, questionable.

Having harnessed the permanent flow, the next step is to determine the need for additional drainage. Where this is necessary surface drainage techniques, as described in Chapter 3, will generally suffice although underground drains may be necessary to meet the leaching requirement where irrigation is practised. The 'ridge and furrow' technique, coupled with correct tillage, has the advantage of providing both drainage and erosion control. At present, underground drainage cannot be recommended for most vlei soils, although, where economically justified, this method has several advantages. Mole drainage in soils reflecting cohesion under compression, such as the KILLARNEY series, may be useful. Flexible plastic pipes, though not yet tried to any great extent saves labour and may have low-cost advantage over tiles. Both methods may be suitable on soils such as the IVANHOE series where the O-horizon is to be drained. Although depth and spacing specifications for the bottomland soils cannot be recommended at this stage it is likely that drains 18 to 24 inches deep will be satisfactory in most cases. In any event, drainage systems should be capable of lowering the water table within 24 hours after rain (U.S.D.A., 1954).

If the safety of the vlei is ever in doubt, disturbance of the soil surface must be avoided. In such cases sod-seeding or similar methods are advocated.

(iii) Utilization of each type of vlei including the 'Umgeni sponge'

There is, as yet, insufficient data to prescribe the management requirements of each type with condifence. On the other hand, their safe use is so important that recommendations based on present-day knowledge and observation should be made to ensure the best possible use for these areas. Knowledge of the relationship between erosion hazard of each type of vlei and criteria such as slope and width, would be of inestimable value in making recommendations for safe-use. For this reason, the average slope gradient for many vleis throughout the Area was determined.

The average value for the Type 1 vleis was 0.6 percent with very few exceeding 1.5 percent. In contrast, the average slope gradient of the severely eroded bottomlands comprizing the highly erodible soils associated with Type 3 vleis was found to be 3.7 percent with a range of between 3 and 5 percent. Severe erosion of narrow and steep bottomlands, especially in landscapes with soils derived from Dwyka tillite, has also been noted outside the Area. On the strength of these findings, the writer recommends that development should be restricted to those vleis with a slope gradient of less than 1.5 percent, preferably less than 1.0 percent. Other factors (such as width) that effect the depth and velocity of flow over the bottomland should also be taken into account.

In general, arable cropping in vlei areas should be avoided until more is known of the consequences. Pasture swards are recommended since they provide the greatest protection, prevent reduction in organic matter content and are more tolerant to impeded drainage than most other crops. Lowering of the water table can also be kept to a minimum. However, other forms of utilization deserve consideration. For instance, poplars may be the most suitable choice on certain types of vleis and, if managed correctly, may in no way endanger the safety of the vlei. On the other hand, it may be preferable to use the site for water storage or simply utilizing the vlei for research or aesthetic purposes (wildlife and recreation). Owing to the poor drainage of bottomland soils sprinkler irrigation is preferred to other systems. However, where 'ridge and furrow' is employed, flooding from the ridge may prove satisfactory.

Type 1 vleis: Utilization of this type has led to much controversy. Most pleas for total protection are made on the grounds of the likely harmful effects to water supplies. A preliminary study supervised by James (1968a, 1968b; Pegram, 1969) suggests that such fears could be without foundation.

Where the bottomlands comprise the KATSPRUIT and IVANHOE series grass-clover swards for silage and/or grazing are recommended. Cool season varieties (fescue or ryegrass) are praticularly suitable although *Paspalum dilatatum* may be chosen if irrigation is lacking. Light textured soils such as the Dell and CHAMPAGNE series require more intensive conservation practice and where absolute safety is in doubt the vlei should be left in its natural state. The vlei soils are generally more fertile than those of the surrounding uplands but nevertheless require judicious liming and fertilization. Phosphorus and nitrogen are often deficient. Type 1 vleis are not recommended for the production of poplars since the soils are unsuitable. If 'ridge and furrow' is employed, annual forage crops (e.g. ryegrass) can be grown for several seasons during which land shaping and consolidation may take place. More intensive usage of this type should await research.

The 'Umgeni sponge': The vleis of the so-called 'Umgeni sponge' warrant special discussion. The area lies between 1676m (5,500 ft) and 1828m (6,000 ft) above sea level along the south-western boundary of the Area (Map 10). It is approximately 20,000 acres in extent and includes 2,400 acres of vleis in which the IVANHOE series is common. In the almost level uplands, humic phase soils of the CLOVELLY series predominate. Unfortunately the term 'sponge' is misleading since the rock formations beneath the area are unlikely to receive and store large quantities of water in sponge-like manner (Phillips, 1968).

Smith (1953) aptly described the area as one of Natal's most valuable assets. The utilization of the area, because of its strategic position at the source of the Umgeni river, has given rise to much debate over the years and recently led to the appointment of a commission to consider the need for protecting the area from intensification. Earlier, Kokot (1963) had suggested that "the role which the sponges have played in keeping the Umgeni so free of silt as it is, seems to have been somewhat over-stressed". In a preliminary hydrological report James (1968a) suggested that the reduction of flow into the Midmar dam resulting from development of these vleis may be of the order of only one percent.

Despite many requests for research very little scientific data is to hand on which recommendations can be based. However, an experiment to study the differences between developed and undeveloped vleis is contemplated (Pegram, 1969). Preliminary investigations show that the drained vleis contribute considerably more water per acre of vlei or catchment than the undrained vleis. These preliminary results have not indicated the detrimental effects generally attributed to drainage (James, 1968b).

From available aerial photography it can be seen that the majority of the vleis in this area were at one time drained and, according to early reports, some drains were constructed over 30 years ago. Recently, the writer had the opportunity of studying the intensive vlei development that has taken place on the farm 'Ivanhoe'. The purpose of this development was to establish permanent pasture. The surrounding uplands are farmed intensively but conservatively. Evidence to date suggests that the pastures have proved highly successful in carrying large numbers of livestock and that there is very little soil loss. Although the influence on water yield and quality is unknown the construction of several storage dams on the farm has probably improved the overall position.

In the writer's opinion intensification within the 'sponge' area should be permitted, provided intensive conservation is applied to all classes of land and the development of the vlei proper is in accordance with the principles already discussed. Similar conclusions were drawn by a committee convened to report on the Umgeni vleis (Dept. A.T.S., 1960). Favourable communications and topographic features have obviously influenced development on the farms, 'Ivanhoe' and 'Runnymead' (outside the Area). On the other hand, poor communications and inaccessibility have largely prevented intensification on the farms 'Woodhouse', 'Normandie', 'FP 37', 'New Forest' and 'Roberts'. For this reason, the writer proposes that they be included in a 'sanctuary' area (Map 9) to be developed for recreation and wildlife. It could also be used for research purposes and water storage projects. Indigenous forests on the farm 'New Forest' provide an added attraction in this area. This proposal does not imply that the writer favours <u>total protection</u> but suggests an alternative form of land use, based on the capability of the land, that fits the <u>master plan</u> for the Area as a whole.

<u>Type 2 vleis</u>: These vleis, comprising the KILLARNEY, Emmaus and Matiwane series, require intensive conservation for safe-use. They can be used for the production of grass-clover swards but are dependent on irrigation for optimum yields. Because of severe compaction, the pastures should be used mainly for hay or silage, especially during summer. Grazing under wet conditions should be avoided. 'Ridge and furrow', together with deep tillage may allow the production of lucerne, though yields tend to decline fairly soon after establishment. Poplars

offer an alternative form of use but require careful investigation into site quality and drainage requirements. Under very special circumstances, where the safety of the vlei is beyond doubt and management is extremely efficient, occasional silage crops (e.g. maize) followed by winter cereals (e.g. ryegrass) under irrigation may be permitted between the plough-out of one pasture and the establishment of the next. The fertility status of these soils is generally high and the lime requirement low. Phosphorus and nitrogen are the main needs.

Type 3 vleis: The exceptionally high erosion hazard of this third category demands that the bottomlands remain permanently under well-managed natural vegetation. Here, the emphasis is on erosion control. Under very exceptional circumstances, including almost level slope gradients, considerable width, irrigation and efficient management, the establishment of permanent pasture or lucerne, may be permitted on the G2-association soils (e.g. RENSBURG series). 'Ridge and furrow' is recommended in such cases.

2) Catchment development

Catchment planning is a practical means of effecting programmes or projects for soil and water conservation, flood control or irrigation. One of the first essentials is to select and define the catchment or hydrological unit (de Kock, 1967). However, catchment planning has not yet been attempted in the Area and there are few instances where this approach to planning could be strongly motivated. Nevertheless, an attempt is made to indicate the major catchments and smaller units that could form the basis for catchment planning should it become widely adopted.

Objectives in planning individual catchments vary considerably. Although soil and/or water conservation are of prime concern, emphasis should also be given to reclamation where needed and to the rational selection of land-use practices (e.g. afforestation). Soil conservation, reclamation and irrigation projects are particularly important in the Mooi river catchment. In the Umgeni catchment, however, protection and development of the water resources, bottomland development and the rationalization of forestry projects should be the main objectives.

Steps in formulating the catchment plan are essentially the same as those for a farm plan (Chapter 8). Since individual farmers are concerned with the implementation of the plan, the objectives of individual farm plans should be related to those of the major project.

Two main features were considered in selecting the catchment areas. Firstly, it is desirable that the objective of the plan should apply to the entire catchment area so that all landowners work towards a common goal. Secondly, there should be reasonably uniform ecological and socio-economic conditions throughout the catchment. This, however, is not always possible where the community pattern is complex.

Map 11, on page 248(i), shows the location of the four main catchments viz., 1) Umgeni river, 2) Lions river, 3) Karkloof river and 4) Mooi river. Much of the Mooi river catchment lies outside the Area. The size of each of these catchments is less than the upper limit of 400 square miles prescribed by de Kock (1967).

The catchments are further subdivided where local conditions or problems require special planning. In some cases even smaller units may warrant consideration. Examples of these include the catchments of the Emoyeni stream in the Dargle area, the Caversham stream near Balgowan and the Yarrow stream in the Karkloof.

On a priority basis the Mooi river catchment (area 4) is the most important since soil conservation is of prime concern. Reclamation of existing erosion is urgently needed in sub-catchments 4d and 4e. The development of the irrigation potential in the latter area also deserves attention. Sub-catchment 1b should also rate highly on a priority list since it is an important catchment of the Midmar Dam. The Montrose Bantu location is situated in this area and many soils are of moderate to high erosion hazard. Pollution of the run-off water could thus become an important problem. Beautification of the landscape forming the backdrop to the dam itself should be included as one of the objectives of the plan for this area. Most of the other catchments rate equally in priority although the Karkloof catchment, with much afforestation and occasional pollution of the river, should probably receive priority over either the Umgeni or Lions river catchments. Planning Umgeni catchment area 1a should include water storage projects. A series of dams on the river and elsewhere may still prove necessary despite the conclusions reached by previous investigations. Development of the important bottomland classes in sub-catchments 1a, 2a and 4a will be of prime concern.

3) Afforestation within the Area

Afforestation is recommended in ecological areas 1b and 2a. Recently, this form of land use has become important with respect to 1) its impact on the development of other lines of agricultural production, and 2) its detrimental effect on water supplies (Nänni, 1970a). An example of the large-scale afforestation is shown in Plate 35. Side-effects include increased land values, reduced availability of farm labour and higher labour wages. Brief reference to afforestation is made since it affects planning the development of the Area. The conclusions reached by the committee appointed to investigate afforestation and water supplies in the Republic have been consulted (Dept. Forestry, 1968).

A feature of many recent plantings is the disregard for land capability and soil and water conservation. For example, it is estimated that between 30 and 50 percent of existing plantations occupy highly productive 'arable' land resulting in direct competition between timber and crop production (Plates 36 and 37). Despite the general disregard for water resources, detrimental effects of afforestation on water supplies have not yet been felt to any marked degree, except where domestic supplies have been affected. Industries and municipalities,

Plate 35. Large-scale afforestation in the Howick Extension Area.

Plate 36. Recent afforestation on valuable agricultural land in the Karkloof area.

Plate 37. Example of afforestation on high potential land (Class I) suitable for intensive crop and pasture production.

being dependent on the larger rivers and storage projects, are not likely to notice these effects.

Several recommendations, based on use-capability, are offered as a guide to planning afforestation projects within the Area. They ignore important economic issues that may well determine the future trends.

(a) There should be rational selection of land. Approximately 55 percent of ecological area lb (230 square miles), excluding indigenous forests, is deemed 'non-arable'. Much of this is suitable for afforestation though the rocky areas require pit-planting. Because of the advantages of first ploughing for establishment, afforestation could be permitted on the steeper arable classes (e.g. Classes III and IV in Chapter 7) leaving the more level areas (Class I and II) for crop production.

(b) Forestry projects should be planned catchment by catchment. In this way the need for protecting vital water resources could be determined on a priority basis and in a systematic manner. The requirements of riparian owners for primary and secondary uses should influence final recommendations. Principles to be followed in assessing catchments in terms of water-use requirements, and their classification into groups prior to prescribing management practices, have been established by Wicht (1958). Phreatic areas should, where necessary, remain unplanted. Planning must also take cognisance of existing legislation.

(c) Afforestation should be integrated with other forms of agricultural production at the farm level. Areas suitable for afforestation should be indicated by a land-use capability classification made prior to the planning phase. Afforestation projects at this level should be encouraged provided the project is economical.

(d) If the prediction that much afforestation will disapper from the 'arable' sites holds good, ways and means of reclaiming such land will require investigation. Costs of clearfelling and stumping are, at the present time, exceptionally high and may be of the order of R400 per acre. A practical method is first to fell the trees at ground level and then to establish pasture (e.g. E. curvula). The land is then brought into regular arable use once the stumps have rotted.

(e) Planning for afforestation should be part of the extension programme. One of the chief aims should be to encourage maximum water conservation by the careful selection of land and the construction of storage dams wherever possible. At the same time the programme should encourage the efficient utilization of all domestic and irrigation water since these are most likely to feel the effects of afforestation. Furthermore, the adoption of practices that will not only protect the natural resources but will prove economical should be encouraged. In this respect the advantages of short rotations should be noted (Dept. Forestry, 1968; Nänni, 1970b).

PART III

LAND CLASSIFICATION AND LAND-USE PLANNING

CHAPTER 7

LAND CLASSIFICATION FOR LAND-USE PLANNING

Productive land is a critical resource. According to Bennett (1948) good land - or lack of good land - always has been a vital factor in the progress or decline of nations and of civilizations. In the Republic there is ample evidence to indicate that this limited resource continues to be over-exploited, mismanaged and eroded. Chief cause, according to Pentz (1949), has been the application of incorrect farming systems - in essence a failure to appreciate thoroughly all the natural factors governing production. Economic pressures, too, have led to intensification of marginal land unfit for arable use. Added to this has been the failure to appreciate the importance of the soil factor in determining the potential of farm land. A principle need in the conservation programme is, therefore, to select land according to its capability and to apply systems of land-use that meet the controls imposed by nature. To this end the classification of land has much to offer.

This chapter deals with land classification as it affects the planning of individual farms. Although social and economic relationships are important in land-use planning these are considered beyond the scope of the discussion. In the development of a proposed capability classification for application in the Howick Extension Area much reliance is placed on inherent natural characteristics, especially soils, and their ecological relationships. Since the capability classification is, in effect, an interpretive grouping of soils it should be considered together with the information presented in Chapter 3.

7.1 Land classification

Land classification, as defined by Jacks (1946), is the grouping of lands according to their suitability for producing plants of economic importance. It is the systematic arrangement of different kinds of land according to those properties which determine their ability to produce permanently. Surveys of natural characteristics constitute permanent records of physical facts while land classification attempts to draw conclusions from them (i.e. scientific appraisal).

A review of literature reveals many different approaches to land classification (Albrecht, 1940; Graham, 1944; Jacks, 1946; Taylor, 1950; Kellog, 1951; Lewis, 1952; Hockensmith, 1958; Whyte & Taylor, 1958; Sirimane, 1959; Smits & Wiggers, 1959; Vincent, 1959; Thomas, 1950; Vink, 1960; Hills, 1961; Klingebiel & Montgomery, 1961; Murdoch, 1961b, 1968; Loxton, 1962b). Graham (1944) recommended that land classification should be based on natural characteristics rather than the skill of the individual operating it, or the prevailing economic conditions. On the other hand, Kellog (1951), in stressing the need to consider 'land' and 'soil' as basically different concepts, suggested limiting the term 'land classification' to one of a specially economic nature since it involves people and economics and everyday problems of production, environment and general social concerns. Classifications based on natural characteristics are generally regarded as permanent, whereas, those based on the relationship of different kinds of land to man and his industries are not. Thomas (1960) concluded that classifications should not be permanent and, since the methods of using or protecting the land change, reclassification is often inevitable.

Land classification should form the starting point of land-use planning and should be directly related to the objective of the plan. The primary objective common to all agricultural land-use plans is conservation of the soil. Secondary objectives, which may be very different, require special ad hoc systems of classification but are nevertheless dependent on the attainment of the primary objective. There is, therefore, a close relationship between the objectives of a plan, the means proposed to attain it and the system of classification. It is, however, often difficult to know where the process of land classification ends and where land-use planning begins. Land classification, starting in its simplest and most fundamental form, gradually becomes merged into land-use planning through several kinds of classification without sharp distinction between them (Jacks, 1946).

1) Alternative types of land classification

There is no such thing as a general system of land classification. Kellog (1951), in fact, regarded the search for a simple all purpose classification according to all significant characteristics and capabilities as hopeless. Five kinds of classification, beginning with natural characteristics and culminating in use-programming, are generally recognized. Although this framework has long been regarded as a theoretical objective in land-use planning, Hills (1961) claimed that there were few examples of its application where all the steps are co-ordinated on an ecological basis.

The five main types of classification are:

(i) those in terms of inherent characteristics (type 1);
(ii) those in terms of present use (type 2);
(iii) those in terms of use-capabilities (type 3);
(iv) those in terms of recommended use (type 4); and
(v) those in terms of programme effectuation (type 5).

Since each type has been discussed in detail by Jacks (1946), Lewis (1952), Hills (1961) and many others, further explanation is purposely avoided. Vink (1960, 1963), however, developed an interesting system for the Netherlands by expanding this framework. Many classification projects can be assigned to one or more of the five basic types depending on the use for which they are intended.

Types 1 and 3 are particularly relevant to this discussion. Classifications in terms of inherent characteristics (type 1) are among the most important since they form the foundation upon which all other types are superimposed. Of 75 miscellaneous projects analyzed by Jacks (1946) 68 were of, or included, this type of classification and in most cases soil was the chief characteristic studied. According to Albrecht (1940), using the soil itself provides a criterion upon which there is none more fundamental. Nevertheless, the relationship between soil and man is important since, at a price, man can change soil to a given specification (Aandahl, 1960).

With a type 3 classification there are as many use-capability classes as there are potential crops and possible methods of producing such crops. This kind of classification may also provide an indication of the probable results that will be achieved in terms of crop production and conservation if the land is put to a particular use.

2) Classification systems in current use

Many systems in current use were studied in an attempt to identify those principles basic to sound capability classifications. Several of these concerning detailed farm planning will be discussed.

The capability classification developed by the United States Soil Conservation Service is essentially an interpretive grouping of soils made primarily for agricultural purposes (Klingebiel & Montgomery, 1961). It has a definite and limited objective - the control of soil erosion - which is evidenced by the priority given to criteria such as erosion hazard and slope. Individual mapping units provide the bases for grouping soils into:

(a) capability units - soils sufficiently uniform to produce similar crop and pasture plants, requiring similar conservation treatment and management, and having comparable potential productivity,

(b) capability subclasses - capability units having the same kind of major conservation problem or limitation, and

(c) capability classes - capability subclasses or units having the same relative degree of hazard or limitation. Arable soils (Classes I to IV) and non-arable soils (Classes V to VIII) are classified according to their potentialities and limitation for the production of common cultivated crops and permanent vegetation respectively. The magnitude of risk or hazard of use increases from Class I to Class VIII.

Criteria for determining capability classes include soil characteristics (e.g. texture, depth, etc.), soil qualities (e.g. erodibility, wetness, etc.) and related features (e.g. overflow, climate, etc.). Moisture deficiency and low temperatures are important climatic limitations affecting capability. Average annual soil loss values for specific slope phases are also used to determine the capability classes. Although criteria and procedures for determining capability classes have been prescribed, final assessment is usually the result of group consultation between soil scientists, crop specialists and farmers.

The U.S. sytem has proved very valuable as a means of introducing farmers to the detailed information recorded on soil maps and, in so doing, has maximized the benefits of the co-operative soil survey programme. American experience shows, however, that the lowest units of the classification (series and phases) are the most useful (Jacks, 1946; U.S.D.A., 1954; Hockensmith, 1958; Klingebiel & Montgomery, 1961; Cook, 1962; Riecken, 1962; Klingebiel, 1963). The system has also proved useful for broad or semi-detailed planning and provided a reliable basis for a valuable inventory of land and water resources (Wadleigh & Klingebiel, 1966).

Jacks (1946) speculated that if ever a universal system of land classification were to develop it would emerge from work done in the United States. Attempts in other countries have been modelled on the U.S. system although sufficient heed has not always been given to the all-important assumptions on which the system is based. Today, with marked advances in technology and changes in economic situation and soil classification, it is possible that the capability classification has lost some of its original appeal. Revision and simplification may thus be justified.

In Rhodesia, the only radical departures from the American system lie in the procedure of the classifying exercise and the definition of the capability classes. The object in this system is to ensure sustained and economic production by classifying different kinds of land to show their most intensive safe-use, management needs and permanent hazards. The lack of pedological significance in the system, an inescapable weakness in any system designed to express hazard of use, and the use of an elaborate code, have been regarded as its major limitations (Thomas, 1960; Murdoch, 1961; Loxton, 1962b). Despite this, the approach has made a unique contribution to encouraging better and safer land use in Rhodesia (Thomas, 1959, 1960; Vincent, 1959; Fed. Dept. Con. & Ext., 1960; Vincent & Hack, 1960).

Detailed and semi-detailed planning in Swaziland is based on soil series and 'sets' of soil series respectively (Murdoch, 1961a, 1961b, 1968). Soil series ratings and slope categories, depicted by a simple two-letter tag, determine the capability classes for dryland and irrigated crops. Climatic and economic considerations are automatically accounted for in the selection of specified cropping systems. Murdoch (1968) suggested that in the U.S. system the capability unit corresponded, more or less, to a slope subdivision of each soil series. He indicated that the system was unduly restrictive with regard to slope limits. In his opinon the U.S. subclasses did not appear to serve a very useful purpose since risks could easily be spelled out by recourse to the basic unit - the soil series. Several questions posed by Murdoch (1968) probably arise because of the limited objectives of the U.S. system. Using the U.S. system, the majority of soil-slope combinations in Swaziland were classified as Class IV.

Planning procedures in the Republic have lacked a standard system of land classification. However, at a symposium held in Pretoria in 1962, it was strongly recommended that a scheme proposed by Loxton (1962a, 1962b) for the application of soil survey procedures in farm planning should be adopted throughout the country and without delay. The scheme embodied many of the Rhodesian principles but was intended only as a short-run measure until systematic soil survey became available.

Progress in the adoption of the scheme has been slow although Grobler, Edwards and Gericke (1970) have recently prescribed and applied a system for classifying arable land and natural veld in terms of productive potential and erosion hazard. In this case effective depth and permeability are used to assess the potential productivity of the arable soils. 'Permeability' is taken as an estimate of the moisture regime. Elsewhere, particularly in Natal, attention has been focussed on systematic soil survey as a prelude to pedological farm planning and sound land use.

Any attempt to apply the U.S. system in South Africa would first demand very careful study of the prescribed assumptions. Problems may also arise from the fact that the classification takes into account the feasibility of improving limitations, yet the required inputs are not indicated. Furthermore, although priorities for the subclass limitations are prescribed, it is sometimes difficult to select the preponderant limitation. For example, erosion hazard (e) takes precedence over other limitations in the classification although wetness (w) may constitute the most important factor in terms of management. In similar vein, a capability classification designed to effect erosion control will have little appeal on farms or in areas where erosion hazard is of little consequence. The grouping of soils in terms of degree of limitation may also result in differences in yield and management need being greater between soils in one class than between soils in different classes. This is viewed as an important drawback of the U.S. system.

These and other aspects will demand serious consideration if a national system of classification is to be developed. It will also require general acceptance of the series concept and the co-operative effort of selected specialists to define criteria and prescribe the procedures for moving logically from soils information to a decision on land capability.

The advantages of planning land use on the basis of individual soil mapping units, without resorting to an interpretive classification, demands careful consideration. It is the writer's opinion that these will, in the long run, outweigh those accruing to a capability classification based on hazard of use. In this respect, it would seem reaonsable to expect a farmer to comprehend from eight to ten separate items. Seldom does the number of soil series on any one farm exceed this amount. This approach will, however, require reliable interpretation of soil data, intensive in-service training for extension personnel and successful educational programmes for farmers.

The following principles for developing a capability classification are emergent from the reivew of systems in current use.

1) The objectives and the underlying assumptions should be clearly defined.

2) Classification should be based on the assessment of inherent characteristics, especially climate and permanent soil features, and not on criteria such as the skill of the operator or the prevailing economic conditions.

3) The system should be pedologically and ecologically sound. Classifications making use of empirical specifications regarding soil properties, or entirely arithmetic systems, are generally of very limited use.

4) A land capability classification should begin with well-defined soils correctly fitted in a soil classification system.

5) The lowest categories (series and phases) of the capability classification are of greatest practical use to agriculture. Progressively fewer and less precise assertations can be made with increasing categorial rank.

6) No system can meet all contingencies. A capability classification designed to effect erosion control is unlikely to satisfy the demands of other objectives. Interpretations for specific uses (e.g. suitability for crops, pasture, timber or wildlife) require a grouping that is different from that of the usual

capability classification.

7) Research data, recorded observations and experience should provide the bases for grouping soils in terms of capability. As new information about soil behaviour becomes available, or large-scale projects affecting the limitations are introduced, reclassification will be necessary.

8) Procedures for classifying land are rarely infallible since final assessment rests with the skill and judgement of the planner.

7.2 A proposed capability classification for farm conservation planning in the Area

The urgent need for improved procedures in farm planning led to the development of a simple (physical) capability classification that is based on the soils information presented in Part I. It requires that detailed soil survey precede the planning exercise and is not intended to detract from the ideal of planning land use on the basis of individual mapping units. The classification is also tested (by planning selected farms within the Area) in an effort to determine the benefits that might accrue from this form of interpretive soil grouping. The results of this are discussed in Chapter 8.

1) The need for a new approach to farm planning

Farm planning has been regarded as the basis of the nationwide conservation programme since proclamation of Soil Conservation Act No. 45 in 1946. Reviewing developments in this field, Penzhorn (1959) wrote "In hoofsaak was dit in Suid Afrika, net soos in die VSA, ook weer die gronderosie probleem wat die finale deurslag gegee het om boerderybeplanning as die basiese hulpmiddel vir die bewaring van die bodem te beskou". He also viewed the decline in soil fertility as a major factor contributing to the economic problems of farmers in the Highveld region. Today, few can deny that despite more than twenty one years of sustained effort, erosion and loss of soil fertility continue apace. Ross (1967), Rubidge (1967), Scott (1967a, 1967b) and others have stressed the lack of progress in conservation. In fact, Ross (1967) estimated the annual soil loss in the Republic during 1921, 1946 and 1966 to be 187, 300 and 400 million tons respectively. The general lack of progress and effectiveness of the conservation campaign led to the promulgation of a new Soil Conservation Act (No. 76) in 1969.

Critical analysis of farm planning procedures in the Howick Extension Area indicates that much of the failure can be attributed to the purely physical nature of the plans. Scott (1967a) noted that in the Republic much emphasis was on 'works' while the provisions of the plans were generally ignored. He emphasized that <u>the attitude with regard to farm planning requires drastic change</u>. In supporting this claim, the writer submits that the final solution lies in the adoption of planning procedures that not only integrate physical, biological and economic aspects but are also pedologically sound.

Rhodesian experience is of particular interest. Loxton, Anderssen and Feldman (1961) reported that a new system was introduced in 1955 "at a time when a state of frustration on the part of Extension Officers had been reached due to negligible progress in conservation farming and a lack of interest on the part of farmers in farm planning". A new system based on the natural fundamentals of land use and incorporating detailed soil investigation met with immediate success. The enthusiasm, characteristic of the Rhodesian extension services, was attributed to:

1) the thoroughness of the planning exercise,
2) the high standard of in-service training, and
3) the strongly developed co-ordination of effort between pedologists, agricultural specialists and research workers.

It would be wise to keep these lessons in mind.

Assessment of the farmer himself is frequently neglected during the planning phase. His resources and skills, his personal goals and even his age, are factors to be considered. Attending to such matters is part of the required thoroughness of the planning exercise. Furthermore, much can be said for efficient and regular in-service training especially with regard to the pedological aspects. In this respect, it is necessary to heed the wisdom of Orchard (1964) who stated that if the success of the extension service is to be measured by the soundness of the farm plans the agricultural community can be persuaded to adopt, then clearly both the planning officer and the farmer must know something about the soil.

The profit motive of conservation farming should be embodied in the new approach. Kolbe (1967) stressed the need to motivate farmers and to provide the correct incentive for conservation measures of a long term nature. He considered the low profitability of efficient conservation as explanation for the modest progress in this field. Scott (1967a) has urged that the economic advantages of applying conservation practices should be iterated and reiterated until generally accepted. Although few facts are readily available for this purpose, the profitability of conservation farming was proved beyond doubt by Penzhorn (1959) in a study of two farms. He stated, "Die uitstekende finansiële sukses met die twee voorbeelde van werklik beplande plase behaal, lewer 'n bewys dat die stelling deur skrywer alreeds herhaaldelik gemaak en waaraan hy vas glo, t.w. dat 'bewaringsboerdery betaal' wel deur genoemde voorbeelde en talle ander, aan skrywer bekend, gestaaf word". Furthermore, Pearson (1967) reported that planned conservation layouts on sugar cane farms resulted in a measured 12 percent increase in annual sugar production. It is examples such as these that must be 'iterated and reiterated'.

2) Objectives, assumptions and nature of the proposed capability classification

The primary objective of the proposed classification, as in most other systems, is to ensure sustained productivity and maximum conservation. The classification, being based on systematic soil survey, is intended to emphasize the production aspects of land-use planning and in this way encourage a more positive approach to soil conservation. In effect the classification is a systematic arrangement of soils according to their capability to produce adapted dryland crops on a sustained basis.

By considering the proposed land capability classes the farmer will be forewarned of where the potential of his farm lies and where not to develop unrewarding land unless forced to. He can then turn to the details of his soil map and select land-use practices to fit the needs of each soil. This introduction to the detailed soils information could be an important advantage of the system. The classification is also designed to restrict land-use practices such as intensive crop production or afforestation to specific classes of land and so permit a more rational approach towards agricultural development.

The following assumptions are made:

1) land capability is determined mainly by the collective effects of climate and permanent soil features;
2) economic considerations such as proximity of markets or resources of the farmer influence final recommendations for land use but are not criteria for classifying land;
3) soils can be used for different purposes;
4) capability groupings will alter as new information about soil behaviour becomes available;
5) the climate of the Area is not too restrictive to permit the regular production of most crops;
6) soils are classified in terms of their inherent characteristics ignoring the feasibility of correcting permanent limitations except in the case of low plant nutrient status;
7) a 'good average' level of management will be applied; and
8) soils are not necessarily grouped according to their productivity or suitability for specific crops.

Since erosion control is one of the main objectives of the classification, the significance of soil damage by erosion is emphasized. Important aspects noted by Klingebiel and Montgomery (1961) are that:

(a) soil depth should be maintained for satisfactory crop production, especially among shallow soils overlying non-renewable substrata (e.g. claypan soils),

(b) soil and nutrient losses result in reduced crop yields and costs for replacement of nutrients and maintenance of yield are higher,

(c) the physical condition of the plough layer may become altered and where gullies have formed these may hinder the use of farm machinery,

and that

(d) soil loss and silt deposition increases the problem and cost of maintaining anti-erosion works and other structures.

3) Ecological and pedological significance

Hills (1961) stressed that land is not well classified until full knowledge of all natural characteristics and their ecological inter-relationships are to hand and their significance in land management is considered. For similar reasons, the proposed classification should be considered together with the pedo-ecological areas (groups I, II and III) defined in Chapter 5. The capability classes are standard for all ecological areas although there is no uniformity in their recommended use and management. Thus, a single capability class does not necessarily have the same use-suitability or agricultural potential in different ecological areas. In farm planning it is essential first to identify the ecological area in which the farm is situated.

Ideally, a system of classification should have pedological significance. This, according to Thomas (1960), is based on the pedological method of considering soil as an organismic whole while the pedological significance of the units depends on their homogeneity in respect of characteristics most closely related to the pedogenic processes. To avoid fallacious views on the proposed system explanation of this aspect is necessary.

The mapping units obviously meet the requirements for pedological significance since they comprise defined soil series. However, this significance is partially lost at the class level where the grouping of soils is strongly influenced by their degree of hazard in use and not the reasons for hazard. Since the factors governing hazard of use are seldom the same as those determining productivity, the capability classes cannot be expected to reflect inherent productivity clearly. Despite this an attempt has been made to keep the heterogeneity of classes with respect to soil features to a minimum. Because of the pedological significance of the mapping units, detailed recommendations for land use should be made at this level.

4) <u>The capability grouping</u>

The capability grouping indicates the relative suitability of the land for agricultural uses. Classification starts with the individual mapping units and proceeds through management groups (Chapter 3) to capability classes which, in turn, are related to higher categories. The categories of the classification are:

(i) <u>Soil mapping units</u>: Soil series, or phases thereof, form the mapping units. They provide the most detailed information and permit the most accurate predictions of soil behaviour and crop yield to be made. Slope and depth are two important characteristics that vary within the soil series and, since they are directly related to hazard of use, their importance should be recognized at the phase level. In mapping the soils all relevant information is recorded by means of a fraction where the numerator refers to the soil series, or phase, and the denominator the characteristics of slope and effective depth. Suggested symbols for the slope and depth classes are presented in section 6 to follow and Appendix 10 respectively. By way of example, the humic phase of the GRIFFIN series (B1-4h), on a slope of 3 to 8 percent (B) and 36 to 60 inches deep (2) would be recorded as:

$$\frac{\text{B1-4h}}{\text{B-2}}$$

(ii) Soil management groups: Soil management groups discussed in Chapter 3 constitute the inital grouping. They comprise groups of one or more individual mapping units having similar yield potential, limitations and management needs and are indicated by symbols representing either soil associations (B1a, B1b, etc.) or soil forms (e.g. HUTTON - H1, H2, etc.). The main criteria for grouping at this level include effective depth, drainage, texture and erosion hazard. In effect, the soil management groups simplify the detailed soil information and are assembled directly into capability classes. No attempt is made to group soils in terms of their overriding kind of limitation as is done in the U.S. system (e.g. subclasses). However, the term 'subclass' is used where land within a single class requires special treatment or where unique conditions prevail. These are usually related to bottomlands where considerable variation in texture and drainage conditions may occur. Indigenous forests occupying upland protected classes are treated in this manner because of their special needs (Appendix 16).

(iii) Capability classes: Capability classes group soils with similar agricultural potential and management requirements for safe-use. The degree to which natural features limit potential, or cause risk of damage, influences the grouping at this level. Although the management problems and limitations may be of the same degree they may be of different kinds. Thus, capability classes can provide information of only a very general nature and lack sufficient detail for specific recommendations about soil management to be made.

Unlike most other systems the capability classes are separated into two groups at the highest level, viz., upland and bottomland classes. For the sake of simplicity Roman numerals are used to designate seven upland classes (I to VII) and three bottomland classes (Ib, Vb & VIIb). Agricultural potential decreases and hazard of use increases from Class I to Class VII and from Class Ib to Class VIIb.

(iv) Land capability divisions: Land capability divisions apply to both uplands and bottomlands. This broad grouping is introduced to indicate general suitability for regular arable use. Main criteria for distinguishing between divisions include slope, rockiness, effective depth and erosion hazard. Definition is based on local interpretation as to what constitutes 'arable' or 'non-arable' land and assumes the use of normal farm machinery. Three divisions are defined, viz.:

1) land suitable for arable use,
2) land unsuitable for arable use but generally suitable for forestry or grazing, and
3) land rendered unsuitable for cultivation, grazing or afforestation by severe limitations and the need for 'protection'. Such land is suitable only for wildlife, recreation, water conservation or aesthetic purposes.

(v) Landscape position: In this, the highest category, the classification differs radically from most other systems. It is an entirely natural grouping separating uplands from bottomlands. These two classes of land differ so markedly in potential, hazard of use and management need that subdivision at this level is considered justified. Uplands and bottomlands are defined in Chapter 1.

The highest categories of the capability classification are shown in Table 52.

5) Definition of capability classes

Detailed definitions of the capability classes are presented in

Table 52 : Categories of the proposed land capability classification for the Howick Extension Area

Landscape position	Land capability division	Land capability classes
Uplands	Arable	I II III IV
	Non-arable	V VI
	Protected	VII
Bottomlands	Arable	Ib
	Non-arable	Vb
	Protected	VIIb

Appendix 16 and examples of each are illustrated by Plates 38 to 49.

The following are brief definitions of the upland and bottomland classes:

UPLAND CLASSES

Arable classes:

Class I Land of very high potential for intensive arable use with few permanent limitations, very low erosion hazard and having a wide range of alternative uses.

Class II Land of high potential for intensive arable use, slight limitations and requiring easily applied conservation practices for safe use.

Class III Land of moderate potential for arable use with moderate limitations and requiring special conservation practices for safe use. Choice of alternative uses is restricted.

Class IV Land of low potential for arable use with severe limitations and requiring the rigid application of intensive conservation practices for safe use. Choice of alternative uses is greatly restricted by the limitations.

Non-arable classes:

Class V Land suitable for the production of either natural or established perennial vegetation. With adequate protection it can be tilled for the purpose of establishment.

Plate 38. Class I land has very high potential for intensive arable use, very few limitations and is suitable for a wide range of alternative uses.

Plate 39. Class II land has high potential for intensive arable use but requires easily applied conservation practices for safe use.

Plate 40. Class III land has moderate potential for arable use and requires special conservation practices. (Trees in left hand photo are on Class VI land i.e rocky outcrop)


Plate 41. Class IV has low potential for regular arable use and requires the rigid application of intensive conservation measures for safe use. Limitations such as slope are severe.


Plate 42 Class V land is non arable and should remain under permanent vegetation, either natural or established pasture including veld reinforcement. Hazard of use is high as a result of severe limitations of slope and unfavourable soil conditions.


Plate 43. Class VI land has severe limitations that restrict its use to natural vegetation for grazing purposes or afforestation.

Plate 44. Class VII (upland protected class) has little or no value for arable use, grazing or afforestation and requires total protection. Eroded areas (right) should be withdrawn from grazing.

Plate 45. Class Ib (bottomland arable class) land comprises deep alluvial soils of high potential arable use but is subject to periodic over-flow.

Plate 46. Class Vb (bottomland non-arable class) comprises hydromorphic 'vlei' soils requiring special treatment.

Class VI   Land of such severe limitations that its use is restricted to the production of natural vegetation for grazing or afforestation (pit-planted).

Protected class:

Class VII   Land of little or no value for arable use, grazing or afforestation. Owing to very severe limitations or special needs it requires total protection but may be used for wild-life or recreation.

BOTTOMLAND CLASSES

Arable class:

Class Ib   Land comprising deep, alluvial soils of high potential for the production of crops, pastures and/or trees.

Non-arable class:

Class Vb   Land comprising the hydromorphic 'vlei' soils with unique management requirements. Under special conditions the production of permanent pasturage may be permitted.

Protected class:

Class VIIb   Bottomlands requiring total protection. Owing to severe limitations or special needs they require to be left in a natural state but may be suitable for wildlife or recreation.

6)   Determination of capability classes

The problem in determining capability classes is to ensure a reasonable standard of uniformity. In the United States and Rhodesia this has been achieved by specifying criteria and standard procedures. According to Thomas (1960) such practice is generally unavoidably elaborate and 'inevitably over-rigid'.

In the proposed classification, the writer has refrained from prescribing definite criteria or minimum standards for each class. This is due, in part, to the general lack of research data relating to rainfall-erosion losses and potential productivity and, in part, to a desire for flexibility in the classifying exercise. Assessment of the effects of many combinations of criteria such as permanent soil features, climate and slope requires much experience and local knowledge. For this reason, considerable reliance is placed on the judgement of the planner. He must approach his task with an open mind and have the ability to upgrade or downgrade a class where necessary. Adjustments of this nature may be required where the level of management is very different from the accepted norm. Such refinement should, however, be a 'mental adjustment not for publication' (Murdoch, 1961). Although the lack of standard criteria does not favour routine checking it is suggested that obvious anomalies will be avoided if data relating to soil series, effective depth, slope and ecological area are accurately recorded.

Since the effect of soil properties varies widely with climate, soil criteria should be prescribed for areas of similar climate. Climate itself, especially limitations of moisture deficiency, short growing season or conditions such as high wind velocity, requires careful consideration. Data of actual and potential evaporation and temperature are important in the determination of land capability and for this reason, much emphasis is given to the EPI values and climatic sub-regions defined in Chapter 5.

(i) Determination of upland arable classes: Within defined ecological areas upland arable classes are determined on the bases of soil ratings (Table 28), individual soil properties (Appendix 9) and slope. However, the relative importance of soil properties should be noted. Available moisture capacity or drainage, for instance, may determine productiveness while slope and erodibility have little direct influence on it, at least, temporarily. In the proposed classification texture and slope take precedence over most other properties since much emphasis is given to the 'safe-use' of the land. Inherent plant nutrient status does not influence the classification of upland arable classes except where the concentration of toxic salts may be so high as to render the land 'non-arable'.

In the absence of critical research data, tentative slope groups for each of the ecological areas are suggested. These limits will, however, require progressive refinement with experience. Table 53 indicates the proposed slope groups.

Table 53 : Slope groups and limits (%) for determining upland capability classes

Slope group	Ecological group (Chapter 5)			General description
	1	2	3	
	%	%	%	
A	0-3	0-3	0-2	Level to nearly level
B	3-8	3-7	3-5	Gently sloping to undulating
C	8-15	7-12	5-8	Strongly sloping
D	15-20	12-20	8-15	Moderately steep and hilly
E	> 20	> 20	> 15	Steep and very hilly

For obvious reasons this first approximation is somewhat conservative. The upper limit for arable classes is set at slope group C which, by comparison to some countries, is particularly stringent. According to Murdoch (1961, 1968) gradients of 20 percent are cultivated in Swaziland and yet the soils are conserved. Similar examples are also to be found in the Area, especially among the highly leached soils, but limits of this nature cannot be recommended in view of the current level of technology.

A guide to the permissible slope groups for each arable class is given in the detailed class definitions (Appendix 16). Although consideration is given only to slope 'steepness' the relationship between slope 'length' and erodibility is of equal importance. This feature is, however, normally accounted for in prescribing recommended erosion control measures.

Table 54 presents a general guide for determining the upland arable classes in defined ecological areas. Important soil and land characteristics of each class, together with examples of soil management groups and series, are indicated. A note is also made of possible variations in depth within series where these influence the classification.

Table 54 : Guide for determining upland arable capability classes

Land and soil characteristics					Examples of management groups and soil series					
Capability class	Slope group	Soil depth and texture[1]	Other characteristics (level phase)	Soil rating	Ecological group 1		Ecological group 2		Ecological group 3	
					Management group	Soil series	Management group	Soil series	Management group	Soil series
I	A	Deep (>36"), clayey and clay loam soils (a and b)	Well drained, very high to high available moisture capacity, no mechanical limitations and very low erosion hazard	1-2	A1 A2 B1a	BALMORAL Broadmoor FARMHILL	D1a E1c E1d	VIMY BERGVILLE AVALON	D1c E1c E1d G2a	Bellevue BERGVILLE AVALON KIORA
II	A	Mod. shallow (20"-36") clayey and clay loam soils (a and b) or deep loamy soils (c)	Well-drained to mod. well-drained, high available moisture capacity, slight mechanical limitation and low erosion hazard	2-3	A1) mod.shallow A2) (20"-36") B1a) B1b B1h B2a B2b (deep > 36")	FARNINGHAM HUTTON GRIFFIN CLOVELLY Humic phase CLEVELAND OATSDALE	D1a) mod.shallow (20"-36") D1b E1a E1b E1c) mod.shallow E1d) (20"-36") E3b	DOVETON MSINGA NEWPORT SOUTHWOLD BERGVILLE AVALON Melrose	D1c} mod.shallow (20"-36") D2a E1g E1h E3b G2b G2c	Bellevue Jagersdrift Majuba Frere Melrose ARCADIA RENSBURG
	B	Deep clayey soils (a)		1-2	As for Class I	-	As for Class I (exclude loamy soils)	-	As for Class I (exclude loamy soils)	-
III	A	Shallow (10"-20") clayey soils (a) or mod. shallow (20"-36" clay loam (b) and loamy (c) soils or deep (>36") sandy soils (d)	Mod. well-drained to somewhat poorly or excessively drained, mod. available moisture capacity, mod. mechanical limitations and mod. erosion hazard	3-4	A1) shallow B1b) (10"-20") B1c A2) mod.shallow B2a) (20"-36") B2b	FARNINGHAM CLOVELLY MISPAH (clayey) HUTTON CLEVELAND OATSDALE		DOVETON ARROCHAR WINTERTON ALBANY SPRINGFIELD LEKSAND GLENCOE WESSELSNEK	D1c} shallow (10"-20") E1c} mod.shallow (20"-36") E6a E6b E3b} mod.shallow (20"-36") E5a} mod.shallow (20"-36") G2b} shallow (10"-20")	Bellevue ARROCHAR WINTERTON ALBANY LEKSAND GLENCOE ARCADIA
	B	Mod. shallow (20"-36") clayey soils (a) or deep (>36") loamy soils		2-3	As for Class II level phase		As for Class II level phase		As for Class II level phase	
	C	Deep (>36") clayey soils (a)		1-2	As for Class I but exclude loamy soils of A2 management group		As for Class I - exclude loamy soils		As for Class I - exclude loamy soils	
IV	A	Very shallow clayey soils (a) or shallow (10"-20") clay loam soils (b) or Mod. shallow (20"-36") loamy soils (c) or deep (>36") sandy soils (d)	Poorly or excessively drained, low available moisture capacity, severe mechanical limitations and high to very high erosion hazard	4-5	B1c) very shallow) phase A2) shallow B2b) (10"-20") B2c	MISPAH (clayey) HUTTON OATSDALE MISPAH (clayey)		ARROCHAR WINTERTON ALBANY LONGLANDS SPRINGFIELD GLENCOE WESSELSNEK WARRICK WASBANK MISPAH (clayey)	Include management groups as for Ecological group 2 but allowance to be made for more severe moisture limitations F1a F1b G2a shallow(10"-20")	ESTCOURT[2] BLUEBANK[2] UMLAAS
	B	Shallow (10"-20") clayey soils (a) or mod. shallow (20"-36") clay loam soils (b) or deep (>36" loamy soils (c)		3-4	As for Class III level phase		As for Class III level phase		As for Class III level phase	
	C	Mod. hallow (20"-36" clayey soils (a) or deep (>36") clay loam soils (b)		2-3	As for Class II leval phase (exclude shallow sandy soils)		As for Class II level phase (exclude shallow sandy soils)		As for Class II level phase (exclude shallow sandy soils)	

1 Textural classes: (a) Clay > 35%, sand < 50%; (b) Clay 15-35%, sand > 50%; (c) Clay 15-35%, sand > 65%; (d) clay < 15%, sand > 65%
2 Claypan soils included in arable classes only under special conditions

The higher capability of the highly leached soils is a result of their more favourable physical characteristics and low erosion hazard. It will be noted that within a particular class the slope group is arranged inversely to soil characteristics contributing most to erodibility. Thus, cultivation is permitted on relatively steep slopes provided erosion hazard of the soils is low. The permissible depth classes prescribed for the highly leached soils are possibly over-stringent since the limiting material, usually shale, is often highly weathered and hence permeable.

An alternative means for determining land capability classes was adopted by Murdoch (1961) and has the advantage of simplicity. In this method, slope is regarded as the chief variable within the series that affects land capability. Classes are determined by combining soil series ratings and slope groups.

Using this approach a further guide to the determination of arable classes is presented in Table 55 overleaf. The relationship between agricultural ratings (Table 28) and slope groups is clearly indicated. Since soils similarly rated may have slightly different textural characteristics an indication of the influence of texture on the capability assessment is also given. Soils are generally downgraded as texture becomes lighter and slopes steeper. Although this method provides a satisfactory guide to capability classes it holds the danger of oversimplifying many complex relationships.

(ii) Determination of upland non-arable and protected classes:

Definitions of the upland non-arable classes are sufficiently detailed to permit their satisfactory determination. Slope and rockiness are the main criteria for establishing these classes although soil properties affecting hazard of use are important where slope gradients do not exceed group C. The need for detailed soil investigation within these classes depends upon the objectives of the plan. A forestry project, for instance, requires detailed soil investigation to establish soil depth and moisture holding capacity. Since soils also influence the

Table 55 : An alternative guide to upland arable capability classes as determined by soil ratings and slope groups

Soil rating	Slope group A	Slope group B	Slope group C
	Ecological group 1		
	0-3%	3-8%	8-15%
1	I	II	III
2	I	II	a) III, b) IV
4	II	III	a) IV
4	II	a) III, b) IV	IV
5	III	IV	—
	Ecological group 2		
	0-3%	3-7%	7-12%
1	I	II	III
2	I	II	a) III, b) IV
3	II	b) III, c) IV	a) IV
4	III	b) IV	—
5	IV	—	
	Ecological group 3		
	0-2%	2-5%	5-8%
1	I	II	III
2	II	III	IV
3	III	IV	—
4	IV	—	—
5	(IV)*	—	—

Textural classes:
(a) Soils with over 35% clay and less than 50% sand
(b) Soils with 15-35% clay and over 50% sand
(c) Soils with over 65% sand

* require special treatment

palability of the natural sward and thus the layout of the fences, accurate determination of soil boundaries for this purpose may be warranted. The same applies where veld reinforcement is contemplated.

Protected classes rarely require detailed investigation and are determined simply by assessing the severity of inherent limitations such as steepness of slope, rockiness, erosion hazard and the need for permanent withdrawal from use or for special protection.

(iii) <u>Determination of bottomland classes:</u> Bottomland classes are determined in accordance with their definition but the accurate identification of the soil series is essential. Arable and non-arable classes are distinguished on this basis. However, complex soil patterns within a bottomland may sometimes render class determination difficult.

7) Recommended use and management of land capability classes

Recommendations at the class level are of a very general nature and are primarily concerned with erosion control. They differ between ecological areas and, in certain cases, may be influenced by economic considerations and personal issues affecting the farmer. In this discussion a brief indication is given of important management practices to be considered in making use-recommendations.

(i) Upland arable classes: Organic matter, in its many forms, has considerable influence on soil productivity and erodibility. Nathanson (1963), in reviewing Jenny's concept of organic matter constants and other studies, stressed the need to determine the extent to which the content of organic matter may be allowed to vary with safety. Despite several studies and reports on conditions specific to South Africa no serious attempt has been made to relate cropping sequence to organic matter status (Theron & van Wyk, 1933; Theron & Haylett, 1953; Theron, 1955, 1957a, 1956b; Haylett, 1959; Penzhorn, 1962; Fuls, 1967). Nevertheless, the rapidity with which organic matter content of soils within the Area is reduced by cultivation is striking.

According to Wischmeier (1962) knowledge of expected soil loss from fields is particularly helpful in effecting erosion control within safe limits. In Rhodesia, for example, the accepted permissible soil loss values for sandy and clayey soils are four and three tons per acre per annum respectively (Vincent & Hack, 1960). Neither organic matter constants nor predicted soil loss values can, however, be used in the Republic because of insufficient experimentation. Recommendations must, therefore, rely almost entirely on assessment of soil properties and observation in the field and should take cognisance of the relationship between productivity level and soil loss. Generally, soil losses decrease as crop yields increase (U.S.D.A., 1965).

Attention is drawn to the following erosion-control practices since they affect recommendations for use and management of the upland arable classes.

Crop rotations, including well-fertilized leys and legume crops, are widely accepted as a means of improving the stability and productivity of arable soils. Although finding little quantitative evidence of the direct effects of rotations on soil loss and productivity, Nathanson (1963) concluded that rotations, especially those including legumes, were sound agronomic practice. Studies in Natal provide no clear directive as to the safest cropping system, the optimum period under ley or the maximum permissible period under row crop for any of the defined soil series. Hildyard (1959), however, reported an increase in amount of water stable aggregates and in the yield of maize following a period under ley. The increase in yield was noticeable for up to three years after the ley was ploughed out. E.curvula proved to be a highly effective ley crop.

Theron (1957a) recommended a minimum period under ley of three to four years and Penzhorn (1959) suggested that the period and extent of the leys should be determined for each soil. Recommended periods for clayey, sandy and very sandy soils were three and nine years, six and nine years, and six and six years respectively. A method for calculating the period of ley and row crop has been prescribed by Grobler et al. (1970) and is based on the assumption that soil formation progresses at a rate of 5 tons per morgen per annum. However, this rate is unlikely to hold for soils such as the ESTCOURT series.

For the upland arable classes it is obvious that the period and extent under ley should increase progressively with increase in hazard of use, i.e. Class I to Class IV. In general, it is suggested that for Classes I and II less than 50 percent of the area need be under ley. A policy of 'long term ley-short term cropping' is recommended for Classes III and IV. Although crop rotations are generally recommended for all arable classes, continuous cropping is no longer the evil it was once thought to be (Cook, 1962). Intensive monoculture can, in fact, be most effective in maintaining organic matter status and reducing soil loss under conditions of high fertilization, high population densities and the return of all crop residues to the soil (Melsted, 1954; Hudson & Jackson, 1959; Saunder, 1959). Under these conditions continuous cropping could be permitted on all Class I land provided adequate precautions are taken against root rot and other diseases.

Crop rotation should provide effective conservation and be profitable for the farmer. However, the most profitable crops grown in the Area are generally the least protective, especially early in the season. Although over 25 percent of the arable land in the Area is usually sown to pasture or ley crops little, if any, attention is given to land capability when the rotation is planned.

The choice of leys will differ for each ecological area. E.curvula has, however, indicated a wide range of adaptability in the Area and is strongly recommended for most conditions. Despite this, there is a need to find a suitable legume crop for use on the partially leached soils, especially those of the El-association. Here the production of rainfed clover is generally unsuccessful and lucerne and/or subtropical legumes may become important.

Strip cropping, or the arrangement of alternative crops preferably on the contour at right angles to the natural slope, can be recommended for all arable classes but is not popular in the Area. Neither is it as effective as mechanical measures that divide the slope into segments. Sod strips should occupy at least 50 percent of the arable area (Cook, 1962).

Crop residue management includes many practices influencing soil loss and is required on all classes of land. Crop residues are most effective when left at the surface but will also reduce run-off and soil loss, especially during the seedling stage, when incorporated (U.S.D.A., 1965). A residue blanket at the surface is recommended for Class I land where continuous cropping is practised.

Green manuring is not generally recommended for any of the arable classes since studies in South Africa suggest that although the practice, especially with legumes, may enhance the mobilization of certain nutrients and may increase the yield of subsequent crops, it cannot be economically justified (Sherbaloff, 1949; Nathanson, 1963).

Tillage practices are important for soil and moisture conservation no matter what the class of land. They deserve special consideration in ecological groups 2 and 3 where moisture conservation and erosion are particularly important. Among the highly leached soils the relationship between primary tillage and efficient amelioration with lime also requires attention. Special note is made of 'no-tillage' and mulching techniques, especially for the production of maize. Although no relevant research data are available for local conditions it is predicted that these methods could become particularly important, especially on sloping land (slope groups B and C). Loss of soil and water resulting from conventional tillage can be greatly reduced by these methods. Investigation should, therefore, be initiated on both highly and considerably leached soils (no-tillage) where maize is rotated with ley crops, and selected moderately leached soils (mulching).

Mechanical erosion control measures are complementary to biological practices. They are most needed on arable Classes III and IV where steep slopes and soils of high erosion hazard predominate. Generally, contour tillage, together with efficient agronomic practice, is sufficient for the adequate protection of Class I land. More stringent measures, including a variety of conservation structures are, however, needed for the protection of all other arable classes. Since construction and maintenance of these structures become progressively more difficult with increasing slope steepness, greater emphasis should be placed on the use of leys for the protection of strongly sloping land.

Continued development of mechanization and increased costs of production will undoubtedly alter the approach to customary mechanical control measures. In this respect is is doubtful whether farmers will always tolerate the inconvenience imposed by some of these methods (e.g. point rows). Continuous cash cropping and straighter rows, even on steep slopes are likely to become common practice. If this prediction is correct mechanical protection methods for the upland arable classes will require modification.

(ii) Upland non-arable classes: Use and management recommendations for the upland non-arable classes are not as complex as those for the arable classes. Recommended use is restricted to grazing by livestock, afforestation or perhaps plantation crops. The three methods of improving veld proposed by Edwards (1966) are particularly relevant to recommendations for these classes. Veld management is of major concern in ecological group 3 for both Classes V and VI and for Class VI in ecological group 2. Veld reinforcement is seen as a special practice for Class V land in ecological group 2 and possibly Class VI in ecological group 1. The latter is speculative since Edwards (1966) concluded that veld reinforcement was of little promise in the Highland Sourveld. Veld replacement has a major role to play on Class V land in ecological group 1 and could be important even on Class VI land. Edwards (1966), however, did not attempt sod-seeding which has recently received much attention (Krog & Theron, 1969; Graven & Theron, 1969; Theron & Cross, 1969). Sod-seeding is seen as an alternative form of management especially on Class V land in ecological groups 1 and 2.

(iii) Upland protected classes: The use and management of upland protected classes depends upon the reasons for protection. Much land included in this class is severely eroded and requires reclamation. In ecological groups 2 and 3 it is suggested that greater attention should be given to the use of well-fertilized *Cynodon dactylon* for this purpose. The natural vegetation of the protected classes should also be maintained in a vigorous condition by applying practices such as judicious burning or, where forests are to be protected, the exclusion of fire. However, light grazing by game species could be permitted.

(iv) Bottomland classes: Recommendations for bottomland arable, non-arable and protected classes are almost entirely dependent on the management needs of the individual soil series. Those relating to the hydromorphic vlei soils are particularly important. Generally, the use of Class Vb land in ecological groups 1 and 2 should be restricted to the production of permanent pastures for which land improvement techniques are required (Chapter 6). In ecological group 3 this land should remain under natural vegetation. No matter what the ecological group or the capability class, utilization of all bottomlands requires management of the highest order.

General recommendations for use and management of all land capability classes are summarized in Table 56.

Table 56 : Recommended use and management of land capability classes

Capability division	Capability class	Ecological group	Recommended use	Management practices: Agronomic practices[1]	Management practices: Supporting conservation practices	Remarks
Upland arable classes	I	1	Very intensive production of wide variety of adapted crops under rainfed conditions or irrigation (sprinkler and flood).	Continuous cropping permissible with residue management of high order. Rotations with short term ley and legume crops preferable.	Ordinary good farming practice, including contour tillage, sufficient for safe use.	Population density important. For maize exceed 15,000 plants/acre. Short growth period and very low plant nutrient status of soils are main limitations.
		2	As above with crops of maize, sorghums and lucerne important. Intensive production of clover-based pastures and winter fodder requires irrigation. Supplementary irrigation desirable.	As above. Residue management and tillage required to conserve organic matter and moisture.	As above.	Maize population of 15,000 plants/acre recommended. Crops to be carefully selected for soils indicating hydromorphism. Low plant nutrient status and moisture deficiency are main limitations.
		3	Crop production under rainfed conditions should include drought resistant varieties. Irrigation highly desirable.	As above.	As above.	Production of crops under rainfed conditions somewhat hazardous owing to droughty conditions.
	II	1	As for class I. Sprinkler irrigation preferable.	Rotations to include leys of moderate duration. Strip cropping and residue management recommended.	Easily applied practices, including contour tillage and broad based terraces, required for safe use.	Humic phase soils require longer period under ley than under crops. Limitations as for class I but with increased erosion hazard.
		2	As for class I but with greater emphasis on cover crops.	As above but with application of tillage and agronomic practices designed to conserve moisture.	As above but reqiring greater emphasis on mechanical control measures especially for E1-association soils on sloping land.	Certain soils may require simple drainage techniques to reduce drainage limitation to a minimum. Limitations as for class I but include problems of impeded drainage and erosion hazard.
		3	As for class I. Specialized crops e.g. cotton may be grown on margalitic soils with irrigation.	As above.	As above.	Droughtiness and erosion hazard main limitations. Mechanical limitation of stones must be easily removed.
	III	1	Annual cash crops to be kept to a minimum. Leys, pastures and timber recommended. Sprinkler irrigation feasible but costly.	Rotation to include leys of long duration. Agronomic practice and tillage to be of high order during cropping period. Minimum tillage recommended.	Intensive mechanical control measures e.g. contour ridges required for safe use on sloping land.	Limitations include increased erosion hazard, especially on shallow, loamy soils, and low plant nutrient status.
		2	Long duration leys (e.g. E.curvula or Rhodes grass) generally recommended. Hardier Pinus spp. can be grown on selected sites. Irrigation not generally recommended.	As above with greater emphasis on deep tillage and subsoiling, especially on grey-brown soils. Minimum tillage to avoid compaction advantageous.	As above. Drainage may be required for certain poorly drained soils.	In addition to high erosion hazard, alternating periods of drought and waterlogging are important limitations. Poor physical condition of soils and steep slopes will determine recommended practices.
		3	As above but excluding afforestation.	As above.	As above.	Major limitations as above. Additional hazard of stones may be costly to remove.
	IV	1	Short periods of annual cropping preferably confined to cover or broadcast crops. Timber recommended for steeper slopes. Sprinkler irrigation recommended owing to high installation costs.	Rotation to include cropping periods of very short duration (1-2 years). Agronomic and tillage practices of high order to be rigidly applied.	Very intensive mechanical and biological measures required. Safe disposal of run-off water, especially important.	Very high erosion hazard and low plant nutrient status main limitations.
		2	As above with afforestation confined to hardier species.	As above with special emphasis on tillage requirements.	As above with additional drainage for certain soils.	Shallow E3- and E5-association soils should preferably remain under permanent cover.
		3	As above but excluding afforestation.	As above. Subsoiling of claypan soils not recommended.	As above. Conservation layout for safe disposal of run-off important.	Claypan soils included only under special conditions. Cost of removing stones will be high.
Upland non-arable classes	V	1	Veld replacement by permanent pasture (e.g. kikuyu), timber and/or orchard crops recommended.	Agronomic practice and tillage to ensure rapid establishment of pasture swards.	Mechanical control measures may be required during establishment period. Road layout in plantations to be carefully planned.	Slope steepness, shallow depth and high erosion hazard main limitations. Land subject to overflow but not typically bottomland included if erosion hazard low, e.g. established waterways.
		2	Land best left under natural vegetation but veld reinforcement permissible on suitable soils Hardier Pinus spp. can be grown. Mow for hay.	—	Sod-seeding to be on contour. Veld management, layout of fences and stock-watering points especially important.	As above.

Table 56 contd

Capability division	Capability class	Ecological group	Recommended use	Management practices: Agronomic practices[1]	Management practices: Supporting conservation practices	Remarks
Upland non-arable classes	V	3	Use natural vegetation for grazing and manage to improve grassland. Thorntree eradication often justified. Mow for hay.	—	Veld management to be of high order.	Clay pan soils included where slopes exceed group A.
	VI	1	Leave under natural grassland or plant trees (pit-planted). Veld reinforcement may be possible on suitable terrain.	—	Correct veld management, layout of camp fences and stockwatering most essential.	Land temporarily withdrawn from cultivation or very uneven land to be included. Rock outcrops are common.
		2	Land to be left under natural grassland for grazing purposes.	—	As above.	As above but including land with abundant termite mounds.
		3	As above.	—	As above	As above and including land with severe thorntree encroachment.
Upland protected class	VII	1-3	Land requires total protection but may be suitable for wildlife and recreation.	—	Special management practices for controlling natural vegetation and erosion may be necessary. Indigenous forests require protection from fire, grazing and exploitation.	Severely eroded land requiring permanent withdrawal from use or land requiring special protection (e.g. forests) to be included. <u>Cynodon dactylon</u> recommended for reclamation of eroded areas in drier parts. Also include miscellaneous land classes such as stream banks, road reserves, etc.
Bottom-land arable class	Ib	1	Well-drained and mod. well-drained soils suitable for intensive production of crops, fodder, pastures or poplars. Poorly drained soils best for pasture. Irrigation recommended.	Rotation with leys beneficial. Residue management important. Ensure protective plant cover for flood period.	Protect against flood damage. Surface drainage required for rapid removal of flood water on clayey soils.	Silt deposition on fodder crops and <u>Moraea spp</u>. may be important limitations. Avoid grazing when wet.
		2	As above with addition of lucerne on well-drained soils.	As above.	As above.	As above.
		3	Suitable for intensive production of lucerne, citrus, vegetables and poplars. Flood or sprinkler irrigation essential.	As above.	As above.	As above and including droughtiness of sandy soils.
Bottom-land non-arable class	Vb	1	With suitable improvement techniques can use for permanent pastures. Sprinkler irrigation recommended.	Pasture establishment must provide rapid plant cover, preferably in autumn under irrigation.	Land improvement to include catchment area and protection of 'key' together with safety of drains. Complete control of water table essential.	Bottomlands should be established section by section. Main limitations include poor drainage, mechanical limitations (e.g. compaction), parasite infestation, severe cold in winter and potential erosion hazard. Water conservation is of prime concern.
		2	As above but including poplars. Sprinkler irrigation essential for maximum production and safe use.	As above. Sod seeding may be best means of establishment	As above but with conservation practice of greater intensity.	As above. Narrow water courses especially of margalitic soils, to be excluded. Compaction an important limitation.
		3	Without irrigation should be left under natural vegetation. Lucerne or pastures permissible on margalitic soils with irrigation and intensive conservation practice.	As above.	Confine land improvement to surface drainage, exclude open drains. Very intensive conservation practices required.	Very high erosion hazard and potential encroachment of thorntrees are main limitations.
Bottom-land protected class	VIIb		Land requires total protection but may be suitable for wildlife and/or recreation.	—	Special management practices may be required to control natural vegetation and erosion or to facilitate reclamation.	Severely eroded bottomlands requiring total protection and narrow waterways with erodible soils to be included.

[1] Judicious lime and fertilizer application assumed.

CHAPTER 8

AN APPROACH TO THE SYSTEMATIC PLANNING OF SELECTED FARMS

The purpose of this discussion is twofold. Firstly, it attempts to indicate how soil survey procedures and the proposed land capability classification may be applied in practice and secondly, it summarizes the principles and procedures to be followed in planning a farm. To meet these objectives several selected farms were planned. The results of three of these are presented in this chapter. Systematic soil survey had, in this instance, preceded the planning exercise.

8.1 Principles and objectives in farm planning

Successful and stable farming is supported by two main pillars; planning and management (Penzhorn, 1961). Planning is defined as the conscious approach of selecting and developing the best course of action to accomplish an objective (Fed. Dept. Soil Con. and Ext., 1960). However, in many instances, the advantages of sound technique and efficient management are lost through poor decisions in the planning phase. Two important requirements in planning are therefore:

1) the clear definition of the objectives to be attained, and
2) an intimate knowledge of what has to be planned or the many factors which may influence the formulation of the plan (Penzhorn, 1961). The physical relationship between the farm and the adjoining land should also be considered.

According to Haw (1959), farm planning involves the systematic assessment of the potential of the land and, apart from its value to conservation, it is essential for proper economic development. Economic considerations, though important, should not be the overriding factor in formulating a plan. Essentials in profit farming are first to find the correct system for the farm and the farmer, and then to operate the system efficiently and economically (Blagburn, 1961). A system based solely on natural characteristics should first be determined and then only should the economic aspects and the skills and preferences of the farmer be considered. Farmers differ widely in their ability to make decisions which no doubt prompted Jacks (1946) to comment that the occupier, as well as his land, may require 'treatment'. Where possible the farmer's preferences should be confined to those land units for which they are best suited.

A farm plan is never final. There is always the need to allow for transitory economic changes, temporary adversity in climatic conditions (e.g. droughts) and the continued advancement in agricultural technology. Adjustment to the plan must, however, acknowledge the original objectives.

Penzhorn (1959) recognized three stages in farm planning viz., physical-biological, economic and management planning. Because of the urgent need for reclamation and conservation he suggested that physical-biological planning should enjoy priority although the ideal of undertaking all three stages together was stressed. The need to arrest erosion on many farms in the Area is as great today as it was when the Soil Conservation Act was first promulgated and, as previously indicated, physical farm planning has been over-emphasized. For this reason, greater efforts should be made to attend to all three of the above phases.

Objectives of the farm plan: As with all forms of land-use planning there is an overall objective and several specific objectives. The latter will change in scope and priority for each farm. The overall objective is to ensure sustained and economic production of farm commodities and, at the same time, to ensure maximum conservation of natural resources. Although the overall objective is of prime concern in this discussion several component aims, some of them listed by Penzhorn (1961), are noted. These are:

1) the optimum exploitation of the productive potential of the farm for the benefits of the farmer (and his country) from a permanent point of view,

2) the maximum conservation of all natural resources, especially soil fertility,

3) adequate monetary returns and economic stability for the farmer and the improved efficiency of his existing enterprizes where these are deemed correct,

4) the removal of the causes of erosion and the reclamation of denuded areas, and

5) a high standard of living and happiness for the farmer and his family.

Effective planning is dependent on the concise and accurate interpretation of each specific objective in relation to the main objective. Many courses of action may be formulated to achieve these objectives but each should be tested for suitability, feasibility and acceptability to the farmer (Fed. Dept. Soil Con. and Ext., 1960). From a purely economic stand point the aim of farm planning is to make the greatest profit concomitant with the maintenance, or improvement, of the capital standing of the farm (Barnard & Weston, 1963).

8.2 Procedures for developing and drafting the farm plan

Penzhorn (1959, 1961) has described in detail the technique of planning farms in the Republic. The ideal of incorporating detailed soil and economic investigations into the planning procedures at that time could not, however, be motivated because of the general shortage in personnel. Although the manpower shortage remains a major problem, recent advances in both these fields make it imperative that they form part of the planning procedure. For this reason, the basic steps for a standard procedure are discussed; a requirement that Loxton (1962a) regarded "best dealt with by the Conservation Service". It is assumed:

1) that the planning officer is adequately trained in the use of aerial photography and soil survey procedures and has experience and knowledge of the area in which he is working, and

2) that the farmer is co-operative and willing to fulfil his obligations.

The value of stereoscopic interpretation in the planning technique is immense. In the writer's experience the task of planning can be greatly simplified by the aid of an inexpensive pocket stereoscope and good quality aerial photographs. Even in extensive farming regions stereoscopic interpretation should be standard procedure. Much information can, by this means, be recorded in map form. Although an accurate map is an indispensible aid to planning it does not constitute a farm plan. Ideally, the map should be accompanied by a schedule of land use indicating the sequence of implementation, a list of essential conservation works and a budget summarizing the financial possibilities of the plan.

Five well-known steps are recognized to achieve a predetermined objective, viz., survey, assessment, planning, implementation and evaluation. It is strongly recommended that farm planning should follow these steps in strict order.

1) <u>Survey</u>

Systematic fact collection is one of the most important steps since it provides an inventory of all factors affecting recommendations for land use. It should include all natural factors, present land use and the desires and preferences of the farmer, together with the economic feasibility of such desires. The description of the natural resources and agriculture of the Area, though given in general terms (Chapter 4), indicates the type of information required. A comprehensive list of required information was also provided by Pentz (1938) and Scott (1954). In the initial phase the planner should also consider the possibilities for modifying any of the environmental factors e.g. eliminating moisture deficiencies through irrigation.

Detailed soil investigation and land capability classification are among the most important parts of the survey phase. The soil survey must provide a concise, unbiased record of the soil resources on the farm. Interpretation of these data should indicate the potential, use-suitability and management needs of the soils that finally determine recommendations for each field. Standard procedures and terminology for this phase were presented by Loxton (1962a) and much relevant information is contained in the literature describing planning procedures employed in Rhodesia. The steps found most suitable in carrying out the detailed soil investigations of the farms studied were:

(a) an initial stereoscopic examination of the aerial photographs to delineate drainage and crest patterns, obvious capability divisions and classes, homogeneous areas of soil or vegetation and provisional sites for dams and soil pits;

(b) a field reconnaissance, in which the farmer participated, to obtain the basic information required for planning, to verify the main features observed stereoscopically, to site the soil pits and to note the main soil series occurring on the farm;

(c) a second stereoscopic interpretation to demarcate accurately the capability divisions and, where possible, to relate field observations to photo patterns so as to establish provisional soil boundaries;

(d) a detailed examination of soil profiles so as to identify soil series and phases and to establish mapping units; and

(e) to map the soils by auger traverse and finalize the land capability classification.

Where systematic soil survey is available the number of profile pits is reduced to an absolute minimum or may even be eliminated. However, in this study, a fairly large number of pits were purposely described in detail. Samples were also collected from each pit to permit accurate identification of the soils. Accurate profile descriptions, though they permit checking are time-consuming. The pits were, however, most useful in stimulating the farmer's interest. No matter how experienced the planning officer becomes, this benefit should not be overlooked.

The boundaries of mapping units and capability classes were recorded with dotted and solid lines respectively. The acreage of each class was also calculated to indicate the overall potential on the farm. Recording only the soil series (or phases), slope and effective depth, had obvious advantage over the use of elaborate codes incorporating many soil features. Although the use of codes is unavoidable where systematic soil survey is lacking, Murdoch (1961) criticized their use on the grounds that they are time-consuming, cumbersome on maps and difficult to compare. Kellog (1951) noted that such codes have appeal because they avoid soil classification and can be used by untrained personnel.

Detailed soil investigations are usually confined to the 'arable' areas. Despite this, the soils of the non-arable classes, especially Class V, were investigated by augering. This proved most valuable in revealing sites suitable for veld replacement or afforestation and permitted the careful siting of internal camp fences.

A basic conservation layout: In the writer's opinion the survey phase should culminate in a 'basic conservation layout' for the farm. Based on the land capability classification it should indicate: 1) basic land forms, 2) homogeneous areas of soil, vegetation and aspect, 3) soil management groups, 4) communications and potential communications, 5) individual fields with the necessary protective conservation measures (hydrological plan), and 6) the basic or skeletal fencing and watering facilities.

Of many other factors to be considered in the survey phase, analysis of the existing farm organization is especially important since it serves to identify major problems and provides an indication of the degree of intensity of production. It also indicates the managerial ability of the farmer and whether or not the existing land use is sound. Incorrect systems may be indicated by either a) deterioration of natural resources, or b) inadequate monetary returns. Scott (1954) suggested that over-intensification and the application of the wrong system of farming usually cause the former while the latter is often the result of a lack of capital, poor managerial ability and inefficiency. With this knowledge the planner can decide whether to change or merely rationalize the existing organization. The problem is more complex when the holding is of sub-economic size.

The intensity or level of production is in essence an economic consideration and is indicated by features of land usage, stocking rate and crop yield (Blagburn, 1961). Efficiency tests should be applied to show the weakness and efficiency of each enterprize and whether the system is economically sound. The farm management advisory service recently initiated in the Natal Region provides a means of diagnosis although many other methods are available (Wallace & Burr, 1963; Barnard & Weston, 1963; van Wyk, 1967a). Production and financial standards such as those used in Britain are highly desirable for diagnosis and planning (Min. Agric. Fish & Food, 1958).

Restrictions imposed by quotas, servitudes and legislation, such as the Soil Conservation Act, No. 42 of 1937 and the Fencing Act, No. 31 of 1963, should also be considered during the survey phase.

2) Assessment

Rigorous analysis and interpretation of all the relevant facts, including economic considerations, should follow the survey phase. Assessment should aim at determining the significance of each factor governing production and to identify the important problems and limitations of the existing organization. Objectives and scope of the farm plan should be finalized at this stage.

3) Planning

Information previously gathered provides the basis for planning the course of action. Although up to this point the farmer has played a relatively minor role in the proceedings, the planning phase should be a joint effort between farmer and planner. A definite sequence, suitable as a standard procedure, was followed in planning the selected forms. The main steps and important features are outlined.

(i) Determination of the system, line and type of farming

This determination is based primarily on the potentialities of each farm and should also take into account the use-capability of the Area (Chapter 6). According to Scott (1954), the system of farming (i.e. intensive, semi-intensive and extensive) is determined by natural limiting factors and their interrelationships. The method is well illustrated in a chart presented by Pentz (1949) although it does not include a suitable soil factor. For this reason the agricultural ratings presented in Chapter 3 were taken into account in planning the selected farms. Ratings of 1 to 2 were related to intensive farming systems, 2 to 4 to semi-intensive systems and 4 to 5 to extensive systems.

The line of farming (e.g. dairy, beef, etc.) is determined by natural limiting factors, together with the ratio of arable to non-arable land. Ratios of less than 1:5 and over 1:10 determine whether a farm is suitable for an intensive or extensive line of farming respectively. On many farms in the Area the ratio is between 1:3 and 1:4 and, in the moist parts, it is often 1:2.5 indicating a very high potential for intensive usage.

The type of farming (e.g. fresh milk, cream, etc.) is determined by considering all the preceding factors plus economic conditions. Details, such as the choice of breed, are mainly determined by the farmer's personal preferences. Single factors such as the incidence of hail may, however, outweigh all others in determining the main and subsidiary enterprizes.

(ii) Consideration of enterprizes and land-use practices

Having established the broader issues of the farm plan, details of the enterprizes and practices to be applied should be considered. Many alternative procedures are possible. For example, Penzhorn (1959) suggested that where 50 to 60 percent of the farm is natural veld, planning should begin with the veld and the livestock required to utilize it. Important principles in this approach are that 1) all the available veld should be utilized, and 2) as far as possible all livestock feed should be produced on the farm.

The procedure adopted in planning the selected farms, all of which are suited to intensive mixed farming, was to consider in order, the livestock enterprize, the crop enterprize, the veld and pasture requirements, afforestation and other issues.

Livestock enterprize: Consideration was first given to:

1) calculating the total number of each class of stock to be run on the farm, and
2) the total feed requirements or 'forage flow' for summer and winter.

The 'block' system advocated by Scott (1954) is convenient for establishing the correct balance between productive and non-productive animals in a herd. For example, a 'block' of 10 dairy cows in milk should, allowing for dry cows and followers, comprise a total of approximately 18 total mature livestock units. Approximately 70 percent of the herd should comprise productive animals if the venture is to prove economic. A simple multiplication of the 'block' for determining the final number of each class in the herd is, however, unduly conservative and the margin of safety for culling and losses is excessive. Thus, the number of followers should decrease proportionately as the herd size increases.

The total carrying capacity is first determined for the winter or 'lean' period of the year by calculating the feed requirements for a 'block' and relating these to the area of available arable land and the expected crop yields. The total summer requirements to be met by pasture, ley and veld are then calculated with each type of feed allocated to different classes of stock. Any excess grazing or fodder should then be utilized by livestock brought in or, where suitable, replaced by an alternative line such as timber. Where beef and sheep are to be farmed the number of sheep should not exceed half the total number of livestock units.

The total number of livestock may be limited by other reasons including available capital, milk quotas or managerial ability. Generally, a dairy herd of 100 to 150 cows in milk is regarded as a maximum if a single manager is to maintain optimum efficiency. Consideration should also be given to breeding policy, disease and parasite control and building requirements.

Crop enterprize: The crop enterprize is largely determined by soil resources but should be designed to meet the demands of the livestock enterprize and add to the profits of the farming venture. Choice of crop is determined by climatic, biological and personal factors. The main consideration in planning the selected farms was to 'fit' the crops to defined soil series. Recommendations concerning fertilization, tillage, conservation and irrigation were based on the information given in Part I.

Veld and pasture: Productive capacity, subdivision and management of veld and pasture are important considerations in farm planning. Principles of management and utilization are, however, purposely excluded from this discussion. Subdivision of the veld areas should form part of the 'basic conservation layout' and is achieved by stereoscopic interpretation and by considering the definitions of non-arable capability classes (Appendix 16). Special attention should be given to Class V land, usually the mowable areas, since afforestation or veld replacement and reinforcement can be recommended if soil conditions are suitable.

Planning the layout and management of cultivated pastures involves many principles, too numerous to be listed here. However, an attempt was made in the planning exercise to estimate the productive capacity of each pasture since, together with the number of herds and the duration of the rest period and period of stay, it determines many final decisions. The period of stay should not exceed 3 days and allowance should be made for variations in growth through the season. This information is used to calculate the number and size of the pasture camps. For example, if the period of rest in autumn or early spring is 42 days and the period of stay is 3 days, a single herd will require: $\frac{42}{3} + 1 = 15$ camps. The requirement in summer, with a 21 day rest period, is 8 camps leaving 7 camps available for silage or hay. An indication of the size of the camps is obtained by either dividing the number of camps into the available area of pasture or by considering the productive capacity of the pasture. For instance, a pasture with a productive capacity of 250 grazing days per acre for the summer period (150 days) can be grazed five times if the average rest period is 30 days. This gives $\frac{250}{5} = 50$ grazing days per acre for each cycle. A herd of 50 cows thus requires one acre per day. With a period of stay of three days the required camp size is three acres. However, such methods can be used only as a very general guide for planning the area of pasture.

Afforestation: Possiblities for afforestation should be considered bearing in mind the use-capability classification for timber (Chapter 6) and the proposed land capability classification (Chapter 7). Important aspects include the size of the project, the programme of establishment, silvicultural practices, fire control and road layout. Layout of extraction roads is one of the first essentials to be planned in developing a forestry project.

Other features: Consideration should also be given to:

(a) matters of soil, water and wildlife conservation including the extent and type of existing erosion and the prescribed control measures, and the supply and cost of domestic and other water (e.g. irrigation);

(b) the system of employment and welfare of labour and, where possible, labour-owned livestock and cropland should be planned as part of the overall organization directly under the management of the farmer himself;

(c) the layout of roads as dictated by natural features such as crests;

(d) the layout and costs of buildings and other improvements and the required machinery;

(e) fire control, bearing in mind legislation and the desirability of siting strategic fire belts at right angles to the prevailing winds (preferably on the crests), and protecting these from erosion; and

(f) the provision of shelter and shade and the beautification of the landscape.

(iii) Economic considerations

Ideally, every farm plan should be accompanied by an economic analysis. Improved economy of the existing organizations can be achieved by:

1) increasing output through better use of existing resources or by using additional resources,
2) adjusting the value of enterprizes in favour of those giving the best results and,
3) reducing costs (Blagburn, 1961).

Estimates of net farm income should be considered against the farmer's commitments. 'Immediate' and 'long term' estimates are necessary because the productive capacity of a farm generally increases with conservation and intensification. Several methods are available for presenting the economic analysis. Budgeting is widely used where there are many alternative enterprizes but has definite limitations (Buckle, 1967). Recently, the linear programming technique described by Heady and Candler (1963) has received considerable attention and holds promise for introduction into farm planning procedures (Kassier, 1963, 1964; Buckle, 1967). The most efficient enterprizes for converting limited resources of land, capital and labour into profit are indicated by this means. However, there are definite conditions to be complied with before linear programming can be recommended. The question of 'specialization' or 'diversification' should also be carefully analyzed before the method is adopted. The linear programming technique was used in planning one of the selected farms.

4) Implementation

Planning is only the beginning of effective land use and is to no avail unless the plan is put into operation (Fed. Dept. Soil Con & Ext., 1960). Implementation of the plan is primarily the concern of the farmer and it is the stage at which many previous attempts at farm planning have come to naught. During this stage consideration should be given to 'how' and 'when' the decisions already made (planning) should be put into effect. A priority sequence for each phase in the development programme should be established and the farmer guided by a list of all activities to be included in the plan.

5) Evaluation

A farm plan, as with all plans, requires periodic evaluation and readjustment. Evaluation should take place before and after each step in the programme has been reached and should be made with respect to the overall objectives of the plan (Fed. Dept. Soil Con. & Ext., 1960).

8.3 Responsibilities in planning

Farm planning is seen as the joint responsibility of the farmer, the extension service and, indirectly, the conservation committee. An attempt should be made to foster a spirit of co-ordinated effort or teamwork between field staff, specialists and researchers. It is, however, unwise for the farm planning task to be rigidly delegated to specific individuals. Although several people are involved in the planning exercise, a situation where the planner is associated with all phases of the exercise is ideal. One possibility is for the technical staff to be responsible for planning the 'basic conservation layout'. These officers would be required to conduct the detailed soil investigation and stereoscopic interpretation and, for this purpose, will require regular in-service training. This could also provide incentive and responsibility for this group of officers, especially the extension technicians, if this rank is to remain.

Extension officers could attend to the production and economic aspects of the plan although their association with all phases is preferable. They, too, will require special knowledge of soils and their influence on land-use practice. In this field they would meet the farmer on common ground and, together with him, could reach land-use decisions field by field. Their role would be especially important in the implementation and evaluation phases.

Farm planning is no longer the prime function of conservation committees. However, they could play an important part in directing planning services to the right quarters and in motivating farmers so that they are receptive to new innovations. An important task would be to draw up codes of practice for land capability classes and soils within the defined ecological areas.

The key figure in the planning exercise is the farmer himself. His will be the final decisions, a task that may take several days, several weeks or even longer. The most important responsibility of the farmer will be to implement the plan and see it to finality while effecting adjustment where necessary. He will also be required to co-operate in acquiring the necessary photographic material, supplying labour, keeping adequate records and furnishing all necessary particulars for planning.

The farm plan write-up should be designed to present all aspects of the plan in a clear and concise manner since all phases must be well understood by the farmer. For this purpose free use should be made of tables and maps. Aerial photographs at a contact scale of 1:10,000 are most suitable for presenting the soil classes and the capability classification. An overlay is possibly the most convenient way of presenting the basic conservation layout.

8.4 Planning selected farms

Three farms were selected to demonstrate the systematic procedures and pedological approach to farm planning and were used to test the proposed land capability classification. The farms represent different ecological areas and cover a wide range of soils. They are, however, limited to intensive and semi-intensive farming systems which are commonest in the Area. For obvious reasons much detail has been omitted from the discussion, viz., rations computed for livestock, recommended fertilizers, etc. A brief outline of each plan is given.

1) 'G L E N F E R N'

'Glenfern' is a 600 acre farm situated within ecological area la (Highland Sourveld) approximately 8 miles from Nottingham Road.

(i) Survey

The climate is typical of climatic sub-region 1. Farm records indicate that a mean annual rainfall of 965 mm (38 inches) is experienced mainly between October and March. The winters are cold with the average number of days with frost per month for the period April to October being 0.3, 7.6, 16.3, 16.0, 11.6, 3.7 and 0.8 days respectively. The duration of the winter feeding period is taken to be at least six months.

The topography is gently undulating with slopes mostly between 3 and 8 percent (Group B). Water supplies, though not well distributed, are adequate with approximately 25 acre feet impounded for irrigation use.

The existing organisation is economically sound (Dept. Agric. Econ., 1967). In the 1966/67 financial year the net farm income per R100 capital was R16.79. The total capital investment amounted to R43,471 of which 44 percent was allocated to land, 21 percent to fixed improvements, 32 percent to dairy livestock and the balance to tractors, motor vehicles and equipment. Other factors of economic importance include a milk quota standing at 140 gallons per day, transport costs to Durban of 2.75c per gallon and a permanent labour force of 8 units all resident on the farm.

Managerial ability, as indicated by the present organization is above average. The farmer's prime interest lies in dairying with pedigree and grade Jersey cattle and his goal is to produce 250 gallons per day from a herd of 100 cows in milk. He favours the sale of in-calf heifers as a subsidiary line and will consider the introduction of cash cropping and fat lambs when the dairy unit has expanded and is well established. His outlook is biased toward 'grassland farming' which is in keeping with the recommended use for ecological area la. The present degree of indebtedness precludes rapid development and exploitation of the high potential of the farm.

<u>Present land use</u>: Dairying (fresh milk) provides the main source of income. The Jersey herd comprises 138 mlu with 87 cows in milk. The sale of surplus dairy stock provides a secondary means of income. The arable area is 226 acres in extent with 20 acres under irrigation (flood) for winter pasture. Rainfed crops include Japanese millet (27 acres) followed by rape and ryegrass, short term grass pastures (26 acres), long term grass-clover pastures (52 acres), <u>E.curvula</u> (50 acres) and permanent kikuyu (50 acres). The pasture species grown also include tall fescue and ladino clover. Silage is produced from millet and excess pasture while <u>E.curvula</u> and the natural veld provide the hay requirements. The natural veld is 360 acres in extent of which 100 acres are mown annually. Although all concentrate feeds are purchased, the present cost of bought feed is R29 per animal unit which is low by comparison with other farms in the Area. This is explained by the high quality of the pastures on 'Glenfern'.

<u>Soils and the land capability classification</u>: The outstanding feature revealed by the detailed soil investigation is the marked uniformity and high degree of leaching among the upland soils, all of which belong to the B1-association. The GRIFFIN, CLOVELLY and MISPAH series are most important. The bottomlands are not extensive and comprise the KATSPRUIT series. Several other features observed during the mapping phase are worthy of note.

(a) The organic carbon content of many of the soils, especially those in local depressions or on level, lower slope positions, is very high (over 5 percent). These soils are closely related to the KRANSKOP and MAGWA forms but in most instances the depth of the humic A1-horizons is shallower than 18 inches. Since considerable difficulty is experienced in classifying these soils without analytical data, an humic phase was established and mapped accordingly.

(b) Determining textural classes required analytical spot checks which, in many cases, revealed that the clay percentage of the 'B-horizon' was often between 50 and 60 percent, very close to the 55 percent limit. Because of the generally light texture of the upper horizons these soils were placed in the 35 to 55 percent range.

(c) In several instances, the yellow apedal B-horizons overlying horizons of intense red colours were narrow and somewhat ill-defined. These soils, though marginal to the A1-association, were mapped as B1-association soils.

(d) Soils with dark brown (10 YR 4/3 to 7.5 YR 4/2) apedal B-horizons were found in close proximity to the dolerite dykes. Although they do not fit any of the current series definitions, they were mapped as a phase of the CLOVELLY series.

(e) Considerable variation in soil depth was noted. However, with the high degree of weathering of the shale, the depth limitation did not appear to be important where the depth to the rock exceeded 20 inches. Allowance for this was made in drawing up the capability classification.

The benefit of the detailed soil investigation on 'Glenfern' was to some extent masked by the uniformity of soil characteristics over the farm, especially the high degree of leaching. The extremely low plant nutrient status is clearly the chief soil limitation and is regarded as the most important single factor likely to determine the success of the farming venture on 'Glenfern'. The main problems, as suggested by the studies previously reported, are severe P-fixation and Al toxicity. The cost of corrective treatment is high and, in view of the large area yet to be cultivated, will continue to drain much of the working capital. The high costs are reflected in the 1966/67 business summary which reveals a fertilizer cost for forage crops of R29.84 per acre.

Physically, the soils are suited to intensive cultivation although a 'powdery' condition soon results from continued arable use. Shallow depth may also hinder tillage operations. The overall assessment of erosion hazard of the soils on 'Glenfern' is low.

The land capability map (Map 12) shows the soil resources on the farm and the land capability classification. A summary of the latter is

LAND CAPABILITY MAP 12

"GLENFERN"

(600.8 acres)

Lions River Soil Conservation District — Ecological Area 1a

LAND CAPABILITY CLASSIFICATION		EXTENT (acres)
UPLANDS		
Arable classes		
I	-	-
II	Gently sloping deep well-drained soils suited to intensive production of crops and pastures. Requires easily applied conservation practices such as contouring, strip cropping and short duration leys. Lime, phosphate and organic matter status require special treatment. Wind erosion a limitation.	351.4
III	Strongly sloping or shallow soils requiring intensive conservation practices for safe use. Leys of long duration to be included in rotation.	86.4
IV	Strongly sloping shallow soils mostly suited to ley crops. Low potential for arable use.	3.5
Non-arable classes		
V	Hilly steep land to remain under permanent vegetation. Land may be cultivated for establishment purposes. Natural veld may be reinforced with suitable species. Suitable for afforestation.	45.0
VI	Hilly, steep and/or rocky land to be left under natural veld for grazing purposes. Afforestation possible if pit planted.	92.5
Protected class		
VII	Indigenous forest to be protected.	1.0
BOTTOM LANDS		
Arable class		
Ib	-	-
Non-arable class		
Vb	Bottomland hydromorphic soils requiring special land improvement practices.	18.0
Protected class		
VIIb	-	-
Miscellaneous		3.0
	TOTAL	600.8

MAPPING SYMBOLS

Soil Series

- B 1 - 4 Griffin series
- B 1 - 6 Clovelly series
- B 1 - 6a Clovelly deep phase (B-horizon, dark brown)
- C 1 - 3 Katspruit series
- h Humic phase (organic carbon 5%)

Miscellaneous Landtypes

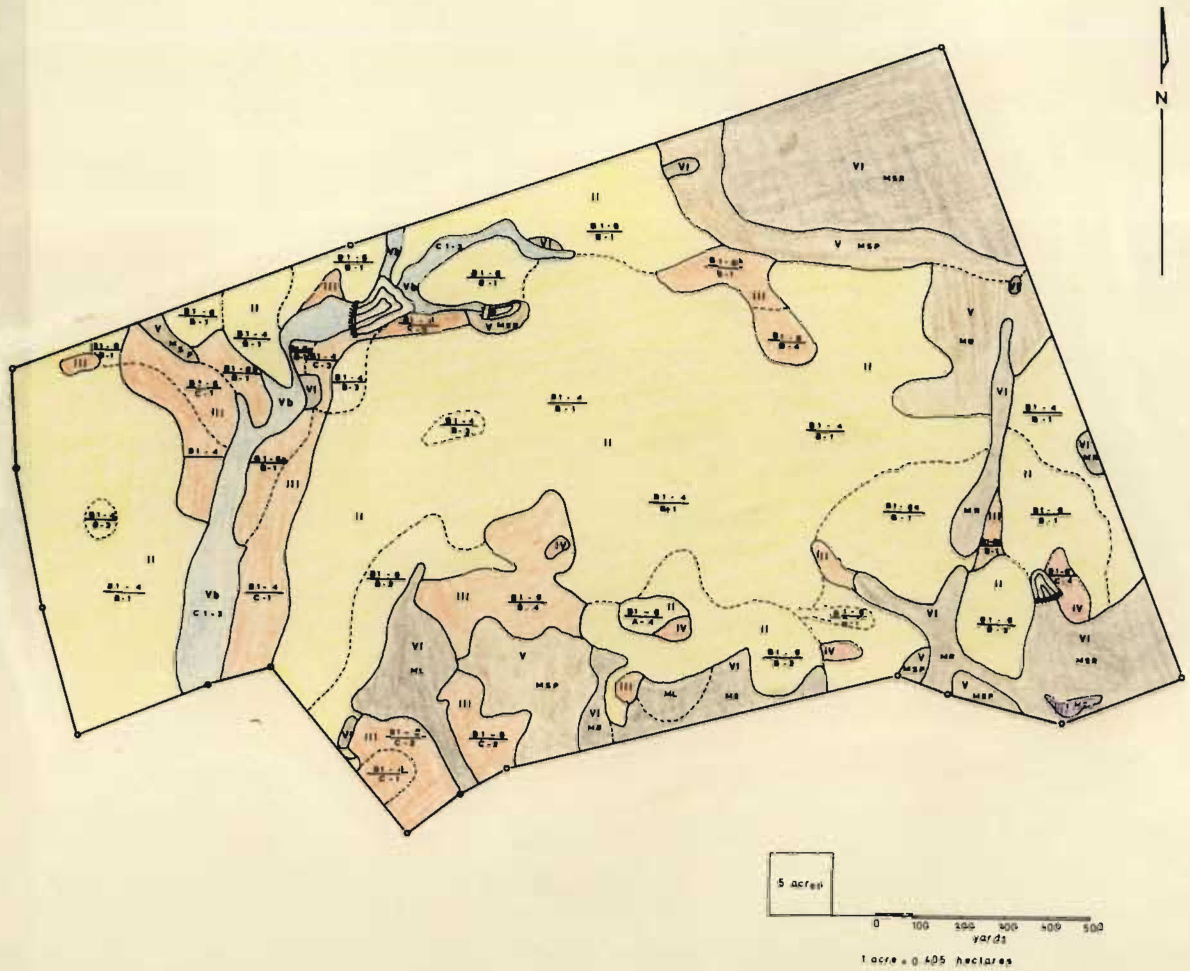
- M Non-arable
- ME Excessively steep (mostly 20%)
- MR Rocky
- MSR Steep and rocky
- MSP Steep but ploughable
- ML Very shallow or litholic soils (may include Mispah series)
- MF Indigenous forest
- MB Excessively uneven

Slopes

- A 0 - 3%
- B 3 - 8%
- C 8 - 15%

Depth

- 1 > 60"
- 2 36 - 60"
- 3 20 - 36"
- 4 10 - 20"
- 5 < 10"



FARM PLAN MAP 15

BASIC CONSERVATION LAYOUT

"GLENFERN"

(600.8 acres)

Lions River Soil Conservation District — Ecological Area Ia

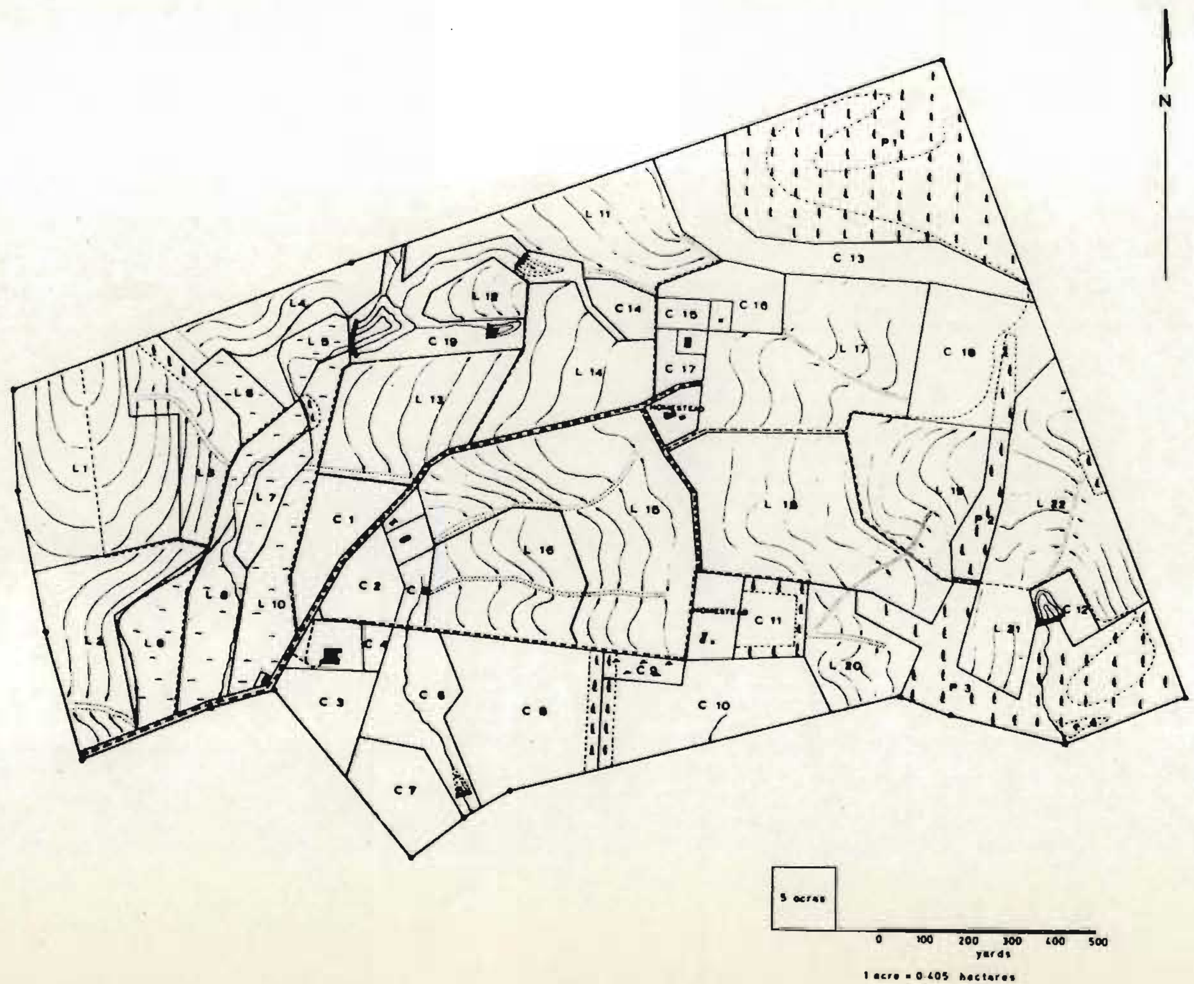
ARABLE LAND			NON-ARABLE LAND		
Dryland			**Permanent pasture**		
L1	29.7	acres	C1	7.4	acres
L2	17.1	"	C2	[illegible]	"
L3	11.1	"	C3	6.7	"
L4	12.4	"	C4	1.7	"
L11	19.1	"	C7	[illegible]	"
L12	4.8	"	C11	[illegible]	"
L13	18.6	"	C14	[illegible]	"
L14	17.1	"	C15	1.7	"
L15	39.7	"	C16	[illegible]	"
L16	18.8	"	C17	[illegible]	"
L17	30.1	"		46.5	"
L18	31.0	"	**Natural veld**		
L19	17.1	"	C6	11.5	acres
L20	10.2	"	**Potential reinforced veld**		
L21	6.9	"	C5	2.2	acres
L22	23.6	"	C8	20.6	"
	307.3	"	C10	15.9	"
Irrigated			C13	16.7	"
L5	3.4	acres	C18	13.9	"
L6	4.0	"		69.3	"
L7	4.2	"	**Plantation**		
L8	13.1	"	P1	42.8	acres
L9	8.4	"	P2	4.3	"
L10	11.7	"	P3	26.0	"
	44.8	"		73.1	"

Miscellaneous

Homestead, sheds and pens	15.5	acres
Recreation, wildlife and dams (C12, C19)	17.5	"
Shelter belts	9.3	"
Labour (C9)	2.0	"
Roads	4.0	"
	48.3	"

SUMMARY

Arable		
Dryland	307.3	
Irrigated	44.8	
		352.1
Non-arable		
Permanent pasture	46.5	
Natural veld	11.5	
Potential reinforced veld	69.3	
Plantation	73.1	
		200.4
Miscellaneous		
		48.3
TOTAL		600.8



presented in Table 57.

Table 57 : Land capability classification for 'Glenfern'

Landscape position	Capability division	Capability class	Extent (acres)
Uplands	Arable	I	-
		II	351
		III	86
		IV	4
	Non-arable	V	45
		VI	92
	Protected	VII	1
Bottomlands	Arable	Ib	-
	Non-arable	Vb	18
	Protected	VIIb	-
		Miscellaneous	3
		Total	600

The exceptionally high potential of the farm is reflected in the high percentage (60 percent) of Class II land. Approximately 73 percent of the farm is potentially arable giving a particularly favourable ratio of arable to non-arable land of 1:0.36.

<u>Basic conservation layout</u>: The basic conservation layout, as determined by the land capability classification, is shown on farm plan Map 13. The map indicates the basic land units, the suggested layout for maximum protection of the arable classes, main access roads, watering facilities and the land to be irrigated. No attempt is made to list all of the proposed works required on the farm since final decisions on the basic layout must await accurate field survey and technical advice. This basic plan is the ultimate layout as envisaged for both plan A and plan B.

(ii) <u>Assessment</u>

'Glenfern' is a farm ideally suited to intensive agriculture. Although it is at present farmed on a rational basis, the rate of development is restricted by the limited capital resources. The possible main lines of farming include dairying (fresh milk), crop production, fat lambs and afforestation. Economic and personal factors indicate that fresh milk production and the breeding of pedigree dairy stock should remain the main lines. Enterprizes such as cash crops, sheep, pigs and timber may warrant inclusion at a later stage in the development. It is recommended that serious consideration be given to the integration of cash crops with the present 'conservative' cropping programme. Major limitations to be faced include the very low plant nutrient status of the soils and the relatively long winter feeding period.

(iii) Planning

The high potential of the farm in relation to the existing organization and the available capital resources necessitates the presentation of two 'production' plans. The first (Plan A) caters for development in the immediate future. The second (Plan B) is a long term plan based on the ultimate potential of the farm. Although an outline of each of these is given, several features basic to both plans should be noted.

The bulk of the winter feed for cows in milk is to be supplied in the form of highly fertilized, winter grazing crops such as ryegrass or foggaged pasture, supplemented by hay and limited amounts of silage. This system, although somewhat controversial, was selected in view of the success so far achieved by the farmer, his personal preferences and the availability of irrigation. The favourable moisture characteristics of all soils on the farm (Chapter 2) suggest that, even under rainfed conditions, satisfactory yields will be obtained if these crops are adequately fertilized.

PLAN A

Plan A envisages the intensification of the existing organization, especially the production from the arable area. The acreage of arable land is not to be increased. The dairy unit is to comprise 100 cows in milk with an average yield of 2.5 gallons/day. In addition, excess dairy stock will be sold as in-calf heifers. Table 58 shows the standard unit or 'block' for calculating the feed requirements, a balanced herd of 100 cows in milk and the proposed herd for 'Glenfern'. Allowance is made for retaining the young stock until sold.

Table 58 : Guide to the number and classes of dairy livestock in a balanced standard herd and the proposed herd for 'Glenfern'

Classes of livestock	Standard unit or 'block' (10 cows in milk)		Standard herd (100 cows in milk)		Dairy herd for 'Glenfern'	
	No	mlu	No	mlu	No	mlu
Cows in milk	10	10	100	100	100	100
Dry cows	3	3	30	30	30	30
Replacement heifers	3	2	30	20	50	33
Heifers (1-2 years)	4	2	32	16	50	25
Calves (6-12 months)	5	1	34	9	50	12
Total		18		175		200
Productive units (%)		72		74		65

The reduction in the percentage of productive units in the herd by retaining heifers for sale is noteworthy. However, since most of the stock to be sold is pedigree, above average prices are anticipated.

The total winter feed requirements (excluding concentrates) for the proposed herd are shown in Table 59.

Table 59 : Winter feed requirements for the proposed dairy herd on 'Glenfern'

Classes of livestock	Number	Minimum daily allowance (lb)		
		Pasture	Silage	Hay
1) Dairy herd				
Cows in milk	100	50	30	10
Dry cows	30	*	35	15
Replacement heifers	30		30	12
Heifers (1-2 years)	32		25	10
Calves	34		15	8
2) Heifers for sale				
Heifers (over 2 years)	20		35	15
Heifers (1-2 years)	18		25	10
Calves	16		15	8
Total requirement (tons)		477	681	280

* Dry cows to be on pasture for 'steaming up' period

During summer the cows in milk, dry cows and heifer calves are to run on high quality pastures and the balance of the herd on the natural veld. Summer pasture needs for the mature cows and heifer calves were calculated on the basis of 100 lb and 50 lb green material per day respectively. Hay (ad lib) is to be made available to all animals on pasture.

Cropping programme and allocation of land: In view of the uniformity of soils and the emphasis on pasture, a simple crop plan is envisaged. The need for protective conservation measures under this system is considerably reduced, except for the short periods under crop or when the pastures are being established. The acreage of each type of feed to be grown is calculated by using appropriate yield estimates. Although conservative, they allow for fluctuations in climate and soil fertility, wastage through trampling and the low-yielding establishment period. A minimum of 15.0 tons/acre winter grazing and 5.0 tons/acre silage are the 'effective' yields expected from the irrigated winter pasture. Rainfed cool-season pasture is expected to produce at least 5 tons/acre as winter grazing and 5 tons/acre as silage in summer. Estimated yields of hay from E.curvula and natural veld are 5.0 tons and 0.75 tons/acre respectively.

The required acreage of summer pasture, winter pasture (followed by silage cut) E.curvula (hay) and natural veld per livestock unit is 0.7, 0.4 and 0.3 and 3.0 acres respectively. Using these standards the final allocation of land for 'Glenfern' is presented in Table 60.

The surplus veld can carry approximately 30 mlu and could be used for any additional livestock on the farm (e.g. horses, etc.). Since the crop plan includes an annual establishment of 10 acres of E.curvula, the production of a similar acreage of cash crop (e.g. potatoes) is permitted when the ley is ploughed out. Approximately one fifth of the dryland grass-clover pastures is to be established annually after the millet crop. The recommended cool season pasture species include ryegrass and tall fescue together with ladino clover. Permanent irrigated pasture is

Table 60 : Proposed allocation of land (plan A) for 'Glenfern'

Allocation of land	Extent (acres)
1) Arable land	
Irrigated pasture for winter grazing and silage	20
Rainfed pasture for winter grazing and silage	36
Millet (silage) followed by pasture establishment	25
Eragrostis curvula (hay)	50
Summer pasture including kikiyu	95
2) Natural veld	
Summer grazing for 63 mlu	190
Mowable veld (hay)	100
Surplus veld	90
	380
3) Homestead and waste	14
Total	600

to be established on the Class Vb land.

The proposed cropping system is such that only simple conservation measures are required. Contour tillage and stable waterways have already proved highly effective. An additional advantage of the proposed system is that there will be no need to expend the limited capital resources on a wide range of machinery and implements.

PLAN B

Plan B envisages the ultimate development of the productive potential of the farm and assumes the availability of adequate capital. The maps presented for plan A also apply to this discussion.

The production of fresh milk will be the main line although an increase in milk quota to 250 gallons per day (i.e. planning for 300 gallons) is assumed. A herd of 212 mlu, including 120 cows in milk yielding at least 750 gallons per lactation, is required to meet these objectives. The sale of dairy stock as a separate enterprize will be eliminated and a sheep unit (fat lamb) introduced once the dairy enterprize is fully developed. A pig enterprize is also planned but is optional since it makes no great demand on the land resources. Its success will be dependent on management and available capital. The crop enterpize is planned to meet the livestock needs and will also include a limited amount of cash cropping (potatoes and cabbages).

Afforestation is to be introduced on Class VI land. In this respect it can be noted that Hubbard (1965) considered afforestation in the area adjoining Kamberg to be economically feasible.

Two additional activities, although not included in the proposed plan, may warrant further consideration. These include the production of <u>E. curvula</u> hay for sale and maize grain as a cash crop. The moderate capability of the area for maize is, however, the main reason for excluding maize from the basic plan. These activities are mentioned under the economic considerations.

The allocation of land for plan B is shown in Table 61.

Table 61 : Proposed allocation of land (plan B) for 'Glenfern'

Allocation of land	Extent (acres)
1) Arable	
(a) Rainfed	307
(b) Irrigation	45
2) Permanent pasture	47
3) Replacement veld (or reinforced)	69
4) Plantation	73
5) Homestead, roads, waste, etc.	59
T o t a l	600

<u>Livestock enterprize</u>: The dairy and sheep units are to be run on separate sectors of the farm. The dairy will run on the area west of an imaginary north-south line on which the two homesteads are situated (Map 13) and the sheep unit to the east of it. The total winter requirements for the dairy unit include 897 tons green pasture, 674 tons silage and 267 tons hay. An allowance of 80 lb green material per day was made for the cows in milk for the winter period compared with 50 lb in plan A. Thus, the total area of land required by the dairy unit is 45 acres of irrigated pasture and 45 acres of dryland pasture for winter grazing and silage, 65 acres of <u>E. curvula</u> for hay, 127 acres of summer pasture of which 30 acres will be permanent kikuyu, and 20 acres of replaced or reinforced veld. In addition to the vlei, the area to be irrigated includes approximately 25 acres of upland soils.

The balance of the land, excluding Class VI, determined the size of the sheep unit. By calculating the winter feed requirements for a 'block' of 100 ewes, 33 cull ewes, 33 replacement ewes and 100 lambs (66 to be sold), a sheep unit of 300 Corriedale ewes was planned. In accordance with the farmers wishes these will be crossed with Southdown and Suffolk rams. The 100 acres of arable land available for this enterprize will produce E.curvula (30 acres) and grass-clover pastures (70 acres). The sheep will also utilize the remaining area of replaced or reinforced veld.

Cropping programme: The cropping programme is essentially the same as that for plan A except for the inclusion of cash crops at the expense of the millet. Potatoes and cabbages fit ideally into the pasture programme since a fixed area of pasture will be ploughed out annually and re-established in later summer. Potatoes are also recommended as the first crop after the virgin veld is ploughed. The cash crop enterprize will include seed potatoes (13 acres), to be rotated with the 65 acres of E.curvula required by the dairy unit, table potatoes (32 acres) and cabbages (5 acres). A total of 50 acres of cash crops, or one sixth of the total arable area, is thus planned. An additional advantage of these crops is that the labour requirements at harvesting need not necessarily clash with other activities on the farm such as the making of silage. If the cash crop enterprize is not included in the plan, additional silage could be produced and 80 to 100 head of beef stock fattened over the winter period.

Pastures and replaced veld: Pastures are to play a vital role in the plan for 'Glenfern' and their success will depend upon efficient management and judicious fertilization. Use of the existing electric fence will be continued until a convenient camp size has been established. Permanent basic fences will then be considered. A system of 'zero' grazing the winter pastures is to be investigated, although the fertility problems associated with this system must be avoided (Edwards, 1959). Approximately 70 acres of Class V land are suitable for gradual replacement by pasture or reinforcement by suitable grass or legume species. The precise method will, however, depend on research being conducted at the present time. Veld fertilization is an alternative form of intensification that could be considered.

Afforestation: The 73 acres of Class VI land are to be planted to *Pinus patula* (pit-planting). Construction of the extraction roads, as indicated on the farm plan map, should receive early attention. The plan will also provide for the establishment of suitable shelter belts which are most necessary on 'Glenfern'.

Conservation practices: Conservation practices are required to protect the area under cash crops. Simple measures such as contour tillage, strip cropping and the provision of waterways are the main practices to be applied. The cost of additional fencing is approximately R500.

Management and labour: The management requirements of plan B exceed the capabilities of one person. The farmer will, therefore, require additional aid if enterprizes other than the dairy are to be introduced. With the exception of the cash crop requirements, all labourers will be resident on the farm. It is suggested that they be confined to camp C9 as shown on the farm plan map, from which there is direct access to both the dairy and sheep units. Seasonal labour required by the cash crop enterprize is readily available.

Communication: The proposed road layout is shown on Map 13. Where possible, these will be aligned on the natural crests or on the contour. Realignment of the present road between L13 and L15 is suggested.

Water supplies: As much water as possible is to be impounded in dams sited in C19 and used for irrigation. Existing stockwatering facilities will have to be extended in view of the proposed extension to the pasture programme and the increase in stock numbers.

Buildings and machinery: The siting of the existing buildings is satisfactory and although the proposed dairy unit can be accommodated in the existing shed, there is need for a workshop and implement shed.

Additional machinery will also be required once the cash crop and hay making enterprizes develop. A pick-up baler should be one of the first items purchased.

Recreation and wildlife: Camp C19 is planned as a recreational area and a wildlife sanctuary. The dams, stocked with trout, will provide ideal facilities for the farmer and his family during their leisure hours. Furthermore, the area will provide a haven for water fowl and other birds native to the area. Beautification of the sanctuary and other parts of the farm by planting suitable trees is recommended.

Economic considerations: Based on the economic results of the existing organization plan A is sound. However, the question arises whether plan B can be economically justified and what enterprizes are the most remunerative. Linear programming was chosen as a means of investigating the merits of the many alternative enterprizes that could be introduced into the plan. There is, however, a general trend towards specialization in the Area so that the advisability of diversification as suggested in the plan is questionable.

All relevant information concerning the linear programme is presented in Appendix 17. The data includes the basic information required for the programme, derived mainly from records kept by the farmer, the input data indicating the constraints or 'activity level' applied to each activity, the activity levels finally selected by computure and the gross profits of each enterprize, and a profit and loss account for the new and existing plans.

The constraints show a total of 399 acres of arable land, including the permanent pastures and a maximum acreage of cash crops similar to that suggested in plan B. A total of 179 acres of maize was also included to test whether this enterprize could be economically justified. This acreage was based on the assumption that at least half the arable acreage should remain under pasture. Furthermore, a maximum of 150 acres of E.curvula was included as an alternative enterprize. This area was regarded as the maximum that could be handled by the available equipment.

A minimum of 73 acres of timber was included in the programme so as to utilize the Class VI land. The maximum area was set at 150 acres since Class V could also be used for this purpose. The livestock numbers are in accordance with the limits imposed by management or the carrying capacity of the farm and are the same as those indicated in plan B. The pig enterprize was limited to a total of 320 baconers.

The final solution is shown in Appendix 7. It shows the enterprizes selected and the activity levels of each. These include dairy - fresh milk (121 mlu), pigs (320 baconers), table potatoes (32 acres), seed potatoes (13 acres), cabbages (5 acres), maize (179 acres) timber (73 acres), winter pasture and silage (49 acres), summer pasture (81 acres) and hay for farm use (40 acres). The outstanding feature of these results is the dominance of the cash crop enterprize since in each case the maximum acreage originally stipulated was selected. The same applies to the pig enterprize. The dairy herd is reduced and the sale of dairy stock, sheep and hay are excluded from the final plan.

The results are given despite several obvious limitations and likely criticism. Maize, for example, is generally unsuitable for the area and is not favoured by the farmer. Despite this, maize production is economically attractive even with a conservative yield of 20 bags per acre. Sheep, though well suited to the area, cannot compete with the cash crops at the current price levels. The net farm income for the new plan (R18,781) is considerably higher than that of the existing plan (R7,817). Under existing farming conditions this is probably over-optimistic. Capital demands of the new plan are also exceptionally high. Despite this, the results reflect the immense potential of the farm, much of which is still to be exploited.

Plan B, as originally described, is biologically and economically sound and is acceptable to the farmer. The economic considerations suggest, however, that serious thought should be given to increasing the cash crop enterprize and introducing pigs at the expense of the planned sheep unit.

(iv) Implementation

The priority sequence for the development of 'Glenfern' in terms of plan B includes:

(a) the development and intensification of the existing dairy unit to a maximum of 120 cows in milk;

(b) the expansion of the existing irrigation facilities including increased water storage;

(c) the gradual inclusion of the undeveloped land and the introduction of a cash crop enterprize (e.g. potatoes);

(d) the completion of the basic conservation layout including fencing, stockwatering, roads and shelter;

(e) the introduction of a sheep and/or pig enterprize;

(f) the replacement or reinforcement of the natural veld on Class V land;

(g) the afforestation of Class VI land; and

(h) the development of the recreation and wildlife sanctuary.

(v) Evaluation

Evaluation will be important in the execution of the plan since determining the rate of development will be a major problem facing the farmer. Much will depend on the availability of capital and to what limits the management and labour resources can be extended. Evaluation should take place after each stage in the sequence has been reached. For this purpose the farmer should solicit the aid of extension specialists.

2) 'W E S T O N'

'Weston' is 2,500 acres in extent and is situated in ecological area 2d some three miles from Mooi River. The farm is run by the Mooi River Agricultural High School. Records kept for many years indicate that the mean annual rainfall is approximately 711 mm (28 inches). In contrast to 'Glenfern', the soils on the farm are partially leached and, as such, have a profound influence on farming practice. Physical characteristics are of prime concern. Detailed soil investigation is thus essential in planning for optimum land use.

In addition to meeting the educational needs of the school, the farm is run as a normal farming venture. The main enterprizes include a dairy unit (60 mlu), a beef unit (250 mlu), a sheep unit (129 mlu), pigs and poultry. The beef and sheep units include 140 breeding cows and 330 Corriedale ewes respectively. The arable area (240 acres) produces maize, Japanese millet, oats and E.curvula to be fed to the livestock. In addition, there are 20 acres of irrigated pasture.

This discussion is directed mainly to the soils and their influence on the land-use plan. The land capability classification and basic conservation layout are presented, together with a brief outline of the production plan.

1) Soils and their influence on the farm plan

The soils were investigated and mapped according to the procedures previously noted. In many instance, the intricate soil pattern made the demarcation of soil boundaries a difficult task, especially where a distinction between the AVALON and SOUTHWOLD series had to be made by augering. Since the majority of soils comprise the E group, colour criteria were found to be particularly useful, especially in differentiating between moderately well-drained and poorly drained soils. Particular importance was attached to the depth phases.

The soil resources of the farm are shown on Map 14. A predominance of E1-association soils and a limited area of E3- and E5-association soils are indicated. D1- and D3-association soils are not widespread. Occurrence of the considerably leached Weston series in the southern tip of the farm suggests moister conditions than elsewhere. The bottomlands comprise both alluvial soils (L1-association) and neutral to alkaline hydromorphic soils (H1-association).

Special consideration was given to criteria such as internal drainage, available moisture capacity, erosion hazard, surface soil characteristics, effective depth and texture since these influence land-use practice. For example, poorly drained upland soils such as the Shandon, ALBANY, WARRICK, KLIPFONTEIN and LONGLANDS series affect both choice of crop and recommended tillage operations. The soils most suitable for arable use include the Weston, Bellevue, Loskop, Rooikop, AVALON, SOUTHWOLD, GLENCOE and LEKSAND series. The ARROCHAR and MISPAH series were deemed less suitable because of their shallow effective depth.

Samples from all profile pits were analyzed and, with the exception of the Weston series, the base saturation values were invariably between 50 and 80 percent. Clearly, the lime and fertilizer needs are very different to those established for 'Glenfern'. Substantial inputs of nitrogenous fertilizer are, however, among the major needs of the grey-brown soils. Furthermore, the very low inherent organic carbon content and low to moderate available moisture capacity of most of the soils make residue management and the conservation of organic materials important issues. Subsoiling is recommended for many of the soils on 'Weston'.

During the mapping phase much surface erosion was noted on the loamy soils and appeared especially severe before a protective canopy was provided by the crop. The cropping sequence for these soils was designed to avoid this problem. In fact, erosion hazard was a major factor influencing the system of farming recommended for 'Weston'.

<u>Use-suitability, limitations and management needs of the soils</u>: A summary of the use-suitability, limitations and management needs of the

soils on 'Weston' is presented in Table 62. A guide to the general potential of the soils for arable use is also indicated by predicted yields of maize. These, however, do not necessarily imply that maize is recommended for all soils.

Within the controls imposed by climate, choice of crop is determined by soil properties. Formulation of the cropping programme for 'Weston' is thus an exercise in fitting crops to soil series so as to comply with their conservation needs and the economic objectives of the plan. Maize is the most suitable crop for large-scale production on the deep, freely drained soils. However, short term leys of well-fertilized E. curvula, together with efficient conservation practice and the return of all crop residues, are essential items for sustained crop production and the safe use of the land.

Long term leys alternated with short periods of broadcast crops, such as Japanese millet and other sorghum varieties, are best suited to the poorly drained and erodible soils. Paspalum dilatatum is an obvious choice as the ley, although the inclusion of Rhodes grass (Chloris gayana) is advocated as a means of early protection against erosion. The presence of clover in the sward can be beneficial but its persistence and production are questionable.

A rotation of long term leys of E. curvula and short periods of maize are best suited to the shallow, grey-brown soils viz., ARROCHAR and MISPAH series. On these soils correct tillage during the cropping cycle, including subsoiling, is essential for maximum production and conservation. A similar rotation, though demanding more stringent conservation measures is also suitable for the well-drained sandy soils. These soils have been found to cause excessive wear and damage to the implements on 'Weston'.

Although the potential for irrigation is largely determined by the siting of the water supply (the Mooi River) it is also dependent on the availability of suitable soils. The best for this purpose include the alluvial soils and Rooikop series at the northern tip of the farm and the

Table 62 : General characteristics, use-suitability, limitations and management needs of soils on 'Weston'

Soil series	General characteristics	Use-suitability	Main limitations	Special management needs	Yield prediction for maize (bags/acre)
	(1) UPLAND SOILS				
D1-2 Weston	Deep, red, well-drained apedal clay loam derived from dolerite. Considerably leached.	Very high potential for intensive arable use. Suitable for wide range of crops and irrigation.	Low plant nutrient status	Judicious application of lime and fertilizer (especially P).	VH (> 35)
D1-7 Bellevue	Deep, red, well-drained structured clay loam derived from dolerite. Moderately leached.	Mod.-high potential for intensive arable use. Suitable for maize, lucerne, ley crops and irrigation.	Unfavourable moisture characteristics (droughty).	Moisture conservation through deep, timeous tillage.	M-H (25-30)
D3-1 Loskop	Mod. deep, red, mod. well-drained clay loam over soft plinthite.	Mod.-high potential for row and ley crops. Similar to Weston series.	Low plant nutrient status	Judicious application of lime and fertilizer.	M-H (25-30)
D3-2 Roolkop	Similar to Loskop series but with content of clay and sand 15-35% and over 50% respectively.	Moderate potential for arable use. Leys of long duration required for steep slopes.	Mod. high erosion hazard unfavourable moisture characteristics and low plant nutrient status.	As above with intensive conservation practice on sloping land.	M-H (25-30)
E1-4 AVALON	Mod. deep, grey-brown, mod. well-drained clay loam to sandy clay loam. Yellow apedal B-horizon overlies soft plinthite.	High potential for intensive production of maize, sorghums, wheat and short term ley crops (e.g. E.curvula and lucerne). Suitable for sprinkler irrigation.	Moderate erosion hazard and unfavourable surface soil characteristics. Impeded drainage at depth may affect deep rooted crops.	Efficient fertilization (especially N) and tillage, residue management and intensive conservation practice on sloping land.	H (30-35)
E1-66 SOUTHWOLD	Mod. shallow, grey-brown, mod.well-drained. Yellow apedal B-horizon overlies sedentary C-horizon. Gravel horizon usually present.	Mod. high potential, similar to AVALON.	As above.	As above. Subsoiling recommended.	M-H (25-30)
E1-7 Shandon	Mod. shallow, grey, poorly drained variant of SOUTHWOLD. Upper subsoil grey.	Low potential for arable use. Long term leys (e.g. Paspalum dilitatum) recommended.	Poor drainage, mod. high erosion hazard, unfavourable surface soil characteristics and droughtiness.	Intensive conservation practice and subsoiling. Avoid tillage or grazing when wet.	L (15-20)
E1-8 ARROCHAR	Shallow, grey-brown, clay loam, to sandy clay loam, usually with gravel horizon at 6-15 inches depth.	Low-mod. potential for regular arable use. Long term leys (e.g. E.curvula) and short period of crop (e.g. maize) most suitable.	Shallow depth and low moisture capacity, high erosion hazard and surface soil limitations.	Intensive conservation practice and deep tillage including subsoiling.	M (20-25)
E1-9 MISPAH	Very shallow grey-brown. A1-horizon overlying shale or sandstone.	Very low potential for arable use. Suitable for permanent swards of E.curvula or Rhodes grass.	As above.	Very intensive conservation practice. Permanent cover recommended.	VL (< 15)
E6-2 ALBANY	Mod. deep, grey, poorly drained, clay loam to sandy clay loam. Grey apedal P-horizon overlies soft plinthite.	Low potential for regular arable use. Best for long term leys (e.g. Paspalum dilitatum). Short periods of broadcast crops (e.g. Jap. millet) permissible.	Poor drainage, mod. high erosion hazard and poor physical characteristics.	Very intensive conservation practice, subsoiling, limited surface drainage, judicious fertilization (especially N). Avoid tillage or grazing when wet.	L (15-20)
E3-2 LEKSAND (variant)	Mod. deep, grey-brown, mod. well-drained sandy loam. Yellow apedal B-horizon overlies reddish horizon of soft plinthite.	Mod.-high potential for arable use if carefully protected. Maize, sorghum, wheat to be rotated with leys of moderate duration (E.curvula and lucerne). Suitable for sprinkler irrigation.	High erosion hazard, low plant nutrient status, impeded drainage at depth, low moisture capacity and excessive wear of implements.	Judicious fertilization, deep tillage, residue management and intensive conservation practice on sloping land.	M-H (25-30)

Table 62 contd

Soil series	General charcteristics	Use-suitability	Main limitations	Special management needs	Yield prediction for maize (bags/acre)
	(1) UPLAND SOILS				
E3-4 LONGLANDS	Mod. deep, grey, poorly drained sandy loam. Grey apedal P-horizon overlies soft plinthite. Sandy variant of ALBANY.	Low potential for arable use. Long term leys (e.g. *Paspalum dilitatum*) recommended.	Poor drainage, high erosion hazard and low plant nutrient status.	Very intensive conservation practice	L (15-20)
E5-1 GLENCOE	Similar to AVALON but yellow apedal B-horizon overlies hard plinthite (ouklip).	Mod. potential for arable use. Maize and ley crops (e.g. *E.curvula*) suitable.	Similar to AVALON but impeded drainage more severe.	Similar to AVALON.	M (20-25)
E5-3 WARRICK	Mod. deep, grey, poorly drained, clay loam to sandy clay loam. Grey apedal P-horizon overlies hard plinthite. Occurs in lower slope position or local depressions.	Low potential for arable use. Permanent swards (e.g. *Paspalum dilitatum*) recommended.	Poor drainage, mod.-high erosion hazard and poor physical characteristics.	Very intensive conservation practice, limited surface drainage and judicious fertilization (especially N). Avoid tillage or grazing when wet.	VL-L (< 15)
E5-4 WASBANK	Mod. deep, grey, poorly drained sandy loam. Sandy variant of WARRICK.	Very low potential for arable use. Permanent swards (e.g. *Paspalum dilitatum*) recommended.	Very poor drainage and high erosion hazard.	Very intensive conservation practice and limited surface drainage. Permanent cover recommended.	VL (< 15)
E5-6 KLIPFONTEIN	Mod.-shallow to shallow, grey, poorly drained, clay loam to sandy clay loam. A-horizon overlies hard plinthite (ouklip).	As above.	Poor drainage, shallow depth and poor physical chracteristics.	Permanent swards preferable. Surface drainage and subsoiling recommended where feasible.	VL (< 15)
	(2) BOTTOMLAND SOILS				
H1-1 KILLARNEY	Very poorly drained hydromorphic soil. pH of gleyed Cg-horizon is over 7.0. Periodically submerged.	To remain under permanent pasture swards (e.g. *Paspalum spp.* and clover) preferably under irrigation. Suitable for poplar.	High erosion hazard if incorrectly drained. Poor drainage and mechanical limitations.	Intensive conservation and land improvement techniques (e.g. ridge and furrow) to effect improved drainage.	—
L1-1 Alluvium (clayey)	Poorly drained, clayey soils occur in 'backswamps'.	As above.	Periodic flooding, poor drainage, mechanical limitations and silt deposition on forage crops.	Surface drainage (e.g. ridge and furrow) and safe disposal of flood water.	—
L1-2 Alluvium (loamy)	Mod. well-drained, loamy soils.	High potential for arable use. Suitable for irrigation. Recommended for intensive production of mixed pastures, lucerne and poplar.	Periodic flooding and slight impeded drainage.	Protection during flood period and surface drainage.	—
L1-3 Alluvium (sandy)	Well-drained to excessively drained, sandy soils lie adjacent to the river.	Mod. to high potential for arable use. Suitable for lucerne and poplar.	Periodic flooding and low moisture capacity.	Safe deposit of flood water.	—

Yield rating: VH - Very high, H - High, M - Moderate, L - Low, VL - Very low

AVALON and Bellevue series near the farm buildings. However, these soils differ markedly in the permissible rate and frequency of application and the period required after irrigation before the pasture can be re-grazed.

The droughty soil climate of many of the soils prevents the successful production of clover under rainfed conditions. However, lucerne holds considerable promise as a source of high quality roughage. It is predicted, therefore, that lucerne will eventually play an important role on the well-drained soils provided sufficient attention is given to correct fertilization and cultural practices (Graven, 1963).

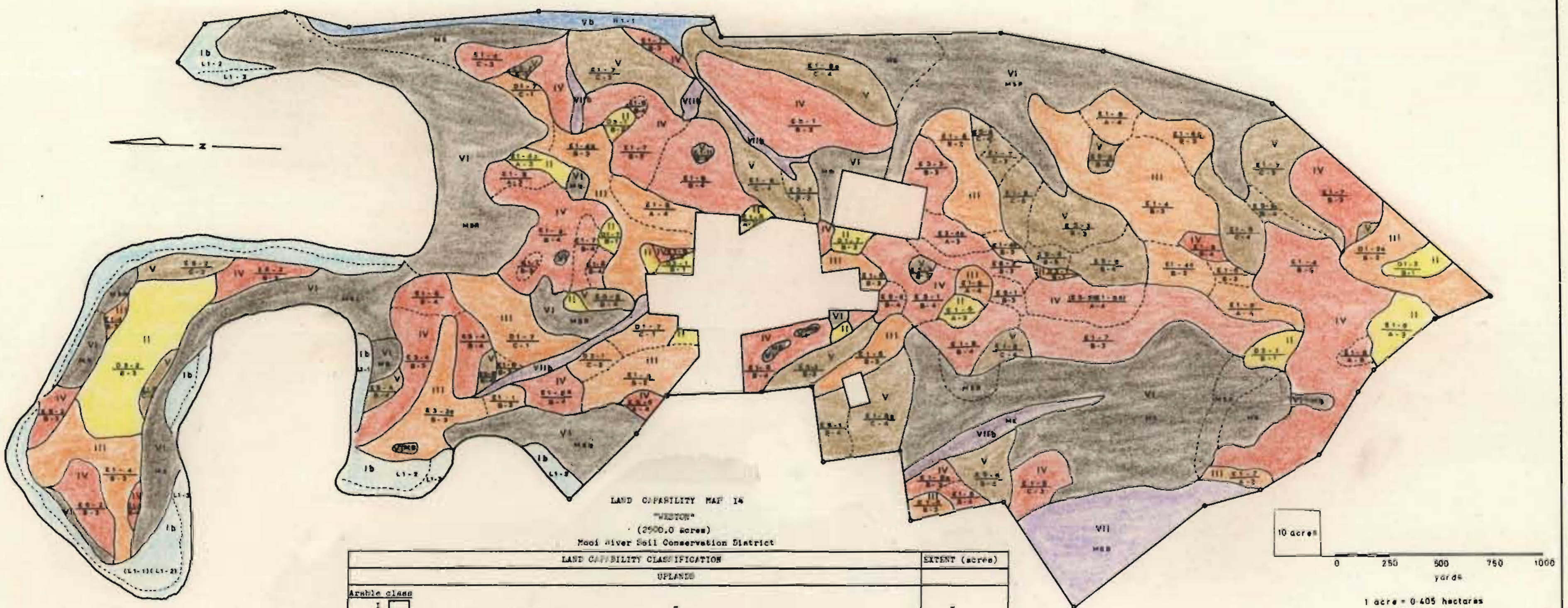
Unfavourable surface characteristics of the El-association soils (Chapter 3), are among the most important limitations. Together with poor drainage, they influence tillage needs profoundly, especially those related to weed control. Soils with such limitations, especially 'puddling', are best suited to long periods under ley and broadcast silage crops. Zero grazing may also be used to avoid excessive compaction. Pig weed (Amaranthus spp.) is a problem on almost every grey-brown cultivated soil on the farm.

2) The land capability classification and the basic conservation layout

The land capability classification and soil resources are indicated on Map 14. A summary of the capability classification is presented in Table 63.

The low potential of the farm for intensive arable use is clearly indicated by the capability classification. Only 10 percent of the arable area is classified as Class II land and over 55 percent as Class IV. A semi-intensive system of farming is thus indicated.

Classes V and VI tend to separate the steep areas predominated by El-association soils from the rocky outcrops characteristic of Dl-association soils. This separation is important for the subdivision and management of the natural veld. Although Class V land is suitable for veld reinforcement, techniques have yet to be perfected for the partially leached soils.



LAND CAPABILITY MAP 14

"WESTON"

(2500.0 acres)

Mooi River Soil Conservation District

LAND CAPABILITY CLASSIFICATION		EXTENT (acres)
UPLANDS		
Arable class		
I	-	-
II	Gently sloping deep usually well drained soils suited to intensive crop production. Requires easily applied conservation practices for safe use.	115.8
III	Mostly strongly sloping or shallow soils of moderate potential for arable use. Intensive conservation practices including leys of long duration are required.	391.8
IV	Strongly sloping, shallow or poorly drained soils of high erosion hazard with low potential for arable use. Leys of long duration and very intensive conservation practices.	610.7
V	Hilly and steep land to remain under permanent vegetation (including very poorly drained and hardpan soils).	303.9
Non-arable class		
VI	Non-arable land mostly very steep and/or rocky land to remain under natural vegetation for grazing purposes.	873.7
Protected class		
VII	Land requiring total protection.	66.6
BOTTOMLANDS		
Arable class		
Ib	Level alluvial soils suited to intensive pasture production. Textural and drainage variation considerable	112.4
Non-arable class		
Vb	Neutral to alkaline hydromorphic bottomland soils suited to production of permanent pasture.	21.3
Protected class		
VIIb	Bottomlands requiring total protection, mostly poorly drained hardpan soils in natural drainage ways. Eroded bottomlands included.	36.3
	Miscellaneous	168.0
	TOTAL	2500.0

MAPPING SYMBOLS

Soil Series

D 1 - 2	Weston
D 1 - 2a	Greybrown A1-horizon
D 1 - 7	Bellevue
D 3 - 1	Lamkop
D 3 - 2	Rooikop
E 1 - 4	Avalon
E 1 - 5	Newport
E 1 - 6	Southwold
E 1 - 7	Shandon
E 1 - 8	Arrochar
E 1 - 8a	Mottled clay underlying rubble horizon
E 1 - 9	Mispah
E 3 - 2	Leksand
E 3 - 4	Longlands
E 5 - 1	Glencoe
E 5 - 3	Warrick
E 5 - 4	Wasbank
E 5 - 6	Klipfontein
E 6 - 2	Albany
H 1 - 1	Killarney
L 1 - 1	Alluvium (clayey-poorly drained)
L 1 - 2	Alluvium (loamy - mod. well drained)
L 1 - 3	Alluvium (sandy - well drained)

Miscellaneous landtypes

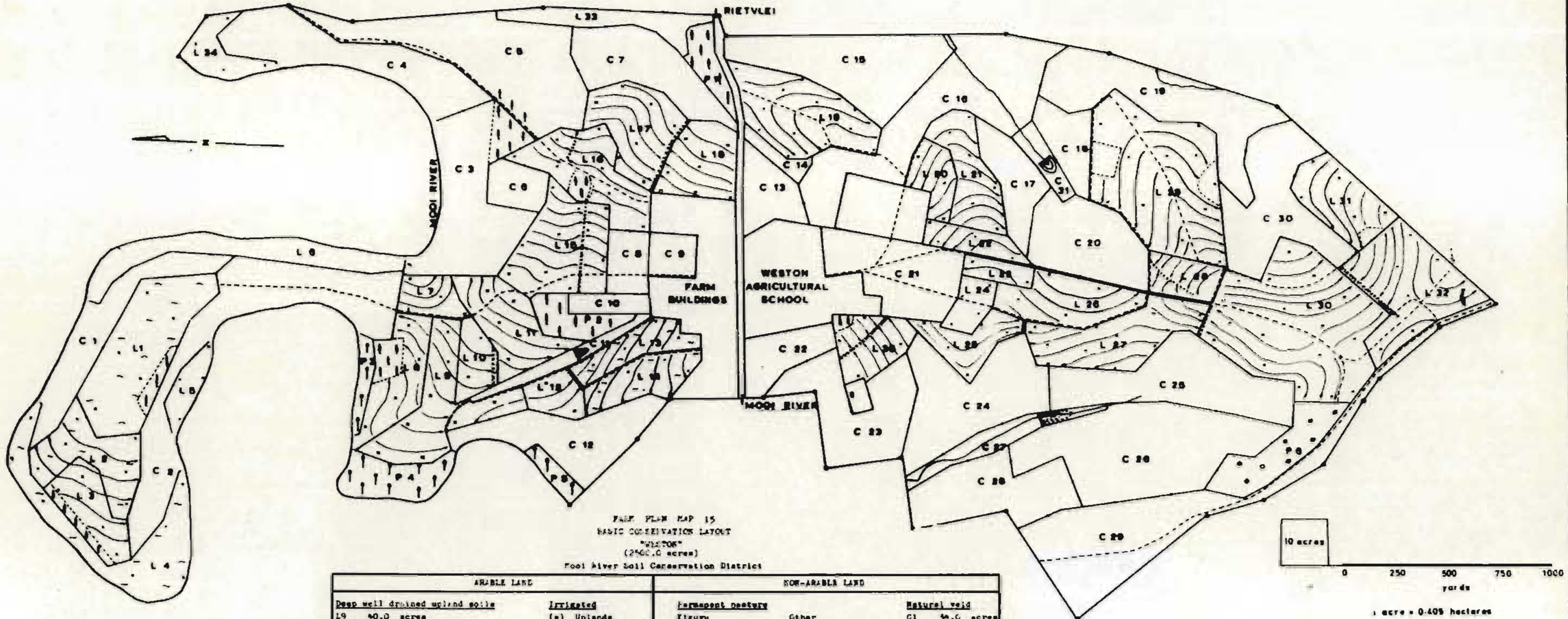
M	Non-arable
MS	Excessively steep
MR	Rocky
MSR	Steep and rocky
MU	Excessively uneven
MEU	Eroded and uneven

Slopes

A	0 - 3%
B	3 - 7%
C	7 - 12%

Depth

1	> 60"
2	36 - 60"
3	20 - 36"
4	10 - 20"
5	< 10"



FARM PLAN MAP 15
BASIC CONSERVATION LAYOUT
"WESTON"
(2500.0 acres)
Mooi River Soil Conservation District

ARABLE LAND

Deep well drained upland soils

L9	40.0	acres
L11	51.5	"
L16	32.1	"
L19	44.2	"
L21	24.6	"
L24	9.1	"
L28	16.5	"
L29	73.8	"
L32	49.7	"
	321.3	"

Shallow and/or poorly drained soils

L3	18.9	acres
L7	9.6	"
L8	19.0	"
L10	13.0	"
L12	11.5	"
L15	42.7	"
L17	31.6	"
L18	24.8	"
L20	12.8	"
L22	11.0	"
L23	7.0	"
L25	17.5	"
L26	28.5	"
L27	34.0	"
L30	93.4	"
L31	[illegible]	"
	405.0	"

Irrigated

(a) **Uplands**

L1	54.4	acres
L2	29.6	"
L13	17.5	"
L14	20.0	"
	121.5	"

(b) **Bottomlands**

L4	34.0	acres
L5	7.7	"
L6	28.0	"
L33	16.5	"
L34	9.6	"
	95.8	"

Total arable 943.6 acres

NON-ARABLE LAND

Permanent pasture

Kikuyu

C8	12.4	acres
C9	9.5	"
C10	7.8	"
C13	18.1	"
C22	17.7	"
	65.5	"

Other

C6	12.4	acres
C17	21.1	"
C18	16.5	"
C20	39.8	"
C21	42.1	"
C28	42.3	"
	174.2	"

Plantations and woodlots

P1	10.1	acres
P2	12.6	"
P3	4.9	"
P4	15.0	"
P5	4.6	"
P6	24.5	"
	71.7	"

Protected land

C11	9.6	acres
C14	5.0	"
C27	21.8	"
C29	64.7	"
C31	7.9	"
	108.0	"

Natural veld

C1	34.0	acres
C2	75.6	"
C3	55.0	"
C4	45.6	"
C5	76.4	"
C7	38.4	"
C12	40.0	"
C15	55.5	"
C16	77.0	"
C19	61.1	"
C23	44.0	"
C24	[illegible]	"
C25	57.0	"
C26	[illegible]	"
C30	[illegible]	"
	[illegible]	"

Miscellaneous

L35 (garden)	[illegible]	acres
School, sports-fields, labour, shelter belts, river frontage	[illegible]	"
	[illegible]	"

TOTAL 2500.0 acres

Table 63 : Land capability classification for 'Weston'

Landscape position	Capability division	Capability class	Extent (acres)
Uplands	Arable	I II III IV	- 116 392 611
	Non-arable	V VI	304 673
	Protected	VII	67
Bottomlands	Arable	Ib	112
	Non-arable	Vb	21
	Protected	VIIb	36
		Miscellaneous	168
		Total	2500

Local depressions on the farm, though not typically bottomlands, are included in Class VIIb since they form the natural drainage ways for the uplands and, as such, have very high erosion hazard. They are best left under natural vegetation and totally protected.

The basic conservation layout is shown on Map 15 and reflects the ultimate layout including arable areas that, for a time, will remain under natural veld. To some extent the layout is influenced by existing improvements. Some areas (e.g. C20) are also to be withdrawn from regular arable use because of unfavourable soil features. The map indicates necessary subdivisions and the general layout of conservation works. However, details of extensions to existing stockwatering schemes or the sites (outcrops of rock or shallow soils) on which feeding pens and similar structures should be constructed are not indicated. The permanent kikuyu camps (C8, C9, C10, C13 and C22) are proposed because of their convenience to the dairy and farm buildings.

3) <u>The production plan</u>

Assessment of all relevant factors, especially the edaphic and rainfall conditions, suggests the need for a semi-intensive farming system with beef and sheep as the main lines. The plan envisages the retention of all the existing enterprizes, most of which are to be expanded.

Afforestation was not considered a suitable proposition for Classes V and VI although Hubbard (1965) reported favourably on stands of Pinus roxburghii and Pinus patula on 'Weston'. However, he considered the rate of growth too slow for a commercial undertaking. Despite this, there is ample scope for woodlots and shelter belts which in time could provide a valuable source of timber. Certain of the bottomland soils are suitable for the production of poplar as an alternative to pastures.

The proposed plan for 'Weston' is considerably influenced by its geographic layout. The northern or peninsular area, although suited to intensification, is situated too far from the main administrative centre for immediate development. It is, therefore, to be run as a separate unit producing lucerne and fat lambs. The production of crops for winter grazing will be confined to the irrigable areas.

Livestock enterprize: Planning the size of the livestock enterprize is based primarily on making maximum utilization of the natural veld and the prescribed ley crops. A dairy unit of 50 cows in milk (90 mlu) is planned to meet the needs of the school and because of the close proximity of the fresh milk market. This unit will utilize the areas adjacent to the farm buildings including 37 acres of irrigated land (L13 and L14) that will supply the winter grazing requirements.

Initially, the sheep unit will comprise 155 mlu including 450 ewes. Because of the availability of high quality roughage (e.g. lucerne) and irrigated pasture the unit is to produce fat lambs. Once all the available arable land is developed a second unit of 150 mlu could be introduced either as hamels or a second ewe flock.

With a beef : sheep ratio of 1:1 the beef unit will also comprise 155 mlu, including 100 Hereford breeding cows. The plan envisages the sale of weaners although these may be kept, fattened and sold as tollies (van Wyk, 1967b). In this case, allowance will have to be made for an additional 85 mlu to be carried on the farm. Once the farm has reached maximum development, the beef unit could also be increased by approximately 100 mlu. The beef will utilize the veld and long term leys in summer and will receive hay and silage in winter.

The small existing pig unit (13 sows) is to be retained.

Table 64 provides a general guide to the winter feed requirements of each livestock enterprize once the farm is fully developed. The needs of the hamel flock (150 mlu) and the tollies (85 mlu) to be fattened are also included.

Table 64 : Winter feed requirements of livestock on 'Weston'

Enterprize	Irrigated pasture (acres)	Silage (tons)	Hay (tons)	
			Lucerne	E.curvula
Dairy (90 mlu)	37	267	32	57
Sheep (305 mlu)	47	640	97	216
Beef (340 mlu)	-	1178	23	454
Total	84	1985	152	727

To determine the feed requirements winter rations were computed using Morrisons standards (Morrison, 1959). However, many alternative rations and methods are possible. For example, a daily allowance of $\frac{1}{2}$ lb lucerne hay per sheep was planned, whereas Barnard and Kotze (1963) recommended approximately 1 lb per head per day to be fed twice weekly at 3 - 5 lb per sheep per feeding. Details of this nature are not taken into account in presenting the basic plan.

Yield estimates of natural veld, pastures and leys enable the summer requirements to be calculated. Those of the dairy unit are 55 acres of kikuyu and 35 acres of long term leys while those of the sheep unit are 163 acres of long term leys and 372 acres of natural veld. The beef herd requires approximately 219 acres of long term leys and the remainder of the natural veld (483 acres).

An amount of 1644 bags of maize is required annually by the dairy, sheep and pig units.

Cropping programme and allocation of land: The cropping programme is planned to meet the livestock requirements and to produce a limited amount of cash crop. Using conservative yield estimates it is calculated that, over and above the livestock needs, an additional 100 acres of maize and 70 acres of lucerne rotated with 15 acres of potatoes could be grown.

The soils of highest potential on the farm (Weston, Bellevue, Loskop, AVALON and SOUTHWOLD), comprising a total of 280 acres (lands 11, 16, 19, 21, 28, 29 and 32), are to be cropped fairly intensively with a rotation of 6 years maize - 4 years *E.curvula*. Of the 168 acres available for maize grain, 80 acres will meet the livestock needs, the balance will be cash crop. This system assumes optimum fertilization and the return of all stover.

Poorly drained soils of limited potential are to be used for long term leys (6 years) of *Paspalum dilatatum*, Rhodes grass and ladino clover in rotation with short periods (up to 3 years) of broadcast silage crops such as Japanese millet. Since the drainage problem is least in autumn and winter, the millet could be followed by roots or other fodder required by the sheep. This area of land (lands 3, 10, 15, 17, 20, 22 and 23) could supply approximately 80 acres of silage and 150 acres of summer grazing.

The shallow, moderately well-drained soils comprising 156 acres (lands 7, 12, 18, 25 and 30) are to be used for a 2 year maize - 4 year *E.curvula* rotation. Of the 50 acres of maize, 20 acres will provide the silage needs of the dairy unit and the balance will be sold as grain.

A total of approximately 200 acres of *E.curvula* is planned which, at 4 tons hay per acre, will comfortably meet the livestock needs.

The programme for the remainder of the arable area is:

Land 9 (40 acres)	-	dryland lucerne for livestock needs;
Lands 13 and 14 (37 acres)	-	irrigated ryegrass and clover pastures for the dairy unit (winter grazing);
Lands 1 and 2 (84 acres)	-	new irrigation block for lucerne;
Land 4 (34 acres)	-	irrigated winter pasture for ewes and lambs and silage in summer;

Lands 5, 6 and 34 (45 acres) - summer pasture;
Lands 33 (16 acres) - permanent summer pasture.

Potatoes (12 to 15 acres) followed by irrigated ryegrass for ewes and lambs could be grown on lands 1 and 2 if the lucerne is to be re-established every 6 to 7 years. However, the dangers of potato scab disease (Actinomyces scabies) and eelworm should not be overlooked.

Veld, veld reinforcement and permanent pasture: In the final plan there will be a total of 855 acres of veld subdivided into a minimum of 15 main camps for summer grazing. Veld reinforcement and possibly veld fertilization should first be tried on a small scale, preferably on the better drained soils in camps C5 or C23. Steps should, however, be taken to prevent erosion following soil disturbance. The permanent pastures will include the kikuyu camps (camps 8, 9, 10, 13 and 22) and the area to be withdrawn from cultivation (camps 6, 17, 18, 20 and 28). The latter are best suited to Paspalum dilatatum and Rhodes grass.

Conservation practices: Intensive conservation practices, mechanical and biological, are required for the majority of soils as indicated by the high percentage of Class IV land. The plan envisages the fencing off of all Class VIIb land and reclamation of the existing donga in C27. Wildlife conservation should also receive attention. The long river frontage provides a suitable habitat for many species of water fowl and provides many areas for recreation. The river itself provides good fishing. The recent introduction of eland (Taurotragus oryx) onto the farm affords the opportunity of studying the suitability of the area for game species of this kind. Other forms of wildlife such as guinea fowl are already well established on the farm.

Economic considerations: No attempt has been made to present a budget for 'Weston'. However, the expected results were calculated using standards obtained from the Mooi River farmers study group and show that the plan is economically sound. A total of over 300 acres of land of moderate to high potential is available for the production of maize. Although estimated yields for the various soils are indicated in Table 62 it should be noted that during the 1966/67 season, yields of over 25 bags of grain per acre were accurately measured on 'Weston' (Scotney & Wiseman, 1967). It is confidently expected that higher yield horizons will be established with improved fertilization (especially N) and tillage and efficient agronomic practice. Study group records indicate an average gross margin for maize grain of approximately R50 per acre which is well within the potential for 'Weston'.

From an economic point of view, the lucerne enterprize will require careful investigation. On the basis of a study conducted by Wood (1965) in the Colenso district, the initial returns can be expected to be poor. These may, however, increase to a maximum of 13 percent on capital after the sixth season. Woods's calculations were, however, based on flood irrigation whereas sprinkler irrigation is to be used on 'Weston'.

4) Implementation

The plan envisages a gradual expansion of all the existing enterprizes. Adjustment of the cropping programme to fit the soil resources is the first essential in the priority sequence. This should be closely followed by the application of a sound system of veld management. The layout of all arable fields and grazing camps, including the necessary conservation works, is also placed high in the priority sequence. Extension of the existing irrigation scheme for the dairy unit and the development of the peninsular area, including a pilot trial of lucerne, should also receive early attention. The rate of expansion of the beef and sheep units should be dictated by the progress of the cropping programme. The development of the 'new' arable areas should be considered only once the production from all existing areas has reached an optimum level.

3) 'R O S E D E N E'

'Rosedene' is situated in ecological area 2b three miles from Merrivale. It is 301 acres in extent and is of below average size for the Area. At present, a dairy unit with 50 cows in milk is the only enterprize on the farm. The intensity of land use in the present organization is generally low. In this discussion only the salient features of the proposed plan and an outline of the soil resources and land capability classification are given.

1) Soils and the land capability classification

The 1:50,000 soil map of the Area provided a remarkably clear indication of the distribution of soils on the farm. These consisted mainly of D1-, E1- and H1-association soils. The detailed investigation revealed that the SHORTLANDS and ARROCHAR series were commonest. Although the presence of the SHORTLANDS series was confirmed by analytical data, identification of the RICHMOND series would have been in keeping with local environmental conditions. It is probable that the S-values of most red, structured soils on the farm are generally close to the 5.0 me% limit so that the presence of both series is likely. The upland soils were also found to be very much heavier than those on 'Weston'. The distribution of the soil resources and the capability classification are shown on Map 16. Several features of the classification are especially noteworthy. Approximately 60 percent of the farm comprises arable classes although, as a result of steep slopes (group C), Class III land predominates. The gently sloping phase of the ARROCHAR series is upgraded because of its heavy texture and relatively low erosion hazard. These soils also occur on the crest of the main ridge passing through the farm and, as such, are not subject to run-off normally expected from surrounding slopes. Unlike the other farms, an area of Class I land is located on 'Rosedene'. This comprises the level phase of the SHORTLANDS series and is suitable for continuous arable use if wisely managed.

LAND CAPABILITY MAP 16

"ROCKDENE"

(301.6 acres)

Lions River Soil Conservation District — Ecological Area 2b

LAND CAPABILITY CLASSIFICATION		EXTENT (acres)
UPLANDS		
Arable classes		
I	Level deep well drained soils with high potential for intensive cultivation.	17.3
II	Gently sloping deep and usually well drained soils requiring easily applied conservation practices.	37.6
III	Strongly sloping or shallow soils of moderate potential for arable use. Intensive conservation practices required.	111.1
IV	Strongly sloping, shallow and poorly drained soils of low potential for arable use. Very intensive conservation practices required.	18.2
Non-arable classes		
V	Hilly and steep land to remain under permanent vegetation.	31.7
VI	Very steep and/or rocky land to remain under natural veld for grazing purposes.	56.6
Protected class		
Ib	-	-
Vb	Neutral to alkaline hydromorphic soils to remain under permanent pasture.	29.1
VIIb	-	-
	TOTAL	301.6

MAPPING SYMBOLS

Soil Series

D 1 - 6	Shortlands series
D 1 - 6a	Shortlands series (topsoil of drift material)
D 3 - 1	Loskop
E 1 - 2	Bergville
E 1 - 6	Southwold
E 1 - 6a	Southwold (dolerite boulders at depth)
E 1 - 7	Shandon
E 1 - 8	Arrochar (clayey)
E 5 - 6	Klipfontein
E 6 - 2	Albany
M 1 - 1	Killarney

Miscellaneous Landtypes

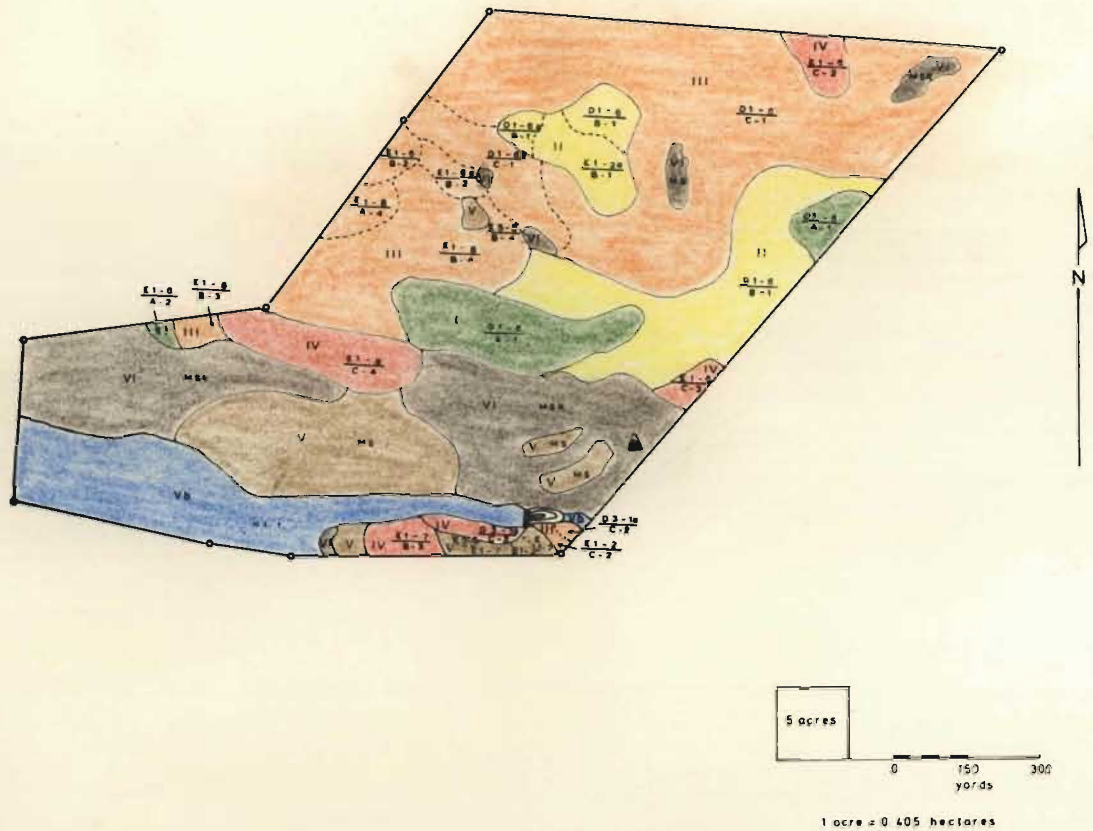
MR	Rocky
MS	Steep 12%
MSR	Steep and rocky

Slopes

A	0 - 3%
B	3 - 7%
C	7 - 12%

Depth

1	> 60"
2	36 - 60"
3	20 - 36"
4	10 - 20"
5	< 10"



FARM PLAN MAP 17

BASIC CONSERVATION LAYOUT

"HOLEDENE"

Lions River Soil Conservation District — Ecological Area 3b

ARABLE LAND

<u>Dryland</u>

L1	15.6	acres
L2	14.3	"
L3	17.0	"
L4	17.8	"
L5	14.6	"
L6	8.4	"
L14	11.3	"
L15	3.5	"
	100.5	"

<u>Long term leys</u>

L11	8.3	acres
L12	10.7	"
L13	8.6	"
L28	6.3	"
	33.9	"

<u>Irrigated pasture</u>

L26	19.3	acres
L27	8.3	"
L29	0.8	"
	28.4	"

NON-ARABLE LAND

<u>Permanent pasture</u> (Kikuyu)

C7	4.2	acres
C8	4.2	"
C9	5.7	"
C10	5.2	"
C16	5.1	"
C17	5.0	"
C18	5.6	"
C19	5.6	"
C21	4.6	"
C22	4.5	"
C23	5.0	"
C24	5.2	"
	59.9	"

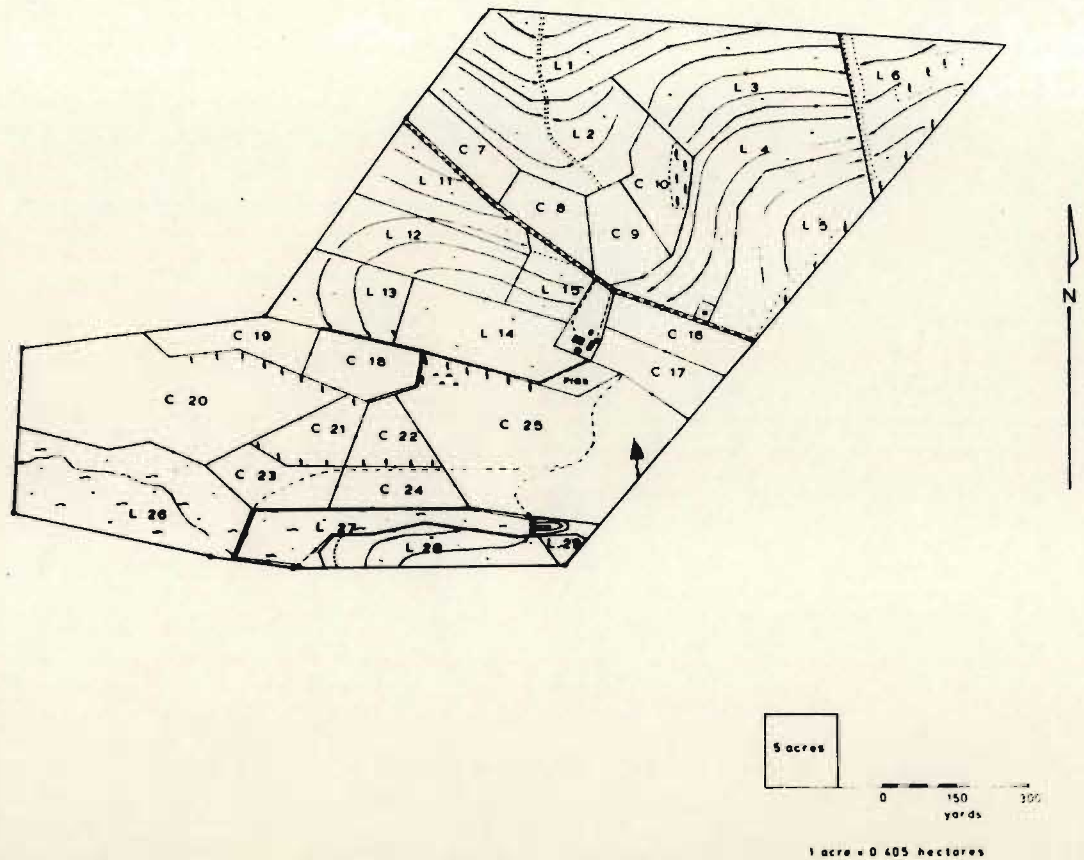
<u>Natural veld</u>

C20	26.0	acres
C25	29.1	"
	55.1	"

<u>Miscellaneous</u>

Homestead, roads waste 23.8 acres

<u>TOTAL 301.6 acres</u>



2) Basic conservation layout

The basic conservation layout is given on Map 17 which shows the location of fences and the proposed contour layout for the arable area including the important waterways. The main area for arable production is situated to the north of the road passing through the farm. Strip cropping with maize and E.curvula and contour drains are the main conservation measures planned for this area. Access roads will be sited on the contour. Although the proposed stockwatering requirements are not indicated on the map, these will be extended to strategic points on the farm. Distribution of existing supplies is poor. Since efficient and safe utilization of the bottomlands is dependent on the availability of irrigation, the enlargement of the existing dam in L27 or the construction of a further dam in the same vicinity is suggested.

3) The production plan

An intensive system of farming with dairy (fresh milk) as the main line is planned since the percentage of arable land is high, the main soils are suited for intensive arable use, the fresh milk market is close at hand and the farmer favours this type of farming. Large-scale cash cropping is not intended since hail occurs regularly during the summer months. For this reason, cultivated pastures are to play a major role in the plan. These will also make good the shortfall in summer grazing experineced under the present organization.

The plan envisages a dairy unit and a pig enterprize. The dairy unit will be restricted to 80 cows in milk until the resources of capital and labour have increased. Development of the dairy unit should take precedence over that of the pig enterprize. Eventually the dairying unit could reach a total of 174 mlu with 100 cows in milk.

The cropping programme is planned on the basis of the soil resources and is to meet the needs of the dairy unit. The winter requirements include 550 tons silage, 200 tons hay and 30 acres of irrigated pasture. The summer needs will be produced from 60 acres kikuyu, 60 acres Paspalum dilatatum and clover and the available natural natural veld (55 acres).

The allocation of land according to the capability classification is outlined.

Arable classes: The plan provides for:-

(a) Class 1 land (L14) to be used for continuous maize with the return of all stover, together with the manure from the dairy and piggery;

(b) a 6 year maize - 4 year E.curvula rotation on Class II land (lands 2, 5 and 11) to provide maize grain (5 acres), silage (15 acres) and hay (12 acres). In this case emphasis is placed on judicious fertilization since the proposed rotation is largely one of nutrient 'removal';

(c) a maize - hay rotation in Class III land (lands 3 and 4) comprising the SHORTLANDS series. This rotation will produce the balance of the E.curvula (28 acres) and maize grain requirements;

(d) Class III and Class IV land (lands 1, 6, 11, 12, 13 and 24) comprising shallow, poorly drained soils and the steep slopes of SHORTLANDS series (lands 1 and 6), to be planted to Paspalum dilatatum and clover for summer grazing. Re-establishment of 10 acres each year permits a silage crop (e.g. Japanese millet) to be grown; and

(e) other arable land (camps 7, 8, 9, 10, 16, 17, 18 and 19) to be planted to permanent kikuyu pastures for summer grazing, especially for the cows in milk.

Non-arable Classes: Provision is made for:-

(a) the natural veld to be replaced by kikuyu on Class V land (camps 21, 22, 23 and 24) and will be grazed by the dry cows;

(b) Class VI land or the steep and rocky land (camps 20 and 25) to remain as natural veld for grazing by young stock and other followers in summer. Should the dairy unit not expand to its maximum this land could be planted to Pinus patula or hand-planted to kikuyu;

(c) the potentially irrigable Class Vb land (lands 26, 27 and 29) to be established to a permanent tall fescue-clover pasture. Periodic re-establishment of strips across the 'vlei' will permit production of approximately 5 acres of ryegrass annually for the cows in milk. In this instance, a system of 'zero' grazing will have to be considered. This pasture will also provide a silage crop in summer. Should the supply of water for irrigation prove inadequate it is suggested that a Paspalum-clover pasture replace the fescue.

The economic aspects of the plan were investigated using standards from the Howick farmers study group. The results of these calculations show that the plan is economically sound. The main features demanding priority when the plan is implemented include adequate provision of summer grazing, the intensification of the cropping enterprize and the development of the irrigation facilities.

8.5 Discussion

This discussion is restricted to the detailed soil investigations and the land capability classification. The 1:50,000 soil map of the Area proved to be of considerable value in determining the soil resources on each farm and their approximate location. It was, however, no substitute for detailed soil mapping. The importance of the soil factor in determining land-use practice was clearly demonstrated in the planning of 'Weston'. The study showed clearly that soil survey procedures in farm planning will have greatest appeal in landscapes characterized by partially leached soils. Here the productive capacity and safe-use of the land are determined mainly by 'physical' soil criteria.

The accurate determination of textural classes, especially among the clayey, highly leached soils often proved difficult. Considerable field experience is thus needed for proficiency. It is also clear that much importance should be attached to the texture of the surface soil because of its relation to erodibility. The scoring technique suggested by Loxton (1962a) for the evaluation of permeability proved reliable but time-consuming. The immense value of systematic survey preceding the farm planning exercise is thus stressed since much time can be saved by simply identifying the particular soil series or phase. Identification of individual 'diagnostic horizons' also proved advantageous since many of these are directly related to land-use practice.

The proposed land capability classification proved to be of considerable value in providing an overall appreciation of available potential, severity of limitations and the degree of possible intensification on the farms. The planning of both conservation and economic aspects were thus placed on a sound footing. The classification is likely to be of greatest value in areas where physical soil limitations determine land-use decisions and where the level of applied technology is low. It is suggested, however, that interpretations made on the basis of individual mapping units will, in the long run, contribute most to the conservation effort. The classification requires further trial and refinement, and the support of much research. Knowledge of rainfall-erosion losses and the productive potential of soils is most needed. It would also be advantageous to define more specifically the criteria for determining capability classes. Despite this, the latitude permitted by the classification was of considerable benefit.

The classification should also be tested, and if necessary modified, in the extensive farming regions where emphasis is on natural vegetation. Although planning in these parts is generally based on the type and condition of the vegetation, the procedures should also include a study of soils. Grouping soils into 'range sites' on the basis of their similarity in characteristics affecting their capacity for producing veld plants should be seriously considered.

Thorough knowledge and understanding of the soil series and their definition are prerequisites for applying the classification. In some cases, especially in the drier landscapes, the classification is possibly over-conservative because of low soil ratings. Although the slope groups are generally satisfactory, further subdivision of group B may be justified where erosion hazard is of prime concern. The two upland non-arable classes (Classes V and VI) are particularly useful and, in most instances, tend to separate doleritic soils from those of shale origin. The capability classification also provides a sound basis for drawing up the 'basic conservation layout'. Whatever course farm planning is to take in the future, the basic conservation layout is seen as an essential step in the planning procedure. In effect it represents a 'mid-point' between physical and production planning.

The need for <u>systematic procedures</u> in farm planning, including detailed soil investigations, cannot be over-stressed. Although the suggested procedure is easily followed it is time-consuming. On an average, the length of time required to map the arable classes was between 0.75 and 1.5 days per 200 acres and depended on the complexity of the soil pattern. The writer contends, however, that this is time well spent if it results in efficient planning. The average time taken for each profile description and each augering, together with notes and including transportation between sites, was approximately 30 and 5 minutes respectively. Merely identifying soil series would, of course, reduce these values considerably. Because of the time factor it is imperative that planning of this nature should be conducted on a strict priority basis with the well-motivated cases enjoying preference.

If the suggested procedures are to be applied in the Area it is essential that an educational programme be initiated to convey all available soil data (Chapter 3) to the farming community. Likewise, officers concerned with the planning will require in-service training so as to become proficient in soil identification and the planning techniques. In this respect, stereoscopic interpretation warrants special emphasis since relatively few officers are able to make maximum use of this valuable aid. The need to improve the quality and scale of aerial photographs is considerable. The available coverage at 1:36,000 is totally unsuitable for detailed planning and should be of the order of at least 1:10,000.

Detailed farm planning should initially form part of the extension programme for the Area. Here, the planning of a number of carefully selected farms should form the main objective. The farms should cover a wide range of soils and other natural factors, and so afford field and research officers the opportunity of determining the most suitable land-use practices for each of the main ecological areas.

SUMMARY

Ever-increasing pressure on limited agricultural resources demands land-use planning of the highest calibre. A reliable inventory of soils is required if the goal of "treating each acre according to its needs and capability" is to be achieved. Not only is land of high potential a limited commodity, but soil itself is a non-renewable resource.

As a result of the wide range in soil forming factors, over 60 soil series exhibiting very different morphological, chemical and physical properties occur in the Howick Extension Area. Classification brings order to the study of the soil populations, often too heterogeneous to comprehend, and enables full use to be made of the growing body of scientific knowledge. A soil survey, presented in map form, shows the overriding influence of climate as a factor of soil formation and permits characterization of landscapes in terms of degree of leaching. Highly leached soils have very favourable physical characteristics but are extremely acid and low in plant nutrients. The converse holds for partially leached soils. Forests retard the leaching process.

Issues important for planning agricultural development are exposed by a study of soil distribution. For example, highly leached soils occupy over 70 percent of the Area - approximately 70 percent of this group comprise soils (Bl-association) known for their complex fertility problems. Bottomlands comprising highly erodible margalitic and claypan soils occupy as much as 20 percent of landscapes in the drier parts. Over 90 percent of these are severely eroded. Thus, the value of soil knowledge in agricultural extension and research is great.

Studies of ionic equilibria endorse the validity of the series concept. The K and lime status of individual soil series are characterized in terms of lime potential, quantity-intensity (Q/I) relations and energies of exchange. A study of selected farm fields reveals exploitation by current farming practice.

Continued increase in fertilizer use creates a demand for

information on the nutrient status of soils and the necessary corrective treatment. Pot experimentation indicates that P-fixation and Al toxicity are serious problems in the majority of highly leached soils. Liming is found to offset the effects of Al toxicity and although the P-requirement is exceptionally high on these soils, much benefit results from band placement of the fertilizer.

On the basis of soil moisture characteristics and other physical properties (e.g. bulk density and porosity), highly leached soils differ markedly from partially leached soils. Particularly favourable moisture characteristics, often exceeding 2 inches/ft total available moisture (TAM), are associated with soils such as those of the FARMHILL, GRIFFIN and HUTTON series. Such data are used to assess and rate the moisture capacity of a wide range of soils.

For practical reasons soil survey data require interpretation and, provided the objective is clearly defined, soils may be grouped for many purposes. Predictions about soil behaviour are thus possible. With the lack of accurate soil-crop data physical criteria, especially erosion hazard and moisture characteristics are used to rate and group soils for several purposes. Yield prediction, agricultural engineering, conservation, use-suitability and the management needs of soils are all important for land-use planning. Soil knowledge also permits the selection of 'bench mark' soils for research purposes. Acceptance of soil knowledge by the farming community requires the adoption of a carefully planned educational programme.

Sound land-use planning is ensured by careful assessment of the agricultural potential of the Area which requires cognisance of all natural characteristics. Furthermore, much is learnt from practices in current use and the successes and failures of past endeavour. Climate is clearly the most important determinant of agricultural potential. An environmental potential index (EPI) based on moisture, heat and rainfall reliability provides a promising means for assessing the controls imposed by climate.

Eight ecological areas are defined after consideration of the interrelationships between all natural factors. These are used to classify land in terms of use-capability and for recommending land-use practices. A master plan for each ecological area is suggested and the essential items for inclusion in the extension programme are indicated. Management of the important 'vlei' areas and afforestation are items receiving special consideration.

Land capability classification is the best means for protecting our most valuable resource (productive land) and enables rational land-use decisions to be made. Study of several methods in current use led to a proposed system for the Area. The system, based on systematic soil survey, is tested by planning three selected farms in detail. Although there is need for refinement the results are encouraging. The detailed planning exercise affords opportunity for presenting basic principles and suggesting systematic farm planning procedures, including both detailed soil investigation and economic analysis. Safe and correct land use requires the adoption of a pedological approach to farm planning and immediate in-service training. In general, the study reveals that the soil series concept is not only sound but provides a logical basis for planning land use.

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REFERENCES

AANDAHL, A.R., 1960. Soil productivity - concepts and predictions. Trans. 7th Int. Cong. Soil Sci. 4, 365-370.

-------------- 1962. The use of soil classification by economists. Proc. Int. Seminar on Soil and Water Utilization, South Dakota, 118-120.

ACOCKS, J.P., 1953. Veld types of South Africa. Bot. Surv. S.Afr. Mem. 28.

ADAMS, F. & PEARSON, R.W., 1967. Crop response to lime in the Southern United States and Puerto Rico. In R.W. Pearson (ed.) Soil Acidity and Liming. Agron. 12, 161-206.

ALBRECHT, W.A., 1940. Land classification in relation to the soil and its development. Missouri Agric. Expt. Sta. Bull. 421, 1-13.

ALLISON, L.E., 1965. Organic carbon. In C.A. Black (ed.) Methods of Soil Analysis (II). Amer. Soc. Agron., Agron. Series 9, Madison, 1367-1378.

BABCOCK, K.L. & OVERSTREET, R., 1955. Thermodynamics of soil moisture - a new application. Soil Sci. 80, 257-263.

BALL, D.F., 1964. Soil classification, land-use and productivity. The Nature Conservancy, Bangor, Caernarvonshire, Rep. 5, 1-16.

BARLOWE, R., 1958. Land Resource Economics. Prentice-Hall Inc., New Jersey.

BARNARD, H.H. & KOTZE, J.J.J., 1963. Value of lucerne for the sheep farmer. Dept. A.T.S., Bull. 364, Govt. Printer, Pretoria.

BAVER, L.D., 1956. Soil Physics. John Wiley and Sons, New York.

BECKETT, P.H.T., 1964a. Studies on soil potassium. I - Confirmation of the Ratio Law. J. Soil Sci. 15, 1-8.

--------------- 1964b. Studies on soil potassium. II - The "immediate" Q/I relations of labile potassium in the soil. J. Soil Sci. 15, 9-23.

--------------- 1964c. Potassium-calcium exchange in soils - specific adsorption sites for potassium. J. Soil Sci. 97, 376-383.

BENNETT, H.H., 1948. Soil conservation. Proc. Inter-Amer. Conf. on Conservation of Renewable Natural Resources, Denver, 349-360.

BIDWELL, O.W., 1966. Educational programs to aid agricultural users of soil survey reports. In L.J. Bartelli et al. (ed.) Soil Surveys and Land-use Planning. Soil Sci. Soc. Amer. and Amer. Soc. Agron., Madison, 147-151.

CRASS, R.S., 1964. Freshwater Fishes of Natal. The Natal Witness (Pty.) Ltd., Pietermaritzburg.

CUNNINGHAM, L.C. & WELLS, R.C., 1966. Crop yields related to soils, plant nutrients and labour incomes on Central Plain region dairy farms. New York State College.

CUTTING, C.V., 1959. A practical aspect of soil classification for agricultural purposes. Docum. 3rd Inter-Afr. Soil Conf., Dalaba.

DAUBENMIRE, R.F., 1948. Plants and Environment. John Wiley and Sons, New York.

DAY, P.R., 1942. The moisture potential of soils. Soil Sci. 54, 391-400.

DE KOCK, D.A. 1967. Catchment planning. Advanced Planning Course for Soil Conservation Committees, Cedara.

DEPARTMENT AGRICULTURAL ECONOMICS, 1964. Business summary (1963/64) for East Griqualand. Natal Region, Pietermaritzburg.

---------------------------------- 1967. Business summary (1966/67) of the Howick and Mooi River Study Groups. Natal Region, Pietermaritzburg.

---------------------------------- 1968. Average business summaries of study groups in the Natal Region. Natal Region, Pietermaritzburg.

DEPARTMENT AGRICULTURAL TECHNICAL SERVICES, 1962. Assessment of irrigation values (cyclostyled). Soils Res. Inst., Pretoria.

-- 1963. Handleiding tot grondbewaringsingenieurswese, Pretoria.

-- 1968. Report on the Umgeni vleis on the farms Ivanhoe and New Forest (unpub.). Natal Region, Pietermaritzburg.

DEPARTMENT OF FORESTRY, 1968. Report of the inter-departmental committee investigating afforestation and water supplies in South Africa, Pretoria.

DE VILLIERS, J.M., 1962. A sutdy of soil formation in Natal. Ph.D. Thesis, Univ. of Natal, Pietermaritzburg.

D'HOORE, J., 1964. Joint Project CCTA/CSA 11, Soil map of Africa at a scale of 1:500,000 (Revised definition). African Soils, 9, 65-73.

DOWNING, B.H., 1966. The plant ecology of Tabamhlope vlei, Natal. M.Sc. Thesis, Univ. of Natal, Pietermaritzburg.

------------- 1968. Notes on the ecology of Natal Highland Sourveld vleis. Proc. Grassld. Soc. Sth.Afr., 3, 131-134.

BLAGBURN, C.H., 1961. Farm Planning and Management. Longmans, London.

BLAGOVIDOV, N.L., 1960. Principles of soil and land evaluation. Trans. 7th Int. Cong. Soil Sci. 4, Madison, 357-364.

BLAKE, G.R., 1965. Bulk density. In C.A. Black (ed.) Methods of Soil Analysis (I). Amer. Soc. Agron., Agron. Series, 9, Madison, 371-372.

BOLT, G.H., 1955. Analysis of the validity of the Gouy-Chapman theory of the electric double layer. J. Coll. Sci. 10, 206-218.

BOLT, G.H. & FRISSEL, M.J., 1960. Thermodynamics of soil moisture. Neth. J. Agr. Sci. 8, 57-78.

BOX, J.E. & TAYLOR, S.A., 1962. Influence of soil bulk density on matric potential. Soil Sci. Amer. Proc. 26, 119-122.

BRAMMER, H., 1959. The tropical black earths of Ghana. Ghana Dept. Agric., Div. Soil and Land-use Survey, Paper, 9.

BROADFOOT, W.M., 1960. Field guide for evaluating cottonwood sites. Southern Forest Expt. Sta., U.S.D.A. Occ. Paper, 178.

BUCKLE, L.J., 1967. Re-organization of the farm 'Little Harmony' using the linear program technique. B.Sc. Thesis, Univ. of Natal, Pietermaritzburg.

BURINGH, P., 1954. The analysis and interpretation of aerial photographs in soil survey and land classification. Neth. J. Agr. Sci. 2, 16-20.

BURNEY, J.R., 1968. A critical appraisal of the Rocky Mountain rainfall simulator as a means for deriving realistic soil infiltration capacity curves. M.Sc. Thesis, Univ. of Natal, Pietermaritzburg.

------------- 1969. Basic soil erosion concepts and the physiographic development of agricultural catchments. Proc. River Engineering Symposium. S.Afr. Inst. Civil Engineers, Univ. of Natal, Pietermaritzburg, Pub. 3.

BUTLER, B.E., 1964. Assessing the soil factor in agricultural production. J. Aust. Inst. Agr. Sci. 30.

CHANNON, P., 1962. Analysis of soils from soil survey in the Lions River district. National Diploma Lab. Tech., Dept. A.T.S., Natal Region.

CHILDS, E.C., 1940. The use of soil moisture characteristics in soil studies. Soil Sci. 50, 239-252.

CLARKE, G.R., 1951. The evaluation of soils and the definition of quality classes from studies of the physical properties of the soil profile in the field. J. Soil Sci. 2, 50-60.

COOK, R.L., 1962. Soil Management for Conservation and Production. John Wiley and Sons, New York, 62-118.

DU TOIT, A.L., 1954. The Geology of South Africa. 3rd Ed., Oliver and Boyd, London.

EDELFSEN, M.E. & ANDERSON, A.B.C., 1943. Thermodynamics of soil moisture. Hilgardia, 15, 31-298.

EDWARDS, D., 1963. A plant ecological survey of the Tugela Basin, Natal. Ph.D. Thesis, Univ. of Natal, Pietermaritzburg.

EDWARDS, P.J., 1959. Zero grazing can reduce fertility of pastures. Fmg. S.A. 35 (4), 40-41.

-------------- 1961. Studies in veld burning and mowing in the Tall Grass Veld of Natal. M.Sc. Thesis, Univ. of Natal, Pietermaritzburg.

-------------- 1966. Veld replacement by improved grassland in Natal. Proc. Grassld Soc. Sth.Afr., 1, 63-67.

-------------- 1969. Fertilization and red clover Trifolium pratense and of 'Lands grass' Setaria pallide-fusca, Panicum laevifolium, Digitaria sanguinalis and D. horizontalis in the Highland Sourveld of Natal. Dept. A.T.S., Tech. comm. 80. Govt. Printer, Pretoria.

ERIKSSON, E., 1952. Cation exchange equilibrium on clay minerals. Soil Sci. 74, 103-113.

FAIR, T.J.D., 1952. Agricultural regions and the European rural farm population of Natal. S.Afr. Geogr. J. 34, 3-19.

FEDERAL DEPARTMENT CONSERVATION & EXTENSION, 1960. Farm planning scheme. Salisbury.

FISHER, A., 1955. The grass ley in South Africa in The Grasses and Pastures of South Africa. Central News Agency, Parow, Cape Province, 685-696.

FISHER, T.R., 1969. Crop yields in relation to soil pH as modified by liming acid soils. Missouri Agric. Expt. Sta. Res. Bull. 947, Columbia.

FOURCADE, H.S., 1889. Report of Natal Forests. W. Watson, Pietermaritzburg.

FULS, P.F., 1967. Die invloed van grondbewerking op die organise fraksie in grond. Proc. Soc. Sci. S.Afr., Pietermaritzburg.

GALLOWAY, H.M., 1966. Soil surveys and urban development - an educational approach. In L.J. Bartelli et al. (ed.) Soil Surveys and Land-use Planning. Soil Sci. Soc. Amer. and Amer. Soc. Agron., Madison, 137-146.

GARDNER, W.R., 1960a. Dynamic aspects of water availability to plants. Soil Sci., 89, 67-73.

-------------- 1960b. Plant-water relationships in arid and semi-arid conditions. Reviews of Research, UNESCO.

---------------- 1965. Dynamic aspects of soil water availability to plants. Ann. Rev. of Plant Phys. 16, 323-339.

GLOVER, J., 1967. The effect of different soil series on root growth of sugarcane. Proc. Soc. Soil Sci. S.Afr., Pietermaritzburg.

GRAHAM, E.H., 1944. Natural Principles of Land use. Oxford Univ. Press, New York.

GRAVEN, E.H., 1963. Dryland lucerne - its production and utilization. Dept. A.T.S., Bull. 364.

-------------- 1967. The management of pot experiments for fertility studies with pasture crops. Proc. Soc. Soil Sci. S.Afr., Pietermaritzburg.

GRAVEN, E.H. & THERON, E.P., 1970. Band placement of lime and superphosphate for ladino clover (Trifolium repens) in an acid oxysol. Proc. Grassld. Soc. Sth.Afr., 5, 106-112.

GREYVENSTEIN, F.S., 1963. Grondverliese onder verskillende toestande. Pedologiese beplanningskursus. Dept. L.T.D., Pretoria.

GROBLER, J.H., EDWARDS, P. & GERICKE, S.J. 1970. Handleiding om grondgebruiksklassifikasie as basis vir bewaringsboerdery te verduidelik. Optimale bodem benutting in die Landbou. Dept. L.T.D., Pretoria, 27-34.

HAW, R.C., 1959. The Conservation of Natural Resources. Faber, London.

HEADY, E.O. & CANDLER, W., 1963. Linear Programming Methods. Iowa State Univ. Press, Ames.

HENKEL, J.S., BAYER, A.W. & COUTTS, J.R.H., 1938. Sub-surface erosion on a Natal Midlands farm. S. Afr. J. Sci., 35, 236-243.

HENNING, M.W., 1949. Animal diseases in South Africa. Central News Agency Ltd., Johannesburg.

HENSLEY, M., 1969. Assessment of the irrigation potential of land. Proc. Irrigation Symposium, Cedara.

HENSLEY M. & SUMNER, M.E., 1967. Available moisture in sandy soils of the Makatini Flats. Proc. National Irrigation Symposium, Pretoria.

HIEMSTRA, L.A.V., 1965. Two useful erodibility indices for cohesive soils. (In press.)

HIEMSTRA, L.A.V. & EDWARDS, P.J., 1965. Method for determining erosion hazard in uncultivated fields of the Natal Tall Grass Veld. (In press.)

HILDYARD, P., 1959. Experiments with grass leys in Natal gave interesting results. Fmg. S.A., 35 (4), 9.

HILL, J.N.S., 1965. Investigation into soil-plant-climate relationships as an aid to irrigation planning for sugar cane in Natal. Ph.D. Thesis, Univ. of Natal, Pietermaritzburg.

HILL, P.R., 1961. A simple system of management for soil and water conservation and drainage in mechanized crop production in the tropics. Empire. J. Expt. Agric., 29.

HILLS, G.A., 1961. The ecological basis for land-use planning. Dept. of Lands and Forests, Res. rep. 46, Ontaria.

HOCKENSMITH, R.D., 1958. Classification of land according to its capability as a basis for a soil conservation programme. Proc. Inter-Amer. Conf. on Conservation of Renewable Natural Resources, Denver, 460-465.

HOSEGOOD, P.H., 1963. A simple method of constructing tension trays. Rhod. J. Agric. Res. 1, 90-93.

HUBBARD, C., 1965. The possibility of integrated forest industry in the Tugela Basin, Natal. Town Regional Planning Commission, Pietermaritzburg.

HUBBLE, G.D., MARTIN, A.E., ISBELL, R.F., BECKWITH, R.S. & STIRK, G.B., 1964. Soil survey and soil assessment. In Some Concepts and Methods in Sub-tropical Pasture Research. Commonwealth Agricultural Bureau, Bull. 47, 49-59.

HUDSON, N.W. & JACKSON, D.C., 1959. Results achieved in the measurement of erosion run-off in Southern Rhodesia. Docum. 3rd Inter-Afr. Soil Conf., Dalaba.

HUGHES, R.E. & MILNER, C.M., 1964. Soil type and productivity in Snowdonia. The Nature Conservancy, Bangor, Caernarvonshire. Rep. 5.

JACKS, G.V., 1946. Land classification for land-use planning. Imp. Bur. Soil Sci. Tech., 43.

JACKSON, W.A., 1967. Physiological effects of soil acidity. In R.W. Pearson (ed.) Acidity and Liming. Amer. Soc. Agron., Agron Series 12, Wisconsin, 43-66.

JAMES, W., 1968a. Preliminary hydrogical report (unpub.). Rep. Umgeni Source Committee, Natal Town and Regional Planning Commission, Pietermaritzburg.

---------- 1968b. Preliminary observations on the water resources of the Umgeni sources (unpub.). Progress Report, Univ. of Natal, Durban.

JAMISON, V.C., SMITH, D.D. & THORNTON, J.F., 1968. Soil and water research on a claypan soil. U.S.D.A. Tech. Bull. 1379. Washington.

JOFFE, J.S., 1949. Pedology. Somerset Press, Somerville.

KASSIER, W.E., 1963. An application of linear programming to farm planning. S. Afr. J. Econ. 31.

―――――――――― 1964. A method of farm enterprize planning. Agrikon, 3 (1).

―――――――――― 1966. A production function study of marginal returns and optimum intensity on East Griqualand farms. S. Afr. J. Econ. 34 (2).

KASSIER, W.E. & MALLETT, J.B., 1966. An economic study of optimum fertilizer applications and plant population in maize. S. Afr. J. Econ. 34 (3).

KELLOG, C.E., 1951. Soil and land classification. J. Farm Econ. 33, 449-513.

―――――――――― 1966. Soil surveys for community planning. In L.J. Bartelli et al. (ed.) Soil Surveys and Land-use Planning. Soil Sci. Soc. Amer. and Amer. Soc. Agron. Madison, 1-7.

KEVAN, D.K. McE. (ed.), 1955. Soil Zoology. Butterworths & Co. Ltd., London.

KING, L.C., 1951. South African Scenery. 2nd Ed. Oliver and Boyd, Edinburgh.

KINMONT, A., 1970. The urban water supply and demand. Proc. Water Natal 1970 Symposium, Durban.

KLINGEBIEL, A.A., 1962. Making soil survey interpretations. Proc. Intern. Seminar on Soil and Water Utilization. South Dakota, 121-124.

―――――――――― 1963. Land classification for land-use planning. U.S.D.A. Yearbook, Washington, 399-413.

KLINGEBIEL, A.A. & MONTGOMERY, P.H., 1961. Land capability classification. U.S.D.A. Handbook 210, Washington.

KNIGHT, B.H., 1952. Soil Mechanics for Civil Engineers. Edward Arnold & Co., London.

KOCH, J.T., 1968. Assessing the potassium status of soils. M.Sc. Thesis, Univ. of Natal, Pietermaritzburg.

KOLBE, F.F.H., 1967. Adult education on conservation. SARCCUS Regional Symposium, Johannesburg.

KOKOT, D.F., 1963. Water resources: "The Umgeni-Umbilo-Umlazi catchment areas". Prel. rep. 4, Natal Town and Regional Planning Commission, Pietermaritzburg, 32-33.

KRAMER, P.J., 1963. Water stress and plant growth. Agr. J. 55, 31-35.

KRANTZ, B.A. & CANDLER, W.V., 1954. Fertilize corn for higher yields. Agr. Expt. Sta. Bull. 366, North Carolina.

KROG, M.M., THERON, E.P. & ANDREW, C., 1969. An experimental sod seeder. Proc. Grassld. Soc. Sth.Afr. 4, 126-130.

LANDSBERG, H., 1958. Physical Climatology. Gray Printing Co., Pennsylvania.

LE ROUX, J., 1964. Cation exchange characteristics of some Natal soils. M.Sc. Thesis, Univ. of Natal, Pietermaritzburg.

------------ 1966. Studies on ionic equilibria in Natal soils. Ph.D. Thesis, Univ. of Natal, Pietermaritzburg.

LE ROUX, J. & SCOTNEY, D.M., 1970. A key to the soils of Natal. Dept. A.T.S., Pretoria.

LEWIS, A.B., 1952. Land classification for agricultural development. F.A.O. Agric. Studies, 18, Rome.

LOW, A.J., 1954. A study of soil structure in the field and the laboratory. J. Soil Sci. 5, 57-74.

LOXTON, R.F., 1961. A modified chart for the determination of basic soil textural classes in terms of the International classification for soil separates. S. Afr. J. Agr. Sci. 4, 507-512.

------------ 1962a. A simplified soil-survey procedure for farm planning. Soils Res. Inst., Dept. A.T.S., Pretoria.

------------ 1962b. A new approach to land capability classification in the Republic of South Africa. Pedological Farm Planning Course, Dept. A.T.S., Pretoria.

LOXTON, R.F., ANDERSSEN, E.C. & FELDMAN, C.D., 1961. Report on detailed investigation of farm planning procedures in the Federation of Rhodesia and Nyasaland (unpub.). Dept. A.T.S., Pretoria.

LOXTON, R.F. & MACVICAR, C.N., 1965. The soil series in relation to agricultural research and land-use planning. Proc. 39th Ann. Cong. S.Afr. Sugar Tech. Assoc., Mount Edgecombe.

LUDORF, R. & SCOTNEY, D.M., 1965. Pedological survey of the Lions River and Mooi River Valley Soil Conservation Districts. (In press.)

LUDORF, R. & CHANNON, P., 1965. Cation studies on a typical soil of the Natal Midlands. Proc. 39th Ann. Cong. S.Afr. Sugar Tech. Assoc., Mount Edgecombe.

LUTHIN, J.N. (ed.), 1957. Drainage of Agricultural Lands. Amer. Agron., Wisconsin.

MACINTIRE, W.E., SHAW, W.M., YOUNG, I.B. & ROBINSON, B., 193[illegible] effects of 12-year residues of lime and magnesia upon subsequent additions of potash. J. Amer. Soc. Agr.

MACLEAN, A.J., 1956. Influence of additions of lime to soils on the availability of potassium and other cations for alfalfa. Can. J. Soil Sci. 36, 213.

MACVICAR, C.N., 1962. Soil studies in the Tugela Basin. Ph.D. Thesis, Univ. of Natal, Pietermaritzburg.

MALLETT, J.B., 1961. A maize plant population and fertilizer study in the Bergville district. M.Sc. Thesis, Univ. of Natal, Pietermaritzburg.

MALLETT, J.B. & SCOTNEY, D.M., 1961. Maize survey in the Lions River district. Unpub. rep., Dept. A.T.S., Natal Region.

MATTHEWS, B.C. & BECKETT, P.H.T., 1962. A new procedure for studying the release and fixation of potassium ions in the soil. J. Agr. Sci. 58, 59-64.

MATTHEWS, P.E., 1969. Diversion of water to the upper region of the Tugela Basin. Natal Town and Regional Planning Commission, Pietermaritzburg.

MAUD, R.R., 1965. The application of geomorphology to pedology. Proc. 39th Ann. Cong. S.Afr. Sugar Tech. Assoc., Mount Edgecombe.

McCRYSTAL, L.P., 1963. Economic development in Natal. The Umgeni-Umbilo-Umlazi catchment areas. Rep. 2, Land and agriculture. Dept. Economics, Univ. of Natal, Durban.

McKNIGHT, J.S., 1962. On the way to intensive culture of cottonwood. Proc. Soc. of Amer. Forest, 44-46.

MELSTED, J.W., 1954. New concepts of management of cornbelt soils. Adv. in Agron. 6, 121-142.

MEYER, W.J. BENDER, W.H., WENNER, K.A. & RINIER, J., 1966. A 'system' of soil survey, interpretation, education and use. In L.J. Bartelli et al. (ed.) Soil Surveys and Land-use Planning Soil Soc. Amer. and Amer. Soc. Agron., Madison, 147-151.

MIDGELEY, D.C., 1952. A preliminary survey of the surface water resources of the Union of South Africa. Ph.D. Thesis, Univ. of Natal, Durban.

MILLER, P.M., 1966. An objective delineation of plant communities in a selected area of grassland vegetation. M.Sc. Thesis, Univ. of Natal, Pietermaritzburg.

MILLER, W.F., 1966. Volume changes in bulk density samples. Soil Sci. 102, 300-304.

MINISTRY OF AGRICULTURE, FISHERIES AND FOOD, 1958. The farm as a business - a handbook of standards and statistics. H.M.S.O., Lr

MOLL, E.J., 1965. An account of the plant ecology of the upper catchment. M.Sc. Thesis, Univ. of Natal, Pietermaritzbu

MÖNNIG, H.O. & VELDMAN, F.J., 1956. Handbook on Stock Diseases. Nasionale Boekhandel Beperk, Johannesburg.

MORRISON, F.B., 1959. Feeds and Feeding. The Morrison Publishing Co., Clinton, Iowa.

MOSCHLER, W.W., JONES, G.D. & THOMAS, G.W., 1960. Lime and soil acidity effects on alfalfa growth in a red-yellow podzolic soil. Soil Sci. Amer. Proc. 24, 501-509.

MURDOCH, G., 1961a. Swaziland soil survey report. (Personal communication).

———————— 1961b. Soil survey - the basis for improved farming. S.Afr. Geog. J. 43.

———————— 1964. Selecting soils for irrigation. Swaziland Min. of Agric. Bull. 11, 4-13.

———————— 1965. Practical value of a soil series classification to agricultural research. Proc. 39th Ann. Cong. S.Afr. Sugar Tech. Assoc., Mount Edgecombe.

———————— 1968. Soils and land capability in Swaziland. Parts I, II and III, Swaziland Min. of Agric., Bull. 24.

MURPHY, P.W., 1962. Progress in Soil Zoology. Butterworths & Co. Ltd., London.

MUNSELL SOIL COLOUR CHARTS, 1954. Munsell Colour Co. Inc., Maryland.

NATAL TOWN and REGIONAL PLANNING COMMISSION, 1961. The water resources and water requirements within the Umgeni river catchment. Rep. 7, Pietermaritzburg.

NÄNNI, U.W., 1970a. The effect of afforestation on streamflow at Cathedral Peak. Rep.1. S.A. For. J., 74, 6-12.

———————— 1970b. Afforestation and related aspects of vleis. Proc. Vlei Symposium, Sth.Afr. Inst. Agric. Ext., Pietermaritzburg.

NATHANSON, K., 1963. Studies in crop rotation and green manuring at Cedara and Ukulinga, Natal. Ph.D. Thesis, Univ. of Pretoria.

NICHOL, W.E. & TURNER, R.C., 1957. The pH of non-calcareous near neutral soils. Can. J. Soil Sci. 37, 97-101.

———————————————— 1958. The pH of strongly acid soils. Can. J. Soil Sci. 38, 63.

NORTHCOTE, K.H., 1964. Some thoughts concerning agronomy and soil classification. J. Aust. Inst. Agr. Sci. 30.

ODELL, R.T., 1958. Soil survey interpretation - yield predict Soil Sci. Amer. Proc. 22, 157-160.

ODUM, E.P., 1959. Fundamentals of Ecology. Saunders, Philadelphia.

OLSEN, G.W., 1966. Improving soil-survey interpretation through research. In L.J. Bartelli et al. (ed.) Soil Surveys and Land-use Planning. Soil Sci. Soc. Amer. and Amer. Soc. Agron., Madison, 147-151.

ORCHARD, E.R., 1964. Maize exports give food for thought. Fmg. S.A. 40 (5), 25.

————————— 1965. Pedological patterns of soil fertility. Proc. 39th Ann. Cong. S.Afr. Sugar Tech. Assoc., Mount Edgecombe.

OSCHWALD, W.R., 1966. Quantitative aspects of soil survey interpretation in appraisal of soil productivity. In L.J. Bartelli et al. (ed.) Soil Surveys and Land-use Planning. Soil Sci. Soc. Amer. and Amer. Soc. Agron., Madison, 147-151.

OVERBEEK, F.Th.G., 1952. Electrochemistry of the double layer. Colloid Sci. 1, 115-193.

PAZZI, J.J.O., 1963. Die bou van plaasdamme. Dept. L.T.D. Pamflet 365, Pretoria.

PEACE, T.R., 1952. Poplars. Forestry Comm. Bull. 19.

PEARSON, C.H.O., 1967. Soil and water conservation. S.Afr. Sugar J. 15, 409-410.

PEGRAM, G.G., 1969. A proposed experiment to study differences in run-off, sediment transport and flood attenuation in the upper Umgeni catchment. (Unpub. rep.) Univ. of Natal, Durban.

——————— 1970. Storage-draft-frequency analysis and simulation applied to the Umgeni catchment: a comparison. Proc. Water Natal 1970 Symposium, Durban.

PENTZ, J.A., 1938. The value of botanical survey and the mapping of vegetation as applied to farming systems in South Africa. Bot Survey, Pamphlet 19.

——————— 1949. An agro-ecological survey of Natal. Dept. Agri. and For. Bull 250. Govt. Printer, Pretoria.

PENZHORN, K.E.W., 1959. 'n Studie van die fisies-bilogiese fase van boerderybeplanning in die Hoëveldstreek van Suid Afrika. D.Sc. (Agric.) verhandeling, Univ. van Pretoria.

————————— 1961. Farm planning. S.Afr. Geog. J. 43, 49-52.

PETERS, D.B., 1965. Water availability. Methods of Soil Analysis (II) Amer. Soc. Agron., Agron. Series 9, Madison, 279-285.

PHILLIPS, J., 1959. Agriculture and Ecology in Africa. Faber,

———————— 1964. Some tentative thoughts about the agricultural forestry and related development of the Tugela Basin and its influent surrounds. 2nd progress rep., Natal Town and Regional Planning Commission, Pietermaritzburg.

———————— 1966. Certain criteria for application in the study of agricultural forestry and related development of the Tugela Basin and and its influent surrounds. 1st special rep. Natal Town and Regional Planning Commission, Pietermaritzburg.

———————— 1968. A note on the occurrence of vlei areas in Natal. (Personal communication.)

PRATT, D.J., GREENWAY, P.J. & GWYNNE, M.D., 1966. A classification of East African rangeland (with appendix on terminology). J. Appl. Ecol. 3, 369-382.

RAGLAND, J.L. & COLEMAN, N.T., 1959. The effect of soil solution aluminium and calcium on root growth. Soil Sci. Amer. Proc. 23, 355-357.

REEVE, N.G., 1966. The assessment of labile acidity in soil. M.Sc. seminar, Univ. of Natal, Pietermaritzburg.

———————— 1968. Amelioration of some acid Natal soils. M.Sc. Thesis, Univ. of Natal, Pietermaritzburg.

———————— 1969. Amelioration of acid soils. Soil Sci. Res. rep. 4, Univ. of Natal, Pietermaritzburg.

REEVE, N.G. & SUMNER, M.E., 1970. Effects of aluminium toxicity and phosphorus fixation on crop growth in Oxisols in Natal. Soil Sci. Amer. Proc. 34 (2).

RENNIE, D.A. & CLAYTON, J.T., 1958. Significance of local types of soil fertility studies. Canad. J. Soil Sci. 4, 146-157.

RICHARDS, L.A., 1965. Physical conditions of water in soil. In C.A. Black (ed.) Methods of Soil Analysis (I). Amer. Soc. Agro., Agron. Series 9, 279-285.

RICHARDS, S.J., 1966. Personal communication (letter to Prof. J.B. Phillips).

RIECKEN, F.F., 1962. Some aspects of soil classification in farming. Soil Sci. 96, 49-61.

ROBERTS, V.E., 1964. The properties and genesis of claypan soils of Natal. M.Sc. Thesis, Univ. of Natal, Pietermaritzburg.

ROBERTSON, W.K., NELLER, J.R. & BARTLETT, F.D., 1954. Effect of lime on the availability of phosphorus in soils of high to low sesquioxide content. Soil Sci. Amer. Proc. 18, 184-187.

ROBINSON, G.W., 1951. Soils, their Origin, Constitution and Cla ation. Thomas Murphy and Co., London.

ROE, H.B. & AYRES, Q.C., 1954. Engineering for agricultural drainage. McGraw-Hill Book Co., New York.

ROSS, J.C., 1967. The present status of resource conservation in Sarccus territories. Sarccus Reg. Symposium, Johannesburg.

RUBIDGE, C.J., 1967. No wonder we are losing. S. Afr. J. Sci. 63, 189-192.

RUSSEL, E.W., 1961. Soil Conditions and Plant Growth. (9th Ed.) Longmans, London.

RYCROFT, H.B., 1942. The plant ecology of the Karkloof forest, Natal. M.Sc. Thesis, Univ. of South Africa.

SALTER, P.J. & HOWARTH, F., 1961a. I - The available water capacity of a sandy loam soil. J. Soil Sci. 12, 326-334.

-------------------------- 1961b. II - the effect of farmyard manure and different primary cultivation. J. Soil Sci. 12, 235-341.

SAUNDER, D.H., 1959. What is the value of green manuring in Rhodesia? Proc. 4th Ann. Conf. Prof. Off. Dept. Res. & Spec. Services. Salisbury, 70-81.

SCHOEMAKER, H.E., McLEAN, E.O. & PRATT, P.F., 1961. Buffer methods for determining lime requirement of soils with appreciable amounts of extractable Aluminum. Soil Sci. Amer. Proc. 25, 274-277.

SCHOFIELD, R.K., 1935. The pF of water in the soil. Trans, 3rd Int. Cong. Soil Sci. 2, 37-48.

--------------- 1947. A ratio law governing equilibrium of cations in the soil solution. Proc. 11th Int. Cong. of Pure and App. Chem. 3, 257-261.

--------------- 1949. Effect of pH on electric charges carried by clay particles. J. Soil Sci. 1, 1-8.

--------------- 1953. Can a precise meaning be given to "available" soil phosphorus? Soil and Ferts. 18, 373-375.

SCHOFIELD, R.K. & TAYLOR, A.W., 1955a. Measurements of the activities of bases in soils. J. Soil Sci. 6, 137-146.

------------------------------ 1955b. The measurement of soil pH. Soil Sci. Amer. Proc. 19, 164-167.

SCHÖNAU, A.P.G., 1968. A site evaluation study in black wattle (Acacia mearnsii De Wild). D.Sc. Thesis, Univ. of Stellenbosch.

SCHUFFELEN, A.C. & BOLT, G.H., 1958. Ionic equilibria in soils. T- Intern. Soc. Soil Sci. 2, 132-136.

SCOTNEY, D.M., 1963. Silage survey in the Lions River Distr- Unpub. rep. Dept. A.T.S., Natal Region.

————————— 1964. Fire - a threat to our forests. Fmg. in S.A. 39 (12), 23-25.

————————— 1970. Vleis of Natal - definition and distribution. Proc. Vlei Symposium, S.Afr. Inst. Agric. Ext., Pietermaritzburg.

SCOTNEY, D.M. & DE JAGER, J., 1969. The assessment of environmental potential. (In press.)

SCOTNEY, D.M. & WISEMAN, I.G.R., 1968. Farming progress indicated by maize survey. Unpub. rep. Dept. A.T.S., Natal Region.

SCOTT, J.D., 1947. Veld management in South Africa. Dept. Agric. Bull. 278. Govt. Printer, Pretoria.

——————— 1951. A contribution to the study of the problems of the Drakensberg conservation area. Dept. Agric. Sci. Bull. 324, Pretoria.

——————— 1954. Pasture management III, lecture notes., Univ. of Natal.

——————— 1967a. Conservation or conversation. Proc. Grassld. Soc. Sth.Afr., 2, 21-29.

——————— 1967b. Farm planning and pasture management as they affect the veterinarian. J. S. Afr. Vet. Med. Ass. 38 (4), 347-352.

SELLERS, J.M., 1946. The origin and development of the merino sheep industry in the Natal Midlands. M.A. Thesis, Natal Univ. College, Pietermaritzburg.

SHERBALOFF, H., 1949. Some aspects of green manuring. Soils and Fertilizers, 12, 155-159.

SHERRY, S.P., 1954. The effect of different methods of brushwood disposal upon site conditions in wattle plantations. II - A study of run-off and erosion during the first two years after clear-felling and regeneration. Wattle Res. Inst. Rep., Pietermaritzburg, 27-36.

SIRIMANE, D.H.L., 1958. Land classification in Ceylon with reference to basic conditions of soil and water conservation. Agr. J. Ceylon, 29-37.

SKEEN, J.B., 1964. Determination of exchangeable aluminium in acid soils. M.Sc. Thesis, Univ. of Natal, Pietermaritzburg.

——————— 1968. The measurement of potassium potentials in acid soils. Ph.D. Thesis, Univ. of Natal, Pietermaritzburg.

SMITH, H.A., 1953. The Umgeni sponge. Proc. 3rd Conf. Umgeni Catch. Assoc., Durban.

SMITS, H. & WIGGERS, A.J., 1959. Soil survey and land classification as applied to reclamation of sea bottomlands in the Netherlands. Int. Inst. for Land Reclamation and Improvement, 4.

SOIL SURVEY STAFF, 1951. Soil survey manual. U.S.D.A. Handbook 18, Washington.

—————————— 1960. Soil classification - a comprehensive system. 7th Approximation. U.S.D.A. Washington.

SOMERS, I.I. & SHIVE, J.W., 1942. The iron-manganese relation in plant metabolism. Pl. Phys. 17, 502-601.

SOUTH AFRICAN BUREAU OF STATISTICS, 1953. Agricultural census 1951-52, No.26, Govt. Printer, Pretoria.

—————————— 1954. Agricultural census 1952-53, No.27, Govt. Printer, Pretoria.

—————————— 1956. Agricultural census 1953-54, No.28, Govt. Printer, Pretoria.

—————————— 1957. Agricultural census 1954-55, No.29, Govt. Printer, Pretoria.

—————————— 1958. Agricultural census 1955-56, No.30, Govt. Printer, Pretoria.

—————————— 1959. Agricultural census 1956-57, No.31, Govt. Printer, Pretoria.

—————————— 1960. Agricultural census 1957-58, No.32, Govt. Printer, Pretoria.

—————————— 1961. Agricultural census 1958-59, No.33, Govt. Printer, Pretoria.

—————————— 1962. Agricultural census 1959-60, No.34, Govt. Printer, Pretoria.

—————————— 1963. Agricultural census 1960-61, No.35, Govt. Printer, Pretoria.

—————————— 1964. Agricultural census 1961-62, No.36, Govt. Printer, Pretoria.

SOUTH AFRICAN SUGAR ASSOCIATION, 1968. Field drainage for sugar cane. S.Afr. Sugar Assoc. Expt. Sta., Bull. 18, Mount Edgecombe.

SOUTH AFRICAN WEATHER BUREAU, 1954. Climate of South Africa. Part 1. Climatic Statistics, Govt. Printer, Pretoria.

—————————— 1960. Climate of South Africa. Part 9. Average monthly rainfall, Govt. Printer, Pretoria.

SPARROW, G.W.A., 1964. Pleistocene periglacial landforms in the Southern hemisphere. S. Afr. J. Sci., 60, 143-147.

—————————— 1965. Soils and landforms. Proc. 39th Ann. Cong. S.Afr. Sugar Tech. Assoc., Mount Edgecombe.

STAMP, L.D., 1959. The measurement of basic land resources with special reference to Africa. Int. Inst. Land Reclamation and Improvement Ann. Rep.

STANHILL, G., 1957. The effect of differences in soil moisture status on plant growth: a review and analysis of soil moisture regime experiments. Soil Sci. 84, 205-214.

STANTON, D.A., 1958. Evaluation of the potassium supplying power of some Natal soils. M.Sc. Thesis, Univ. of Natal, Pietermaritzburg.

STEPHENS, C.G., 1953. Soil surveys for land development. F.A.O. Agric. Studies, 20, Rome.

STOCKSTAD, O., 1958. Soil survey interpretations for engineering purposes. Soil Sci. Amer. Proc. 22, 164-166.

STORIE, R.E., 1933. An index for rating the agricultural value of soils. California Agric. Expt. Station Bull. 556.

———————— 1959. Revision of the soil-rating chart. California Agric. Expt. Station Leaflet.

SUMNER, M.E., 1957. The physical and chemical properties of Tall Grass Veld soils of Natal in relation to their erodibility. M.Sc. Thesis, Univ. of Natal, Pietermaritzburg.

———————— 1965a. Assessment of potassium status of soils - recent developments. Proc. 39th Ann. Cong. S.Afr. Sugar Tech. Assoc., Mount Edgecombe.

———————— 1965b. Quantity-intensity relationships as a measure of the fertility status of soils. Univ. of Natal, Pietermaritzburg.

———————— 1965c. Soil Science IIIa lecture notes. 1st Ed. Univ. of Natal, Pietermaritzburg.

———————— 1965d. Soil Science IIIc lecture notes. Univ. of Natal, Pietermaritzburg.

TAYLOR, J.K., 1950. Land classification in Australia. Aust. J. Sci. 12, 127-130.

TAYLOR, A.W., 1958. Some equilibrium soil studies on Rothamstead soils. Soil Sci. Soc. Amer. Proc. 22, 511.

TAYLOR, H.C., 1961. The Karkloof forest: a plea for its protection. Forestry in Sth.Afr. 1.

TAYLOR, S.A. & BOX, J.E., 1961. Influence of confining pressure and bulk density on soil water matric potential. Soil Sci. 91, 6-10.

THERON, E.P. & CROSS, G.W., 1969. Veld replacement studies; the efficiency of paraquat. Dept. A.T.S. Natal Region, Res. Project N-Ce 111/3. (In press.)

THERON, J.J., 1957a. Leys essential for your soil. Fmg S. Afr. 33, 44-45.

\-\-\-\-\-\-\-\-\-\-\-\-\-\- 1957b. The organic matter of the soil. Handbook for Farmers in S. Afr. 2, 20-24.

THERON, J.J. & VAN WYK, L.P., 1933. Green manure and soil fertility. Univ. of Pretoria, Bull. 25, 1-26.

THERON, J.J. & HAYLETT, D.G., 1953. The regeneration of soil humus under a grass ley. Emp. J. Exp. Agric. 21, 86-98.

THOMAS, R.G., 1959. Classification of soils for land-use purposes in the Rhodesias. (Part I.). Docum. 3rd Inter-Afr. Soil Conf., Dalaba.

\-\-\-\-\-\-\-\-\-\-\-\-\-\- 1960. The development and pedological significance of land-capability classes. Proc. 5th Ann. Conf. Prof. Off. Dept. Res. and Spec. Services, Gwebi.

THOMAS, R.G. & THOMPSON, J.G., 1959. The classification and assessment of soils for irrigation in Southern Rhodesia. Docum. 3rd Inter-Afr. Soil Conf., Dalaba.

THOMPSON, G.D. & COLLINGS, D.F., 1963. Supplementary irrigation. S.Afr. Sugar Assoc. Expt. Sta. Bull. 17, Mount Edgecombe.

THORNE, D.W. & PETERSON, H.B., 1954. Irrigated Soils. Blakeston Co. Inc., New York.

THORNTHWAITE, C.W., 1948. An approach toward a rational classification of climate. Geogr. Review, 38, 55-94.

TINGLE, A.C., 1966. Silviculture, volume and yield of <u>Populus deltoides</u>. Ann. Univ. Stell. Vol. 41, Ser. A, No. 10.

\-\-\-\-\-\-\-\-\-\-\-\-\-\- 1968. Personal communication.

TINKER, P.B., 1964. Studies in soil potassium. III. Cation activity rations in acid Nigerian soils. J. Soil Sci. 15, 24.

TISDALE, S.L. & NELSON, W.L., 1966. Soil Fertility and Fertilizers. Macmillan Co., New York.

THORRINGTON-SMITH, E., 1960. Towards a plan for the Tugela Basin. Natal Town and Regional Planning Commission, Rep. 5, Pietermaritzburg.

TREWARTHER, G.T., 1954. An Introduction to Climate. McGraw-Hill, New York.

TSCHEBOLORIOFF, G.P., 1952. Soil Mechanics, Foundations and Earth Structures. McGraw-Hill Book Co., New York.

TURNER, J.L., 1970. Geology and geomorphology of vleis in Natal. Proc. Vlei Symposium, Sth.Afr. Inst. Agric. Ext., Pietermaritzburg.

TURNER, R.C. & NICHOL, W.E., 1962a. A study of the lime potential. I. Conditions for the limie potential to be independent of salt concentrates in aqueous suspensions of negatively charged clays. J. Soil. Sci. 93, 334-382.

——————————— 1962b. A study of the lime potential. II. Relation between lime potential and percent base saturation of negatively charged clays in aqueous salt suspensions. J. Soil. Sci. 94, 58-63.

UNITED STATES DEPARTMENT OF AGRICULTURE, 1954. A manual on conservation of soil and water. S.C.S. Agric. Handbook 61.

——————————— 1965. Predicting rainfall-erosion losses from cropland east of the Rocky mountains. S.C.S. Agric. Handbook 282.

VAN DER EYK, J.J., 1965a. Climate as soil forming factor in Natal. Proc. 39th Ann. Cong. S.Afr. Sugar Tech. Assoc., Mount Edgecombe.

——————————— 1965b. A physiographic classification of the soils of Natal. (Cyclostyled), Pietermaritzburg.

——————————— 1965c. Soils of the Tugela Basin - a draft copy of series definitions. (Personal communication.)

VAN DER EYK, J.J., MACVICAR, C.N. & DE VILLIERS, J.M., 1969. Soils of the Tugela Basin - a study in sub-tropical Africa. Natal Town and Regional Planning Commission, Pietermaritzburg.

VAN DER BANK, W.J., 1964. Mechanical composition of red ferruginous Natal soils. M.Sc. Thesis, Univ. of Natal, Pietermaritzburg.

VAN LAAR, A. & TINGLE, A.C., 1965. Economic aspects of Poplar growing for matchwood production. S. Afr. For. J. 53.

VAN REEUWIJK, L.P., 1967. Pedogenetic and clay mineralogical studies. M.Sc. Thesis, Univ. of Natal, Pietermaritzburg.

VAN ROOYEN, T.H., 1964. Pedogese van die Kranskop en Clovelly series in Natal. Magistergraad verhandeling, Univ. van Natal, Pietermaritzburg.

VAN WYK, S.P., 1967a. Kort metode van diagnose van leemtes in 'n boerdery. (Personal communication.)

——————————— 1967b. The economics of fattening beef cattle. Fmg. S.A. 43, 47-55.

VEIHMEYER, F.J. & HENDRICKSON, A.M., 1948. Soil density and root penetration. Soil Sci. 65, 487-493.

VERSTER, E., 1964. 'n Mineralogiese ondersoek van sekere Natalse rooigronde. Magistergraad verhandeling, Univ. van Natal, Pietermaritzburg.

VINCENT, V., 1959. Land capability-classification (Part II). Docum. 3rd Inter-Afr. Soil Conf., Dalaba.

VINCENT, V. & HACK, H.R., 1960. Land use and recommended farming systems for different land-capability classes in different areas in Southern Rhodesia. Proc. 5th Ann. Conf. Prof. Off. Dept. Res. and Spec. Services, Gwebi.

VINK, A.P.A., 1960. Quantitative aspects of land classification. Trans. 7th Int. Cong. Soil Sci. 4, Madison, 371-378.

------------- 1963. Planning of soil surveys in land development. Int. Inst. Land Reclamation and Improvement, 10.

VOMOCIL, J.A., 1965. Porosity. In C.A. Black (ed.) Methods of Soil Analysis (I). Amer. Soc. Agr., Agron. Series 9, 299-313.

WADLEIGH, C.H. & KLINGEBIEL, A.A., 1966. An inventory of land and water resources. In M. Stelly (ed.) Our Heritage of Land and Water Resources. Amer. Soc. Agron. Pub. 7, 1-22.

WALLACE, D.B. & BURR, H., 1963. Planning on the farm: the use of gross margins and common costs in the analysis and re-organization of farming systems. Rep. 60. Univ. of Cambridge.

WEAVER, J.E. & CLEMENTS, F.E., 1938. Plant Ecology. McGraw-Hill Book Co., New York.

WEBSTER, G.R. & HARWARD, M.E., 1959. Hydrogen and calcium ion ratios in dilute equilibrium solutions as related to cation saturation. Soil Sci. Soc. Amer. Proc. 23, 446-451.

WESTIN, F.C., 1962. Soil resource knowledge for effective development. Proc. Int. Seminar on Soil and Water Utilization, South Dakota, 17-19.

WESTVELD, R.H., 1951. Forestry in Farm Management. John Wiley and Son Inc., New York.

WHYTE, R.O. & TAYLOR, B.W., 1958. A comprehensive approach to land classification. Int. Seminar on Land Development for Agricultural Uses, Wageningen.

WICHT, C.L., 1958. The management of water catchments. African soils.

WILCOX, J.C., 1959. Rate of soil drainage following an irrigation. I - Nature of soil drainage curves. Canad. J. Soil Sci. 39, 107-109.

------------- 1960. II - Effects on determination of rate of consumptive use. Canad. J. Soil Sci. 40, 99-104.

------------- 1962a. III - A new concept of the upper limit of available moisture. Canad. J. Soil Sci. 42, 123-128.

————————— 1962b. IV - Effects of consumptive use and soil depth on the upper limits of available moisture. Canad. J. Soil Sci. 42, 129.

WILSIE, C.P., 1962. Crop Adaption and Distribution. W.H. Freeman and Co., San Francisco.

WISEMAN, I.G.R. & SCOTNEY, D.M., 1968. The production of ryegrass in the Howick Extension area. (Unpub. rep.) Dept. A.T.S., Natal Region.

WISCHMEIER, W.H., 1962. Erosion rates and contributing factors in semi-arid regions. Proc. Int. Seminar on Soil and Water Utilization, South Dakota, 127-131.

WOODRUFF, C.M., 1955. The energies of replacement of Calcium by Potassium in soils. Soil Sci. Soc. Amer. Proc. 19, 167-170.

————————— 1967. Crop response to lime in the Midwestern United States. <u>In</u> Acidity and Liming. Amer. Soc. Agr., Agron Series, No. 12, Wisconsin, 207-227.

WOODRUFF, C.M. & McINTOSH, J.L., 1960. Testing soil for potassium. Trans. 7th Int. Cong. Soil Sci. 3, 80.

WOODS, D.B. & MOLL, E.J., 1967. Multivariate analysis of grassland in the Three Rivers Area of Natal. Proc. Grassld. Soc. Sth.Afr., 2, 103-111.

YATES, D.W., 1966. The pattern and structure of fresh milk dairy farming in the Durban milk shed. M.A. Thesis, Univ. of Natal, Pietermaritzburg.

ZANDSTRA, H.G. & MACKENZIE, A.F., 1968. Potassium exchange equilibria and yield responses of oats, barley and corn on selected Quebec soils. Soil Sci. Amer. Proc. 32, 76-79.