COMPARATIVE EVALUATION OF *CELTIS AFRICANA* IN LESOTHO WITH THAT IN KWAZULU – NATAL, SOUTH AFRICA

by

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ABSTRACT

Research was conducted in three study sites in Lesotho, and the fourth, which was used on comparative basis, was in KwaZulu-Natal, South Africa.

The study was suitable for Lesotho as it is a small country with very limited natural resources. Lesotho's weak economy, exacerbated by the increasing population, needs concerted efforts to redress its socio-economic problems. This study is one of such efforts to explore the potentials of the indigenous forests with the aim of addressing wood demands. *Celtis africana* is one of the species with a proven record in Lesotho to have been a well adapted, resourceful timber tree in the past. Over-exploitation has degenerated it to its brink of extinction. It is against this background that this research was conducted with the aim of restoring *Celtis africana* to its original status in Lesotho.

The results revealed that due to climatic conditions, seeds from Kwazulu-Natal are heavier than those from localities in Lesotho. However, wood densities from study sites in Lesotho are higher than those of KwaZulu-Natal. Pre-treatment method of manual scarification showed the best outcomes in terms of germination percent and vigour while the control was the last. The diverse nature of *Celtis africana* allows it to survive and prosper in a wide and varying range of habitats. Its pliable and adaptive characters are manifested by its ability to adapt in novel environments. Under ideal warm and moist conditions *Celtis africana* keeps its foliage all the year round, but in dry or abnormally cold years it becomes a deciduous tree. Though it is distributed in a variety of habitats, *Celtis africana* prefers moist habitats. It also demonstrates greater "affinities" for the carbonates in the soils, in particular, calcium carbonate ($CaCo_3$) and dolomite ($CaMgCo_3$).

More research and determined reforestation programmes are required in order to improve the status of *Celtis africana* in Lesotho. Its natural existence in Lesotho can curtail expense of provenance identification. Both extension strategies and silvicultural operations, which can assist in tree improvement, should be adopted. Social benefits

which, are rendered by *Celtis africana* in South Africa, can be emulated and adopted in Lesotho. Other than being an admired and valuable recreational tree (planted in parks and in the homesteads), it is a protected tree in South Africa.

Key words: Climate, altitude, utilization, habitat and carbonates.

PREFACE

The research work described in this dissertation was conducted at the University of KwaZulu – Natal, Pietermaritzburg and in designated study sites in Lesotho from December 2003 to January 2005, under the supervision of Michael Underwood.

The dissertation represents my original work and has not been submitted in any form for any degree or diploma to any University. I declare that where use has been made of the work of others, due acknowledgements have been made.

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January 2005

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Mr. Michael Underwood (Supervisor)

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INTRODUCTION

1.1 EVOLUTION OF INDIGENOUS SPECIES

Evolutionary processes imprint a variety of forms of life in different environments that we live in. The resultant geographical patterns are a work of many years of evolutionary changes enhanced by biological and abiotic factors. Each ensueing biome elicits its own way of existence, thus, modelling its unique ecosystem. Though evolution has distinct arrangement of these patterns, there is never a mirror image or true replica of them in terms of species diversity. The resulting plant associations and co-associations, constitute a natural vegetation, similarly termed indigenous vegetation, which is composed of different species. Ridley (1996) defines species as groups of interbreeding natural populations that are reproductively isolated from other such groups.

1.2 HUMAN INTERACTIONS WITH ECOSYSTEMS

Man, apart from haphazard natural disasters (such as avalanches, volcanic eruptions, meteorites, floods etc.), becomes the greatest disturbance to the harmonious coexistence within the biological diversity, through his sustained activities. In a short space of time, mankind tends to undo what natural processes have achieved over long and protracted periods of time. The critical level is reached demands from the existing biodiversity, far more exceed the natural resilience to maintain the state of equilibrium. The ever-growing populations often need more food, shelter and energy. An unabated drive to meet some of these basic needs leads to over exploitation of natural vegetation such as forests. Need for fencing materials, telephone and electric poles and construction materials, add to high demands from the forests. Large-scale clearings of forests as a preparation for agricultural and residential sites, in addition to overgrazing, also contribute significantly to the deforestation and soil degradation. Rowe *et al.* (1987) state that between 1850 and 1980 about 15% of the earth's forests and woodlands of North Africa and the Middle East declined by 60%; those of South Asia, by 43%; of tropical Africa, by 20%; and Latin America 19%. Loss of forests continues to be a problem in these regions. In a much broader perspective, this adverse human interaction with the environment may lead to the narrowing of the germplasm or at worst, total species extinction. As human influences on natural systems extend to the furthest reaches of the planet, a challenge for the twenty-first century is to reconcile resource use with an equitable life for current and future generations of people, while conserving the millions of other species with which we share the planet (Kanashiro *et al.*, 2002). This is the situation perceived by Sharma (1992) that the world today faces the challenge of achieving a balance between development and maintenance of natural systems and, thereby, ensuring the integrity and stability of forest ecosystems.

1.3 LACK OF AWARENESS OF SOCIO -ECONOMIC IMPORTANCE OF THE INDIGENOUS VEGETATION

In many parts of the world, indigenous vegetation is on the brink of extinction because of the high demands for natural resource to satisfy the insatiable needs of mankind. What the people do not realise is the socio-economic potential, which this natural resource can have and the vital role it can play in maintaining a healthy environment. This oversight is further worsened by the inadequate research and the consequential lack of information in the dynamics of the ecosystems. In many cases, the prevailing status of the indigenous forests is a true reflection of the national policies. They are often deficient of sound silvicultural management and protection that can focus sustainable production and development. Bazuin (2000) asserts that although several policies have put considerable efforts in conservation actions, the need to act is growing and the focus is mainly on ecosystem conservation. Much less attention has been paid to the issue of conservation and sustainable use of the forest genetic resource.

The ever-depleting natural resources and consequential environmental degradation, can ultimately lead to adverse impacts on countries' economies, particularly in developing countries whose economies are weak. Indigenous forests should be regarded as a natural free gift with no inherent establishment efforts or expendable input costs. The issue, which should also be considered is that, efforts to reclaim the already depleted natural resources may prove to incur more expenses than those which can be embarked upon in asserting preventative measures. In the same vein, expenses can be waved away by deploying and incorporating the readily available indigenous knowledge in the management of the resource. Lal (2000) supports the idea that, the use of the indigenous knowledge in the management of forests for sustainable production of Non-Wood Forest products (NWFP's) and healthy environment is essential. There are some traditional indigenous systems, which still auger well with empirical silvicultural principles and can be incorporated in forest management.

Currently, woodland resources provide a wide range of goods and services, especially for the rural communities, but the exploitation of these resources lie outside the formal market economy. Conventional national accounts do not recognise the drawing-down of the woodland resource base and, consequently, the woodland resource's contribution to both the local and the national economy is largely unknown. The anomaly is further exacerbated by the insufficient data on the true values of woodland resource (Temu, 1993).

1.4 BACKGROUND INFORMATION IN RELATION TO *CELTIS AFRICANA* IN LESOTHO

Among the indigenous species embedded in ecological zones in Lesotho, is *Celtis africana.* Historical records indicate that the species was once a valuable source of saw timber for construction in the past (May, 2001). In recent times, the indigenous vegetation has degenerated to acute levels. It is speculated that, the scenery of isolated patches of small, thrifty trees and shrubs, were once more dense and extensive than they are at present (Staple and Hudson, 1938). Germond (1967) mentions that the endemic degradation of Lesotho's indigenous vegetation has largely been attributable to the following factors:

1. Displacement of Basotho by the settlers from the forested lowlands, west of Caledon River, to the high treeless slopes of Maloti Mountains (during the Great Trek) encouraged hoarding of wood from for the construction of new homes.
2. The tranquillity and stability that followed the British Protectorate mandate to Lesotho (Pax Britannica) resulted in rapid population increase. Lesotho was a British Protectorate (1868-1966) and was officially known as Basutoland. This growth resulted in correspondingly increased impact on the woodlands.
3. Rinderpest epidemic of 1896-7 led to the loss of 75% of the bovine population of Lesotho. The loss varied directly with the reduction in yield of the traditional fuel, which is cow-

dung, called *lisu* or *khapane* in Sesotho (Figure 1). The consequence of this ordeal was to resort to more use of wood as a source of fuel energy, which was to the detriment of natural vegetaton.

4. Two of the very coldest winters on record culminated in the unprecedented snowfall of 1902, further impacted upon the already critically low supply of timber for fuelwood. This snowfall is still remembered as the Great Snowfall (Lehloa le Leholo). In this era (1897-1902), the hills and kloofs were thoroughly deforested. Trees were not only felled but also uprooted.

Figure 1: A girl collecting cow-dung (*khapane*) from the veld for fuel in the rural areas.

However, though Lesotho has reached the state of being almost treeless, its wood related needs are enormous. Fuelwood is the most needed type of wood resource, although domestic fuel preferences may vary according to the regions in the country (Figure 2). Fuelwood is the preferred, most affordable type of domestic energy and until recently, the highly demanded forest produce.

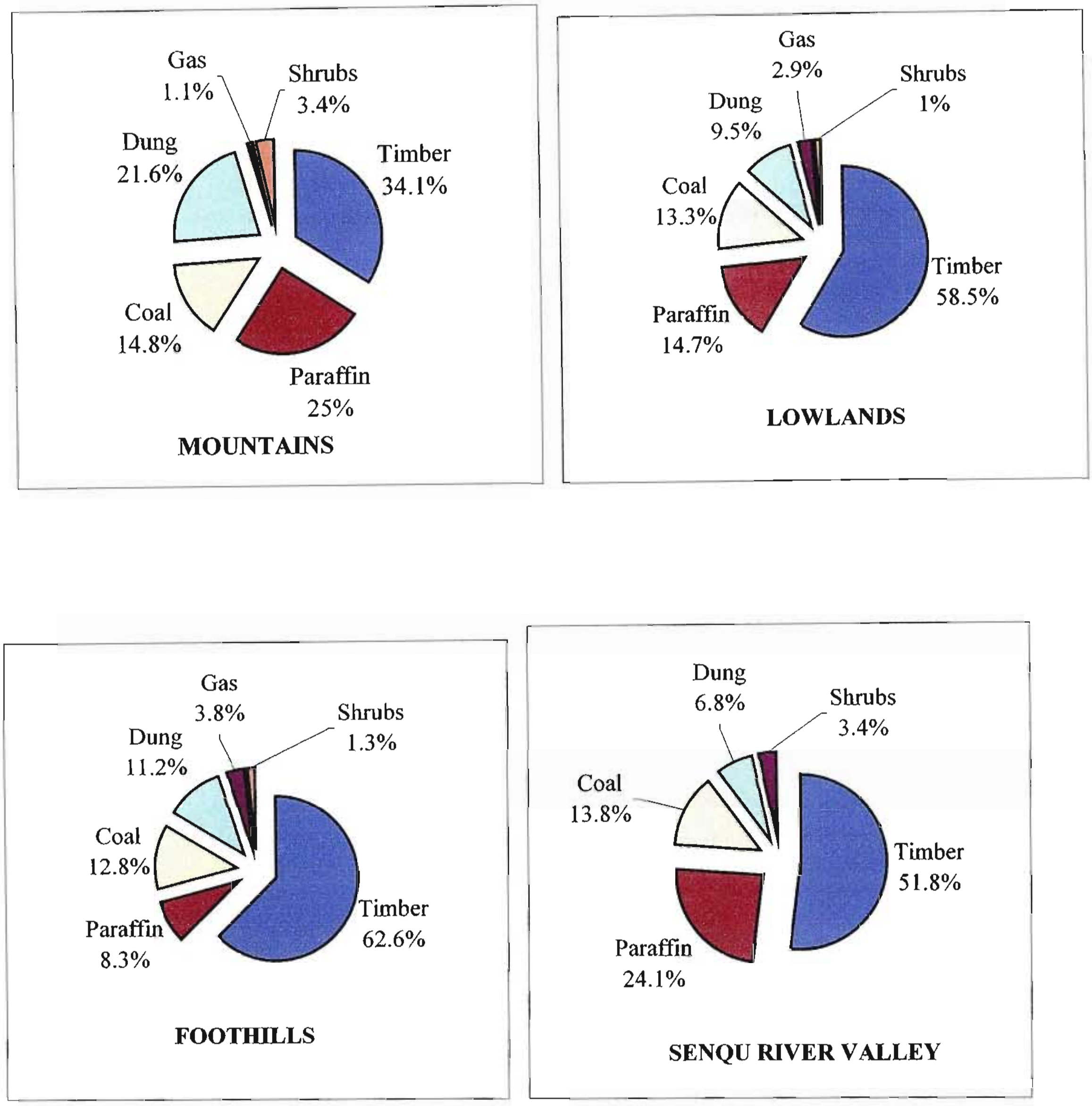


Figure 2: Energy sources in different regions in Lesotho (Hall and Green, 1989).

Efforts to redress the high demands for fuelwood were stepped up with the introduction of Lesotho Woodlot Project (LWP) in 1973. LWP initiated systematic and professional forestry. At any rate, the project inherited scanty information pertaining to the local indigenous species and with this advent of systematic tree planting, the inaugural investigations, focussed only on plantation forestry. Research on indigenous species as a whole appears to have been very limited (Hall and Green, 1989) and the assumption has always been that only fast growing exotics could meet the needs of the country.

It is within the context of the above discourse that this thesis seeks to encourage and emphasise research on indigenous *C. africana*, which may have great significance in addressing the woody-biomass related needs of Lesotho.

1.5 AIM AND OBJECTIVES OF THE RESEARCH

The aim of the research is to have an insight in the status of *Celtis africana* in Lesotho and explore its characteristics in relation to its form and patterns. Comparisons of the ecotypes in Lesotho with those in KwaZulu-Natal will assist to set a baseline from which to assess species variations, hence, determine a set of guidelines, which could be used for its potential utilization and domestication.

Specific objectives.

(a) To note the uses and potentials of the species in Lesotho and KwaZulu-Natal.

(b) To examine possible morphological differences between Lesotho and Kwa Zulu-Natal *C. africana* strains; specifically, examine seed, leaves, bark and stem.

(c) To compare germination percent of different seeds from different locations, including the one from KwaZulu-Natal.

(d) To compare the vigour of the seeds from different locations.

(e) To compare the wood densities of trees from different locations.

CHAPTER 2

LITERATURE REVIEW ON *CELTIS AFRICANA*

2.1 INTRODUCTION

Any species is formed by a group of similar individuals, which may differ from one another in some respects but share certain permanent characteristics in common. Taxonomic features may help to distinguish one plant species from other related species or sub-species. These taxonomic features may help botanists or taxonomists to place the species into the right nomenclature. This scheme of classification helps to place the species into its basic respective units of classification of order, family, genus or even sub-species.

2.2 NOMENCLATURE OF *CELTIS AFRICANA*

The nomenclature of *Celtis africana* Burm. F., was first published by the botanist N.L. Burnmann (Palmer, 1977). *C. africana* is commonly known as "camdeboo" or "white stinkwood" (Palmer and Pitman, 1972; Palmer 1977; Randall, 2004). It derives the name, stinkwood, from the unpleasant odour of its freshly cut wood (Palgrave, 1977; Paul and Palgrave, 1985). True stinkwood is *Ocotea bullata*, which belongs to the laurel family (Lauraceae) and is therefore, unrelated to white stinkwood (Riley, 1963; Palgrave, 1985). *C. africana* Burm. F. is synonymous with *C. rhamnifolia* Presl. and *C. kraussiana* Bernh. (Dyer, 1956; Letty, 1962; de Winter *et al.*, 1966; Palmer and Pitman, 1972; Immelman *et al.*, 1973; Jeppe, 1974).

The genus is a Latin name used by Pliny, and is also an ancient Greek name for one of the plants reputed to be the Lotus of the ancients (Fanie and Venter, 1966; Jackson, 1990; Mbambezeli and Notten, 2003). Von Breitanbach (1974), states that, Celtis was the name by Pliny for the Mediterranean nettle-tree, *C. australis*. The specific epithet, *africana,* means African (Mbambezeli and Notten, 2003).

Guillarmod (1971) lists *molutu* and *mohatl'a-khomo* as two synonymous Sesotho names for camedeboo. Staples and Hudson (1938), Guillarmod (1971) and May, (2000) refer to *molutu* as synonymous to *lesika*. In Xhosa, white stinkwood, is called umVumvu and in Zulu inDwandwazane (De Winter *et al*., 1966; Wager, 1989).

2.3 FAMILY AND GENUS OF *CELTIS AFRICANA*

White stinkwood belongs to the Elm family or Ulmaceae (Gogh and Anderson, 1988; Jackson, 1990). Immelman *et al*. (1973) declare it an African elm. Steentoft (1988) asserts that *Ulmaceae* is synonymous with Afefe family and it is represented by four genera in large part of tropical Africa. Jackson (1990 in: Webster; 1961) asserts that *Ulmaceae* is a Greek name for the African Lotus. The family occurs mainly in the northern hemisphere (Letty, 1962; Ridley, 1963). It includes about 15 genera and 150 species mostly in the temperate regions (Riley, 1963; Porter, 1967). Eighteen species of elm occur north of the Himalayas and east of the Rocky Mountains (Mitchell and Wilkinson, 1982).

Ulmaceae falls under the order *Urticales*, with other three families, which are *Urticaceae, Cannabinoceae and Moraceae* (Porter, 1959; Gonquist, 1970) see Table 1. In some Floras the genus, *Ulmus*, is placed in the related family, *Urticaceae* (Brimble, 1973) and the example that can be cited is that of Phillips (1917).

Jackson (1990) states that *Ulmaceae* is dicotyledonous. Ridley (1963) states that there are three genera of the elm family in southern Africa, which, are *Trema, Chaetachme* and *Celtis*. The latter is a genus of about seventy species of unarmed or spiny trees or shrubs. They are widely distributed throughout the tropical and temperate regions of the world. The genus is found in north America, south-eastern Europe, and the Near and Far East (China, Korea, Japan) even large part of Australia (Figure 3). Although celtis belongs to the elm family, the members of this genus differ radically from the elm proper. The leaves of celtis have three veins, not only the central one, but also two lateral arising at the base of the leaf. Even though the genus consists of a large number of species, the majority are not hardy and their cultivation is often far from simple. So the prices of the seedlings are inevitably high; a reason, nowadays for the disappearance of most sorts of them from nurseries (Boom and Kleijn, 1966).

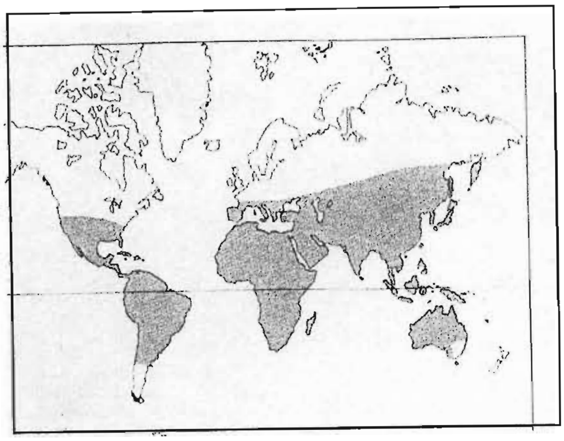


Figure 3: World distribution of the genus, celtis (Hora, F.B., 1981).

Table: 1. Comparison of families of Urticales (Porter, 1967).

Characteristics	**Ulmaceae**	**Urticaceae**	**Cannabinaceae**	**Moraceae**
Growth form	Trees and shrubs	Herbs, shrubs or trees in the tropics	Herbs or vines, not woody	Nearly all trees or shrubs, except Dorstenia
Plants with milky juice	No	No	No	Yes
Aromatic plants	No	No	Yes	No
Leaves alternate or opposite	Alternate	Alternate or opposite	Alternate or opposite	Alternate, rarely opposite
Flowers polygamous, dioecious or perfect	Perfect, polygamous & monoecious	Monoecious, dioecious or at times perfect	Mostly dioecious	Monoecious or dioecious
Fruit type	Samara or drupaceous	Akene, nutlet or sometimes drupaceous	Akene or nutlet	Usually a multiple

Two species, *Celtis durandii* (false white stinkwood) and *C. mildbraedii* (Natal white stinkwood) occur in Zimbabwe, Mozambique, South Africa and Lesotho (Riley, 1963). Mzambezeli and Notten (2003) state that there are only five species of *Ulmaceae*, which are indigenous to southern Africa. These are the three *Celtis* species mentioned above, *C. africana*, *Trema* *orientalis* (trema/pigeon wood) and *Chaetacme aristata* (Chaetacme/false white pear). Riley (1963) mentions that there are about fifty species of Trema, which are also widely distributed throughout the tropics and the sub-tropics. They consist of trees and shrubs. *Trema guineesis* has been noted for its several uses. Its leaves are used for making sand-paper, and cough medicine is extracted from them, while its bark is used to make ropes water-proof. *Chaetachme* has four species in Africa and Madagascar. One is found in Transvaal and from Natal to the Uitenhage division of the Cape Province. Related exotic species, *Celtis australis* (nettle-tree*), C. sinesis* (Chinise hackberry) and *Ulmus parviflora* (Chinese elm) are cultivated in gardens in South Africa and do occasionally escape into natural areas where they may be confused with indigenous species (van Wyk and van Wyk, 1998; Mbambezeli and Notten, 2003).

2.4 GENERAL DISTRIBUTION AND HABITAT OF *CELTIS AFRICANA*

Celtis africana/white stinkwood is a widely distributed tree from the Cape Peninsula, northwards, through many provinces of South Africa, and the neighbouring countries of Lesotho, Swaziland and Botswana (Figure 4). It extends throughout tropical Africa as far as Ethopia (Codd, 1951; Van Wyk, 1972; Immelman *et al.*, 1973). Although camdeboo occurs in Botswana, there is no record of it growing in neighbouring Namibia (Dyer, 1956; Palmer and Pitman, 1972). Codd (1951), notes that the species grows throughout the tropical East Africa, particularly in Uganda. Drummond (1981) and Keay (1989) specify that it extends from Ghana in tropical Africa to Sudan, Arabia and south to Angola and South Africa, but it is rare in Nigeria. Friis Ib (1992) mentions that it is widely distributed in the North West Highlands as far north as Eritrea (16° N). Instances of its occurrence are also recorded in the South East Highlands and the mountain chain of northern Somalia as far east as the Ahl mountains (49° E).

2.4.1 Habitat of *Celtis africana*

Celtis africana grows in a varied range of habitats from the coast up to the altitudes of 2 134 m (Palmer and Pitman, 1972). Darani (2000) states that it grows at an altitude of 2 400 m. It grows by the streams or rivers and in high rainfall areas, on koppies, on termite mounds, in woodlands or on rocky outcrops (Drummond, 1981; Thomas and Grant, 1988; Fanie and Venter, 1996). Palmer and Pitman (1972), mention that on rock, it may be no more than a shrub a few metres high. In the forest, it may grow to a height of about 25 m, with a tall, straight clean bole, though sometimes it may be buttressed. On deep soils, in the open, it may have a short bole and a spreading crown. Although *C. kraussiana* is widespread and occurs in a variety of habitats, it usually thrives well where the rainfall is high or where water is available (Palgrave *et al*., 1989). Conversely, in Ghana, Hawthorne (1990) describes it as a tree of dry forests. Friis Ib (1992) describes the habitat of *C. kraussiana* as that of Afromontane rainforest, undifferentiated Afromontane forest (mixed Podocarpus forest, Juniperus-Podocarpus forest) and dry single-dominant Afromontane forest (*Juniperus* and *Juniperus-Olea* forest), persisting in gully forests; riverine forest; also in secondary montane evergreen bushland. Elsewhere, it is found in transition zone between closed forest and upland rainforest. The altitudinal range in these places is 1 200-2 500 m and rainfall varies between 800 and 2 000 mm/year. In Kenya, it is commonly associated with muchunu (*Brachylaena hutchinsii*) and cedar (*Juniperus procera*) at an altitude of 1 600-3 000 m. Acocks (1953) indicates that in South Africa, *C. kraussiana / C .africana* may be found in a variety of veld types that fall within different forest types. (Veld type is a unit of vegetation whose range of variation is small enough to permit the whole of it to have the same farming potentialities). In Table 2, the forest and veld types in which the species may be found are the following:

Table 2: Summary of veld types embracing *C. africana* in South Africa (Acocks, 1988)

No	Biomes	Veld type
I	Coastal Tropical Forest Types	1. Coastal Forest and Thornveld
		2. The Pondoland Coastal Plateau Sourveld
		3. The Ngongoni Veld
		4. Turf Bushveld
II	Temperate and Transitional Forest and Scrub Types	1. (a) Highveld Sourveld
		(b) The Dohne Sourveld
		2. Natal Mist Belt Ngongoni Veld
		3. Transitional Cymbopogon-Themeda Veld
		3. Highland Sourveld to Cymbopogon-Themeda Veld Transition
		5. Themeda-Festuca Alpine Veld
III	False Grassveld Types	1. The Northern tall Grassveld

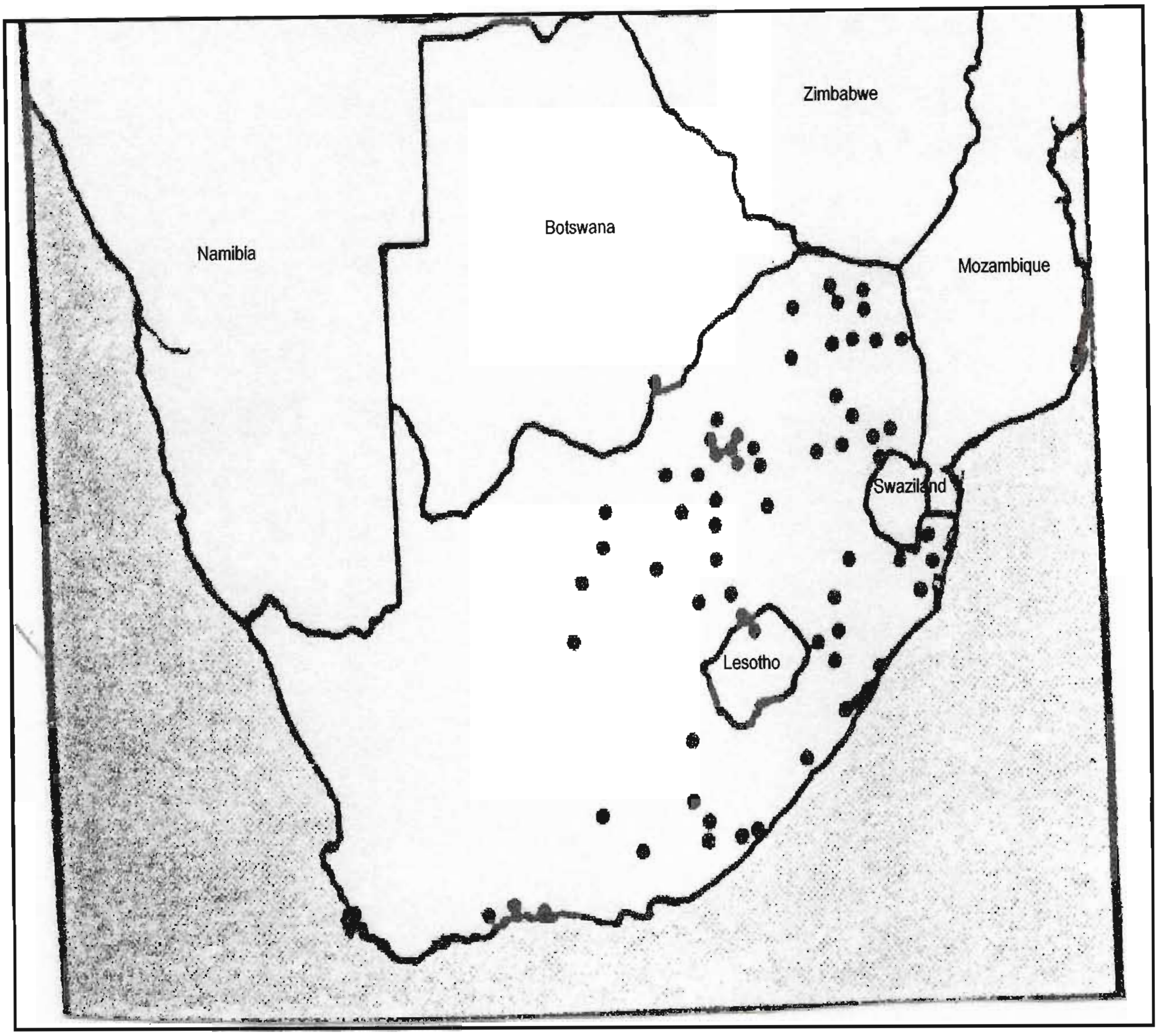


Figure 4: Distribution of *Celtis africana* in southern Africa (Killick *et al.*, 1973).

The status of *C. kraussiana* and other species found in respective veld types in South Africa is shown in Appendix 1).

Adamson (1938) points out that *C. kraussiana,* is common among the associations that constitute transitional vegetation between typical savannas of the Bush Veld and the Grasslands. On some of the eastern mountain slopes, the Scattered Bush occupies steep slopes up to 1 220 m. The higher levels and more gentle slopes are grass covered, whereas, steep ridges, valleys and gentle slopes bear bushes to higher altitudes. The woody vegetation assumes an open nature and dwarfed character due to prevailing frequent frost. This consequential environmental effect is highlighted by the sharp contrast of increase in height and density in any sheltered grooves. In very sheltered areas, trees such as *C. kraussiana* and others, which are not so prominent in the community, may build small scrubs of woodland, which have an almost closed canopy. Along the streams and rivers, larger trees may occur and do not form anything more than a narrow fringe along the stream-beds.

Fanie and Venter (1996) mention that camdeboo is not restricted to a specific type of soil. It can be grown in all classes of soil (von Breitanbach, 1965; van Wyk, 1972) but reaches its best development on deep alluvial soils alongside the streams (King, 1952). Jeppe (1974) and van Wyk and van Wyk (1998) specify that, it grows in sinkholes on dolomite formations. In the west of South Africa, it occurs on low altitude grassland on sandy deposits in the dolomite areas. It also regerates in dry and scrub forests near the coast or in the estuary localities (von Breitanbach, 1985). In the southern Cape, it can occasionally be found in dry high-forest and scrub forest types usually near the coast (von Breitenbach, 1974). In the winter rainfall area of the south Western Cape, it is rare today only remnant patch in the forest above Kirsternbosch is recognisable (Dyer, 1956). Generally in South Africa, white stinkwood occurs from the Cape in the south of the country, through Cape Midlands, Eastern Cape, Natal, Free-State and Northern Province (Figure 4) (von Breitenbach, 1965; van Wyk, 1992; Fanie and Venter, 1996).

In Lesotho, *molutu* occurs at the altitudes below 1 500 m in the Senqu Valley or 1 800 m or more in the Foothills (May, 1994; 2001). It is not rife above the Clarence Formation. It is common scenery along the roadside in the Quthing River Valley, though the trees are of modest size when compared to less accessible patches elsewhere (May, 2001).

In Lesotho there are no recorded forest types. The National Rangeland Inventory (NRI), whose main objective was to determine the livestock carrying capacity, has recorded only indigenous vegetation, which is relevant for agricultural purposes. Concurrently, NRI has identified plant communities and their vegetative compositions and focussed upon communities, which were composed of mixed of grasses, forbs, and shrubs. Of these associations, some were recorded as being "dominated by native trees" but with no specific classification of forest types (May, 2000). In total, NRI identified 12 vegetation types (Table 3), of which those which were "dominated by native trees", covered an estimated area of 34 000 ha.

Table: 3 Vegetation Types in Lesotho (May, 2000).

No	Vegetation type	Area (ha)
1.	Hyparrhenia type.	350,190
2.	Eragrostis/Aristida type.	147,555
3.	Themeda type.	474,797
4.	Festuca type.	358,316
5.	Chrysocoma/Artemesia type	359,680
6.	Leucosidea type.	131,201
7.	Rhus type.	110,771
8.	Merxmuellera type.	106,356
9.	Shallow Rocklands.	158,202
10.	Residential Areas.	69,431
11.	Cultivated Fields.	765,512
12.	Boglands.	2,224
	Total	3,034,235

Staples and Hudson (1938) mention that *C. kraussiana* is often found in Seboku grassland in the sheltered valleys at altitudes below 2 300 m. Seboku is Sesotho term for the grass *Themeda trianda,* also known in South Africa as "redgrass" or "rooigras" and sometimes "sweet grass" or "sweet veld". Sesotho names and botanical names of some common species in forestry are shown in appendix 2. This zone is characterised by natural vegetation made up of a mixture of small evergreen trees and shrubs. *Cheche* bush (*Leucosidea sericea*) is by far the most prevalent species. Other species are *kolits'ane (Rhus pyroides), lelora (Chilianthus corrugatus),* and *mohloare or* wild olive *(Olea verruscosa).* Ecologically, it is a zone of an evergreen scrub type, and it is very different in character to low growing Sehalahala scrub type. Sehalahala is a Sesotho term for "small bush". By far the most important species in the extensive scrub area is *Chrysocoma tenuifolia,* which in the north is generally called sehalahala. Elsewhere in South

Africa it is known as "bitter Karroo bush" or "bitter bossie" At the higher altitudes trees are entirely absent and there are no indications that they ever existed under such conditions (Staples and Hudson, 1938; May, 2000).

2.5 DIAGNOSTIC FEATURES OF *CELTIS AFRICANA*

Species may behave differently in different zones depending on adaptation to novel localities. This may result in organ modifications, hybrid zones or even plant extinction. Due to wide range and diverse conditions, *C. africana* may be characterised by diversity or morphological changes.

2.5.1 Stem form and crown.

Celtis africana/camdeboo ranges from being a small to a large tree. It varies greatly on growth and form depending on the prevailing conditions under which it grows (Palmer and Pitman, 1972). Growth form varies according to rainfall, and trees become smaller in areas of lower rainfall (Thomas and Grant, 1998). Under forest conditions a tree may reach a height of 30 m (Immelman *et al.*, 1993) and produce a clean straight bole up to 1 m in diameter. The trunk is often fluted (de Winter *et al.*, 1973). Camdeboo is a single-stemmed tree with a straight trunk (Figure 5) that branches to form a dense, round or semi-circular spreading canopy (Drummond, 1981; Thomas and Grant, 1998). The grey branches are often obscured by the leaves, which hang from thin twigs and can move easily in the wind (Thomas and Grant, 1998). In winter the branches become more conspicuous (Goth and Anderson, 1988).

2.5.2 Bark.

The bark of *C. africana* is smooth and whitish to pale grey with characteristic fine, horizontal or transverse ridge, becoming blotchy and scarry with age (Figure 6). It may be loosely peeling in very old trees (Wager, 1989). New branches, branchlets and twigs are also pale-grey with regular raised darker rings around them (de Winter et al., 1973); von Breitenbach, 1974). Branchlets have rust coloured hairs (Darani, 2000).

Figure 5: Single-stemmed *C. africana* with straight trunk that branches to form a dense, semi-circular spreading canopy (Drummond, R.B., 1981).

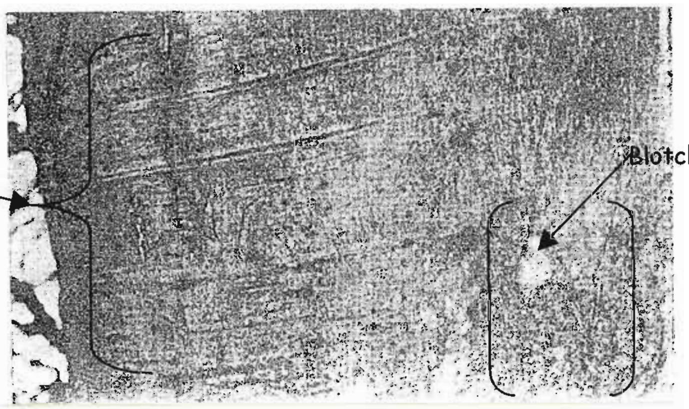


Figure 6: Grey trunk of *Celtis africana* bearing horizontal ridges (Killick *et al.*, 1966).

2.5.3 Flowers.

C. africana has pale yellow flowers which appear briefly in spring at the same time as new foliage (Pienaar, 1996). Male flowers (Figure 7) are found in subsessile or stalked fascicles of 4-7 flowers clustered at the base new velvety twigs (Figures 7 and 10) or the lower leafless nodes of the branchlets (Palmer, 1977). The flower may be represented by the floral formula *⊕ K4-5 C0 A5* G(2) (Figure 8). The formula explains that the flower is actinomorphic (radially symmetrical) with no differentiation into sepals and petals and, therefore, collectively constituting a perianth with 4-5 segments. The ovary is superior (Figure 9) and the stigmas are sessile (Phillip, 1926). Darani (2000), sates that stamens become correspondingly 4-5 opposite the perianth segments (Figure 10). Female or bisexual flowers (Figure 11) which are1-2, but more often solitary, occur at the upper nodes, generally in clusters in the axils of a young leaves (Battiscombe, 1926; Dale and Greenway, 1961; Mbambezeli and Notten, 2003). Flowers are small, star-like, yellowish green and inconspicuous. They may be unisexual or hermaphrodite (Figure 11), being clustered on very abbreviated peduncles.

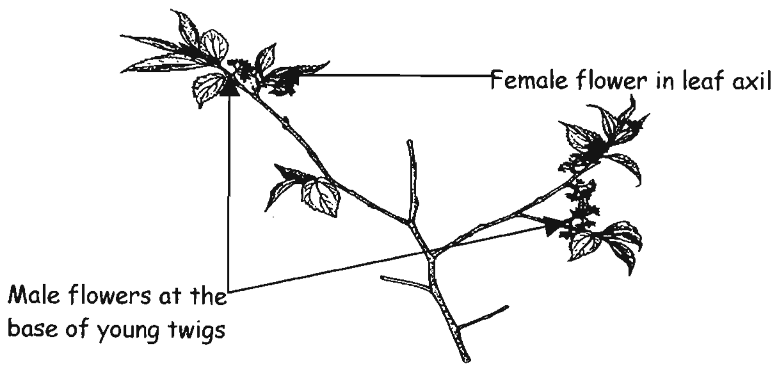
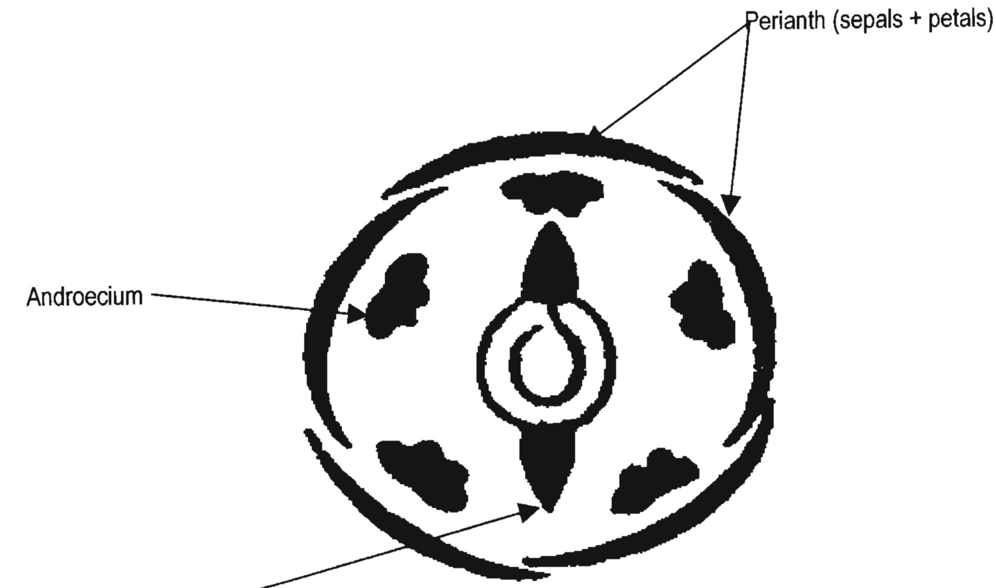


Figure: 7 Flowering young velvety twig of *C. africana* (Drummond, R. B., 1981).



⊕ **K4-5 C0 A5 G(2)**

Figure 8: Generalised floral diagram of *Celtis africana* (Steentoft, M., 1988).

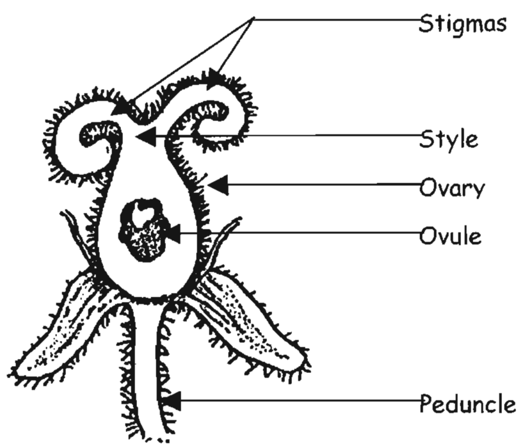


Figure 9: Longitudinal section of a superior ovary of *C. africana* (Dale and Greenway, 1961)

The flowers either self-pollinate or are pollinated by bees covered with pollen from hermaphrodite and male flowers (von Breitenbach, 1974). The pollen is very light and bursts from the cells as the filaments, which are initially bent, spring and straighten up (Dyer, 1956).

The slender pedicels (about 5 mm long) of the female flowers, which are directed under the spreading leaves, become rigid and bear a single pea sized green fruit at the apex (Ibid), and often fall with the male inflorescence, but in the females they persist and elongate to about 1.5 cms long (Dyer, 1956; Palgrave, 1985). Von Breitenbach (1974) mentions that white stinkwood flowers appear every second year from October to February, but perfect fruiting occurs once in four years.

Flowers may naturally show different characters in order to perpetuate the plant existence. A flower may assume monoeicism or hermaphrodism in order to ensure mating.

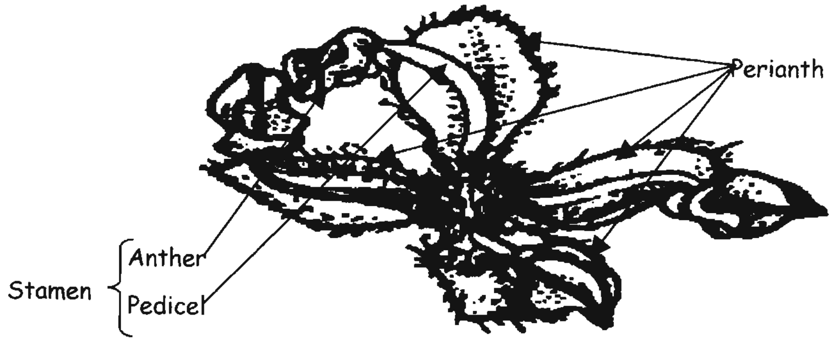


Figure 10: Male flower of *Celtis africana* (Drummond, R. B., 1981).

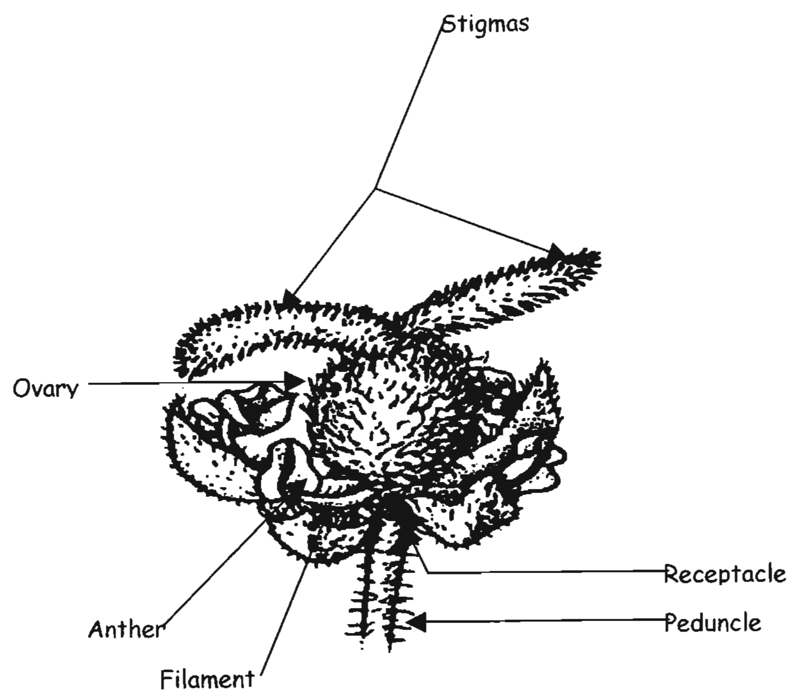


Figure 11: Hermaphrodite flower of *Celtis africana* (Drummond, R. B.,1981).

Flowers on the same tree may be in such a manner that self-pollination may not be possible or pollen may not mature at the same time as the recipient stigma in order to avoid epistatis.

2.5.4 Leaves

Mature summer and autumn leaves of *C. africana* are dark green (Palgrave, 2000). Young spring foliage is tender or pale fresh green and turns yellow before falling in winter (Pooley, 1994). At the coast, and occasionally inland, stinkwood may keep its old leaves until the young ones appear. Generally, inland trees are deciduous (Gogh and Anderson, 1988).

Thomas and Grant (1988) show that leaves may vary in length (10 mm-100 mm) and width (10 mm-50 mm) and the upper surface of the fresh new leaves is glabrous, becoming smoother as they mature. The leaves are conspicuously 3-veined from asymmetrical base (Figure 12). They are simple and alternate (Figure 13) with lanceolate to linear-lanceolate stipules 4 mm - 6 mm long (Henkel, 1934). The apex is shortly and abruptly attenuate, ovate and obliquely or subannate on one side with serrated upper two thirds of the margin and entire in the lower part (Henkel, 1934; Palgrave, 1996). Twigs are reddish, ferruginous-pubescent when young. Slash is dark brown, mottled, either diffuse or obscurely layered. The slash turns rapidly dark brown (Dale and Greenway, 1961).

Under novel conditions leaves may ecophecene. Again leaf sizes of the same species may be affected by climatic conditions such as rainfall, day length and edaphic factors such as soil fertility.

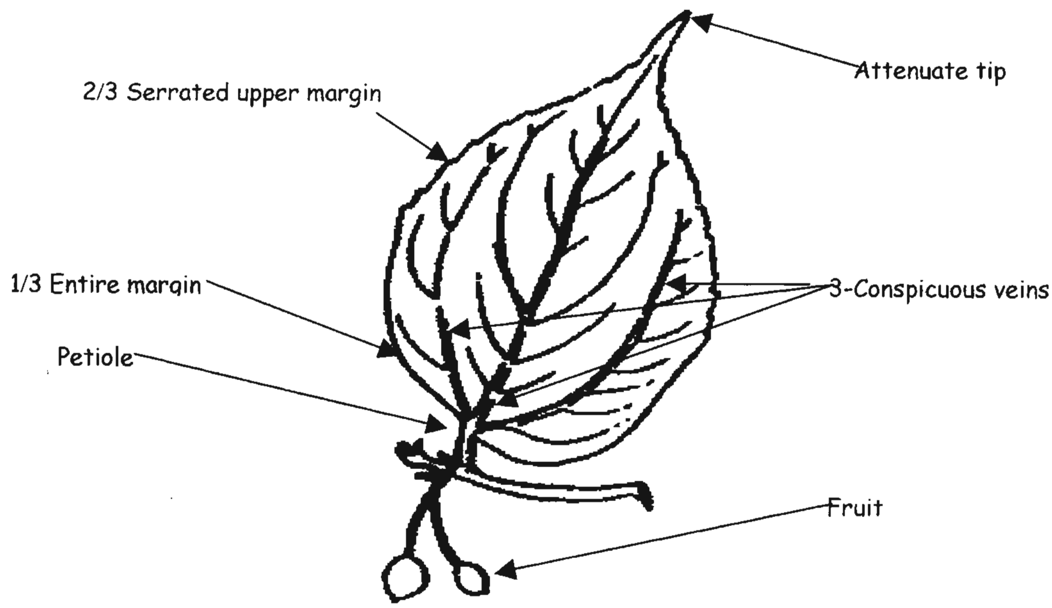


Figure 12: Leaf venation of *Celtis africana*

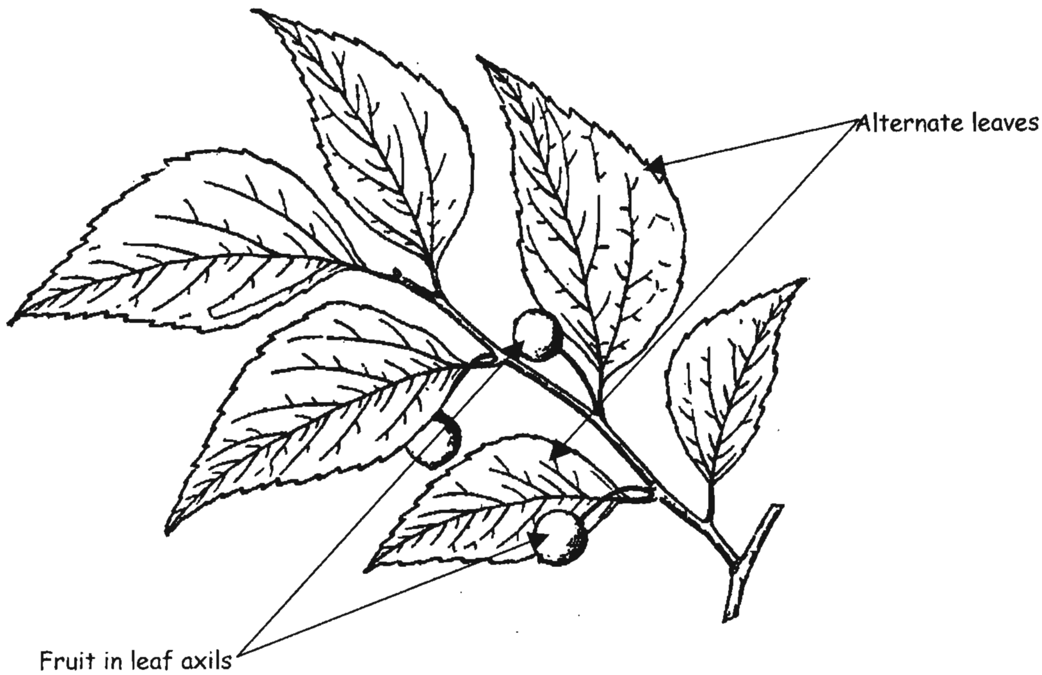


Figure 13: Alternate leaf arrangement of *Celtis africana*(Von Breitenbach, F. 1965)

2.5.5 Fruit and seed.

The fruit of *C. africana* is a pea-sized drupe, 8 mm-13 mm in diameter (Jeppe, 1974; Paul and Palgrave, 1985; Thomas and Grant, 1985; van Wyk, 1990). The green fruits develop in leaf axils at the tip of small stalks (Figure 14), about 13 mm long (Figure 14), and mature after 1-2 months (von Breitenbach, 1965; Wager, 1989; Mbambezeli and Notten, 2003). They mature in January to February, turning yellowish brown, and fall immediately after ripening (Van Wyk, 1972).

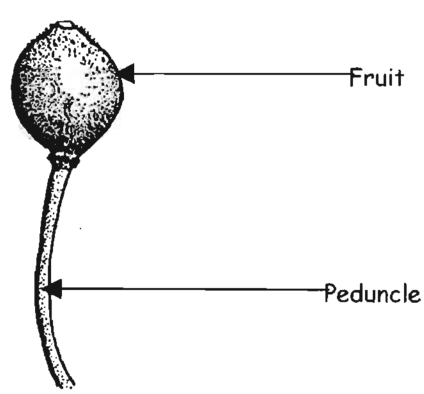


Figure 14: Pedunculate fruit of *Celtis africana* (Dale and Greenway, 1961).

Seed of *C. africana* is without an endosperm (Phillips, 1926) and 10 000 seeds weigh approximately 1kg (Van Wyk, 1972; Fanie and Venter, 1996).

Plants are easily raised from seed and the species regenerates freely under garden conditions (Immelman *et al*., 1973). Fanie and Venter (1996) state that only fresh seeds, collected from trees, should be used for sowing, as seed lying on the ground becomes invariably infested with insects. Germination usually takes place within 8-30 days if the seeds are sown in warm but shady area. The germination percent is estimated at 50%-70% (Fanie and Venter, 1996). Germination period under normal forest conditions is 2½ - 3½ months while the germination capacity is 30% - 40% (von Breitenbach, 1965; Van Wyk, 1972). Seedlings grow rapidly up to 2 m per annum in deep alluvial soil (von Breitenbach, 1965).

The species is fairly cold and drought resistant (Van Wyk, 1972), but seed should be collected from frost-hardy trees for sowing if the seedlings are to be planted in areas that experience frost. Trees from such areas are genetically adapted to the cold conditions. Seed should be sown in seedling trays filled with river sand and compost (5:1). Seed should be covered with thin layer of river sand and kept moist (Fanie and Venter, 1996).

Seed size, hence, seed mass may vary according to edaphic factors. Seeds from wet habitats tend to be bigger than seeds from drier sites.

2.5.6 Wood.

Wood of camdeboo is white to yellowish or occasionally pale grey. Sometimes it is tinged with green (Palmer and Pitman, 1973). It has a woolly texture after sawing and polishes fairly well, showing a moderately marked grain. It shows no distinction between sapwood and heartwood (Jeppe, 1974); Drummond, 1981). Van Wyk (1990) emphasises that it has no heartwood. The distinctive feature of the wood is that it is ring porous with rays which, are conspicuous on all planes (Kromhout, 1967) and the arrangement of the vessels is in wavy oblique lines in the late-wood portion of the growth ring. It is a tough, strong wood and is pliable and easily bent after soaking in water. Bolza and Keating (1972), state that its timber air-dries quickly with little deterioration, but it is liable to stain badly in early stages. Dipping in anti-stain solution before stacking is recommended. Though it kiln-dries well, some cupping may occur, and collapse around knots is frequent. The wood works well in most operations if sharp tools are used. Reduced cutting angle of 15^{o} is necessary in order to prevent tearing of grain when machine quarter-sawn. It glues well and takes nails moderately well with a slight tendency to split. Green wood is 1028 kg/m^3 while that of dry wood is 750kg/m^3- 755 kg/m^3 (de Winter *et al.*, 1973; van Wyk, 1990) with long fibre. The average linear shrinkage across the grain from green to air-dry is 4%. Growth rings are obscure and the medullary rays are fine. The wood is liable to blue-stain when freshly cut, and borer attack. It tends to warp and split on sawing or seasoning (von Breitenbach, 1965; Dale and Greenway, 1921).

Habitat and climate have a significant role in influencing the wood density. The faster the growth, the less dense is the wood. It follows, therefore, that favourable conditions for faster growth may enhance less dense wood.

2.6 PESTS AND DISEASES

2.6.1 Pests.

Leaves, and young shoots of white stinkwood, are browsed by cattle and small stock. The fruit, is eaten by monkeys and baboons (Thomas and Grant, 1988; May, 2000; 2001). The foliage is the food of larvae of long–nosed butterfly of forest and bush, popularly known as African snout (*Libythea labdaca laius*) (Palmer and Pitman, 1972; van Wyk and van Wyk, 1998). Von Breitenbach (1965) states that fly (Diptera) or snout beetle (curculioidae, coleoptera) destroy many embryos. Van Wyk and van Wyk (1998) further mention that the leaves of *C. africana* are eaten by charaxes.

Seed is also eaten and dispersed by birds. The main dispersal birds are rameron pigeon, willow warbler, black-eyed bulbus, mouse birds and crested barbets (Drummond, 1981; Mbambezeli and Notten, 2003).

2.6.2 Diseases.

Van Wyk (1972) says that Mycosis is the most common disease affecting *C. africana.* The species is susceptible to attack by *uncinula polychaeta* DOIDGE, which results in mildew, *Daedalea eatoni* BERK, *Fomes applanatus* (P) WALLR, F. conatus FR. Pleurotus species, *Polyporus colossus* FR., *Polystrutus zonatus* FR., and *Schizophyllum commune* FR which cause trunk rot. The latter is the most prevalent in the coastal forests.

Pests and diseases of species in one area may not necessarily be common in another area. Severity of attack may either increase or decrease along the gradient of altitude or climatic conditions. In some cases the species may be a second host.

2.7 THE SOCIO-ECONOMIC IMPORTANCE OF *CELTIS AFRICANA*

As a timber tree, *C. africana* shows little promise in cultivation (Immelman *et al.*, 1973) and it is of very little use commercially (de Winter *et al.*, 1973). However, the following recorded uses of socio-economic importance are noteworthy and cannot be overlooked:

1. Camdeboo is one of the finest indigenous trees for shade and ornament (Cunliff, 1957; King, 1952; Goth and Anderson, 1988; Small, 2003). It is an excellent street tree, which is commonly planted in avenues and parks. It is increasingly becoming more popular as a bonsai and a garden tree (Pooley, 1994). Camdeboo is strikingly attractive during winter when its light trunk and branches stand out against the dark evergreen foliage in the background (Jeppe, 1974). At any rate von Breitenbach (1965) and Palmer and Pitman (1972) cautions against it being planted too near herbaceous beds where its spreading roots can prove disastrous;

2. The wood of Camdeboo can be used in many small-scale domestic industries. Its wood is utilized for furniture making and it is ideal shelving. It is suitable for planks, making of yokes, wagons, panelling, split handles for spades and it can be used as a valuable source of energy (fuelwood) as well. After soaking in water, it can be used for bentwood chairs and tent-bows (Dyer, 1956; Immelman *et al.*, 1993). It makes excellent veneer and is also

suitable for railway sleepers (von Breitenbach, 1974). In Kenya, it is used for toll-handles and temporary mining construction (Eggling and Dale, 1951);

3. The leaves and young branches are eaten by domestic stock, especially cattle and game (kudu, nyala, bushbuck, impala, and grey duiker). Animals are more selective to the adult leaves than the young ones and will even pick up leaves from the ground (Fanie and Venter, 1996);

4. Some communities believe that the wood of the tree has some protective magical powers. They believe that when its wood is mixed with crocodile fat, it can be charm against lightning or evil spirits (Pooley, 1974; Thomas and Grant, 1998; Mbambezeleni and Notten, 2003);

5. Smitter (1955), points out that, plants have the potential of being used as indicators of the occurrence of subsurface water. Many countries such as United States of America, Mexico, Australia and some countries in the Middle East have already embarked on large-scale research on the study of plant indicators of ground water. *Celtis africana* is considered to be one of excellent indicators of ground water on Highveld.

2.8 CONCLUSIONS

Contemporary botanists may name same species differently in their respective places of discoveries. The example that can be cited is that of camdeboo named *Celtis africana* Burn. and *Celtis kraussiana* Bernh.

Morphological characteristics like colour, crown and branching habit, organ features can be used to identify trees and classify them in their appropriate orders, families and species. However, plants may behave differently due to novel environments e.g. *C. africana* is an evergreen tree under coastal climates but it is deciduous further inland.

Plants of a particular species have preference of similar habitats and form similar patterns with other plant species even when they are in different geographical areas. *C. africana* is found in close association with Grewia occidentalis in both KwaZulu-Natal and Lesotho As a result, habitats and related plant associations may be indicative of individual plant species or *vice-versa.*

CHAPTER 3

DESCRIPTION OF LESOTHOAS THE COUNTRY OF THE MAIN STUDY AREAS AND NICHES OF CELTIS AFRICANA IN SOUTH AFRICA

3.1 LOCATION OF LESOTHO AS THE MAIN COUNTRY OF STUDY

Lesotho has an area of 30 300 Km^2 and lies between Latitudes 28° and 31° South, and Longitudes 27° and 29° East. Lesotho is completely surrounded by the Republic of South Africa (Figure 15). Its population is estimated at about 2.5 million and increases by between 2.5 - 3% per annum. An internal population movement exists from the mountain areas to the Foothills and Lowlands, which are more densely populated. Population density is about 40 / km^2 (Social Forestry, 1997).

3.2 GEOLOGY

The geological pattern from one part of the country to another shows very little variation, and as a result the stratigraphic succession and structure is simple (Bennie and Partners, 1972). It forms part of the Beaufort and Stormberg series of the Karroo system, which ranges in age from Triassic to the Upper Triassic and Jurassic (Table 4 and Appendix 3). The lowest members of the succession are undisturbed sedimentary rocks that are capped by basaltic lava. Numerous dolerite intrusions occur both as dykes and large sills (Carroll and Bascomb, 1967; Russell, 1979). Figure 16 illustrates major geological and physiographic formations in River Valley. This is a common phenomenon that valley courses seem to have been influenced to a large extent by the igneous intrusions.

The geological sequencing is important because it determines the parent materials of the study areas and is comprised of organic and inorganic detritus. Organic matter is constituted of the dead and the dying plants and animals while the mineral matter, which is the predominant component of parent material, is made up of the basic rock-forming minerals. The minerals may be in a consolidated state like granite, conglomerate or mica while on the other hand, they may be in unconsolidated state like glacial till, marine sand etc. (Richard and Binkley, 2000). Parent material is the final product of weathering and is enhanced by chemical and physical breakdown and disintegration of the exposed faces of the bedrock. This stage of soil development is influenced by the interaction of five soil forming factors, which are geologic materials, climate (mainly temperature and precipitation), topography (steepness and aspect of slope), vegetation and time. Geologic material provides parent material, climate influences the rate of weathering of the geologic materials, topography determines the stability of the landform and the rate of erosion (process of removal) and deposition (process of addition), vegetation provides organic matter for the soil and time determines continuity of influence of all the factors.

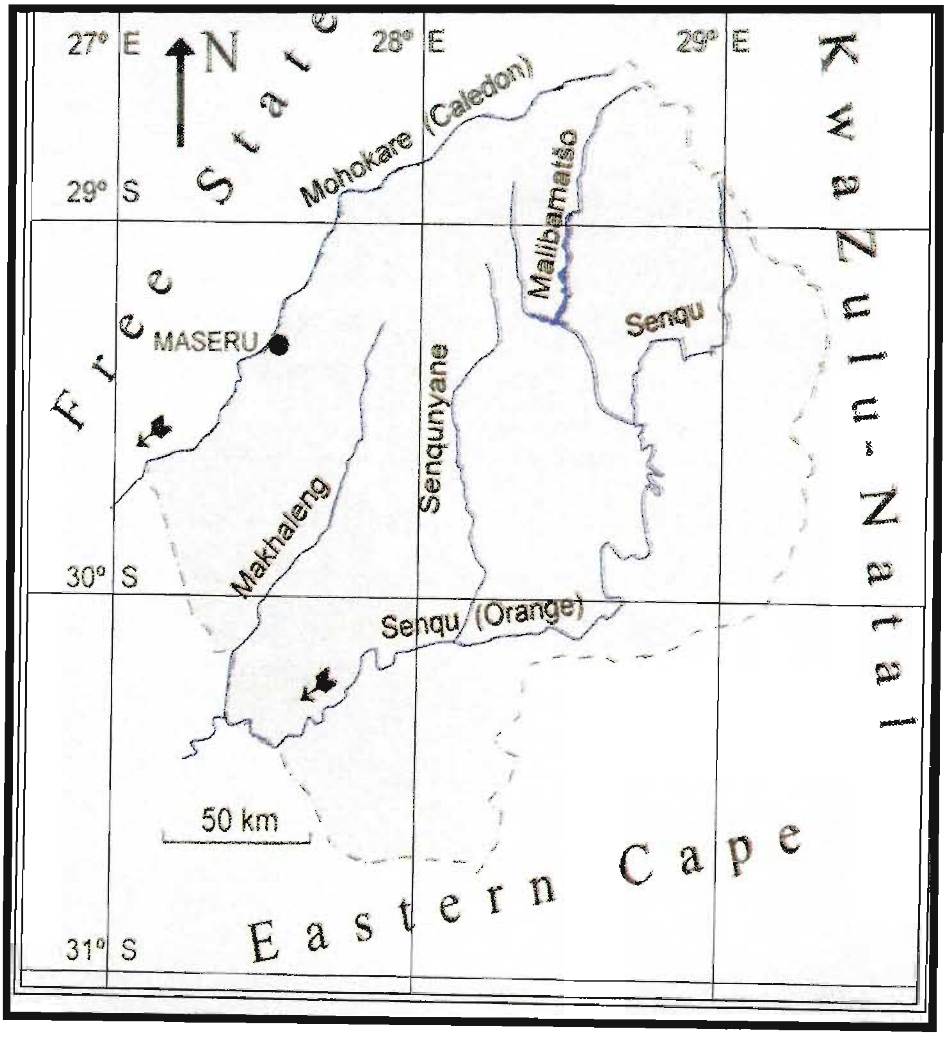


Figure15: Location Map of Lesotho, also showing main rivers and surrounding provinces of South Africa (National Environment Secretariat, 2000).

Table 4. The geological succession in Lesotho (Bennie and Partners, 1972).

<table>
<tr><td rowspan="5">Karroo System.</td><td rowspan="4">Stormberg Series.</td><td>Lower Jurassic</td><td>Drakensberg Beds.</td></tr>
<tr><td rowspan="3">Upper Triassic to Rhaetic.</td><td>Cave Sandstone.</td></tr>
<tr><td>Red Beds</td></tr>
<tr><td>Molteno Beds</td></tr>
<tr><td>Beaufort Series.</td><td></td><td>Upper Beaufort Beds.</td></tr>
<tr><td colspan="2">Dolerite intrusions.</td><td colspan="2">Rhaetic and Lower Jurassic.</td></tr>
</table>

3.3 SOILS

Jackson and Raw (1981) define soil as the material that plants grow in. It contains various proportions of mineral and organic materials and extends from the ground surface to the lower limit of root growth. It is formed by the interaction of complex processes including the physical and chemical weathering of geologic or parent rock material that provides mineral substrate, the incorporation of and decay of organic matter (mainly as plant remains that soil microorganisms decompose) and the movement of soluble or suspended materials in percolating or diffusing water.

Since soils are derived from parent materials of different mineral composition, this variability results in soil properties that influence both the composition of the forest and its rate of growth. As parent rocks weather and soil develops, it is influenced not only by the mineralogy of the rocks but also the physical factors of the environment. The biota of the area also contributes to mineral weathering and the build up of the organic material in the soil. Eventually, a series of horizons form in a typical, well-developed forest soil. These are organic layer **O**, an organically enriched mineral layer **A**, an eluviated layer **E**, an illuviated layer or zone of accumilation **B**, and a mineral layer, which is little altered by soil forming processes, **C**. The formation of these distinctive soil horizons results from pedogenic processes (Fisher and Binkley, 2000).

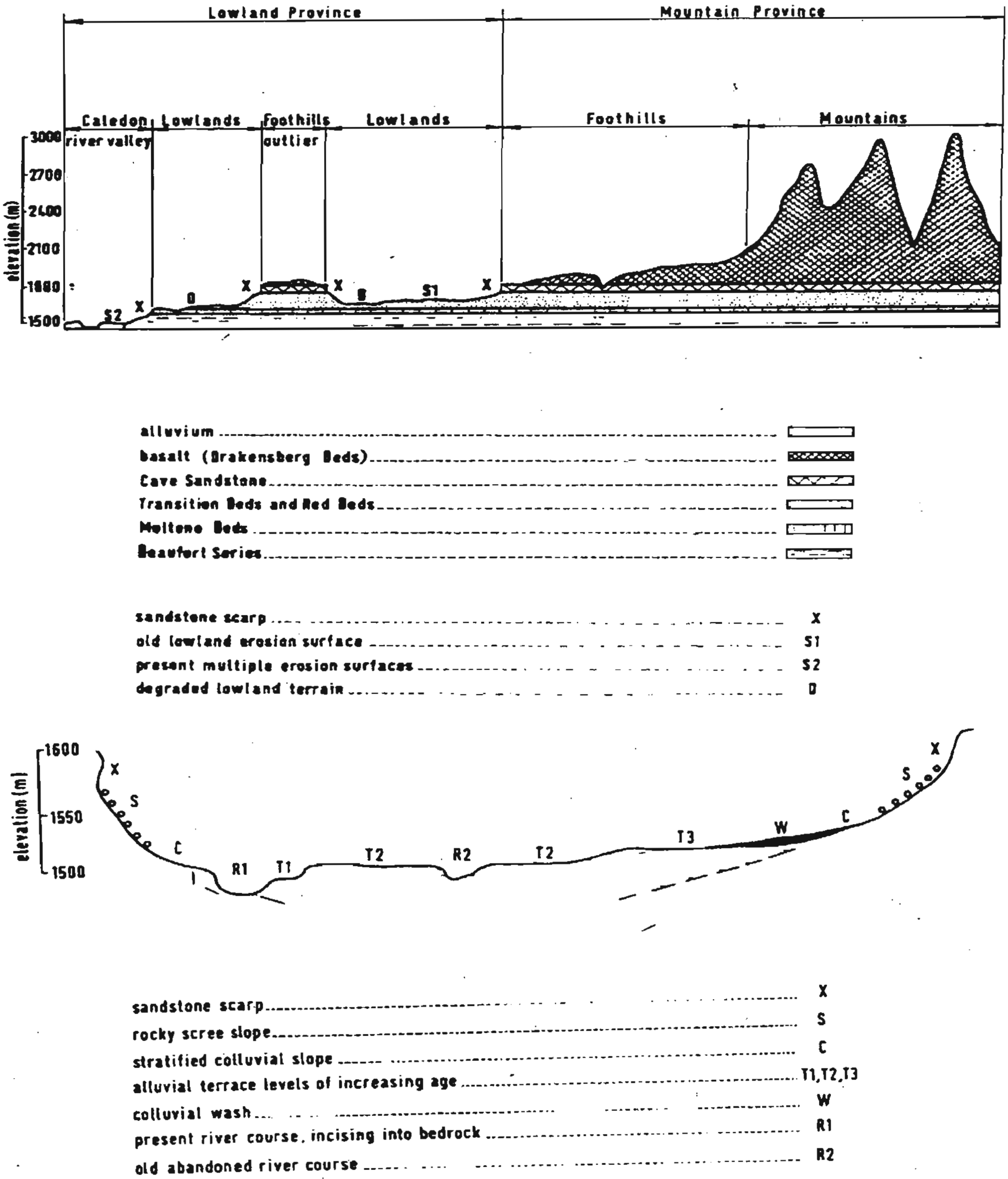


Figure 16: Simplified physiographic and geological formations of Lesotho's Major River Valley with multiple terraces and flanking sedimentary rocks (Bennie and Partners, 1972).

Variability among the soils in Lesotho is much more pronounced despite the small size of the country. This may be attributable to the wide variability in topography and parent materials **(R)** rather than to vegetation and climate. To a large extent the properties of soils in Lesotho reflect the influence of the main soil forming factors (Rooyani and Badamchian, 1986). Parent materials for the soils of Lesotho have been derived from the existing geologic material. The geologic materials being, basalt rocks, sandstone and shale.

The duplex soils make up the most extensive soil series in the low-lying regions of Lesotho. They have three distinct horizons, **A**, **B** and **C**. There is a marked difference between the **A** and **B** horizons where there is an abrupt transition from the light textured surface layer to a relatively fine sandy clay, to clay with a strong development of prismatic structure in the **B** horizon. There is usually a higher proportion of clay in the **B** horizon than in **A** horizon due to downward movement of clay. Clay content may vary between 28% and 72%. Most duplex soils reflect a wetter and warmer climate than the present day climate. These soils have well developed **E** horizon (Rooyani and Badamchian, 1986). Leaching causes an accumulation of salts in the **C** horizon (Russell, 1979).

Many mountain soils have generally assumed a dark **A** horizon, which is a manifestation of a vegetation of a country which is predominantly covered with grasses. Other than being characterized by dark colour, the **A** horizon is rich in organic matter and also thick. The moderate leaching and illuviation is facilitated by the sub-humid temperate continental climate of the country (Rooyani and Badamchian, 1986).

Soils, like climate, play vital roles in the development of forests. They provide water, nutrients, and support for trees and other forest vegetation.

3.4. VEGETATION

3.4.1 Vegetation of South Africa

Vegetation Map of Africa classifies the African vegetation by sixteen main vegetation types and its spatial distribution by "phytogeographial areas" or "phytochoria". (A phytochorion is an area or group of areas of similar geographical characteristics as reflected in the types of plants that grow there). Twenty phytochoria are recognized for Africa, seven of which (three of them in southern Africa) are noted as regional centers of "endemism" i.e. areas where there are at least 1000 endemic species and at least 50% of all species are confined to the phytochorion. The Afromontane region is represented by highlands, mainly in the eastern and southern Africa.

Adjacent to Afromontane Region is Afroalpine Region. According to Low and Rebelo (1996), each vegetation type had to be delimited in relation to coherence of array of communities, which share common species (or abundance of species), possession of similar vegetation structure (vertical profile), and sharing of the same set of ecological processes. They would thus have similar uses, management programmes and conservation requirements.

Map of Africa delineates Forest biome in the frost-free areas with mean annual rainfall of more than 525 mm in the winter rainfall region and more than 725 mm rainfall in the summer rainfall region. South Africa Forest biome is shown on Figure 17.

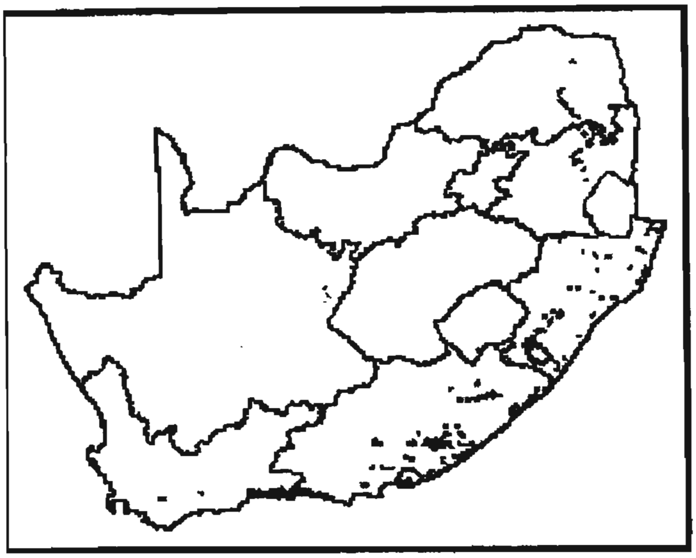


Figure 17: Forest biome in South Africa (Vegetation of South Africa, 2004)

3.4.1.1 **Coastal Forest**.

Typical Coastal Belt is taken to be synonymous with Transitional Coastal Forset, Dune Forest, Alexandria Forest and Tongoland-Podoland, Undifferentiated Forest. It extends over 947 km.

The rainfall in the Coastal Forest is normally greater than 700 mm. Temperatures are not extreme due to maritime influence. Other than rainfall and temperatures, wind and incidental salt spray is another factor. There is generally little soil development and the vegetation develops on deep consolidated calcareous sands. Common shrubs are *Scutia mytina, Capparis sepiaria* and *Carissa bispinosa*. Plants of the forest floor include *Dactyloctenium australe*, *Cyperus albostriatus* and *Achyranthes aspera*.

3.4.1.2 **Afromontane Forest**.

Afromontane Forest is synonymous with Knysna and Montane Forests. The forest type covers 5964 km^2 (Figure 18). The rainfall can exceed 2000 mm in some regions but generally it averages about 700 mm. It occurs throughout the year, or during winter or summer, depending on the region. At higher altitudes the temperatures may be extreme and snow may occasionally occur.

Generally, soils are well developed and mature. Leaching does occur in the higher-rainfall regions. Soils tend to be shallow on steeper slopes, but may be deep in the valleys.

Shrubs and climbers are *Maytenus heteophylla*, *Scutia myrtina*, *Carissa bisponia* and *Secamone alpinii*. Undergrowth grasses include *Oplismenus hirtellus*, and *Centella asiatica. Stipa dregeana.*

3.4.1.3 Sand Forest.

Sand Forest is synonymous with Typical Coast Belt Forest described in section 3.4.1, and Zululand Palm Forest. It occupies only the tropical and subtropical coastal belt of KwaZulu-Natal as far south as Port Shepstone (Figure 19). Some traces may be found along the Great Kei River. In the KwaZulu-Natal it is extensive in the north-east. Sand Forest thrives in the hot tropical with summer rainfall.

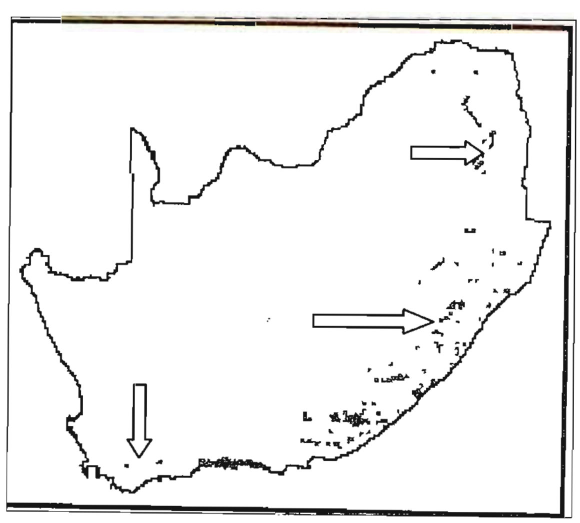


Figure 18: Afromontane / Knysna (A4), North – eastern Mountain Sourveld (A8), Highland and Dohne Sourveld (A44 a and b). (Vegetation of South Africa, Lesotho and Swaziland, 2004).

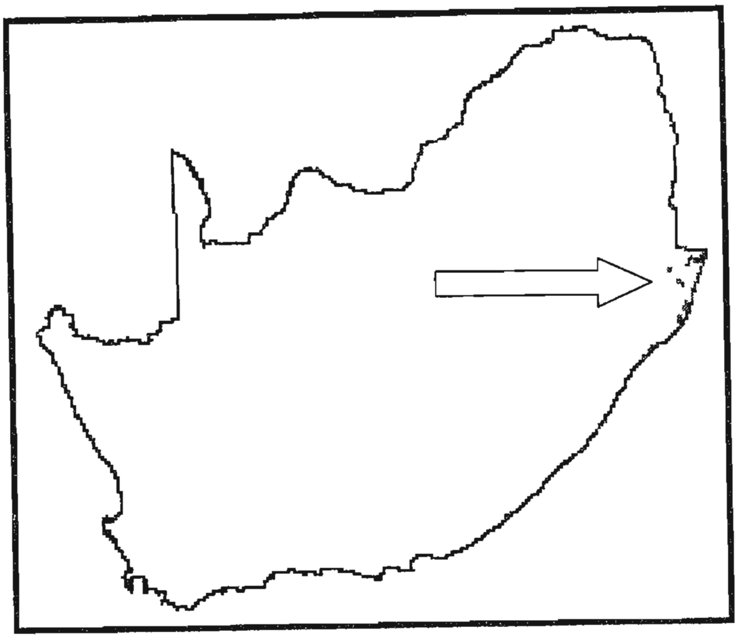


Figure 19: Coast Belt Forest (A1 a), Zululand Palm Forest (Vegetation of South Africa, Lesotho and Swaziland 2004).

3.4.2 Vegetation of Lesotho

Lesotho is predominantly a grassland country with natural tree growth occurring only in small patches. Carroll and Bascomb (1967, in; Acocks 1953), assert that the conditions are too dry or too frosty to permit the development of trees.

As pioneer species, cushions of *Selaginella* with a few xermorphic grasses and shrublets of *Cliffortia ramosissaima, Lightfootia albens* or *Helichrysum infaustum* develop along cracks in the rock on bare cave sandstone surfaces. Dense cushions of *Helichrysum sessiliodes* penetrate cracks in bare basalt surfaces at higher altitudes (Schmitz, 1984).

The grasslands may be climax communities. Some botanists regard such grasslands as fire sub-climax communities. Many years of veld fires, overgrazing and land mismanagement have exerted a great influence on the formation of the present vegetation, and have encouraged the invasion of the grasslands by shrubs. A sub-climax succession to shrub may occur at any altitude if the site has sufficient shelter (Russell, 1979). Dense scrub, rich in species, with some components of tree and shrub layer occupy many river valleys, particularly in the central part of the country (Schmitz, 1984). Trees such as *Grewia occidentalis* (*lesika*), *Celtis africana* (*molutu*) and *Maytenus heterophylla* (*sefea-maeba*) are found near rocky outcrops throughout the low lying areas and in the warm valleys of the Senqu (Orange) and Quthing Rivers.

Seboku Grassland occupies 56% of the Maloti (including Senqu Valley). Letsiri Grassland occupies 31% and the Sehahala Scrub 13% (National Environment Secretariat, 2000).

According to National Environment secretariat, (2000) Map of Africa classifies the western part of Lesotho under Highveld Grassland, the Maloti summit plateau under Afroalpine Grassland while the remainder of the Maloti is the transition area from Afromontane Grassland (Figure 20).

Table 5 below shows vegetation biome of the whole of southern Africa. It depicts the total area of the vegetation type in southern Africa, the proportion of the vegetation type that is conserved and the proportion of the area, which the vegetation type occupies.

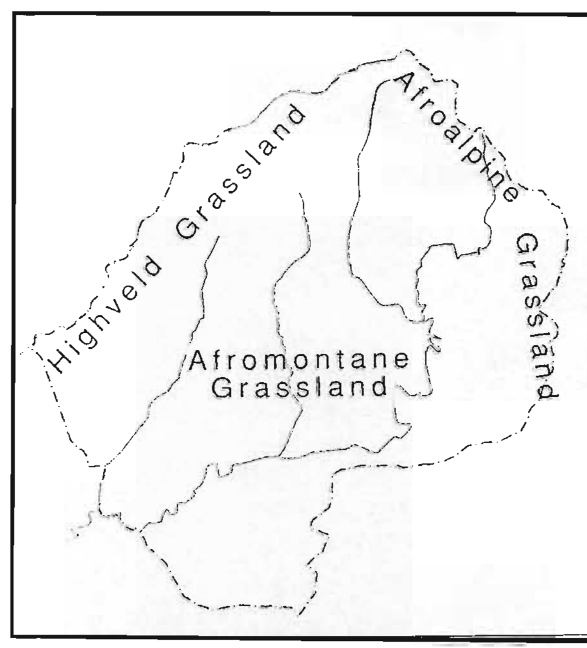


Figure 20: Grassland biomes in Lesotho (National Environment Secretariat, 2000)

3.5 PHYSIOGRAPHIC ZONES OF LESOTHO

Lesotho is divided into two major physiographic provinces, Lowlands and Mountains.

The Lowlands form part of the South African Highveld while the mountains form part of great Drakensburg range. The province of the mountains is further subdivided into Foothills and mountain zones (Russell, 1979). The fourth zone, after the Lowlands, is Senqu Valley (Figure 21). The four-zone classification is primarily based on landforms rather than vegetation systems.

Table 5: Vegetation types of the southern Africa by biomes (Low and Rebelo, 1996).

Southern Africa.	**Area (km^2)**	Proportion conserved. (%)	Proportion of area the vegetation occupies (%)
Forest Biome.			
Afromontane Forest.	5 964	17.64	0.47
Coastal Forest.	947	9.51	0.07
Sand Forest.	354	44.62	0.03
Fynbos Biome.			
Grassy Fynbos.	6 313	16.14	0.50
Laterite Fynbos.	616	0.47	0.05
Limestone Fynbos.	2 148	13.84	0.17
Mountain Fynbos.	27 462	26.14	2.16
Sand Plain Fynbos.	5 208	1.05	0.41
Renosterveld Types.			
Central Mountain Renosterveld.	7 611	3.63	0.60
Escarpment Mountain Renosterveld	5 900	0.13	0.46
NW Mountain Renosterveld	1 641	0.00	0.13
S & SW Coast Renosterveld	14 074	1.42	1.11
West coast Renosterveld	6 141	1.76	0.48

The area as occupied by zone, percentage of total area and altitudinal range are shown in Table 6.

3.5.1 Lowlands zone.

Lowlands zone largely lies in the west of Lesotho. It falls below the creamy-white cliffs of the prominent Clarens-Formation (formerly known as "Cave Sandstone". It rests on the Elliot Formation, and its thickness varies from 100 to 200 m (Friedrichshall, 1985). The summit ranges at about 1800 metres above the sea level. Its escarpment divides the Lowlands from the Foothills (National Environment Secretariat, 2000). The lowlands contain arable land and it is estimated at about 400 000 ha, and again the majorityof the population and towns are found in this zone. Similarly, most of forest plantations (woodlots) are found in this zone (Figure 28) in order to meet the high demand for highly populated area (Tenei and Potter, 1981).

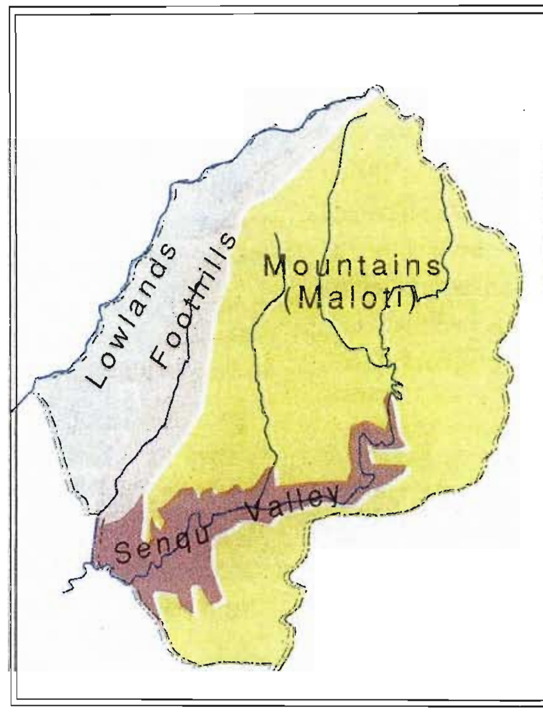


Figure 21: Physiographic zones in Lesotho (National Environment Secretariat, 2000)

The rainfall is variable around an average of 740 mm in the northern Lowlands and 500 mm in the southern Lowlands. The general increase of the rainfall is from west to east (Mc Xee and Bevan, 1975).

Table : 6 Principal physiographic zones in Lesotho, by area, total percentage and altitudinal range (May, 1994).

Zone	Area (km^2)	Percent of total.	Altitude range (m)
Lowlands	5 760	19%	1 400-1 800
Senqu Valley	2 430	8%	1 400-1 800
Foothills	2 430	8%	1 800-2 200
Mountains	19 730	65%	2 200-3 400

A large part of the Lowlands zone has been described, by Carroll and Bascomb (1967), as Cymbopogen-Themeda Grassveld. The most important component of this veld is *Themeda trianda* stands of which are virtually found on soils derived from dolerite. *Hyperrhanea* grass is very common. Eragrostis and other hardy grasses replace *Themeda* in overgrazed areas. Sour grasses become more rife in the wetter northern section of the Lowlands. This area is the transitional zone from *Cymbopogon-Themeda* Grassveld to the Highland Sourveld.

3.5.2 Foothills zone.

The Foothills zone can be interpreted as low mountain area separating the Lowlands and the Mountains (Figure 11). It comprises the gently sloping pediments at the base of the mountains and the ensuing plateaux is at elevations ranging from 1800 m to about 2100 m (Tenei and Potter, 1981). Many of the plateaus have been covered by outpourings of the Drakenberg lavas. The soils overlying Clarence Formation are yellowish brown and coarse to medium in texture

(Russell, 1979). Carroll and Bascomb (1967, in; Acocks 1953), mention that most of the grassland of the Foothills zone and the lower Mountain slopes are *Themeda-Festuca* Alpine veld type. *Themeda trianda* is still the dominant species.

Rainfall ranges from 900 mm to 1200 mm and is more reliable than in the Lowlands (Tenei and Potter, 1981).

3.5.3 Mountain zone.

The basaltic mountains cover at least 67% of Lesotho, mostly as a sequence of steep ridges and deep valleys. The zone projects the highest point in the whole of southern Africa, Thabana-ntlenyane, at an elevation of 3500 m above the sea level. The steep mountain slopes level off at about 2 800 metres to an extensive rolling upland plateau. This plateau forms a major part of the Gondwana surface. The steepness of the slopes allows only poor profile development in the soils in this zone. This accounts for the widespread distribution of shallow, immature soils. Dry and cold winter climate of Lesotho is not conducive for chemical weathering, and the cold winter of the upper mountains inhibits soil development. Strong winds in this dry season desiccate and erode the soil. Deep soils occur only where the topography is flat enough to permit the accumulation of colluvial material. This kind of colluvial soils cover flats in valley floors and the remnants of dissected valley floodplains (Russell, 1979). Black soils formed in the mountain valleys have a clay texture throughout the profile (Rooyani and Badamchian, 1986). The sandstone layers in Lesotho generally are made up of sedimentary materials which are about 200 million years old. This substratum weathers into sand (dominated by the mineral quartz), which consequently forms sandy soils reach in quartz (Op cit). In the Mountain zone, soils developed from basalt have a medium to fine texture (Table 7). The basaltic rock, which constitutes the underlying stratum of the Mountain zone, moderately weathers into calcium rich clay (Op cit). In the Mountains zone, the average rainfall can be as high as 1500 mm (McKee and Bovan, 1975)

On the highest mountain slopes, above an elevation of about 2600 metres, short-leaved and short-stemmed grasses of the *Fescue* type predominate. The grass cover of the tops of mountains is sparse, and much bare ground is exposed (Carroll and Bascomb, 1967).

3.5.4 Senqu Valley zone

The Senqu Valley zone derives its labelling from the mountainous terrain dissected by the river Senqu (Orange) Valley. Large part of it lies below 1 700 m. It represents a narrow tongue of the Lowland province, by which it is deeply enclosed (Figure 21). The lowest point in Lesotho is at 1 388 m, and lies in this valley where Senqu (Orange) River leaves the country at the border with South Africa. There is generally less rainfall due to rain-shadow emanating from the adjacent mountains (May, 2002).

The Clarance Formation and Red Beds strata influence the pattern of soil formation by extensive dolerite intrusions and basaltic materials washed down from the adjacent mountains, are also important as parent material (Bennie and Partners, 1972). The land so geographically dissected, forms sharp ridges or plateaus. Arable, dark, clay loam soils, result from the weathered basalt deposited from higher mountains (Wenner, 1982).

Table: 7 Mechanical analysis and textural classes of certain soils by physiographic zones in Lesotho (Rooyani and Badamchian, 1986).

Zone	Depth (cm)	Clay (%)	Silt (%)	Sand (%)	Texural classes
Lowlands	0-7	7.0	14.4	78.6	Loam –sand
	16-23	9.0	19.0	72.0	Sandy-loam
Lowlands	15-40	8.0	33.9	58.1	Sandy-loam
	40-75	42.5	25.1	32.4	Clay
Lowlands and Foothills	0-10	18.0	31.8	45.4	Loam
	25-45	27.0	27.6	41.9	Clay-loam/Clay
Moutains	0-15	10.0	48.1	41.9	Loam
	15-23	12.0	46.2	41.8	Loam

3.6 GENERAL CLIMATE OF LESOTHO

Climate, vegetation and soils form an interdependent, dynamic interelationship. When member of this complex undergoes change, the others also change, and a new equilibrium is realized. According to Friedrichshall (1985), the criteria established by FAO for assessing major climatic divisions for Lesotho are as follows:

(a) mean monthly temperature of all months less than 18 °C is sub-tropic.

(b) if the rainfall occurs mainly in the warmer part the year; summer rainfall.

(c) mean temperatures less than 20°C during growing period i.e. October –April; cool.

It follows from the above description, therefore, that the climate of Lesotho is cool, sub-tropic with summer rainfall.

3.6.1 Precipitation

Precipitation is a natural process, which provides the environment with moisture from the atmosphere. It can occur in the form of snow, sleet, rainfall, frost or humidity.

3.6.1.1 Rainfall

The mean annual rainfall varies widely according to different geographical locations in the country. It is higher in the north and gradually decreasing towards the south (Bennie and Partners, 1972; Friedrichhall, 1985). Bennie and Partners (1972) mention that the lowest estimated long-term monthly mean is 54 mm for Fort Hartley in the Senqu Valley zone. The highest estimated annual mean is 1 420 mm in the Mountain zone at Oxbow Meteorological Station at an elevation of 2 600 m. Carroll and Bascomb (1967) mentions that the total annual rainfall for the whole country averages 740 mm. Rainfall is normally concentrated in the summer months. About 80% of the rainfall occurs between October and March (Tenei and Potter, 1981) and very little falls during the months of May to September (Figure 22).

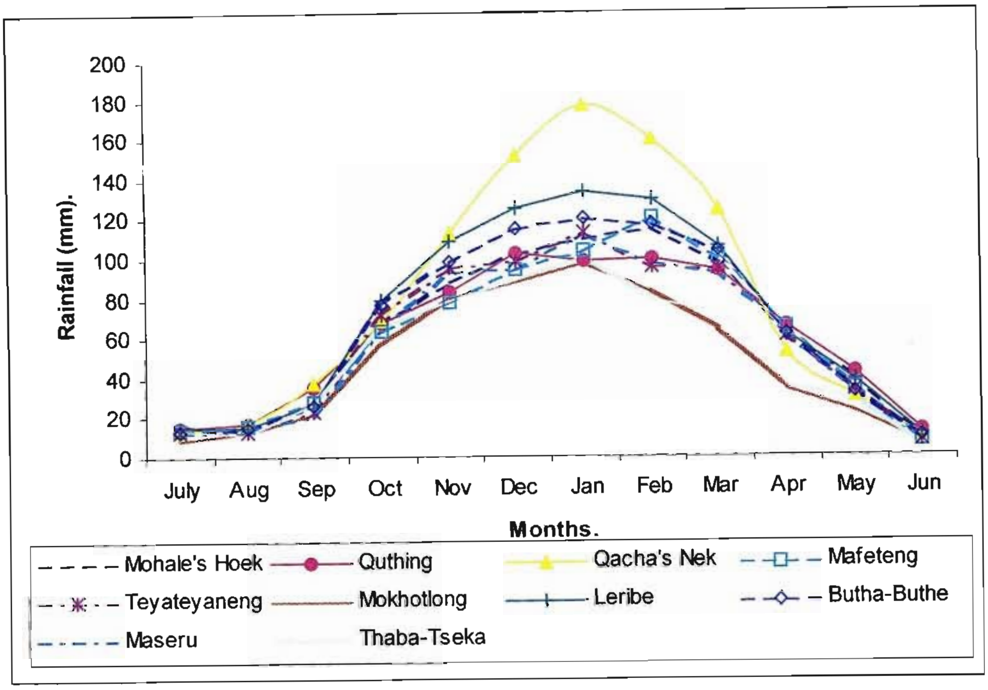


Figure 22: Long-term mean monthly rainfall for the ten districts of Lesotho (Jaymaha, 1980)

Summer rainfall is usually in the form of heavy storms, sometimes accompanied by hail. Lesotho has the greatest hail frequency in the whole of southern Africa and, as result, netting in the summer months is necessary (Tenei and Potter, 1981). Annual total and seasonal total rainfall vary from year to year. Prolonged serious droughts in the summer months are rare. The pattern of rainfall and temperature is shown on Gaussen-Walter climatic diagram in Figure 26.

3.6.1.2 Snow

Snow falls frequently during winter months at high elevations between May and September. It covers the upper slopes of the mountains for several months of the year. In the Lowlands it does not last long but it has been recorded there even in December (McXee and Bevan, 1975).

Snow can increase the amount of precipitation quite significantly though it can as well have an impact on decrease in temperature. Again heavy snow tend to break stems and branches of trees This phenomenon encourages rotting at the points of breakages.

3.6.1.3 Relative humidity

In the Lowlands, the mean annual relative humidity is at about 60%, with a tendency for the higher values to occur in the north. Maximum humidity usually occurs around March-April, when mean monthly values are in the range of 59-72% and minimum humidity occurs in August-September when mean monthly values are around 49%.

The diurnal variation of relative humidity is more or less the reverse of the temperature variation, maximum values occurring just before sunrise, and minimum values in the early afternoon. The diurnal range is estimated at 45% (Bennie and Partners, 1972). The average monthly relative humidities (percentages) at 08:00 and 14:00 hours are shown in Figures 23 and 24.

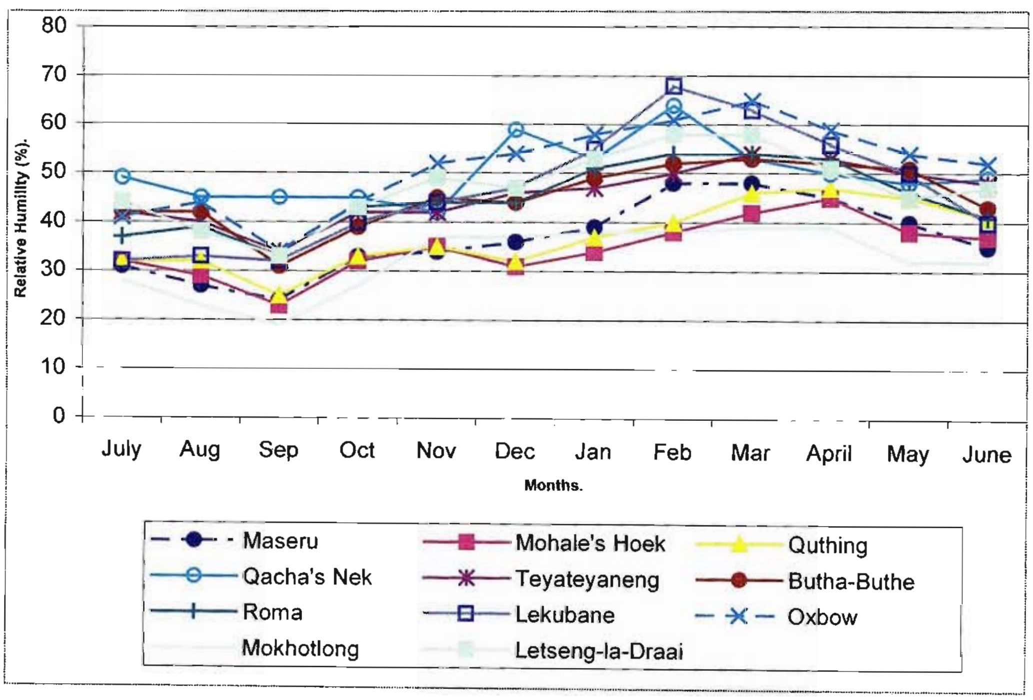


Figure 23: Mean monthly relative humidity at 08:00 hrs at eleven weather stations (Jaymaha, 1980)

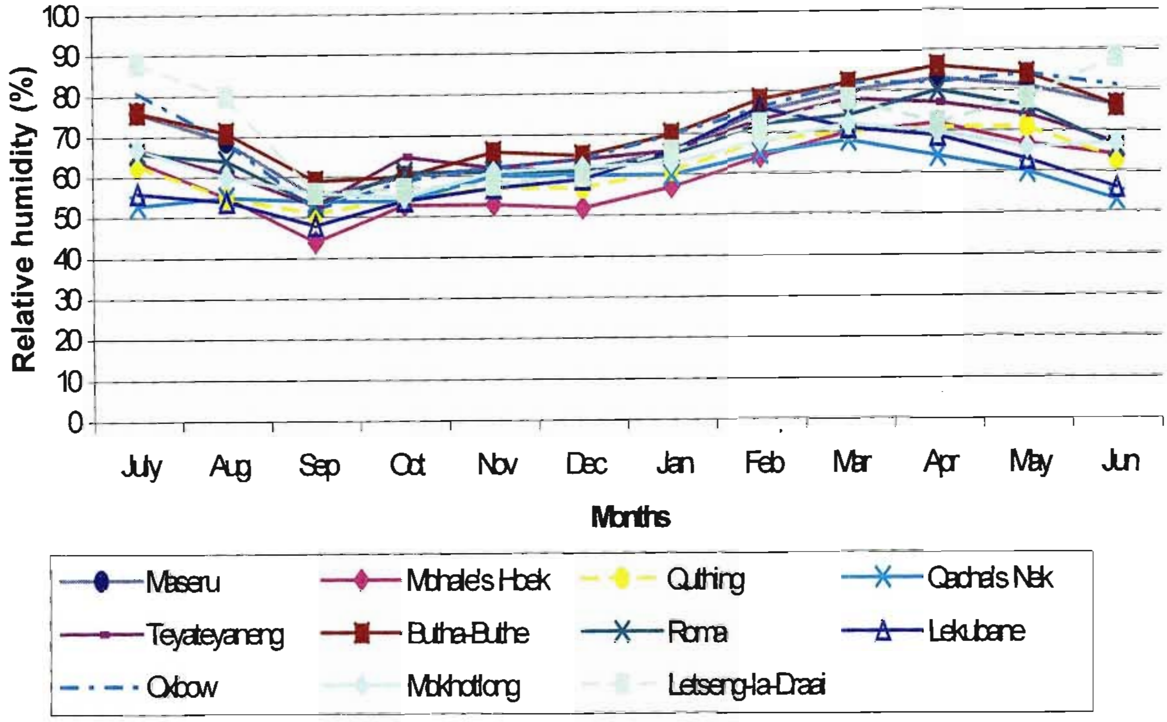


Figure 24: Mean monthly relative humidity at 14:00 hrs at eleven weather stations (Jaymaha, 1980)

For a given relative humidity value the water potential difference increases with increasing temperature and so a simple correlation between transpiration rate and relative humidity can be expected only at a particular temperature (Sutcliffe, 1979). It is, therefore, obvious that there is a relationship among the amount of water present in a given volume of air, rate of transpiration and atmospheric temperature. Plants may react by closing the stoma in their leaves or shedding their leaves if they experience excessive water loss and it is noteworthy that transpiration occurs more rapidly when the air surrounding a plant is dry than when it is wet because the water potential gradient is larger.

3.6.2 Evaporation.

The October-March Potential Evapotranspiration (PET) values decrease by about 50 mm in every 300 m increase in elevation. The total PET has an average of about 800 mm for Foothills and the available October-March rainfall of about 850 mm has a moisture deficit of about 27% (Friedrichshall, 1985). Russell (1979) asserts that evaporation may be as high as 2 040 mm per year in Maseru in the Lowlands and as low as 1 557 mm at Oxbow in the mountains (Appendix 4). Evaporation has a direct bearing on the moisture on the ground and, hence water which is available for plant use. The more the evaporation there is, the more the water loss.

3.6.3 Temperature.

The temperature in Lesotho varies from place to place according to altitude and decreases by 1.7 °C for each 300 metres increase in altitude (Russell, 1979). Monthly mean temperature varies from 20.3 °C in January to 7.85 °C in June. Maximum mean temperature is highest in November, December and January with up to 29.5 °C, while the lowest, mean minimum temperatures occur in June/July at 4 °C. This is depicted in Figure 25, which is derived from the long-term data. Extreme maximum temperatures do reach 39 °C from December to January in the Lowlands (Appendix 5). In the winter months extreme minimum temperatures may go as low as –20 °C (Appendix 6). Frost occurs on the average of 40 times per year in the Lowlands and over 100 times in the mountains. First and last frost days vary in each district in relation to its geographical position but commonly the start in April and, in some cases they do occur in December (Appendix 7).

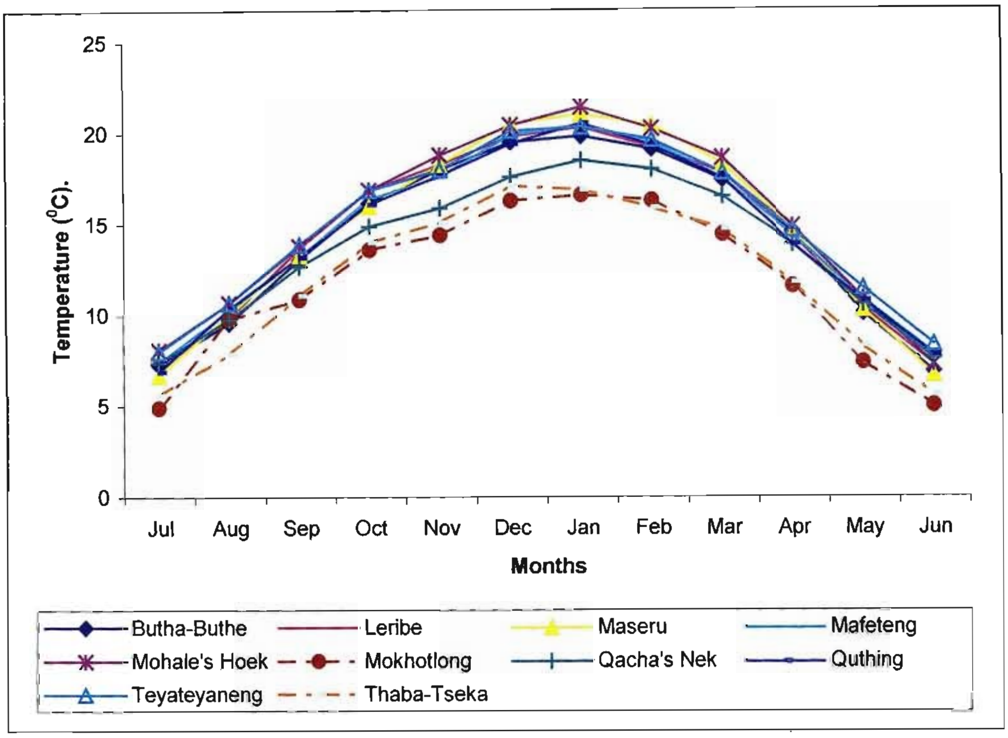


Figure 25: Long-term mean monthly temperatures for the ten districts of Lesotho (Jaymaha, 1980)

High temperatures could be hazardous to trees or crops. Though the high temperatures can rarely be the direct cause of destruction of trees under normal circumstances, they can induce water transpiration in plants and consequently lead to rapid dehydration of the plant cells. Also, in the case of perennial plants such as trees, growth processes commence when the soil surrounding their roots is sufficiently moist and warm. The particular combinations of moisture and heat depend on the type of plant and genotype.

Cloud amount during summer is higher while in winter is lower. This additional clouding during the warmer months has a modifying effect on plants in general. The amount of sunlight in a particular locality is generally sufficient for the growth and development of native plants under natural conditions. However, the incidence and spread of diseases and pests are greater under persistent cloudy skies (Jayamaha, 1980).

The percentage of possible sunshine hours is lowest in February with 68% and highest in July with 85%, but always exceeds 50% during the growing period (Friedrichshall, 1985). Mean duration of Bright Sunshine, in hours per day, for Maseru is 6.7 (Appendix 7). Sunshine is closely related to temperature factors and the impact of the intensity and duration of solar radiation is experienced mainly in association with the prevailing air and soil temperatures. During the early stages of the growth of a plant, bright sunshine is beneficial when it accompanies relatively cooler air because it could help to prevent the soil from remaining too cold to allow the plant to grow. In moderate intensities it would stimulate plants to their optimum development but direct sunshine in conjunction with atmospheric heat could raise the ambient temperatures beyond the maximum limits, which can damage the plants.

Rainfall and temperature are very important, closely related environmental factors, for tree survival. The Gausen-Walter climatic diagram, shown in Figure 26 below, reflects the patterns of these two essential factors. Both of their peaks culminate in when trees are at their lush and are in urgent need of their sustenance. In winter when their physiological processes are low or when they are dormant the rainfall and temperature are also low.

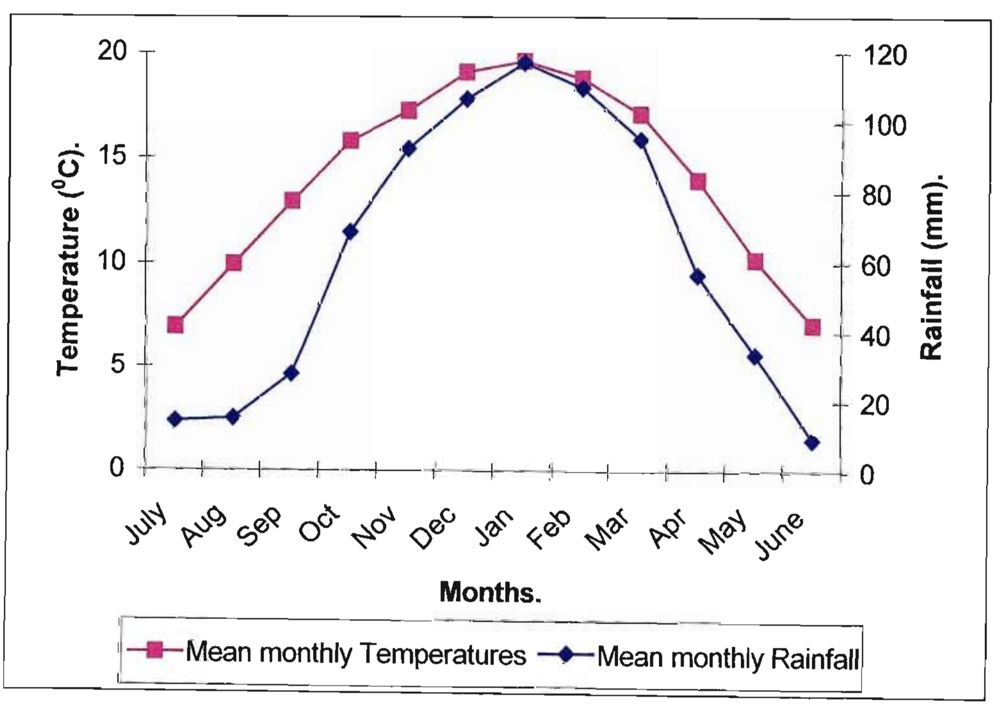


Figure 26: Gausen – Walter climatic diagram (Motselebane and Mokhahlane, 2001)

3.7 CONCLUSIONS

An interaction of both climatic and edaphic factors is very important in tree growth. Soil conditions, which are greatly affected by parent material, influence soil nutrition and soil moisture. Temperature and precipitation are the main climatic factors, which have great impact on tree growth.

Extreme cold or hot temperatures have unfavourable influence on metabolic processes of a plant. Dry conditions as well hamper tree growth.

The availability of precipitation in the environment has an important effect on plant distribution both on a world-wide basis and at local levels. Water plays an important part in the sustenance plants. Sutcliffe (1979) lists some of the important roles of water in plants as:

1. essential constituent of protoplasm (often comprising more than 90% of its total mass.

2. the solvent in which materials are transported in the xylem and phloem.

3. it makes it possible for plants to absorb a large amount solar radiation without an injurious rise in temperature, as it acts as heat sink due to its high specific heat.

4. it maintains the rigidity (turgidity) of cells, and hence of the plant as a whole. When cells lose their turgidity, the plant droops or wilts and stops growing.

CHAPTER 4

INDIGENOUS TREES AND SHRUBS IN RELATION TO FOREST MANAGEMENT

4.1 INTRODUCTION

The total area of Lesotho covered by native trees is estimated at 34 684 hectares with an average crown cover varying between 11 and 21 percent (Chakela, 1997). The existing forest patches and wooded areas are not classified and properly delineated. Their management is decentralised from the mainstream government ministries and is vested in the powers of the chiefs.

The objective of this chapter is to set perspective as to how forestry is organised and managed in Lesotho and to show how indigenous forests fit in the system.

4.2 THE INDIGENOUS TREES AND RELATED LEGISLATION

Lesotho is constitutionally governed by both customary and Roman-Dutch-law. The Land law, and conservation law in particular, is regulated by the laws of Lerotholi. They are a collection of rules, which are in part customary laws. They are so called after Paramount Chief Lerotholi who confirmed a number of laws, which had been passed by the Basutoland Council established in 1903. According to May (1992), the first legal provision was made in 1938, under which indigenous trees could be protected, this is "Basutoland Natural and Historical Monuments, Relics, Antiques, Flora and Fauna Proclamation " 1938 (Proclamation No. 40 of 1938), dated 16th September, 1938. Initially, two species of aloe were the only plants given protection under this proclamation.

4.2.1 The Land Act No. 17 of 1979 and afforestation programmes.

The Land Act No. 17 of 1979 confers irrevocable and absolute powers on the Basotho Nation. No person, other than the state, shall hold any title to land except as provided for customary law or under this Act. Where the customary law is inconsistent with the Act, the Act shall prevail. The

Act provides for a possibility of land allocation (Form C) for specific purposes (also afforestation) for up to 99 years. After expiry of the allocation time, the title can be renewed, and holders of allocation title can pass on the Form C to their family members.

Land for agricultural purposes can be held under three different titles, namely the allocation, the lease and the licence:

(a) under Land Act No 17 of 1979, an allocation cannot be mortgaged and, until recently, it was not transferrable when it can be inheritable on the individual house level. Allocations are, however, still revocable for various reasons, such as failure to cultivate one's arable land for more than three years in succession, inability or indifference of the owner to control soil erosion. On the other hand, if the allocation is revoked, the owner is compensated for any improvements carried out as an incentive for improvement.

(b) a lease gives to the lessee the exclusive possession to the leased land (the duration of the agricultural lease is not stipulated in the 1979 Land Act so far, although a minimum of 10 years for any type of lease is mentioned). The lease right can be transferred or sold, sub-leased, mortgaged, or passed on to an heir, subject to the minister's approval.

(c) licence title is provided for agricultural land, which is situated in declared urban areas. It is a less secure title in so far as it cannot be transferred, sub-leased, mortgaged, or inherited. It can be terminated on three months notice, without paying compensation if the land is required for urban land use. This type of tenure is a form of land tenure (under Land Act of 1979), and as regards purposes, granting authority, charges, transferability, inheritability and termination is shown in Appendix 8.

Land Act 1979 also makes a provision for the declaration of Selected Development Areas (SDA'S) and Selected Agricultural Areas (SAA'S). If, in the public interest, for purposes of selected development, or for the purposes of development in agriculture, an area can be declared as such, and titles held in these areas are extinguished, but substitute right may be granted such as compensation in cash, or re-allocation.

4.3 TREE PLANTING BY OWNERSHIP

Forest ownership in Lesotho is subject to the Land Act described above. Having satisfied the requirements as stipulated, forest resources may fundamentally be categorised into five main types in terms of ownership. According to Chakela (1997), the main patterns of ownership, consist of (1) indigenous trees and shrubs (2) government-owned plantations (3) private treelots (4) trees in individual homesteads and (5) trees in the urban environment.

4.3.1 Indigenous trees and shrubs.

Despite a lack of proper classification and delineation, indigenous trees and shrubs are categorised into basic types, but with a number of subtypes. The first main type comprises of mixed evergreen and deciduous forest patches of the Lowlands and Foothills (Figure 27). It is found below the escarpments, in valleys and gullies, and other similar localities that provide partial protection from winter veld fires, frosts or damage by overgrazing. Trees in this category may grow to a maximum height of 12 to 20 metres. Species present commonly include *Celtis africana*, *Olea europaea var. africana*, *Kiggaleria africana* and *Pittosporum viridiflorum*. The other species, which are shade tolerant in youth, are *Ilex mitis* and *Scolopia mundii.* The canopy trees, of which only a few species may reach the height of 11 m, commonly include *Maytenus hetrophylla*, *M. undada* and *M. acuminata.*

Figure 27: Mixed indigenous, evergreen and deciduous forest patch, in the Lowlands

Figure 28: Forest patch dominated by *Leucosidea sericea* in the Lowlands.

The other main type is dominated by *Leucosidea sericea* (Figure 28). Depending on the degree of openness of *Leucosidea*, its principal associates may be *Rhamnus prinoides* and *Rhus divaricata* (Chakela, 1997).

4.3.1.1 **Management of indigenous trees and shrubs.**

In terms of management, indigenous trees and shrubs are commonly considered to be local communal resource (Mothea, 1993). Their management is vested in Village Development Committies (VDC's) with the local chiefs as automatic members. The management is guided by formal rules, regulations, customs and traditions. Government ministries, in particular, the Ministry of Forestry and Land Reclamation, have no direct control on local communal resource except on national policies and solicited technical advices. The general objective of management is the protection of indigenous trees and shrubs, as insurance of a sustained supply of wood resource, pastures and protection against soil erosion. Depending on individual chief, the competency of decision making may demonstrate signs of weakness and in such cases subjects may take matters into their own hands (Hall and Green, 1989).

The regulated cuttings entail demarcating the area destined for cutting for a prescribed period e.g. seven days or two weeks each year, for five or ten years in succession. Cutting is normally allowed at the onset of winter. The chief decides on the quota and may impose a levy either in cash or kind. In some cases indigenous trees are used selectively. Valued species such as *Olea europaea var. africana,* are protected and only used for special purposes e.g. tool handles. There is a considerable interest nationally in the preservation of rare species of indigenous trees and shrubs and the sustainable management of less threatened wooded areas. However, there is very little information available on their distribution, ecology and growth patterns (National Forestry Action Plan, 1991).

4.3.2 Government owned plantations.

Forest policy in Lesotho is implemented by the Ministry of Forestry and Land Reclamation, in conjunction with its allied ministries of Agriculture and Local Government. Non-Governmental Organisations (NGO's) such as Durham Link, Care International (Lesotho) and Red Cross all of which play an important role in assisting the Ministry in afforestation projects and regional forestry programmes.

Between 1973-87 a donor funded Lesotho Woodlot Project (LWP) pioneered a systematic tree planting in Lesotho in the form of woodlots (Figure 29). The LWP initiated the first Forest Act, which was first promulgated in 1978 and then followed by Forest Regulations in 1980. The Act set restrictions for the use of forest reserves (woodlots) by the public, such as precautions against fires and prohibitions of removal of "forest produce". It distinguished between "acts prohibited without a licence" and "acts absolutely prohibited" (Witzsch, 1992).

The LWP established a forest fund, which was meant for post project Forest Division tobe self-sustainable. 20% of the revenue collected was given to Village Development Committees in order to fund community-based projects

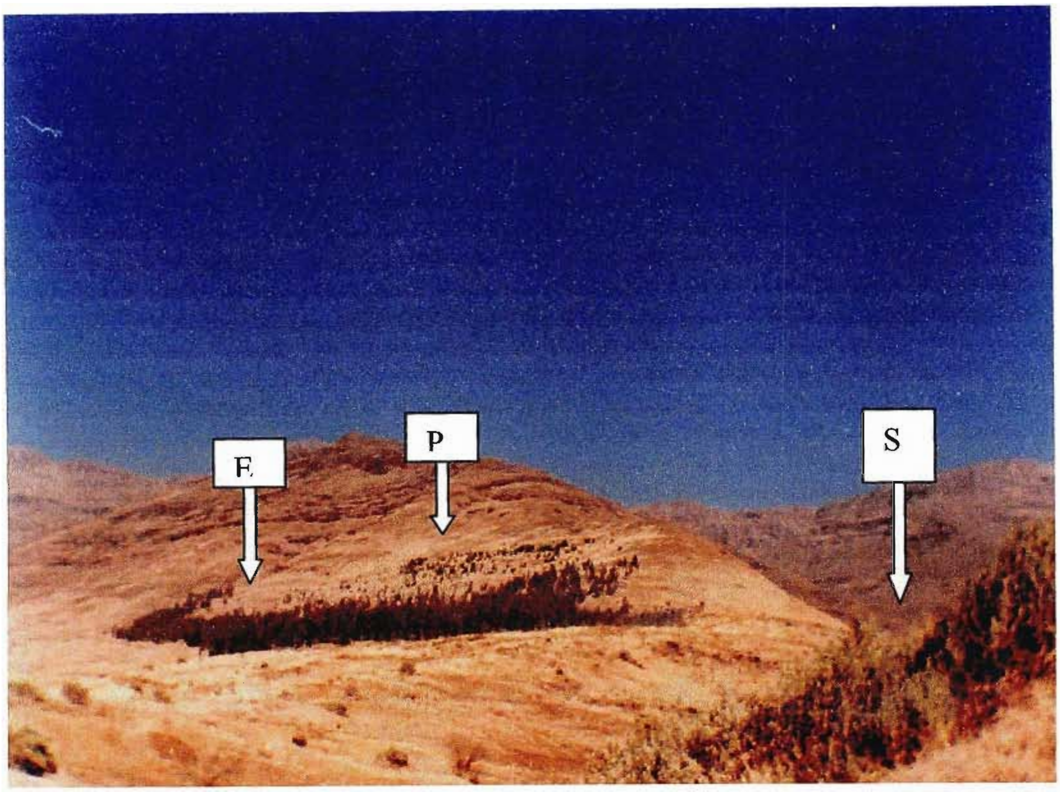


Figure 29: A four year-old woodlot planted with *Eucalyptus rubida* (E) and *Pinus radiata* (P) in the neighbourhood of a patch of *Leucosidea sericea* (S) at Malefiloane in the Butha – Buthe district. This is in the Foothills zone. Radiata is planted on much higher and more barren slope than rubida.

The LWP changed the Government trend of mainly concentrating on planting poplars and willows, to planting eucalypts and pines. It introduced formal research in 1979 (Forestry Action Plan, 1991) and trials were established in the following domains; species and provenance trials, fertiliser application, establishment research and forest inventory. Many technical recommendations were derived and incorporated in the Foresters' Operations Manual.

During mid-80's, a number of area-based projects were established closely associated with LWP. They were engaged in forestry/agroforestry and soil conservation activities, and most of them had forestry research element in their programmes:

(a) The Matelile Rural Development Project had the largest programme of species introduction trials (on and off-farm) with an emphasis on multipurpose trees and shrubs.

(b) The Soil and Water Conservation (SOWACO) project embarked on direct sowing and testing of various species on a formal and various on-farm trials.

(c) The Semonkong Project established small species trials. It was dealing with the coldest conditions of any of the area-based projects.

In 1990 Matelile, Semonkong and SWaCAP projects jointly funded the visit of a consultant from New Zealand on poplars and willows and as a result clones of both species were imported.

Plantation forestry has made a great input in generating the woody biomass in Lesotho. However, geographically, plantations (woodlots) have a skewed distribution, with the majority located mainly in the Lowlands and Foothills (Figure 30).

By districts, half of the area established and survived is in Leribe making 50% of the total, followed by Maseru making 30% of the total area afforested (Appendix 9). For silvicultural reasons, eucalypts are generally predominant in the north, pines in drier sites and cypress at higher elevations (Chakela, 1997).

4.3.3 Trees and small -holdings (treelots) owned communally or individually.

The Land Act 1979 provides for a possibility of land allocation (Form C) for specific purposes (afforestation) for up to 99 years. The applicant either must identify a suitable land, usually not suitable for agriculture. When an ideal piece of land has been identified, the applicant fills in an application form (Form A), which is forwarded to the VDC. Members of the VDC have to first rectify the suitability of the plot, measure it and set the borders.

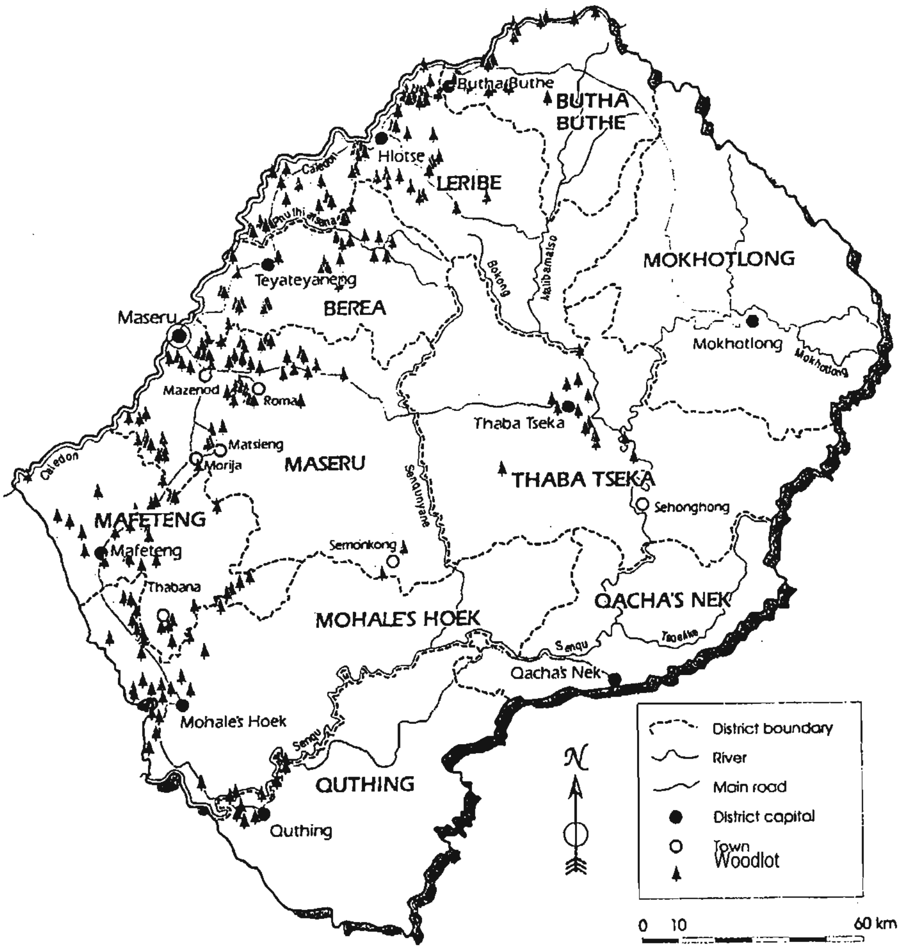


Figure 30: Distribution of plantations (Woodlots) in Lesotho (Chakela, 1997)

If the application is successful, Form C is issued with the title. Allocation is then, registered at District Administrative level. The land, thus allocated for tree planting, is usually marginal or derelict, abandoned fields or even largely eroded gullies (Social Forestry, 1997).

The procedure is a prerequisite for small smallholders, landless families and communal groups interested in establishing, maintaining and safeguarding trees and shrubs, either on individual or communal basis. After expiry of the allocation time, the title can be renewed. Holders of the allocation titles can pass the Form C on to their family members. There has not been comprehensive survey of private tree planting or ownership (Chakela, 1997). The species, which are popularly planted privately, are grey poplars and weeping willows for the purposes of arresting soil erosion (Figures 31 and 32).

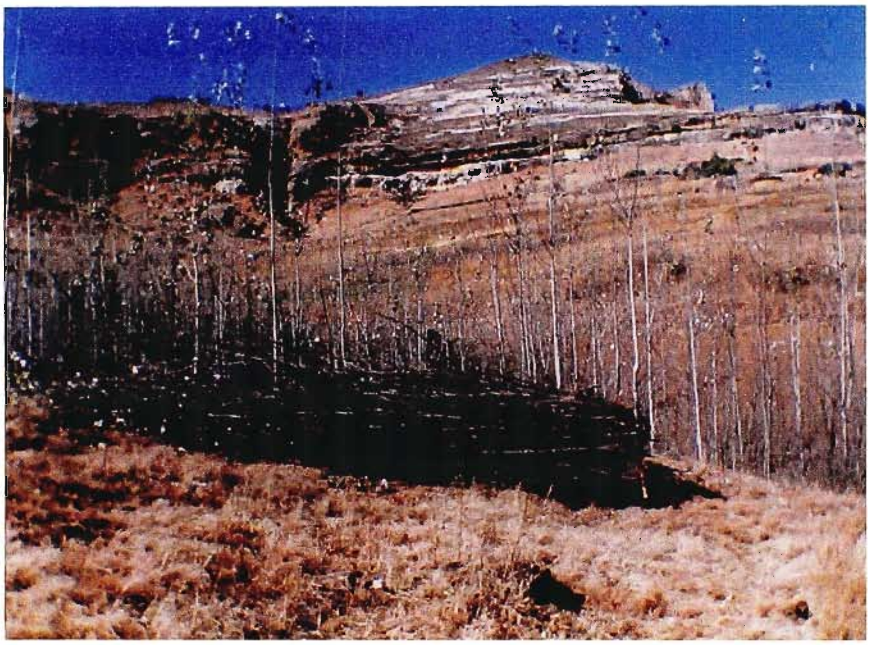


Figure 31: Individually owned small holding of *Populus canescens* planted alongside the Stream, in order to combat soil erosion and to serve as a source fuelwood. Felled and extracted coppices are stacked in preparation for the onset of winter

Figure 32: Felled and stacked logs of *Salix babylonica* are done at the onset of winter. Weeping willow is, as well, planted along side rivulets in order to arrest soil erosion and stabilise the river banks.

In Lesotho, as in many other developing countries, the deterioration of local communal woody resources has outpaced the efforts to manage these resources in a sustainable way. This has resulted in a deficit in the order of 275,000 tons in 1984, and is expected to reach 660,000 tons by the year 2010 (Mothea, 1993). A further problem is that there are no comprehensive records available to donors, consultants or concerned Basotho as to what has been tried before and what happened in those initiatives. As a result, many of the new forestry programmes, which target the private sector, repeat the same mistakes which had without addressing the reasons for those failures (May, 1992).

4.3.3.1 Trees owned by individuals in the homesteads.

According to the survey conducted by Hall and Green (1989), it found that 86% of all the rural households had, at least one tree. About 66% of the interviewees indicated that they owned fruit trees, mainly peach trees. Trees in and around the homesteads are planted for a variety of reasons. It may be for marking the boundaries, shade, and decorations, but all contribute towards woody biomass. Tree ownership by type for the individual household is shown in (Appendix 10).

4.3.4 Urban and roadside planting

Tree planting for social amenity is not an uncommon sight in Lesotho towns. Trees are planted along road-sides and regularly for commemorations and to decorate government complexes.

Tree planting generally, (it be government owned plantations, privately owned, public amenity), serves its intended purposes but there is always fuelwood and other wood products which come as a spin-off.

Under Lesotho conditions the importance of *Celtis africana* is not recognised because indigenous forests are not highly regarded. Lack of proper classification and statistical data on indigenous forests further exacerbate the possibility of proper forest management.

4.4 CONCLUSIONS

In Lesotho, plantation forestry is given predominance over natural forests. This is vindicated by the fact that indigenous forests are left in the jurisdiction of the chiefs who do not have forestry expertise. Chiefs' decisions may not be compatible with proper forst management principles. Again agriculture takes precedence over forestry as Land Act no 17 of 1979 stipulates that afforestation can only be implemented where agriculture is not suitable. One would have thought that proper land-use evaluation based on needs assessment and species preferences could be given a priority.

Forestry objectives in Lesotho focus mainly on fuelwood supply and give no attention to other wood related products. It is possible that climatic conditions in Lesotho can favour some of the best timber species from certain indigenous or exotic species.

CHAPTER 5

METHODS AND MATERIALS

5.1 INTRODUCTION.

The research was conducted in four localities altogether. Three were in Lesotho, which were Hilton, Mokhalinyane and Fort Hartley (Table 8). The fourth was Dargle, which is near Pietermarizburg in the Republic of South Africa. GPS was used to locate and establish altitudes and the coordinates for all localities in the two countries.

Table 8: Geographical locations of the study areas.

Locality	Altitude (m)	Latitude	Longitude	District / City / Province	Country
Dargle	1356	29° 28' 33″S	30° 04'17″E	KwaZulu-Natal.	RSA
Fort-Hartley	1447	30° 20' 09″S	27° 43'57E	Quthing.	Lesotho
Mokhali-nyane	1613	29°30' 28″S	27° 21'58″E	Maseru.	Lesotho
Hilton	1600	29°19' 07″S	27° 29'19″E	Maseru.	Lesotho

5.2 ASSESSMENT OF SEED MASS.

A Step-ladder, pruning-shears and plastic bags were used to collect seed. Seed collected from parent trees in four localities were extracted, macerated and dried. Seeds from each locality were thoroughly mixed individually and sub-divided into four equal groups. One hundred seeds were randomly selected from each group and their respective mass was determined. The average mass was determined for each locality.

5.3 GERMINATION TESTS.

A representative random sample was drawn from the mixed seeds for each area. Three samples were selected from each seed mixture and subjected to three different pretreatments. The first sample was pretreated with hot water. Water was heated to the boiling point, then removed from the heat source and immediately poured on the seeds in a glass container. The seeds (volume of 1:5 seeds to water) were stirred vigorously for three minutes and the left to soak as the water cooled to room temperature. The second sample was subjected to chemical scarification, as described by Goor and Barney (1968). The seeds were completely immersed in concentrated sulphiric acid (H_2SO_4, 95%) in a glass for a period of one hour. The seeds were then removed from the acid and immediately washed thoroughly with distilled water. The third sample was scarified as described by Msanga (1998). Seeds were rubbed on a sand-paper until a faint colour of the inner coat appeared. The best site for scarification is that part of the seed coat where the radicle will emerge. Care was taken to avoid overtreatment, which might cause damage to internal seed structures. Where damage occurred, the seed was discarded. The fourth untreated part or zero treatment served as a control. For each seed treatment, twenty four seeds were placed within the space of two times the average seed width on the surface of the filter paper (Whatman No1), in a petrie dish. One seed was placed at the center, then, surrounded by rims of 9 and 14, respectively, in order to total 24 in each Petrie dish. The filter papers in the petrie dishes were moistened with distilled water at the beginning of the test. Thereafter, the substrata were kept moist at all times, but not so wet that a film of water formed around the seeds. This was replicated three times. Germination tests were carried out indoors in Labcon LTGc 20-40-low temperature growth chambers (Figure 33) with lights switched off continuously. The temperature was set constantly at 25° C with humidity at 80%.

5.3.1 Germination periods.

The number of seeds germinating were assessed daily and recorded until all possible germination had ceased. Infected and germinated seeds were discarded. As regards germination, the seeds were considered to have germinated when the protruding shoot (epicotyl) had reached at least 1-2 mm in length and exhibit negative geotropism.

Both the germination capacity i.e. the percentage of seeds that germinate during a period of time ending when germination is practically complete, and germination vigour i.e. the number of days required for the total germination to complete, and germination vigour i.e. the number of days required for the total germination to occur (Sherpherd, 1986) were assessed. Analysis of variance

Variance (ANOVA) for a completely ranomised design was used to analyse the data at 5%.

The imbibition period (the number of days from sowing to the completion of germination), and the differential germination (the number of days from the commencement of the completion of germination, or the time between the imbibition periods and total germination) were recorded.

5.3.2 Germination percentage

At each evalution the number of seeds in each replicate was expressed as percentage of seeds sown. From this, an average germination percent for the locality was calculated by adding all the replicate percentage values, and then dividing by their total number i.e.3.

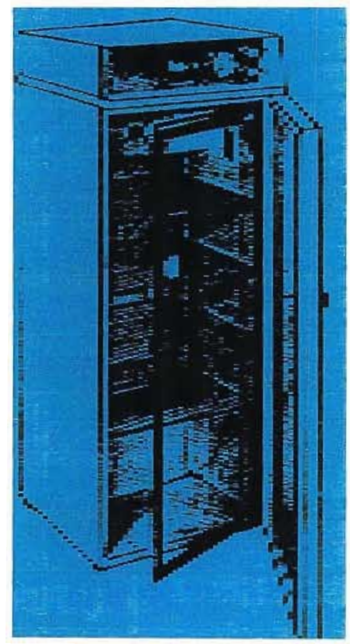


Figure 33: A germinator cabinet (Msanga, H.P.,1998)

5.3.3 Germination energy

Germination energy i.e. germination percentage attained when the mean daily germination speed (cumulative germination percentage divided by the time elapsed since sowing date) has reached its peak was obtained (Msanga, 1998). Hebblethwaite (1980) describes germination vigour as synonymous with germination energy or germination vitality.

5.3.4 Germination value

Germination value (Gv) for every treatment in each locality was calculated. Germination value is a composite value, which combines both germination speed and total germination. It provides an objective means of evaluating the results of germination tests, and allows comparisons among seedlots of the same species (Msanga, 1991). Djavanshir and Pourbeik (1976) state the formula for calculating Germination value as follows:

$$Gv = (\Sigma \frac{DGs}{N}) \frac{Gp}{10} \text{..............................} \textbf{Formula 1}$$

Where:

Gv = Germination value;

Gp = Cumulative germination percent after a specified time;

DGs = Daily germination speed; obtained by dividing the cumulative germination percent by the number of days since sowing i.e. $\frac{Gp}{D}$ where D = Number of days since sowing.

ΣDGs = The total obtained by adding DGs figures obtained from the daily counts.

N = The number of the daily counts, starting from the date of first Germination

5.4 ESTABLISHMENT OF RELATIONSHIP BETWEEN DIAMETER AT BREAST HEIGHT AND HEIGHT

In order to establish a relationship between the diameter at breast height (dbh) and the tree heights, two circular sample plots were established in each locality. A total number of eight trees with largest diameters were measured for height and dbh in each plot of 0.50 ha. Total number of stems in 0.50 ha, were recorded and converted to basal area and volume per hectare. Only trees with the dbh of 10 cm and above were measured.

The plots were randomly established on the ground. The central point (rock, tree, stump etc.) was marked with a white paint. Trees falling within the radius of 39.9 m were measured as they were within the plot of 0.50 ha (Hamilton, 1985). Travel between successive sample plots followed a straight transverse line with fixed directional compass bearing. Using a 30-metre tape, following sample plot was fixed at 100 m interval.

A diameter tape and Blume-Leiss were used to measure dbh and tree heights respectively.

Regression analysis was used to evaluate the association between explanatory variable dbh and dependent height. Regression line is the line of best fit in a scatter diagram on data points. Regression line gives an average value of Y associated with a particular value of X. A regression equation is associated with the relationship of Y to X (Freese, 1984). The method of least squares was used to estimate unknown statistical parameters.

5.5 LEAF-BLADE ASSESSMENT.

In a plot of 0.50 ha, six trees were randomly selected and then ten leaves randomly collected from each crown level. All the leaves from each crown level were thoroughly mixed and a representative sample of eight leaves was drawn randomly from each plot.

The leaf-blades were measured for lengths and breadths. Arithmetic means were obtained to represent sizes for respective localities. Analysis of variance was conducted and significance level was tested at 5% level. Colours of the stems and leaves were determined through the aid of Methuen Handbook.

5.6 DETERMINATION OF WOOD DENSITIES.

In each locality four trees were ransomly selected from which two wooden blocks were obtained Wooden blocks (1 cm x 1 cm x 1 cm) shaped from the branches at man's height, were used to determine the density, i.e. mass per unit of volume, for each locality.

The procedure for determining density (green density) for smaller blocks and those of irregular shapes, was as described by Desch and Dimoodie (1981):

1. masses (in grams) for all samples of wooden blocks were determined using an electronic scale.

2. samples were oven dried overnight at 100 °C.

3. oven dry mass was determined by weighing.
4. wood pores were sealed with paraffin wax. After setting the scale at zero, by means of a sharp pointed pin, samples were introduced into a beaker filled with water in order to determine their volumes by displacement.

According to Hamilton (1985) green density i.e. fresh felled density is the sum of two components, namely, basic density and moisture content. Basic density is the mass of oven-dried wood relative to its green volume. Moisture content is the mass of the green timber less the oven-dry, expressed as a percentage of the oven-dry mass.

Thus, if :

V = green volume (cm^3)

W = green mass (g).

w = oven-dry mass (g)

then: basic density (d) $= \frac{w}{V}$ g/cm^3............................**Formula 2**

moisture content (mc) $= \frac{W - w}{w} x100$ ....**Formula 3**

green density (D) $= \frac{W}{V}$ or $d\left[\frac{mc + 100}{100}\right]$ g/cm^3........**Formula 4**

5.7 STATISTICAL ANALYSIS

Statistical analysis was conducted using Genstat 7th version.

CHAPTER 6

DESCRIPTION OF THE STUDY AREAS IN KWAZULU-NATAL, (RSA) AND LESOTHO

6.1 DARGLE – STUDY AREA IN KWAZULU-NATAL IN SOUTH AFRICA.

The locality is in the Republic of South Africa within the vicinity of Dargle which about 45 Kms from Pietermaritzburg. It is located within Kilgobbin farm, which belongs to Fannin family. The area lies between latitude 29° 28′ 32″ and 29° 28' 32.5″ South and longitude 30° 04' 17″ and 30° 04 20″ East (Figure 34). It is at 1 356 m above the sea level.

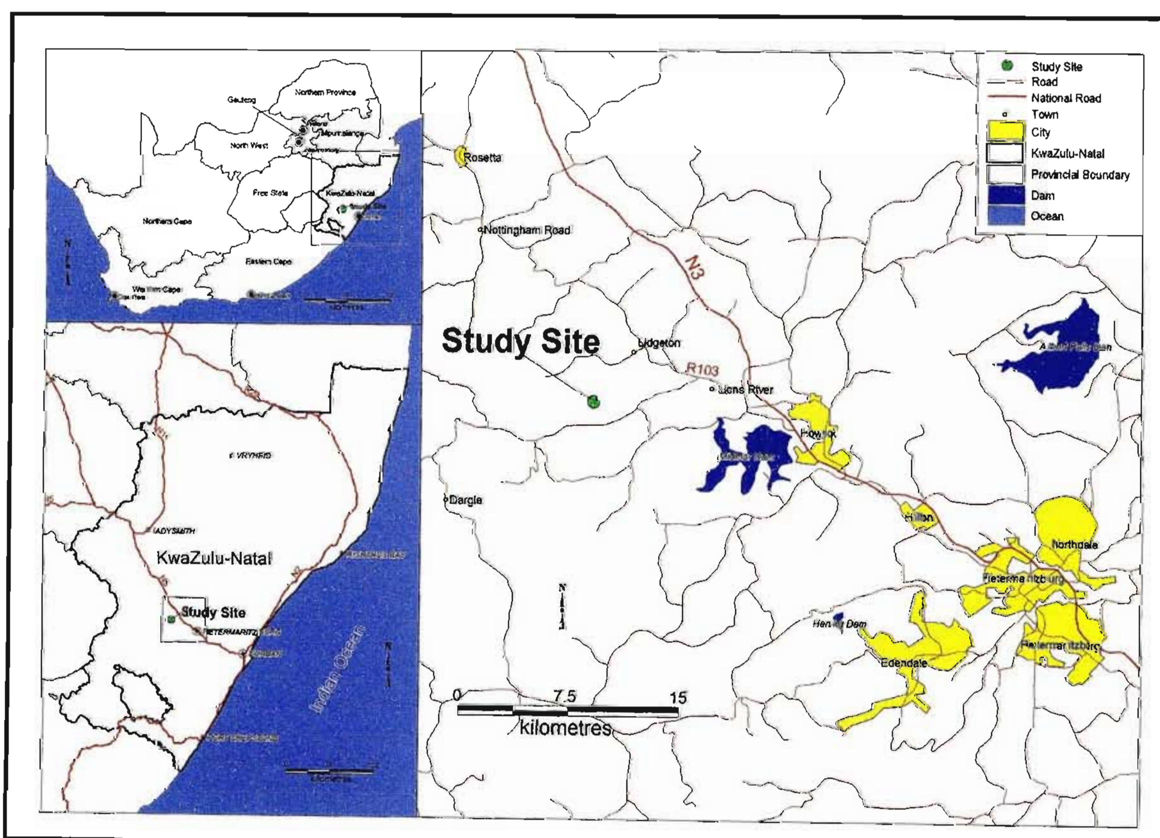


Figure 34: Study site at Dargle in KwaZulu-Natal

The forest is on east facing slope with an approximated gradient of 5-12%. The terrain is mainly rolling and partly broken. Potential soil erosion hazard is moderate. The area falls within Upland. Kilgobbin is a well protected and conserved farm as it falls under Nature Conservancy. Its indigenous vegetation and fauna are largely still intact.

6.1.1 Geomorphology, Geology and soils

KwaZulu-Natal is predominantly underlain by two prominent geological formations, which are the Kaapvaal Craton and the Natal Metamorphic Province (Figure 35). The two foundations have had two distinct influences on the subsequent geological successions in the Province. Kaapvaal Craton lies towards north of Tugela River and is mainly characterized by basalt, which has been intruded by granite. The weathered and eroded sediment of the Kaapvaal Craton has been transported and washed into shallow basins. Rocks ensueing from both Kaapvaal Craton and Natal Metamorphic Province are perceptibly evident in the Tugela Valley, Valley of Thousand Hills and along the south coast of KwaZulu-Natal (Uken *et al.*, 1984).

The soils in the region are categorized according to a natural resources classification system for KwaZulu-Natal. The Bioresource Programme (2004) defines the soil type, climate altitude, terrain form and vegetation of the area in terms of Bioresource Unit (BRU). BRU is an ecological unit within which factors such as soil type, climate, altitude, terrain-form and vegetation display a sufficient degree of homogeneity. Bioresource (BRG) is a specific vegetation type characterized by interplay of climate, altitude and soil factors and which consists of one or more BRU's. Bioresource Programme (2004), mentions that the area of arable soils is approximately 50% of the BRG and potential soils make up about 35% of the area.

Particular problems of the soils are P-fixation and Al-toxicity and are highly leached. 25.1% of the soil ecotypes is shallow while 15.9% is moderately to poorly drained (Table 9). An ecotope is a class of land defined in terms of soil-form, texture, depth, wetness, slope and soil surface characteristics e.g. rockiness. Each ecotope has a narrow range of

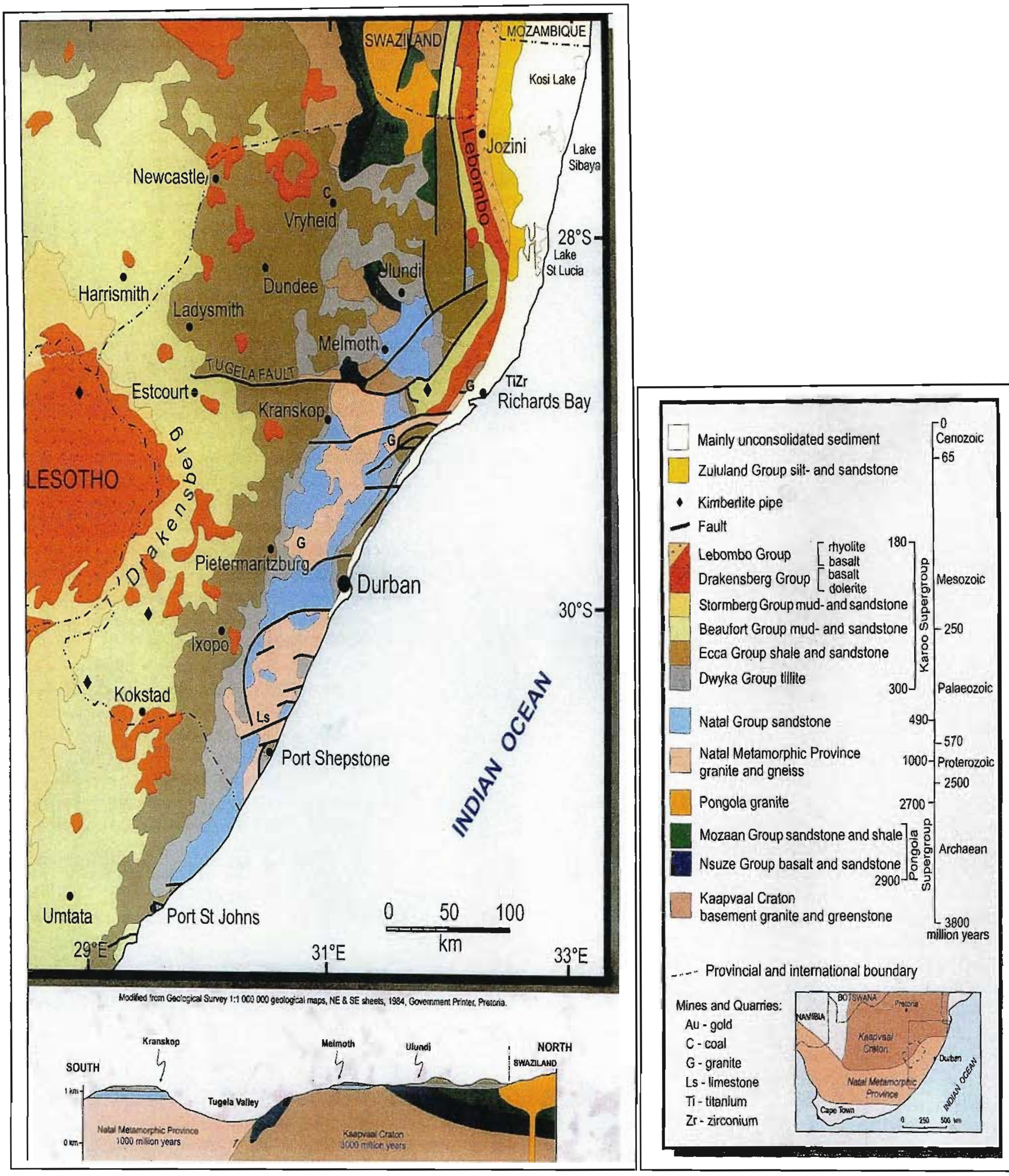


Figure 35: Geological map showing underlying strata of Kwazulu-Natal province (Urken *et al.*, 1984)

environmental variation such that uniformity exists in terms of land use. These soils also are susceptible to erosion hazard if they are not correctly managed. Site selection for any activity must be carefully considered to avoid degradation of natural resource. The pH metre indicated slightly alkaline pH of 7.5.

Table 9: Soil characteristics, clay content and soil depth by proportion of total area (Bioresource Programme, 2004)

No.	Soil characteristic.	Clay content %.	% of total area.
A	Humic.	>35	0.04
B	Well-drained.	15-35	74.84
C	Alluvial.	<15	0.81
D	Modelled and moderately drained.	-	1.26
E	Modelled and poorly drained soil.	-	1.10
		Depth (mm).	
F	Young soils.	300 – 500	10.56
G	Other poorly drained soils.	200 – 300	3.01

Other than Podocarpus species, the other indicator species are *Acacia mearnsii, Aristida junciformis, Bothriochloa insculpta, Buddleja salviifolia, Greyia sutherlandia, Hyparrhenia hirta, Lantana camara, Leucosidea sericea,* Protea species, *Pteridium acqualinum, Rubis cuneifolia* and *Solanum mauritianum.*

6.1.2 Vegetation.

The vegetation is primarily grassland and a very isolated area of forest. The main feature of this BRG is the mixed Podocarpus forests, which are largely in the transitional zone that adjoins the higher-lying Moist Highland Sourveld. The forests are commonly found on the cooler south-facing aspects, which are more moist and much protected from fires. However, most forests have been extensively exploited, and Podocarpus species, in particular, were felled for building timber in the past. Bioresource Programme (2004), after Taylor (1963) estimates that there has been a reduction in forest patches ranging between 25% and 75 % since1900. This has been mainly due to uncontrolled fires and encroachment by commercial timber plantations. At any rate, the Moist Midland Mistbelt, especially the indigenous forests, have very good potential for tourism and recreation.

6.1.3 Climate.

This locality is within the Bioresource Group, which falls in the Moist Midlands Mistbelt. It has a temperate climate.

6.1.3.1 Precipitation

Relative Humidity is at its peak from January to February when it is around 70% and is at its minimum from July to August at 59% (Figure 36).

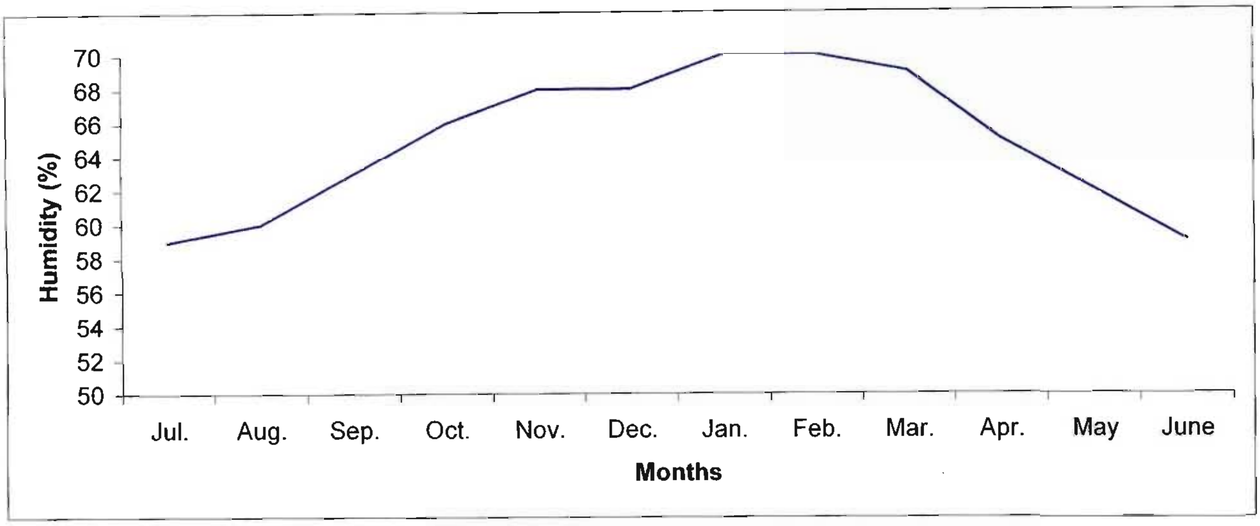


Figure 36: Mean monthly humidity (Bioresource programme, 2004)

The annual rainfall ranges from 800 mm to 1 276 mm with annual mean of 985 mm. Rainfall reaches its peak in summer between December and January at about 225 mm (Figure 37). The rainfall decreases from February to winter months, reaching its minimum of between June and July. Much of the rain comes in the form of cold frontal activity, mainly in winter, spring and early summer. An average of 60 days with thunder-storms, is recorded per annum, and storms are rife in summer and autumn. Heavy mists are a common phenomenon in this area. These mists supply additional moisture, especially to the forests, which have the ability to effectively intercept the moisture-laden air. On the average, there are about 46 misty days in a year. Climatic hazards entail occasional droughts, usually of short duration, occasional hail, frost, which varies from slight to severe, and excessive cloudiness during the summer growing season.

6.1.3.2 **Temperature.**

The mean annual temperature is around 15.9 °C. Maximum and minimum annual temperatures are 22.1 °C and 9.7 °C respectively. Temperatures are highest between January and February at about 16 °C and are lowest in June-July at about 10 °C (Figure 37).

Hot, north-westerly ("berg") winds, followed by sudden cold temperatures or cold fronts, render unpredictable conditions, particularly in the spring and early summer. Annual sunshine hours per day are estimated at 6.4 from October to March while the mean annual hours are 6.7. Frost hazard is generally considered to be moderate.

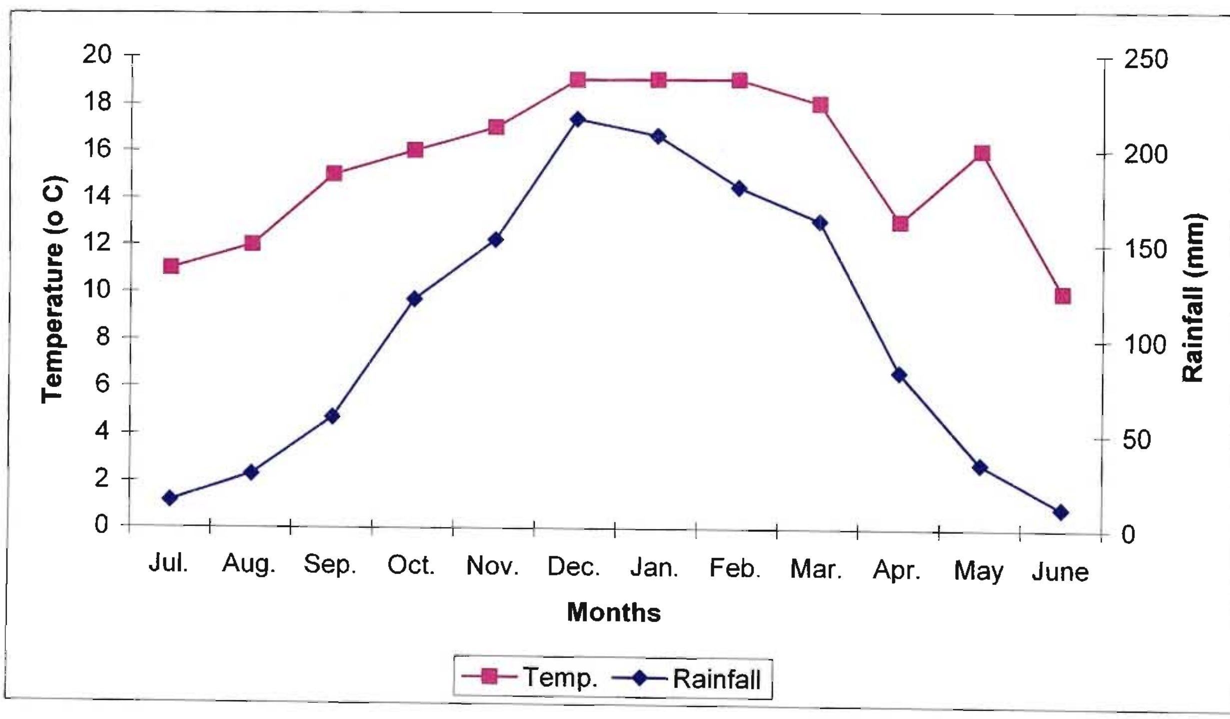


Figure 37: Gausen Walter climatic diagrams (Bioresource programme, 2004)

The mean annual A-Pan (mm) evaporation is estimated at 1 667 mm (Bioresource programme, 2004). Evaporation, as well, reaches its peak in summer (December-January) at about 175 mm and slows down in winter reaching its lowest point in June at about 91 mm (Figure 38).

The sunshine hours per day give the annual average of 6.4 in October to March, while the mean annual hours are 6.7.

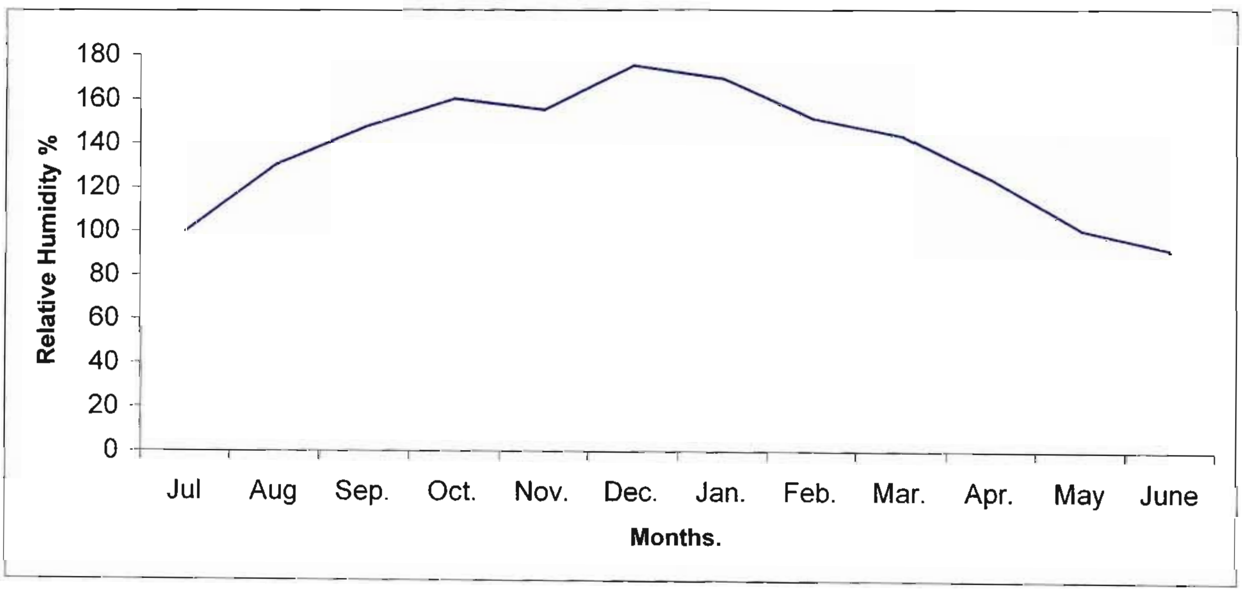


Figure 38: Mean monthly A-pan evaporation (Bioresource programme, 2004)

6.2 FORT-HARTLEY- STUDY AREA IN LESOTHO

Fort-Hartley lies between Latitude 30° 20' 09″ and 30° 19' 55″ South and Longitude 27° 43' 57″ and 27° 12' 00″ East (Figure 39). It is in the Quthing district, which is about 250 kms south of Maseru. It is in the Senqu Valley in the neighbourhood of Pokane village along Senqu River Terrace. The altitude is around 1 400 m above sea level.

6.2.1 Geomorphology, geology and soils

The relief is on a slope of river terrace with a slope around 10%. The aspect of the area is facing south-east. The erosion ranges from moderate to severe due to gully erosion.

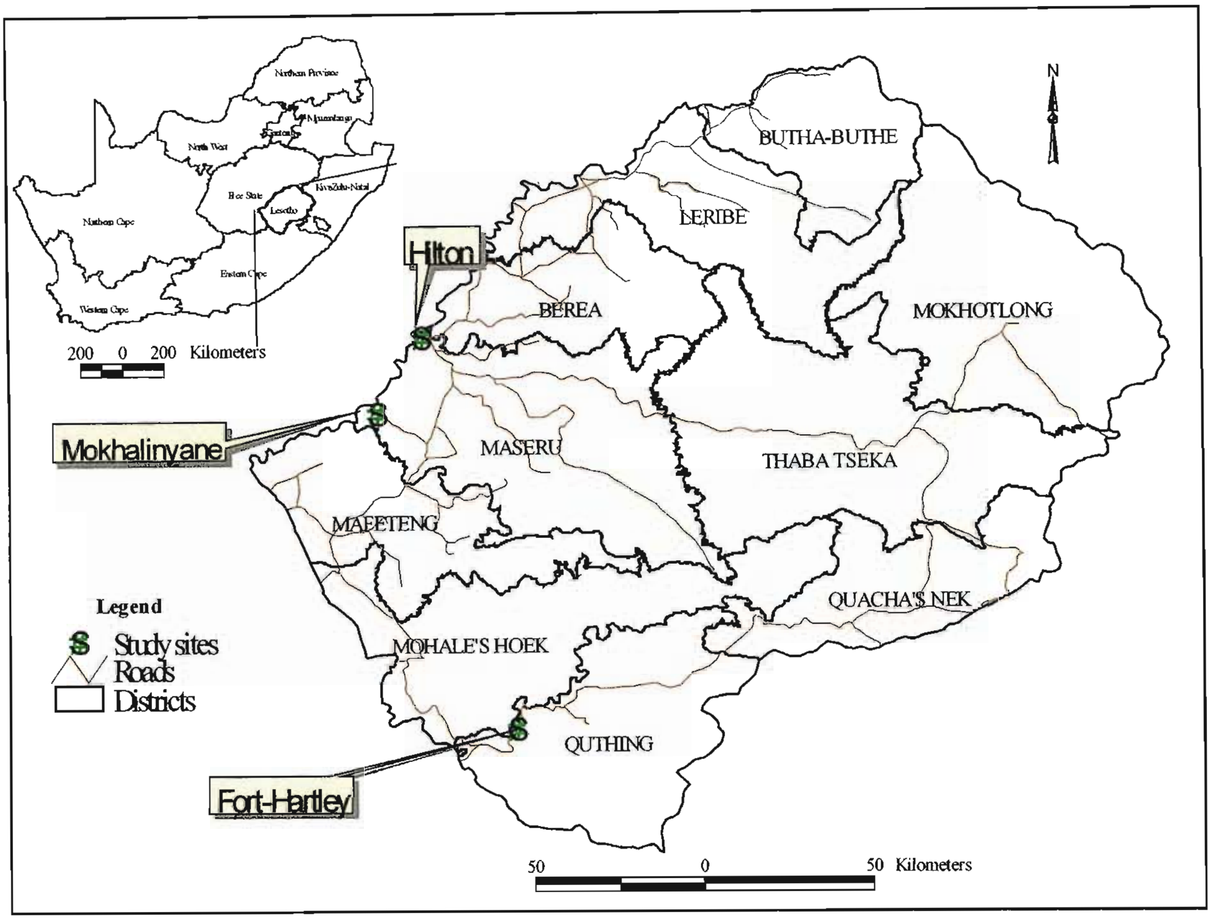


Figure 39: Location map for three study areas in Lesotho

The soil parent material originates predominantly from alluvial deposits and the permeability of the soil is moderate to rapid and excessively drained while the ground water is very deep. According to Mothokho and T'sehlana (unpublished), the soil survey showed that permeability of the soil moderate to rapid and soils are excessively drained. The ground water is deep. Calcium nodules were observable on the upper part (down to 23 cms) or down to transitional river terrace. Generally, the soils can be classified as course and loamy. The profile did not reflect distinct horizon differences.

A : 0 – 23 cm : Munsell Colour Chart indicated dark brown (10yr 3 /3) fine sandy loam. Very weak medium.
Subangular blocky structure. Very friable. Common fine fibrous root. Slightly acid (ph 6.5) clear smooth boundary.

B: 23 cm –150 cm: Munsell Colour Chart showed Dark greyish brown colour (10yr 4/2). Soil was silty clay-loam. The structure is weak to medium subangular and blocky with few fine course roots.
The pH metre showed a neutral pH of 7.0.

6.2.2 Climate.

The climate is similar to that described for Senqu Valley zone in section 3.5.6 and for Lesotho in section 3.6.

6.2.2.1 Precipitation

Humidity gradually increases from November and reaches its climax in February to March at around 64%. It is at its lowest point in July when it is about 55% (Figure 40).

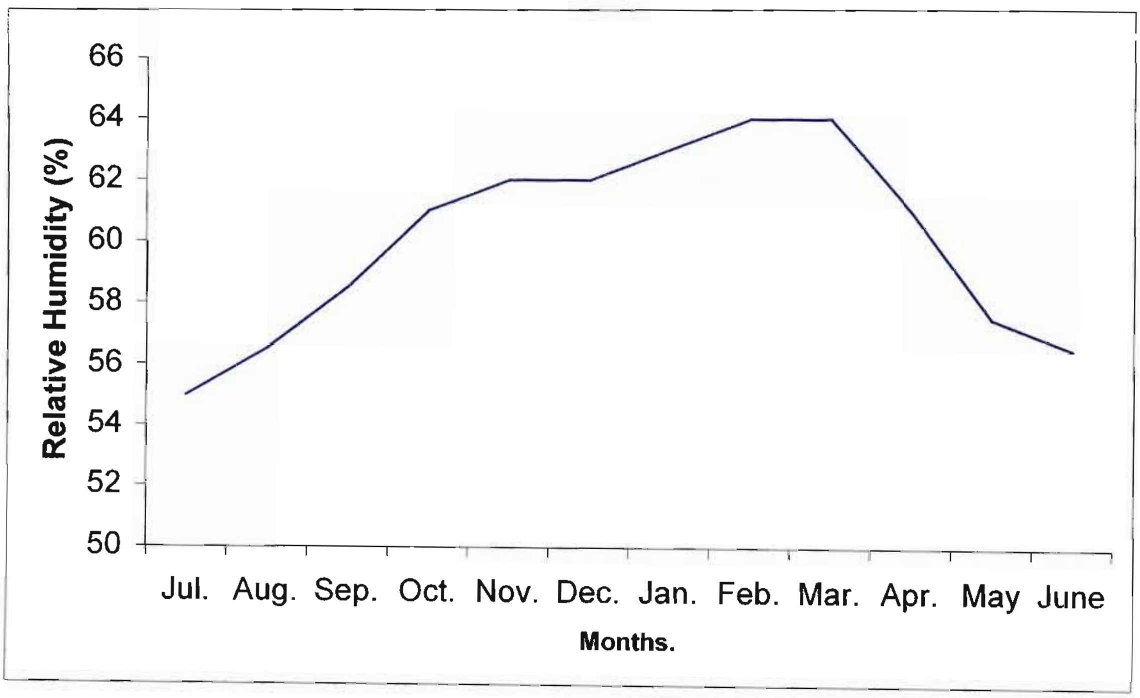


Figure 40: Mean monthly humidity (Motselebane and Mokhahlane, 2001)

Since Senqu River is subtended by mountain ridges on either side, the resulting valley is subjected to orographic rains. The ensuing shadow rains tend to be reduced as compared to general country rainfall. Otherwise, the general rainfall pattern follows that of the general country rainfall. It shows an upward trend from September and reaches its peak in January when it reaches 103 mm. It tails off from April to July when monthly rainfall averages 16 mm (Figure 41). Kunz (2004) estimates the annual rainfall for the locality as being 754 mm.

6.2.2.2 **Temperatures.**

The trend of the mean monthly temperature reaches its peak from January to February at 20 °C and decreases from March until it reaches the lowest point at 8 °C in July (Figure 41).

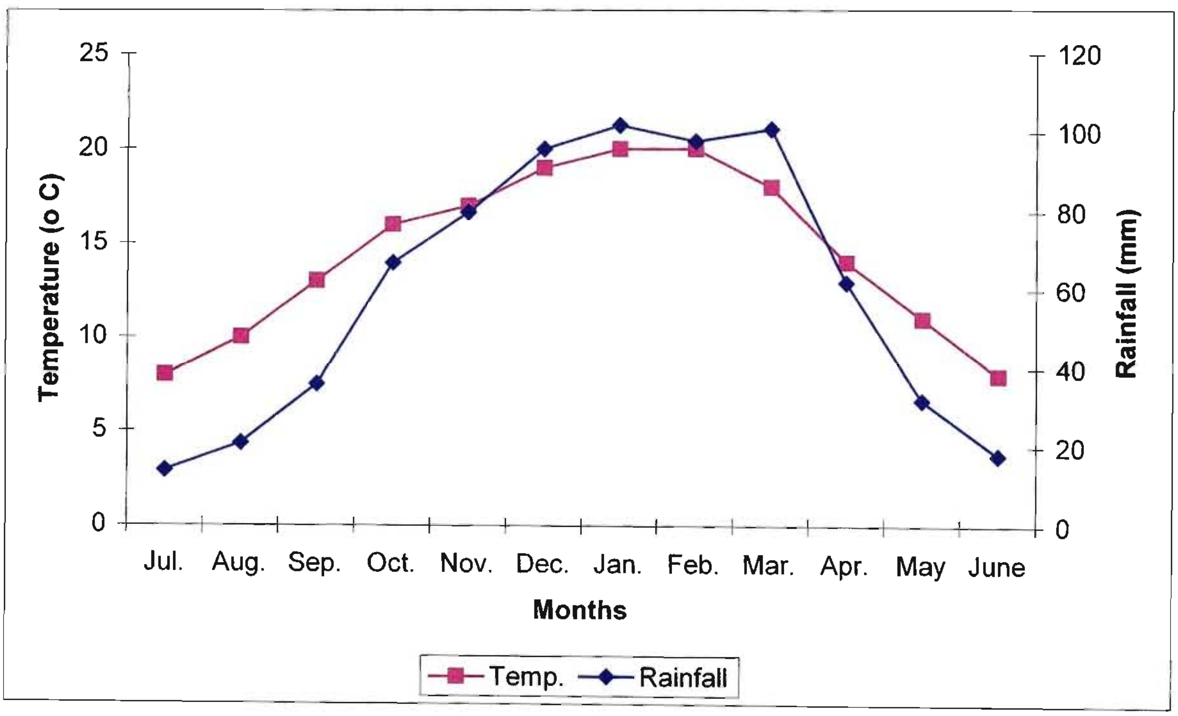


Figure 41: Gausen Walter climatic diagrams (Kunz, 2004)

6.2.3 Vegetation.

The forest floor is characterised by *Hyparrhenia hirta* and herbs such as *Hermannia depressa*, and *Melolobium microphyllum*. The woody species such as *Maytenus heterophylla* is found in patches in open spaces. *Celtis africana* forms the upper canopy in association with *Olea africana* and *Rhus undulata var. burchellii.*

6.3 MOKHALINYANE – STUDY AREA IN LESOTHO.

The study area is in Lesotho, in the locality of Mokhalinyane village. It is about 25 kms south of Maseru. It lies between Latitudes 29° 30' 28″ and 29° 30' 27.3″ South and Longitudes 27° 21' 58.3″ and 27° 20' 48″ East (Figure 39). It is 1 613 m above the sea level.

6.3.1 Geomorphology, geology and soils

The locality is on the side of the slope, which is facing north-east. The gradient of the slope is 15% while permeability is rapid and gully erosion is very severe.

According to Mothokho and Ts'ehlana (unpublished) the underlying material is light yellowish brown, weakly cemented platy sandstone that overlies indurated sandstone.

A : 0 - 30 cm: Munsell Colour Chart indicated a dark brown colour (10yr 3/3). Fine sandy loam, very weak, fine subangular blocky structure. Very friable and non-sticky. Common fine, and medium fine, and medium fibrous roots. The pH is 8. There is a clear, smooth boundary.

B: 30 - 40 cm: Munsell Colour Chart showed a dark brown colour (10yr 3/3). Loamy fine sand. Very weak fine subangular, blocky structure and friable. Slightly sticky, common fine fibrous roots.

R: - 40 cms: The site is on a sandstone bedrock.

According to the classification of Department of Soil Conservation (1972), these are Ntsi soils. They are gently rolling to hilly, and are shallow. They occupy geologically eroded plateaus and plane or convex sloping to steep upper and middle slope positions in sandstone, bedrock-controlled terrain. The surface soil is typically dark brown, and dark yellowish brown loamy fine sand about 27 cms thick.

6.3.2 Vegetation.

The ground-floor is dominated by grasses. Herbaceous plants include *Aster filifolius* (in isolated patches in the open or on the frnges of the forest), *Clutia pulchella, Myrsine africana* and *Euclea crispa.* Higher woody species included *Rhamnus prinoides, Rhus erosa, Buddleia salviifolia* and *Cliffortia ramosissima. Indigofera spinescens* found in the open spaces or on the fringes of the forest. *Celtis africana* formed the higher canopy with *Olea africana* and *Rhus undulata.*

6.3.3 Climate.

The climate of the area is the same as that of the rest of country. It is typical of the Lowlands climate with hot summers and cold winters.

6.3.3.1 Precipitation

Humidity is lowest in July when it is at about 50.5%. It is at its peak in February at 64.5% (Figure 42).

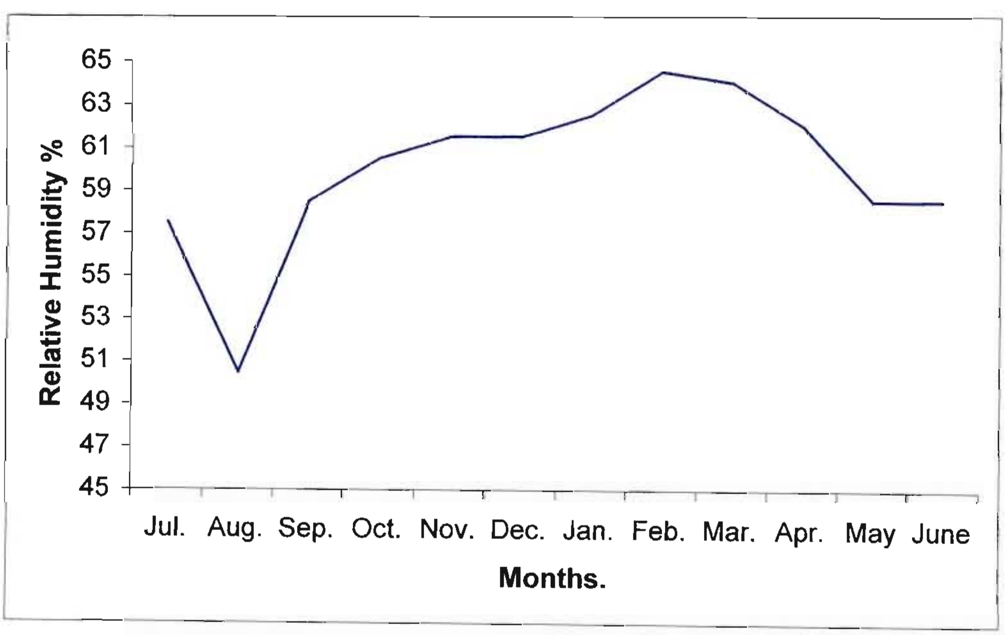


Figure 42: Mean monthly humidity (Kunz, 2004)

Rainfall is lowest in June to July when monthly rainfall averages 10 mm. Perceptible increase starts in October and reaches its peak in February when mean monthly rainfall reaches a high of 100 mm (Figure 43).

6.3.3.2 Temperatures.

Temperatures are lowest from June to July when minimum temperatures reach 0 °C. They are highest from December to January when maximum temperatures average 27 °C. Mean monthly temperatures is shown in Figure 43.

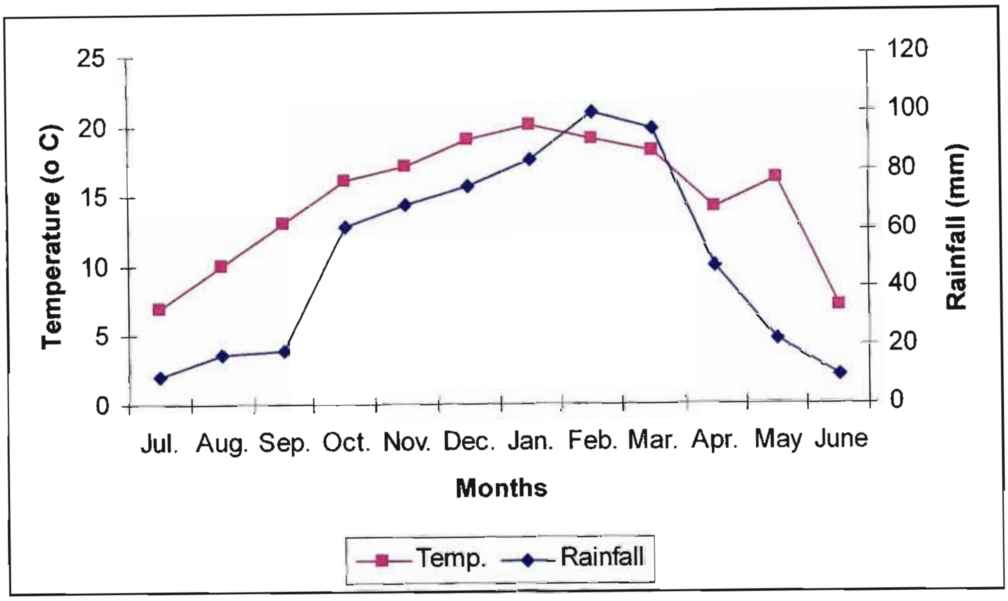


Figure 43: Gausen Walter climatic diagrams (Kunz, 2004)

6.4 HILTON - STUDY AREA IN LESOTHO

Hilton lies between latitudes 29° 17' 20" and 29° 18' 07" S and 27° 29' 05" and 27° 29' 30" E (Figure 39). It is in the Lowlands at an altitude of 1 600 m. It is in the central part of the capital city Maseru.

The area derives its name from a hotel (formerly known as Hilton and currently Lesotho Sun), which owned the wooded study area.

6.4.1 Geomorphology, geology and soils

The aspect is southwest facing along a escarpment with a slope averaging 15%. The sheet erosion is severe but the area is fenced, so some vegetation is still being in a natural state. There is perceptible intrusion by *Pinus pinaster* and *Acacia dealbata* growing naturally from the seeds washed downhill into the site from higher grounds above (Figure 27).

According to Mothokho and Ts'ehlana (unpublished), the soil survey was as follows:

A: 0 - 30cm. The soil is Dark brown. According to Munsell Color Chart the soil is described as (10yr 3/3) dark brown. It is fine sandy loam, which is very weak, fine, sub-angular. It has a Blocky structure. It is very friable, non-sticky with medium fibrous roots.
Neutral acid (pH 8). The horizon has a clear, smooth boundary.

B: 30 - 40cm. At this depth the soil colour according to Munsell Colour Chart, is dark brown (10yr 3/3). It is loamy fine sand with weak fine subangular blocky structure. It is friable, slightly sticky with common fine fibrous roots.

R - 40cm. The site is on a sandstone bedrock.

According to Soils of Lesotho (1979) this type of soils is shallow. Such soils occupy geologically eroded plateaus and plane or convex, sloping to steep upper and middle slope positions in sandstone bedrock terrain. The surface soil is typically dark-brow and dark yellowish brown loamy fine sand about 27 cms thick. The underlying materialis light yellowish brown weakly cemental platy sandstone that overlies indurated sandstone.

6.4.2 Vegetation.

Grasses constitute the floor cover while coteneaster species and *Rhus gerrardii* grow in the open patches and along the margins of the forest. *Olea africana* forms the upper canopy with *C. africana*. In most cases the branches of the latter are interlaced with the branches of *Grewia occidentalis*. *Halleria lucida* forms the middle canopy while grasses form the forest floor.

6.4.3 Climate.

The climate of the study area resembles much that of Lesotho. The area falls within the Lowlands zone of the country and its climate is typical of the overall sub-region.

6.4.3.1 **Precipitation**

Humidity starts to rise in September and reaches its climax in February when the mean monthly humidity is around 63%. It starts to decline March and reaches its lowest point in July to August at about 54% (Figure 44).

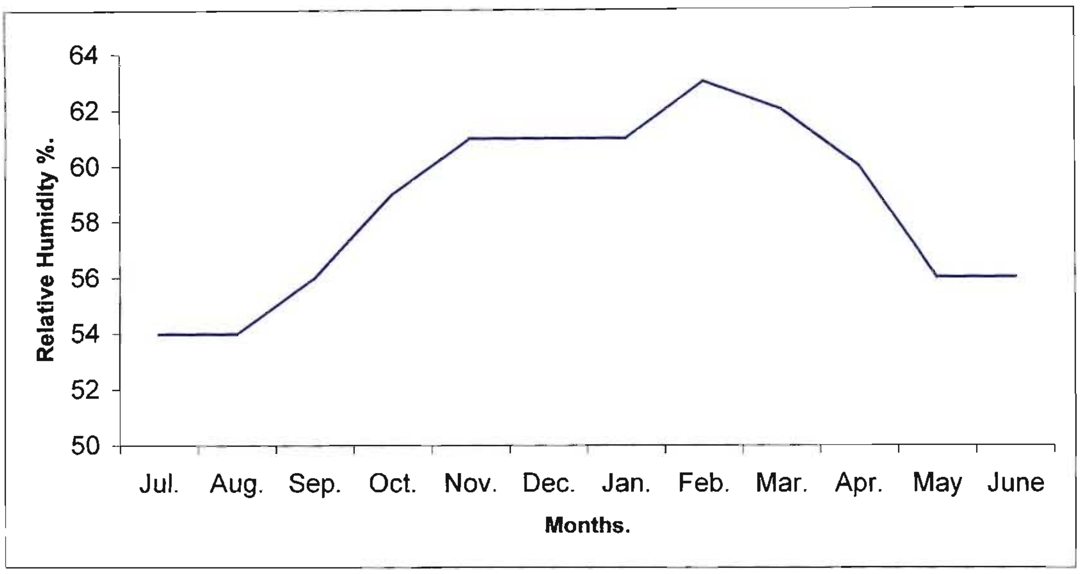


Figure 44: Mean monthly humidity (Kunz, 2004)

The rainfall pattern is as described in section 3.6.1. The mean annual rainfall is 589 mm (Kunz, 2004). The mean monthly rainfall starts increasing in September and reaches its peak in January at about 118 mm. It starts decreasing in March and reaches its lowest point in July at around 11 mm (Figure 45).

6.4.3.2 **Temperature.**

Mean daily maximum temperature reaches its peak in 28 °C. Mean daily temperature is 0 °C in June to July. At its peak mean monthly temperature is about 21 °C in January. At its lowest point in June and July is 7 °C (Figure 45).

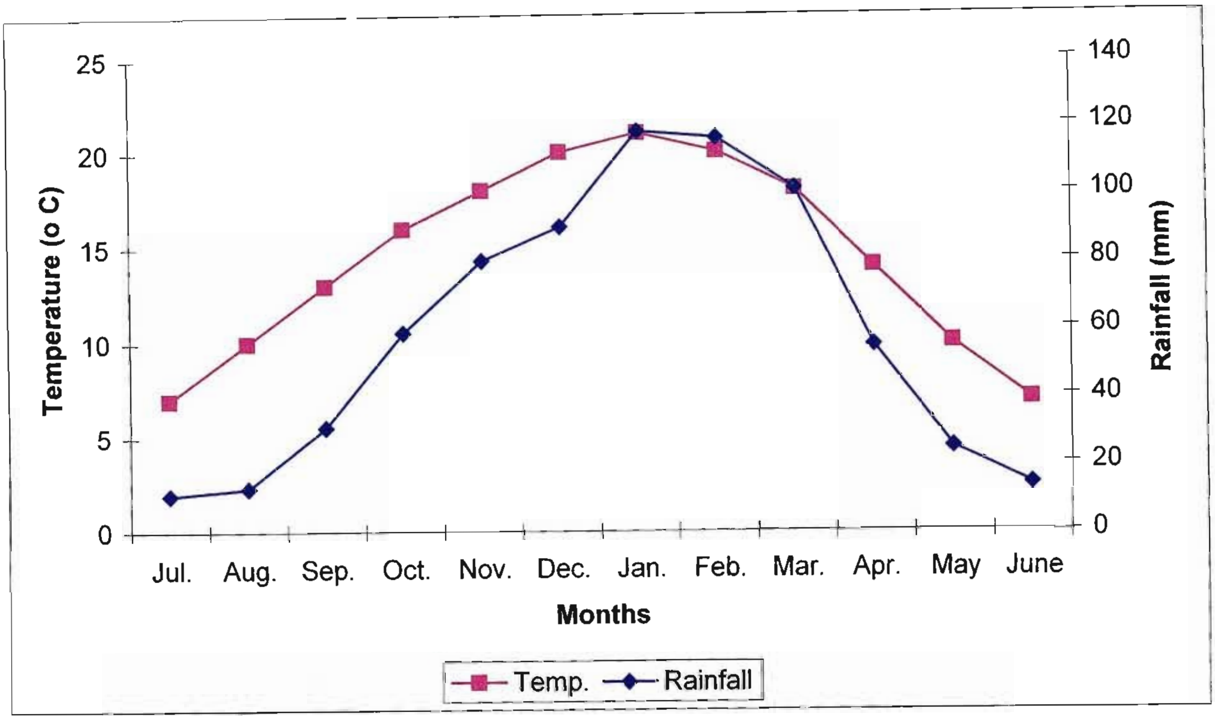


Figure 45: Gausen Walter climatic diagrams (Kunz, 2004)

6.5 CONCLUSIONS

In all four localities the range of altitude in which *C. africana* occurs is between 1 300 m and 1 600 m above sea level on average. The lowest elevation is that of Dargle in KwaZulu-Natal with 1 356 m and the highest is Mokhalinyane in Lesotho with 1 613 m.

The species which, are commonly found in association with *C. africana* in the localities, are *Hyparrhenia hirta, Buddleja salviifolia, Leucosidea sericea and Grewia occidentalis.* Under Lesotho conditions *C. africana* proves to be a climax species because in undisturbed fenced areas it is found among the "dominants".

The two main climatic factors (precipitation and temperature), which influence tree growth, follow the same trend in prescribed periods both in Lesotho and KwaZulu-Natal. Their lows are in June-July and peaks in December-January. They only differ in intensity and range.

CHAPTER 7

DATA ANALYSIS AND DISCUSSION OF RESULTS BY TREATMENTS

7.1 INTRODUCTION

Analysis of the data and evaluation of the results form a basis for implementation of the right plans supported by empirical decisions. The notion is to compare the outcomes and choose and implement the best results. The objective in this chapter is that, the results from each investigations carried out are tabulated for scrutiny and comparison so that the best decision can be made.

7.2 VARIABLES SHOWING STAND CHARACTERISTICS

7.2.1 Frequency distribution

Values for the study plots were analysed and converted into units per hectare in order to facilitate comparison of the ensuing results. Parameters, which are evaluated, are stems per plot/hectare, basal area, volume, mean dbh and height. Stand characteristics like frequency distribution were examined to check whether the data could be arranged in appropriate arrays. Frequency distribution is important because it facilitates identification of the lowest and highest values (Johnson, 2000). In crop mensuration, the breast-height diameters ($d_{1.3}$) of individual trees are usually callipered in 1 to 5 cm diameter classes. By thus arranging the population according to the observed value $d_{1.3}$, a tally is obtained by successive classes of increasing diameter along with their corresponding numerical frequencies. One might refer to numerical tree classes which, depending on the chosen observed value (d1.3, height or volume) and the class range, will depict a different and more or less comprehensive subdivision of the population of the stand (Assmann, 1970). Diameter classes may also help to classify the forest into different social tree classes, i.e. upper storey, middle storey and lower storey.

7.2.2 Dbh and height as estimators in forest measursments

Relationship between dbh and height was evaluated. The relationship between dbh and height is critical for calculating tree volumes and in determining yield prediction models. These are important factors in which can aid a forester in determining site productivity. In order to determine by how much height is associated with dbh regression analysis was used as explained in section 5.4.

In all four localities extrapolation from the scatter diagrams, of the data points (X's, Y's), indicated the forms of relationship which were linear, hence, fitted a linear regression model E (Y) = $\alpha + \beta X$, where the regression parameters α and β are unknown (or better still, for forestry purposes, the model is commonly expressed as $Y = b_0 + b_1X$, where b_0 and b_1 are unknown regression parameters). This is the regression equivalent of the common mathematical expression of a straight line.

The equations $\hat{Y} = a + bX$ were adopted as the lines of best fit, whereby, $\hat{Y}$'s, a's and b's were estimates of Y's, $b_{0's}$ and $b_{1's}$ respectively. The data points (X_i, Y_i) are scattered about these lines, and, each observed Y_i deviates from the fitted values $Y_{i's}$ by residuals of Y_i (Kassab, 1988). The estimates a's and b's were obtained from minimized sums of squares, and then their values substituted in the equations in order to obtain the lines of best fit or Regression Lines. The fitted lines were drawn on the scatter diagrams by determining two points (through substitution of two values of X in the equation of the line) and joining them by straight lines.

The measure of the goodness of fit of the line to the data or the extent to how well a regression fits the data, is determined or measured by the proportion of the total variation in Y that is associated with the regression, which is the Coefficient of Determination or R^2. Johnson (2000) expresses the Coefficient of Determination by the formula:

$$R^2 = \frac{\left[\sum_{i=1}^{n}\left(x_{1i}-\bar{x}_1\right)\left(x_{2i}-\bar{x}_2\right)\right]^2}{\sum_{i=1}^{n}\left(x_{1i}-\bar{x}_1\right)^2\sum_{i=1}^{n}\left(x_{2i}-\bar{x}_2\right)^2} \text{ ....} \textbf{Formula 5}$$

The values of R^2 are $0 \leq R^2 \leq 1$ and the closer the R^2 is to 1, the better the fit (Kassab, 1988).

7.2.3 Importance of seed mass in forestry

Seed mass was calculated by using formula 1. Seed sizes vary within and among genotypes (Young *et al.*, 2000). The influence of habitats can enhance the ability of seed masses to predict seed storage behaviour. The bigger size of seeds of the same species may indicate the origin of wetter habitats (Guarino *et al.*, 1995). Seed size and seed mass, are two related factors (Hebblethwaite, 1980), which cause variation in vigour. This is so because large seeds produce large root systems due to more food reserves in the endosperm (a phenomenon called "Triebkraft" or "driving force"). Hebblethwaite (1980) further mentioned that nutrition and health can affect the seed size. Similarly, Baldwin (1942) emphasised that the largest and heaviest seeds are the best as they have more nutrition reserves, germinate more promptly, and such seeds produce more vigorous seedlings at the start of germination.

The main objective of assessing the seed masses from the four localities has been to identify localities for best performing seeds. The causes for variability among seed masses may be hereditary or environmental. The determination of seed size is important because it can facilitate estimates both in terms of finance and field operations. Knowledge of seed size for a particular seed-lot can enable management to make reasonable estimates for budget purposes.

7.2.4 Germination tests and their significance in forestry

Germination tests were done as described in section 5.3. Germination is the renewal and development into a new plant by an embryo after seed dormancy. Imbibition period is the first stage of germination. The process of germination happens to a seed after it has been liberated from its parent plant as a means of maintaining species' continuity.

Germination, purity and health are the three criteria of seed quality which are well established and which are determined by routine tests (*Op cit*). Baldwin (1942), mentions that older seeds germinate more slowly than fresh ones. He further cautions that older seeds contain a greater percentage of non-viable or week seeds. Germination quality of seed provides an indication of the percentage of seeds in a given lot that may be expected to produce seedlings. It also provides a quality index by which one seedlot may be compared with another. Similarly, it can be used to compare one tree nursery with another using the same seedlot. Equally, it can be used as a method of assessment in evaluation of seed pretreatment and sowing techniques. Thus, germination percent becomes the most important of the attributes being tested for germination quality. It can enable the nurseryman to plan his sowing programme in advance with a degree of confidence that his forecast does not deviate much from reality. The four pre-sowing seed treatments (manual-scarification, hot-water, acid and control) were intended to assess the level of their effectiveness in overcoming the mechanical resistance to the embryo growth and increased water intake (process of germination) in *C. africana* seed. The main objective was to test germination and energy or vigour of the seeds. Germination tests were done in order to determine and use seed of superior quality or establish a basis for plant improvement. Such tests are necessary not only for multiplication of improved or superior tree stocks but also for certification in commercial seed production.

7.2.5 The impact of photosynthesis and climatic factors on leaf dimensions

Leaf assessment for colour and width and length was done as in section 5.5. Leaves are the main plant organs that perform photosynthesis. Photosynthesis is the manufacture of plant food from raw materials, using light as a source of energy and releasing oxygen as a by-product. Raw materials are carbon dioxide and water and combine through the agency of chlorophyll to form glucose. Ackerley *et al.* (2001) mention that leaf traits play important role in carbon assimilation, water relations and energy balance in plants. The process of photosynthesis is expressed by the following equation: $6\ CO_2 + 6\ H_2O + \text{light energy} \rightarrow C_6H_{12}O_6 + 6\ O_2$ (Cronquist, 1961). It follows, therefore, that the interaction of tree leaf size, availability of raw nutrient materials and climatic factors are important for the production of tree biomass.

The length of time the trees are exposed to light conditions (photoperiod) has a great influence on trees. Distribution of some species is limited by their photoperiodic responses. On a large scale, topography and elevation strongly influence microclimate and the distribution of plant species and their associated attributes (Ackerly *et al.*, 2001). In like manner, photoperiodism can influence flowering periods of trees and vegetative growth (*Op cit*). Observations have indicated that some species, which are exposed for longer periods to day-light, can attain the greatest production of dry matter. Miller (1938) mentions that in the experiments conducted by Adams (1920), in all cases, the plants exposed longest to the action of light gave the greatest average weight and the greatest height. Altitude has a major effect on leaf morphology and physiology within a species. High altitude species tend to be morphologically and physiologically distinct from closely related species from lower altitudes. Leaves generally decrease in length, width and area with increasing altitude while leaf thickness increases with increasing altitude, causing a reduction of specific leaf area (Bout and Okitsu, 1999; Hovenden and Schoor, 2003). In addition to a general thickening of the leaf lamina, increasing altitude can also lead to increases in the relative thickness of cuticle, epidermis and, in some cases, the development of a hypodermis. The relationship between altitude and leaf morphological, and anatomical variables has resulted in the estimation of past climatic conditions from both historic and fossil leaves (Hovenden and Schoor, 2003). Totland (1999) gives the example of current phenomenon of global warming, which increases the leaf and seed sizes. Jacobs (1999) purports the relationship between climate and leaf form by citing the example of the data base, used in testing of a model, consisting of leaf form and climate data for 30 equatorial African sites. Temperature and rainfall parameters were estimated from equatorial fossil leaf assemblages.

Leaf assessment is important not only for species identification only but also its colour can indicate any abnormalities such as nutrient deficiencies and any disease. However, colour can differ among genotypes. In some species it may change in accordance with season of the year. Leaves contain a chemical pigment called chlorophyll, which makes leaves look green. As summer turns into autumn, the shorter days and cooler nights trigger two major changes in the leaf, both of which have consequences for its colour. Chlorophyll production slows down and eventually stops, the remaining chlorophyll breaks down and the green colouration fades to reveal the yellow carotene. Carotene is another chemical pigment found in leaf cells throughout the growing season and has a secondary role in photosynthesis (Personal Online Colour Analysis By Scarlet Pixel, http://www.scarletpixel.com/ 11/21/2004). The yellow colour of carotene is not visible in spring and summer leaves because it masked by the green of chlorophyll.

7.2.6 Wood density as a parameter in determining wood quality

Wood density and moisture content were determined as described in section 5.6. Desch and Dinwoodie (1981) define wood density as the mass of unit volume, and is therefore obtained by dividing the mass by the volume. It is expressed in kilograms per cubic metre but sometimes grams per cubic centimeter. Dinwoodie (1981) relates wood density to the relative proportions of the various types of cells and absolute wall thickness. The density of wood is mainly determined by its porosity. The higher the void volume of wood the lower is its density. The void volume of wood depends on the proportion of early wood in relation to latewood. Various extractives among species in varying proportions render different wood densities. Banks (1954) mentions moisture content as another factor, which has a profound effect not only on the strength of wood but also on its density. Moisture content is the amount of water contained in wood and is expressed as a percentage of the oven-dry mass of the wood. Wood in the green state contains more water than in a dry state. Wood density does not only vary between species but also between genotypes. Within species, variations may be due to site conditions, genetic differences or the location of wood on the tree. Wood density is one of the parameters, which determine the wood strength, quality, sawing and treatment properties.

Amid conflicting reports as to whether the strength of wood is directly controlled by the rate of growth, Smith *et al.* (1997) asserted that it is an erroneous lore. They denied that rapid growth produces strong wood in ring-porous hardwoods, weak wood in conifers and no appreciable difference in diffuse-porous hardwoods. It had been a belief that thinning or any other measure that increased diameter growth of conifers weakened the wood. According to Smith *et al.* (1997), the difference in the strength, density and structure of wood may be caused by biological functions of xylem, which are mechanical support and water conduction. Logically, when trees are small and young, their stems do not have to be particularly strong. Some fast growing, weak-bodied, pioneer species never escape this stage but topple over before they become very tall. As long as a tree continues to grow in height, the load of its own mass and the force of wind increase so does the strength of the stem. If the tree becomes very old, it shifts to the production of very thin annual layers of soft, weak wood of the kind prized for fine veneers and cabinet making. This type of wood is produced by the necessary renewal of the conduction xylem in trees that are no longer adding to the load on their stems because their height growth and crown expansion have nearly stopped. Such trees have already developed the stem strength necessary to support the crown.

In relation to the proportion of early and late-wood affecting the strength and density of wood, Smith *et al.* (1997), after Larson (1963), mentioned that any treatments such as thinning, fertilizing, irrigation, edaphic factors and climate that may prolong or increase diameter growth during the summer, usually increase the proportion of late-wood, which is produced mainly at that time. Smith *et al.* (1997), after Zahner and Whitmore (1960), state that the amount of early-wood can be very similar between thinned and unthinned stands, and most of the additional ring width is late-wood. As the late-wood is denser and stronger, wide rings formed well below the base of the live crown will form wood, that is heavier and stronger than wood with narrow rings from the same stem position. Van Vuuren *et al.* (1978) mention that variations in wood density are attributable to differences in ages of trees or the position in the stem but may be due to inherent characteristics.

7.3 STUDY PLOTS AS SOURCES OF FIELD DATA FOR THE VARIABLES

Study plots were established as in section 5.4. The objective of the establishment of the plots was to get a representative data for each locality. Eight trees were measured and recorded per plot i.e. 16 trees per locality. Raw data for tree measurements are shown in appendix 11. Number of stems for both *Celtis africana* and other tree species were recorded per plot for respective localities. Leaves were measured for lengths and widths and colours were determined. Seed masses were determined and germination tests conducted. Methods used were as described in chapter 5.

7.3.1 Study plots for Dargle

Data pertaining to number of stems per plot, basal area, volume, mean dbh and height are shown in table 10. Using calculations based on the field data, the volumes per hectare for plots 1 and 2 were found to be 25 m^3 and 71 m^3 respectively. Plot 1 had a total of 48 stems per hectare, 18 of which were *Celtis africana*. Plot 2 had 38 stems in a hectare and 20 of them were *Celtis africana*. Though plot 1 had more stems per plot, plot 2 had more volume.

Table 10: Data on number of stems, mean dbh and height, basal area and volume per Plot (0.5 ha) at Dargle.

	No. of stems per plot					
	C. africana	Other tree spp.	B.A. (m^2)	Vol. (m^3)	$\bar{x}$ dbh (cm)	$\bar{x}$ Height (m)
Plot 1	9	15	0.8374	12.5929	34	13
Plot 2	10	9	1.2635	35.5817	36	18

In plot 1 there was no dbh count that appeared more than once. The heights of 9 and 10 metres had the highest frequency of 2 each (Table 11). In both plots dbh and height frequency counts were very low.

Table 11: Data on frequencies of dbh's and heights for plots 1 and 2 (0.5 ha each) at Dargle

Plot 1				Plot 2			
DBH (cm)	Frequency	Height (m)	Frequency	DBH (cm)	Frequency	Height (m)	Frequency
17	1	9	2	11	1	7	1
22	1	10	2	12	1	8	2
28	1	11	1	20	1	17	2
29	1	14	1	22	1	24	1
32	1	17	1	27	1	25	1
33	1	21	1	39	1	36	1
39	1	-	-	75	1	-	-
68	1	-	-	84	1	-	-

7.3.2 Study plots for Fort-Hartley

Number of stems, basal area and volume together with mean dbh and height for plots 1 and 2 are shown in table 12. Using calculations, there were 32 stems per hectare in plot 1 while there were 48 in plot 2. In plot 1 volume per hectare was 12 m^3 and in plot 2, 14 m^3.

Table 12: Data on number of stems, mean dbh and height, basal area and volume per Plot (0.5 ha) at Dargle.

	No. of stems per plot					
	C. africana	Other tree spp.	B.A. (m^2)	Vol. (m^3)	$\bar{x}$ dbh (cm)	$\bar{x}$ Height (m)
Plot 1	11	5	0.4929	5.9229	27	11
Plot 2	12	12	1.5905	7.1466	29	11

Frequency count in both data arrays of dbh and height were very low. Data in both cases were insufficient to show any meaningful significance. In plot 1, dbh of 17 cm and a height of 9 m had the highest frequency of 2 each. Dbh in plot 2 did not indicate any difference in frequency. Height of 11 m had the highest frequency of 3 (Table 13).

Table 13: Data on frequencies of dbh's and heights for plots 1 and 2 at Fort- Hartley

Plot 1				Plot 2			
DBH (cm)	**Frequency**	**Height (m)**	**Frequency**	**DBH (cm)**	**Frequency**	**Height (m)**	**Frequency**
17	2	7	1	16.5	1	8	1
18	1	9	2	21	1	9	1
25	1	10	1	26	1	10	1
29	1	11	1	27	1	11	3
30	1	12	1	30	1	13	1
34	1	13	1	31	1	15	1
43	1	15	1	40	1	-	-
-	-	-	-	44	1	-	-

7.3.3 Study plots for Mokhalinyane

Plot 1 had a total number of 13 stems. This converts to 26 stems per hectare, of which, 18 were *C. africana* and 10 were other tree species. Plot 1 had 13 m^3 and plot 2, 10 m^3. These figures have been derived from table 14, which shows mean dbh and mean height, number of stems, basal area, and volume per plot of 0.50 ha.

Table 14: Data on number of stems, mean dbh, mean height, basal area and volume per Plot (0.50 ha) at Mokhalinyane.

	No. of stems per plot					
	C. africana	Other tree spp.	B.A. (m^2)	Vol. (m^3)	$\bar{x}$ dbh (cm)	$\bar{x}$ Height (m)
Plot 1	8	5	0.5511	6.6787	28	11
Plot 2	9	3	1.2635	35.5817	25	10

The dbh measurements that showed the highest frequency of 2 each were 17 and 21 cm in plot 1. A height of 9 m indicated the highest frequency in an array of height data. Measurements in plot 2 had no frequency higher than 1. In plot 2 the height measurements of 7, 10 and 11 metres showed the highest frequency of 2 each (Table 12). Frequency counts for data arrays of dbh and height are very low but are better than for plots in Dargle and Mokhalinyane localities.

Table 15: Data on frequencies of dbh's and heights for plots 1 and 2 in Mokhalinyane

Plot 1				Plot 2			
DBH (cm)	**Frequency**	**Height (m)**	**Frequency**	**DBH (cm)**	**Frequency**	**Height (m)**	**Frequency**
17	2	8	1	15	1	7	2
21	2	9	3	16	1	9	1
28	1	10	2	18	1	10	2
31	1	14	1	21	1	13	2
40	1	15	1	24	1	-	-
47	1	-	-	26	1	-	-
-	-	-	-	40	1	-	-
-	-	-	-	43	1	-	-

7.3.4 Study plots for Hilton

Data for plots 1 and 2 shown on table 16 was used to calculate volumes per hectare for the two plots. Volume per hectare for plot 1 was 2.6 m^3 and for plot 2 was 0.20 m^3.

Table 16: Data on number of stems, mean dbh's and heights, basal area and volume per Plot (0.50 ha) at Hilton.

	No. of stems per plot					
	C. africana	Other tree spp.	B.A. (m^2)	Vol. (m^3)	$\bar{x}$ dbh (cm)	$\bar{x}$ Height (m)
Plot 1	9	9	0.1373	1.3165	14	8
Plot 2	9	12	0.0118	0.1088	13	9

Frequency for dbh data in plot 1 was 2 in all cases. For the height, 8 m had the highest count of 2 (Table 17). Frequency counts for both data arrays for dbh and height are very low. This is an indication of lack of proper management control.

Table 17: Data on frequencies of dbh's and heights for plots 1 and 2 at Hilton

Plot 1				Plot 2			
DBH (cm)	**Frequency**	**Height (m)**	**Frequency**	**DBH (cm)**	**Frequency**	**Height (m)**	**Frequency**
17	1	9	2	11	1	7	1
22	1	10	2	12	1	8	2
28	1	11	1	20	1	17	2
29	1	14	1	22	1	24	1
32	1	17	1	27	1	25	1
33	1	21	1	39	1	36	1
39	1	-	-	75	1	-	-
68	1	-	-	84	1	-	-

Data from each plot were too few to make any significantly observable array of frequency distribution. It is advisable to use arrays which can make 8 and more but less than 20. If fewer than 8 classes are used, the lumping or aggregation becomes excessive and too much information is lost. On the other hand, if more than 20 classes are used the information becomes difficult to interprete (Johnson, 2000).

7.4 DBH AND HEIGHT VARIABLES

7.4.1 Relationship between dbh and height for Dargle

In plot 1 the dbh range was 17 cm – 68 cm and that of height was 9 m – 21 m. In plot 2 the range of the dbh was 11 cm – 84 while that of the height was 7 m – 36 m.

The scatter diagram indicated a dispersed pattern of data, which indicated very weak correlation. However, the data were discernibly linear in relationship (Figure 46).

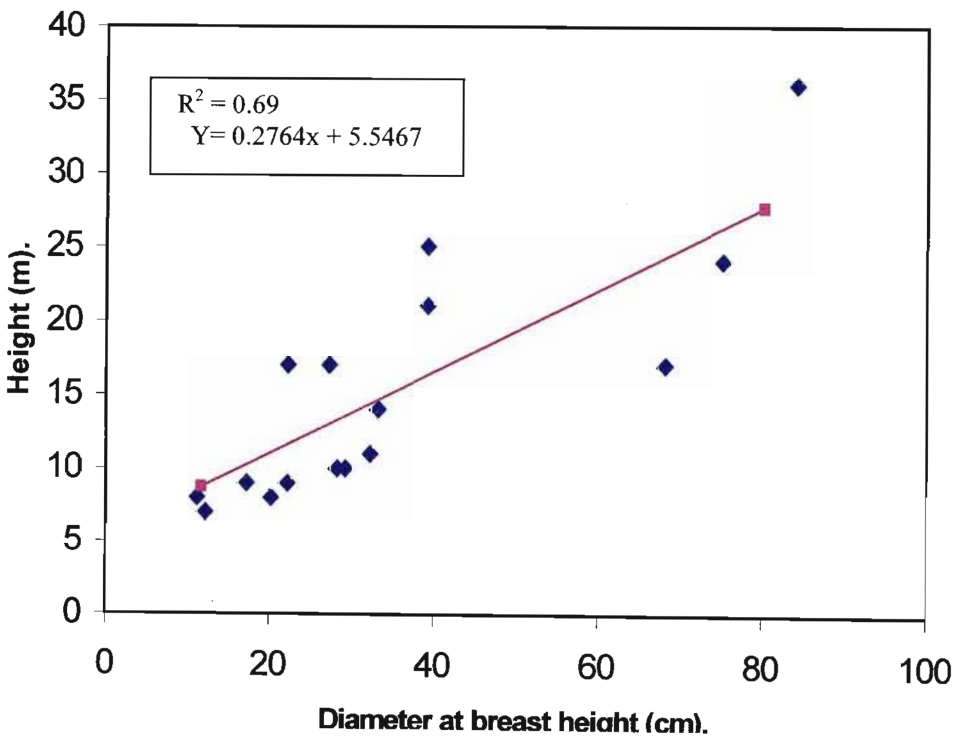


Figure 46: Diameter at breast height versus height for Dargle

In a regression analysis conducted, height was treated as a dependent variable. The regression results are shown in table 18.

Table 18: Summary statistics of regression analysis of dbh's and heights at Dargle

Source of variation	d.f.	s.s.	m.s.	F	P
Regression	1	664.8	664.85	30.46	<.001
Residual	14	305.6	21.83		
Total	15	970.4	64.70		

At 5% significant level test, dbh was significantly related. The change of the explanatory variable dbh explained 69% variation of the dependent height ($R^2 = 0.69$).

7.4.2 Relationship between dbh and height for Fort-Hartley

Dbh in plot 1 ranged between 16 cm and 44 cm. The range of height was 7-15 m. In plot 2 the minimum dbh was 21 cm and maximum was 44.

The data of the dbh and height on the scatter diagram, gathered in a narrow ellipse but showed a linear relationship (Figure 47).

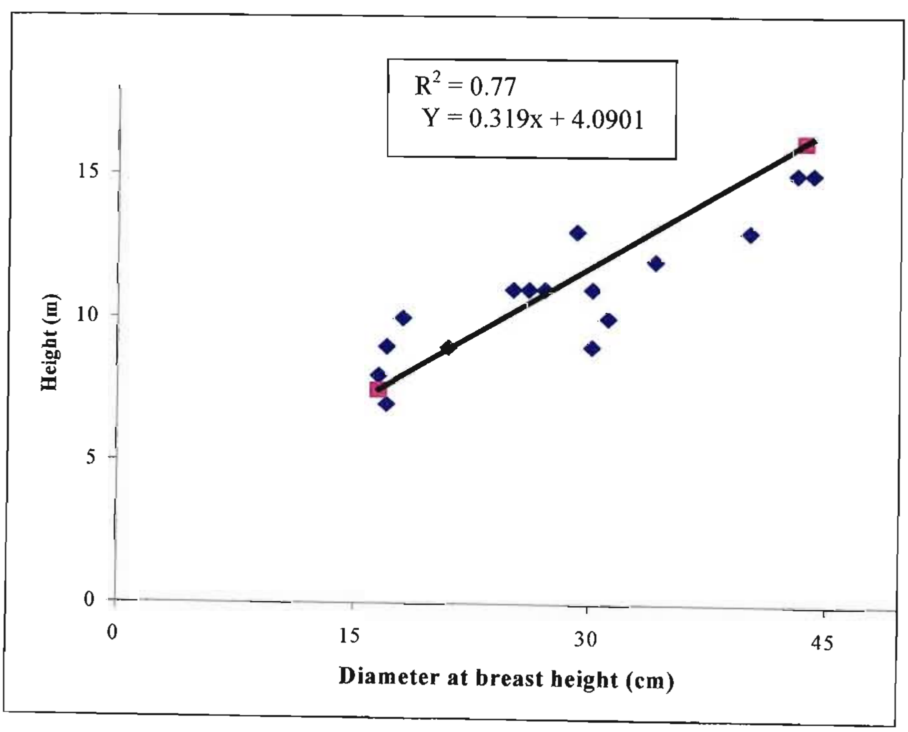


Figure 47: Diameter at breast height versus height for Fort-Hartley

The change of the explanatory variable dbh explained 77% variation of the dependent height (R^2 = 0.77). The results of regression analysis are tabulated in table 19.

Table 19: Summary statistics of regression analysis of dbh and height at Fort-Hartley

Source of variation	**d.f.**	**s.s.**	**m.s.**	**F**	**P**
Regression	1	61.53	61.531	47.28	<.001
Residual	14	18.22	1.301		
Total	15	79.75	5.317		

Dbh and height relationship was significant at 5% level test.

7.4.3 Relationship between dbh and height for Mokhalinyane

The dbh ranged between 17 and 47 cm. The range of height was 8 – 15 m. Basal area for plot 1 was 0.60 m^2 and volume 7 m^3. For plot 2 the basal area was 0.5 m^2 and volume 5 m^3. Average volume per hectare was 12 m^3.

The dbh and height data for the locality showed a linear relationship on the scatter diagram (Figure 48) though the data points on the scatter diagram formed a broad ellipse, which indicated a weak relationship.

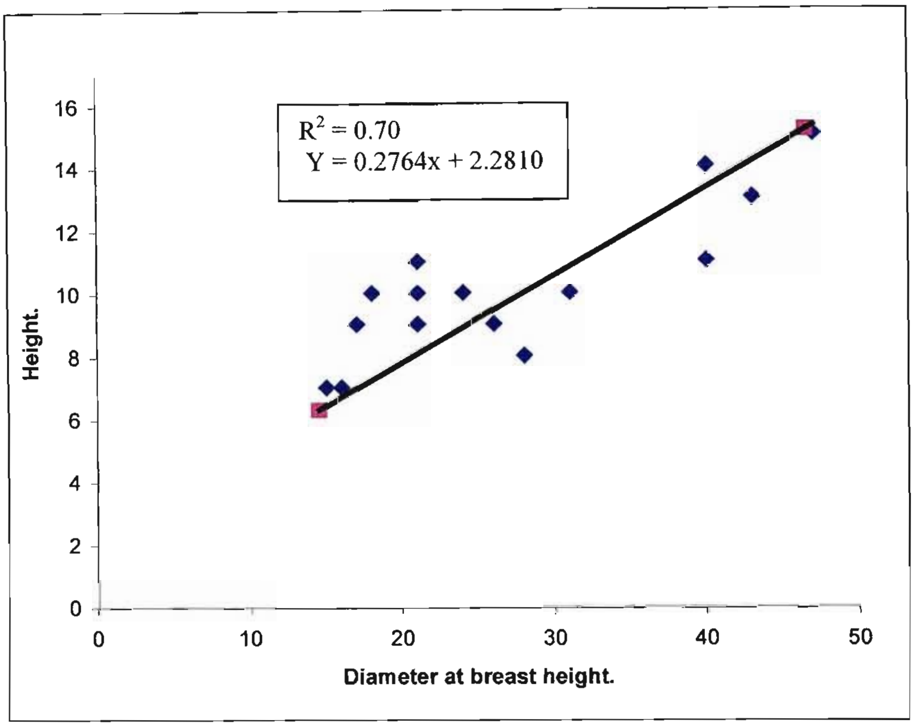


Figure 48: Diameter at breast height versus height for Mokhalinyane

Regression analysis was done in order to evaluate the relationship between dbh and height. The results of this evaluation are shown in table 20. The change of the explanatory variable dbh explained 70% variation of the dependent height ($R^2 = 0.70$).

Table 20: Summary statistics of regression analysis of dbh and height for Mokhalinyane

Source of variation	d.f.	s.s.	m.s.	F	P
Regression	1	54.50	54.505	32.83	< .001
Residual	14	23.25	1.660		
Total	15	77.75	5.183		

Relationship of dbh and height was significant at 5% level test.

7.4.4 Relationship between dbh and height for Hilton

The dbh for the locality ranged between 10 cm and 22 cm while the range for the height was 5-13 m. Dbh and height data for the locality showed a linear relationship on a scatter diagram (Figure 49) but the data showed a broad ellipse, which indicates a weak relationship between dbh and height.

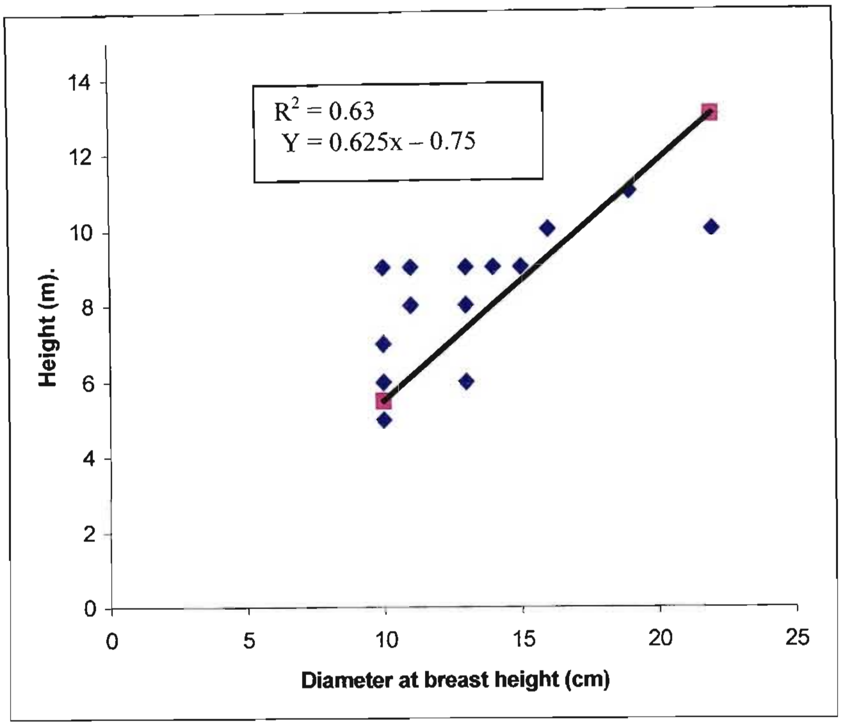


Figure 49: Diameter at breast height versus height for Hilton

Table 21 show summary statistics of the regression analysis. The change of the explanatory variable dbh explained the 60% variation of the dependent height ($R^2 = 0.60$).

Table 21: Summary statistics of regression analysis of dbh and height at Hilton

Source of variation	d.f.	s.s	m.s.	F	P
Regression	1	45.20	45.203	23.84	< .001
Residual	14	26.55	1.896		
Total	15	71.75	4.783		

Regression analysis test at 5% indicated that the relationship between dbh and height was significant.

7.5 SEED COUNT

The experiment was conducted in order to establish the number of seeds per kilogram for the locality. Experiment was conducted as in section (5.2).

7.5.1 Seed count for Dargle

Table 22 below gives the summary of the results by group numbers, and net mass of the seed.

Table 22: Mass of seeds by groups of 100 seeds for Dargle.

Goup No	Net Mass of seed (g)
1	10.564
2	10.632
3	10.566
4	10.530
Mean	**10.573**

The arithmetic mean for the net weights of the four groups was computed as 10.573 with Standard Deviation of 0.043. That of the number of seeds is 100. The means seeds and weights were used to calculate the seed number of seed per given kilogram as follows:

$$\text{Number of seeds per kilogram} = 100^* \frac{1000}{10.573} kg^{-1} = 9\ 459 \text{ seeds } k^{-1}$$

Random samples of seed groups showed little variation in mass, with the Standard Deviation of 0.043.

7.5.2 Seed count for Fort-Hartley

Materials and methods were as in section 5.2. Table 23 gives the summary of the results by group numbers, and net mass of the seed.

Table 23: Mass of seeds by groups of 100 seeds for Fort-Hartley

Goup No	Net Mass of seed (g)
1	9.530
2	9.286
3	9.194
4	9.314
Mean	**9.331**

The arithmetic means for the four groups of seed numbers and seed mass were computed and used to calculate the seed number per given kilogram for the Locality, as in section 5.2.

Number of seeds per kilogram = $100*\frac{1000}{9.331}kg^{-1}$ = 10 717 seeds kg^{-1}

Random samples of the seed groups showed little variation in their mass with Standard Deviation of 0.1422.

7.5.3 Seed count for Mokhalinyane

Materials and method were as 6.5.5 above. The summary of the results by group numbers of 100 and net mass of seed are tabulated in table 24.

Table 24: Mass of seeds by groups of 100 seeds for Mokhalinyane

Goup No	Net Mass of seed (g)
1	8.114
2	8.158
3	8.074
4	7.794
Mean	**8.035**

Random samples of the seed groups showed little variation in their mass with Standard Deviation of 0.1634. The arithmetic means for the four groups of seed numbers and seed mass were computed and used to calculate the number per given kilogram for the locality, as in section 5.2.

$$\text{Number of seeds per kilogram} = 100^* \frac{1000}{8.035} kg^{-1} = 12\ 446 \text{ seeds k}^{-1}$$

7.5.4 Seed count for Hilton

Materials and methods were as in section 5.2 above. The summary of the results by group numbers of 100 and net mass of seed tabulated in table 25.

Table 25: Mass of seeds by groups of 100 seeds for Hilton

Goup No	Net Mass of seed (g)
1	8.844
2	8.990
3	9.032
4	8.908
Mean	**8.944**

The arithmetic means for the four groups of seed numbers and seed mass were computed and used to calculate the number per given kilogram for the locality, as in section 5.2.

$$\text{Number of seeds per kilogram} = 100^* \frac{1000}{8.944} kg^{-1} = 11\ 181 \text{ seeds k}^{-1}.$$

7.6 LEAF MEASUREMENTS

Leaves were measured as in section 5.5. Raw data for four localities are shown in appendix 11. Mean lengths and widths were shown in table 26.

7.6.1 Leaf measurements for Dargle

Leaf lengths for Dargle locality were found to average 64.0 mm with a standard deviation of 15.36. The width averaged 33.00 mm with a standard deviation of 9.82

7.6.2 Leaf measurements for Fort-Hartley

The averages of leaf lengths and widths are 54 mm and 35 mm respectively. The standard deviation of the lengths 14.13 is while that of the widths is 12.18

7.6.3 Leaf measurements for Mokhalinyane

Leaf lengths had the average of 56 mm and a standard deviation of 16 while widths had the average of 32.30 mm with a standard deviation of 10.00.

7.6.4 Leaf measurements for Hilton

For Hilton locality the average leaf length was 50 mm with a standard deviation of 15 and the average for the widths was 33 mm with a standard deviation of 9.82.

7.7 DETERMITION OF WOOD DENSITIES OF *CELTIS AFRICANA*

7.7.1 Wood densities for *C. africana* at Dargle

Means of wet and dry wood masses, moisture content and volume were determined and used to calculate both dry and wet densities. Oven-dry density (d) was calculated by using formula (5.6.3) while wet density was determined by formula (5.6.5). Calculations of the results are shown below. Raw data of wood samples for wet and dry weights, volume and moisture content are shown in appendix 15.

$$\text{(a) moisture content} = \frac{0.69 - 0.61}{0.61} * 100 = 13.11\%$$

$$\text{(b) oven-dry density} = \frac{0.61}{1.17} = 0.520 \text{ g/cm}^3 = 520 \text{ kg/m}^3$$

$$\text{(c) wet density} = \frac{0.69}{1.17} = 0.590 \text{ g/cm}^3 = 590 \text{ kg/m}^3$$

7.7.2 Wood densities for *C. africana* at Fort-Hartley

Means of wet and dry masses (Appendix…), moisture content and volume were determined and used to calculate both dry and wet densities. Oven-dry density (d) was calculated by using formula 3 while wet density was determined by formula 5. Results were as follows:

(a) moisture content $= \dfrac{1.23 - 1.10}{1.10} * 100 = 11.82\%$

(b) oven-dry density $= \dfrac{1.10}{1.59} = 0.692\ g/cm^3 = 692\ kg/m^3$

(c) wet density $= \dfrac{1.23}{1.59} = 0.774\ g/cm^3 = 774\ kg/m^3$

7.7.3 Wood densities for *C. africana* at Mokhalinyane

Means of wet and dry masses (Appendix 15), moisture content and volume were determined and used to calculate both dry and wet densities. Oven-dry density (d) was calculated by using formula (5.6.3) while wet density was determined by formula (5.6.5). Results were as follows:

(a) moisture content $= \dfrac{0.76 - 0.68}{0.68} * 100 = 11.76\%$

(b) oven-dry density $= \dfrac{0.68}{0.93} = 0.731\ g/cm^3 = 731\ kg/m^3$

(c) wet density $= \dfrac{0.76}{0.93} = 0.817\ g/cm^3 = 817\ kg/m^3$

7.7.4 Wood densities for *C. africana* at Hilton

Means of wet and dry masses (Appendix 15), moisture content and volume were determined and used to calculate both dry and wet densities. Oven-dry density (d) was calculated by using formula (5.6.3) while wet density was determined by formula (5.6.5). Results were as follows:

$$\text{(b) moisture content} = \frac{0.82 - 0.73}{0.73} * 100 = 9\%$$

$$\text{(c) oven-dry density} = \frac{0.73}{0.99} = 737 \text{ g/cm}^3 = 737 \text{ kg/m}^3$$

$$\text{(c) wet density} = \frac{0.82}{0.99} = 0.830 \text{ g/cm}^3 = 830 \text{ kg/m}^3$$

7.8 GERMINATION TESTS

7.8.1 Germination tests for Dargle

Germination period for the four treatments has taken a total number of 24 days from the beginning of sowing to the completion of germination.

Germination energy has been extrapolated from table 26. In the table it is identified by noting the figure in the cumulative percent column, the variable, which is in the same row with or opposite to the highest daily germination speed (DGs). The Germination values have been calculated using the formula 1.

For acid treatment, germination started after 9 days. It took 11 days for to germination to get completed since the first germination. From sowing to completion of germination, germination process took 20 days.

Table 26: Daily germination speed and germination value for Dargle

Acid treatment

Day	Gp	DGs	$\sum$ DGs	N
9	9.72	1.08	1.08	1
10	30.55	3.06	4.14	2
11	47.22	4.29	8.43	3
12	55.56	4.63	13.06	4
13	66.67	5.13	18.19	5
14	72.22	5.16	23.35	6
15	77.78	5.19	28.54	7
16	83.33	5.21	33.75	8
17	90.28	5.31	39.06	9
18	**97.22**	5.40	44.46	10

Control

Day	Gp	DGs	$\sum$ DGs	N
11	1.39	0.13	0.13	1
12	1.39	0.12	0.25	2
13	9.72	0.75	0.99	3
14	29.16	2.08	3.08	4
15	59.72	3.98	7.06	5
16	69.45	4.34	11.40	6
17	80.55	4.74	16.14	7
18	84.72	4.71	20.84	8
19	**91.67**	4.82	25.67	9
20	95.83	4.79	30.46	10
21	97.22	4.63	35.09	11
22	97.22	4.42	39.51	12
23	98.61	4.29	43.80	13

Hot-water treatment

Day	Gp	DGs	$\sum$ DGs	N
7	8.33	1.19	1.19	1
8	37.50	4.69	5.88	2
9	51.39	5.71	11.59	3
10	61.11	6.11	17.70	4
11	70.83	6.44	24.14	5
12	80.55	6.71	30.85	6
13	**93.05**	7.16	38.01	7
14	100.00	7.14	45.15	8

Manual-scarification treatment

Day	Gp	DGs	$\sum$ DGs	N
6	9.72	1.62	1.62	1
7	38.89	5.56	7.16	2
8	69.44	8.68	15.84	3
9	**83.33**	9.26	25.44	4
10	88.89	8.89	34.33	5
11	95.83	8.71	43.04	6
12	100.00	8.33	51.37	7

In the control, germination started after 11 days. It took 13 days to complete germination from the first germination. It took a total number of 24 days to germinate from sowing to the completion of germination.

Germination in the hot-water treatment started after 7 days. Complete germination after the first germination took 8 days. In all, it took 16 days for germination to be completed since sowing.

For manual-scarification treatment, germination started after 6 days. It took 7 days to complete germination after the first germination. Germination process took 13 days to complete since sowing.

Categorization by imbibition period for each Dargle treatment

Manual-scarification treatment was the first to start germination on the 6th day and it was also the first to complete it within 13 days from sowing. Second to start germination was hot-water treatment on the 7th days, followed by acid treatment in 9 days. Control was the last to start germination on the 11th day. Second to finish germination was hot-water treatment in 16 days followed by acid in 20 days. Control was the last, finishing in 24 days (Figure 50).

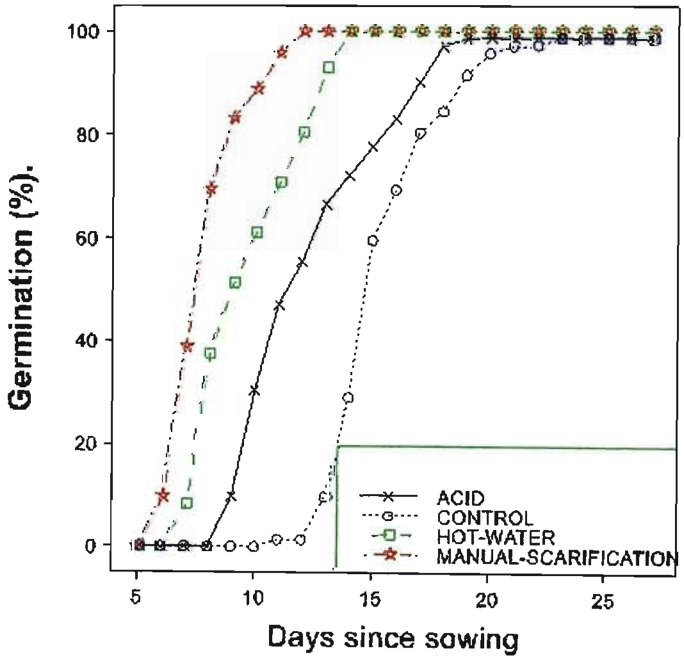


Figure 50: Cumulative percent versus day of germinating for Dargle

Categorization of germination variables.

Germination percent for both hot-water and manual-scarification treatments was the highest at 100 while that of control and acid treatments were second with 99. Acid treatment exhibited the highest Germination energy of 97 followed by hot-water treatment with 93. Third was control with 92 and the last was manual-scarification with 83. For tabulated summary of the results see table 23 below.

Table 27: Summary of germination percent, energy and value for the four treatments of Dargle

Treatment	Germination %	Germination energy	Germination value
Acid	99	97	44
Control	99	92	33
Hot-water	100	93	56
Manual-scar	100	83	73

7.8.2 Germination tests for Fort-Hartley

Germination period for the four treatments has taken a total number of 28 days i.e., since sowing until the completion of germination.

Germination energy has been extrapolated from table 28 while the Germination values have been calculated from the formula 1.

The evaluation of germination depicted that germination for the acid treatment started after 9 days. Following the first germination, it took another 9 days to complete germination of the remaining seeds. From sowing to completion of germination it took a total of 18 days.

For the control, germination started after 14 days. It took 14 days to complete germination after the first initial germination. It took a total number of 28 days for complete germination to occur.

Table 28: Daily germination speed and germination values for Fort-Hartley

Acid treatment

Day	Gp	DGs	$\sum$ DGs	N
9	8.33	0.93	0.93	1
10	25.00	2.50	3.43	2
11	47.22	4.29	7.72	3
12	59.72	4.98	12.70	4
13	68.06	5.24	17.94	5
14	77.78	5.56	23.50	6
15	**86.11**	5.74	29.24	7
16	91.67	5.73	34.97	8
17	94.44	5.56	40.53	9

Control

Day	Gp	DGs	$\sum$ DGs	N
14	12.50	0.89	0.89	1
15	30.56	2.04	2.93	2
16	45.84	2.86	5.79	3
17	62.50	3.68	9.47	4
18	66.67	3.70	13.17	6
19	72.22	3.80	16.97	7
20	77.78	3.89	20.86	8
21	84.72	4.03	24.89	9
22	**88.89**	4.04	28.93	10
23	90.28	3.93	32.86	11
24	91.66	3.82	36.68	12
25	95.83	3.83	40.51	13
26	95.83	3.69	44.2	14

Hot water treatment

Day	Gp	DGs	$\sum$ DGs	N
9	16.67	1.85	1.85	1
10	41.67	4.17	5.97	2
11	59.72	5.43	11.4	3
12	80.56	6.71	18.11	4
13	**91.66**	7.05	25.16	5
14	93.05	6.65	31.81	6
15	97.22	6.48	38.29	7
16	98.61	6.16	44.45	8

Manual scarification treatment

Day	Gp	DGs	$\sum$ DGs	N
7	16.67	2.38	2.38	1
8	34.72	4.34	6.72	2
9	48.61	5.40	12.12	3
10	61.11	6.11	18.23	4
11	69.44	6.31	24.54	5
12	**79.17**	6.60	31.14	6
13	81.94	6.30	37.44	7
14	91.67	6.55	43.99	8
15	93.05	6.20	50.19	9
16	95.83	5.99	56.18	10
17	97.22	5.72	61.9	11

In the hot-water treatment, germination started after 9 days. It took 8 days to complete germination after the initial germination. Complete germination from sowing to the finish took 17 days. Germination variables were as follows:

First germination occurred after 7 days in the manual-scarification treatment. After the first recorded germination, complete germination took 11 days. In all, it took 18 days for the seeds to germinate from sowing to the end of germination.

Categorization by imbibition period for each treatment

Manual-scarification treatment was the first to start germination on the 7th day. Second to start germination were acid and hot-water treatments on the 9th day. The last to start germinating was the control on the 14th day.

Hot-water treatment took the shortest time to complete germination from the time of the first germination with 8 days. It was followed by Acid treatment with 9 days and then Manual-scarification treatment with 11 days. The control was the last with 14 days.

Hot-water treatment took the shortest time of 17 days to complete germination from the time of sowing to its completion. It was followed by Manual-scarification and Acid treatments with 18 days each. The last was the Control with 28 days. The results on ranking by germination periods are depicted in Figure 51 on page 112.

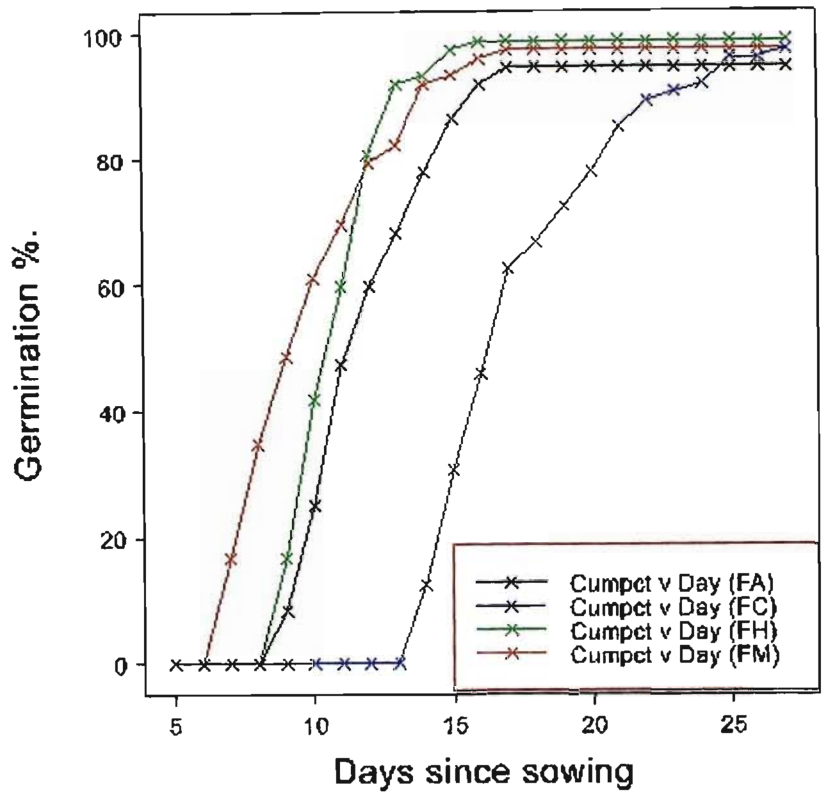


Figure 51: Cumulative percent versus day of germinating for Fort-Hartley

Categorization of germination variables for Fort-Hartley.

Germination percent was highest in Hot-water treatment with 99% followed by both Control and Manual scarification treatments both with 97% each. The last was Acid treatment with 94%.

The Germination energy was highest in Hot-water treatment at 92 followed by Control with 88.89. Acid treatment was the third with 86 and lastly, Manual-scarification with 79.

The germination value was highest in Hot-water treatment at 55 followed and then by Manual-scarification with 55. Acid treatment was the third with 43 and lastly Control with 33. Summary of the results is in table 29.

Table 29: Summary of germination percent, energy and value for the four treatments of Fort-Hartley

Treatment	Germination %	Germination energy	Germination value
Acid	94	86	43
Control	97	89	33
Hot-water	99	92	55
Manual-scar	97	79	55

7.8.3 Germination tests for Mokhalinyane

Germination period for the four treatments has taken a total number of 28 days i.e., since sowing until the completion of germination. Germination energy has been extrapolated from table 30 and the Germination values have been calculated using the formula 1.

In the acid treatment, the first germination was recorded on the 8th day after sowing. Again it took 8 days to complete germination. Germination period took 16 days in all from the period of sowing.

For the control, the first germination was recorded on the 13th day after sowing. It took another 15 days to complete germination after the first germination. In all it took 28 days complete germination from sowing to the end.

The first germination started on the 9th day in the hot-water treatment. It took 9 days to complete germination since the first germination. From the day of sowing to the completion of germination it took 18 days.

Table 30: Daily germination speed and germination value for Mokhalinyane

Day	Gp	DGs	$\sum$ DGs	N
8	12.50	1.56	1.56	1
9	30.55	3.39	4.95	2
10	45.83	4.58	9.54	3
11	59.72	5.43	14.97	4
12	75.00	6.25	21.22	5
13	86.11	6.62	27.84	6
14	**93.06**	6.65	34.49	7
15	97.22	6.48	40.97	8

Control

Day	Gp	DGs	$\sum$ DGs	N
13	8.33	0.64	0.64	1
14	16.67	1.19	1.83	2
15	20.83	1.39	3.22	3
16	33.34	2.08	5.30	4
17	48.61	2.86	8.16	5
18	55.56	3.09	11.25	6
19	65.28	3.44	14.68	7
20	66.67	3.33	18.02	8
21	73.61	3.51	21.52	9
22	**77.78**	3.54	25.06	10
23	80.56	3.50	28.56	11
24	84.72	3.53	32.09	12
25	87.50	3.50	35.59	13
26	88.89	3.42	39.01	14
27	90.28	3.34	42.35	15

Hot-water treatment

Day	Gp	DGs	$\sum$ DGs	N
9	2.78	0.31	0.31	1
10	33.33	3.33	3.64	2
11	55.55	5.05	8.69	3
12	69.44	5.79	14.48	4
13	**84.72**	6.52	21.00	5
14	87.50	6.25	27.25	6
15	95.83	6.39	33.64	7
16	97.22	6.08	39.71	8
17	100.00	5.88	45.60	9

Manual-scarification treatment

Day	Gp	DGs	$\sum$ DGs	N
7	11.11	1.59	1.59	1
8	45.83	5.73	7.32	2
9	63.89	7.10	14.42	3
10	77.78	7.78	22.20	4
11	**86.11**	7.83	30.02	5
12	88.89	7.41	37.43	6
13	100.00	7.69	45.12	7

For the manual-scarification treatment, the first germination started on the 7th day. It took 7 days to complete germination from the day of first germination to completion of germination. It took 14 days to complete germination from the day of sowing.

Categorization by imbibition period for each treatment

Manual-scarification treatment was the first to start germination the 7th day. It was followed by Acid treatment in the 8th day. Hot-water treatment was the 3rd on the 9th day. Control was the 4th having started on the 13th day.

Manual-scarification was the first to complete germination from the day of sowing to the completion of germination in 14 days. It was followed by Acid treatment in 16 days. Hot-water treatment was the third in 18 days. The Control was the last to complete in 28 days.

Manual-scarification took the shortest time of 7 days to complete germination from the first day of germination. It was followed by acid treatment with 8 days. Last, was the Control with 15 days. The time taken to germinate in relation to cumulative percent is shown in Figure 52.

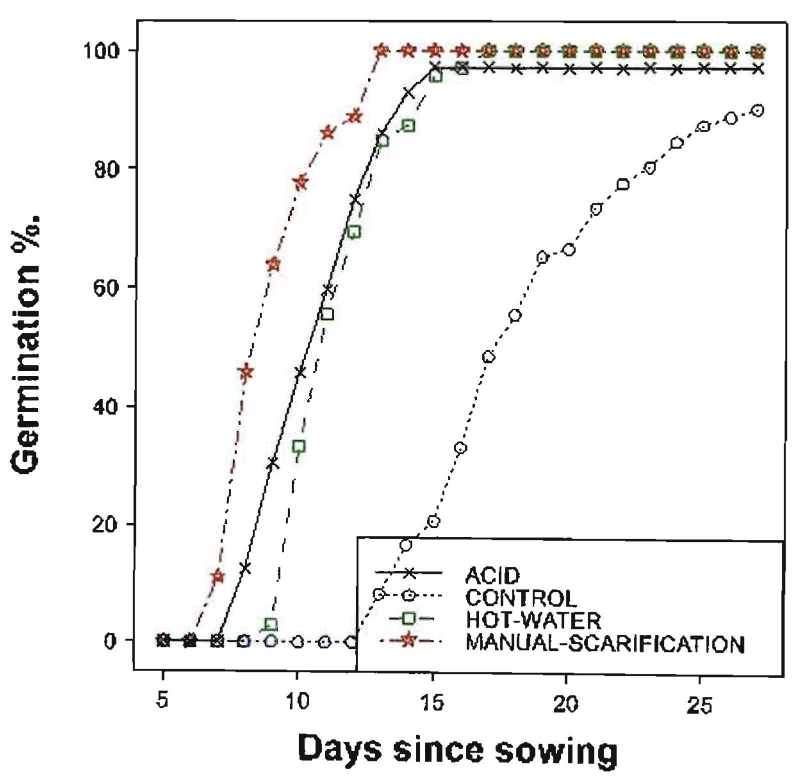


Figure 52: Germination percent versus day of germination for Mokhalinyane

Categorization of germination for Mokhalinyane variables.

Both hot-water and manual-scarification treatments attained 100% of germination percent. They were followed by acid treatment with 97%. Control was the fourth with 90%.

Germination energy was highest in acid treatment with 93. It was followed manual- scarification with 86. Hot-water treatment was third with 85. Last was Control with 78.

In terms of germination value, manual-scarification had the value of 64. It was followed by hot-water with 5. Acid treatment was the third with 50. Control was the last with 25. For tabulated summary of the results see table 31 below.

Table 31: Summary of germination percent, energy and value for the four treatments of Mokhalinyane

Treatment	Germination %	Germination energy	Germination value
Acid	97	93	50
Control	90	78	25
Hot-water	100	85	51
Manual-scar	100	86	64

7.8.4 Germination tests for Hilton

Germination period for all four treatments has taken a total number of 24 days from the beginning of sowing. Germination energy has been extrapolated from table 32 and Germination values were calculated using the formula 1.

First germination started on the 9th day in the hot-water treatment. Germination took 12 days to complete since the first germination. It was a total number of 21 days to germinate since the date of sowing.

Germination first started after 8 days in the manual-scarification treatment. From the first germination it took 9 days to complete. It was a total of 17 days to complete germination from date of sowing.

For acid treatment the first germination occurred after 10 days after sowing. I took 9 days for germination to complete since first germination. It is a total number of 18 days from sowing to the end of germination.

Table 32: Daily germination speed and germination value for Hilton

Acid treatment

Day	Gp	DGs	∑ DGs	N
10	6.94	0.69	0.69	1
11	20.83	1.89	2.58	2
12	45.83	3.82	6.4	3
13	61.11	4.70	11.1	4
14	75.00	5.36	16.46	5
15	81.94	5.46	21.92	6
16	**87.50**	5.47	27.39	7
17	90.28	5.31	32.7	8
18	93.06	5.17	37.87	9

Control

Day	Gp	DGs	∑ DGs	N
14	2.78	0.20	0.2	1
15	12.50	0.83	1.03	2
16	27.78	1.74	2.77	3
17	48.61	2.86	5.63	4
18	70.83	3.94	3.94	5
19	**79.17**	4.17	9.8	6
20	83.33	4.17	13.97	7
21	84.72	4.03	18	8
22	84.72	3.85	21.85	9
23	86.11	3.74	25.59	10

Hot-water treatment

Day	Gp	DGs	∑ DGs	N
9	9.72	1.08	1.08	1
10	34.72	3.47	4.55	2
11	54.16	4.92	9.48	3
12	72.22	6.02	15.49	4
13	**83.34**	6.41	21.91	5
14	84.72	6.05	27.96	6
15	94.44	6.30	34.25	7
16	95.83	5.99	40.24	8
17	97.22	5.72	45.96	9
18	97.22	5.40	51.36	10
19	97.22	5.12	56.48	11
20	98.61	4.93	61.41	12

Manual-scarification treatment

Day	Gp	DGs	∑ DGs	N
8	4.17	0.52	0.52	1
9	20.83	2.31	2.83	2
10	50.00	5.00	7.84	3
11	66.67	6.06	13.90	4
12	75.00	6.25	20.15	5
13	**84.72**	6.52	26.66	6
14	88.89	6.35	33.01	7
15	93.05	6.20	39.22	8
16	97.22	6.08	45.29	9

In the control, first germination started after 14 days. It took 11 days to complete germination from the date of first germination. The total number of days to complete germination from the date of sowing was 24.

Categorization by imbibition period for each treatment

Manual-scarification treatment was the first to start germination on the 8th day after sowing. It was also the first to complete germination after 17 days from time of sowing. Second to start germination was Hot-water treatment on the 9th day and also it was the second to finish germination. Acid treatment was the third to start germination on the 10th day and again it was the third to complete germination on the 19th day. Control was the last to start on the 14 the day and also it was the last to complete on the 25th day (Figure 53).

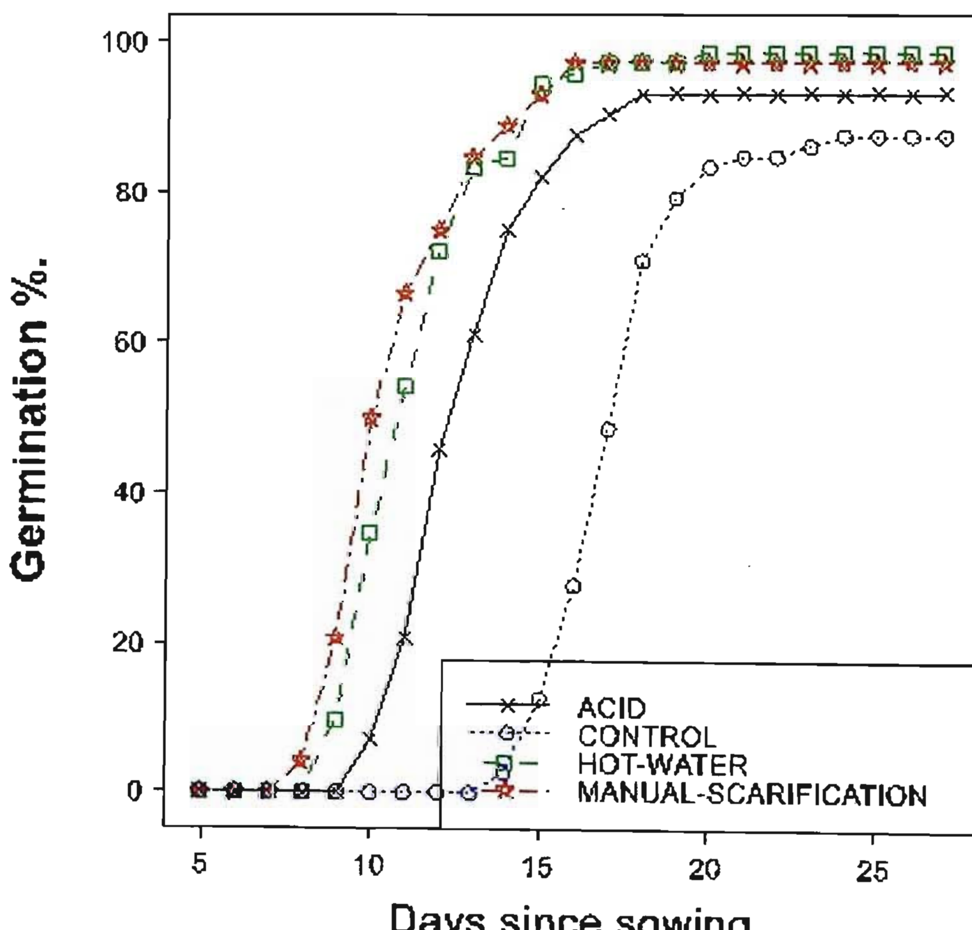


Figure 53: Germination percent versus day of germination for Hilton

Categorization of germination variables for Hilton.

Germination percent was highest in Hot-water treatment with 99. It was followed by Manual-scarification treatment with 97. Third, was Acid treatment with 93 and lastly, was Control with 89. The results are tabulated in table 21.

Acid treatment exhibited the highest Germination energy of 88 followed by Manual-scarification 85. Third was Hot-water treatment with 83, which was lastly followed by Control with 79.

Germination value was highest in Hot-water treatment with 50, followed by Manual-scarification with 49. Third, was Acid treatment with 39, which was lastly followed by Control with 23. Tabulated summary of the results is in table 29.

Table 33: Summary of germination percent, energy and value for the four treatments for Hilton

Treatment	Germination %	Germination energy	Germination value
Acid	93	88	39
Control	88	79	23
Hot-water	99	83	50
Manual-scar	97	85	49

7.9 CONCLUSIONS

Though trees do inherit characteristics, they are to a large extent influenced by environment. Species in the same genotype develop structures with different sizes depending on what environment they are subjected to. Leaves as organs that manufacture plant food perceptibly increase their sizes when climatic conditions like temperature and precipitation are favourable. Altitude, as it is associated with temperatures, also play a pivotal role in the growth patterns of trees. Tree species diversity is also greatly affected by climatic conditions. Where growing conditions are harsh, chances of many species to survive become minimal.

Germination is affected by the speed at which water is able to penetrate the seed cover to the embryo in order to trigger growth. Consequently, careful opening of the seed coat by manual scarification significantly enhances speed of germintion.

The results of the oven-dry wood densities compared favourably with the results of De Winter *et al.* (1973) and van Wyk (1990), which were 750 kg/m^3 – 755 $kg/^3$. However, the results could have been better if wood samples had been taken from the right positions not from branches at a man's height. Wood from the branches includes pith. Rightly, the samples should have been taken between on the stem half-way between bark and pith. Secondly, oven-dry densities were not accurate because greenweight was not taken immediately after cutting of the trees and as result some moisture content had been lost.

These results are generally discussed in the following chapter 8.

CHAPTER 8

SUMMARY RESULTS AND GENERAL DISCUSSIONS

8.1 INTRODUCTION

In this chapter the results of the localities are summarized in order to facilitate comparison by localities. Such a comparison is essential because it enables one to rank localities by performance or quality. Such a ranking is important in the decision-making as it provides information on whether the project is worth embarking upon or not. It can also prescribe by how much the project should be improved in order to meet the required standards. It thus may avoid unnecessary costs.

8.2 STEMS AND VOLUME OF *C. AFRICANA* PER LOCALITY PLOT/HECTARE

The results showing number of stems and basal area per plot and volume per hectare are shown in table 34.

Table 34: Data on number of stems, basal area and volumes per plot/hectare

	Average no. of stems per plot				
Locality	***C. africana***	**Other tree spp.**	**B.A/plot (m^2)**	**Volume/plot (m^3)**	**Volume/ha (m^3)**
Dargle	10	12	1.0505	24.0873	48.1746
Fort-Hartley	12	9	1.0417	6.5348	13.0696
Mokhalinyane	9	4	0.9073	21.1302	42.2604
Hilton	9	11	0.0746	0.7127	1.4254

In ranking Dargle had the highest number of 22 stems in a plot (44 stems per ha.). Equally, it had the highest number of 12 stems of other tree species (24 stems per ha.). In a plot it had 10 stems of *Celtis africana* (20 stems per ha.). Again it had the highest volume of 24.0873 m^3 per plot (48.1746 m^3 per ha.). Mokhalinyane had second highest volume production of 21.1302 m^3 per plot or 42.22604 m^3 per hectare. Fort-Hartley ranked second in terms of number of stems per plot, with 21 (42 stems per hectare). It had the highest number of stems of *Celtis africana* with 12 per plot (24 stems per hectare.). Hilton was the last in all respects except in the number of other tree species per plot whereby it ranked second with 11 (22 stems per hectare.).

8.3 DBH AND HEIGHT PARAMETERS OF *CELTIS AFRICANA*

Values derived from raw data (Appendix 11) showing minimums, means, maximums and standard deviations for dbh and heights by locality, are shown on Table 35.

Table 35: Means, minimums and maximums of dbh's and heights for the four localities

	Dbh (cm)					Height (m)			
Locality	**No. of trees**	**Min**	**Mean**	**Max**	**Stdev**	**Min**	**Mean**	**Max**	**Stdev**
Dargle	16	11	35	84	22.02	7	15	36	8.04
Fort-Hartley	16	16	26	44	9.00	8	11	15	2.30
Mokhalinyane	16	15	24	47	10.56	7	10	15	2.28
Hilton	16	10	14	22	4.14	5	8	13	2.19

By ranking, Dargle had the highest values in the two variables measured for dbh and height. Fort-Hartley had highest minimum height and highest mean and was the third in values for maximum dbh. Mokhalinyane was the third in mean dbh and mean height. Hilton was the last for all measurements. Dbh and height means followed the same rankings. Dargle had the highest values in both cases while Hilton got the lowest. Dargle highest standard deviatins in both dbh and height. This situation indicates highest variability in all localities.

8.3.1 Frequency distribution of dbh and height by localities

Data for the plots 1 and 2 were combined for the locality in order to determine frequency distributions for the localities. Raw data are shown in appendix 11. Height classes in metres were arranged at 4 m intervals while that of dbh classes were in 5 cm intervals.

8.3.1.1 Height and dbh frequencies for Dargle

Frequency distributions by classes of heights and dbh's for Dargle are shown in table 36.

Table 36: Dbh and height frequency distributions for locality of Dargle

Height frequencies		**Dbh frequencies**	
Class limit (m)	**Frequency**	**Class limit (cm)**	**Frequency**
6 - 10	7	5 - 10	0
11 - 14	2	11 - 15	2
15 - 18	3	16 - 20	2
19 - 22	1	21 - 25	2
23 - 26	2	26 - 30	3
27 - 30	0	31 - 35	2
31 - 36	1	36 - 40	2
		41 - 45	0
		46 - 50	0
		51 - 55	0
		56 - 60	0
		61 - 65	0
		66 - 70	1
		71 - 75	1
		76 - 80	0
		81 - 85	1

For the height frequency 6 – 10 class limit appeared as the value of most frequent occurrence (mode) with frequency of 7. The distribution is skewed towards lower classes. Frequency of 1 for class limit 31- 36 appears as an outlier. For the dbh the frequency mode was class 26 – 30 with frequency 3. Class limits above 36 – 40 were outliers.

8.3.1.2 Height and dbh frequencies for Fort-Hartley

Frequency distributions by classes of heights and dbh's for Fort-Hartley are shown in table 37.

Table 37: Dbh and height frequency distributions for locality of Fort-Hartley

Height frequencies		Dbh frequencies	
Class limit (m)	**Frequency**	**Class limit (cm)**	**Frequency**
6 - 10	7	16 - 20	4
11 - 14	7	21 - 25	2
15 - 18	2	26 - 30	5
		31 - 35	2
		36 - 40	1
		41 - 45	2

Two height classes of 6 – 10 and 11 –14 shared the mode with 7 each. The mode of dbh was class limit 26 – 30 with 5.

8.3.1.3 Height and dbh frequencies for Mokhalinyane

Frequency distribution of heights and dbh's for Mokhalinyane are shown in table 38.

Table 38: Dbh and height frequency distributions for locality of Mokhalinyane

Height frequencies		Dbh frequencies	
Class limit (m)	**Frequency**	**Class limit (cm)**	**Frequency**
6 -10	11	11 - 15	1
11 - 14	4	16 - 20	4
15 - 18	1	21 - 25	4
		26 - 30	2
		31 - 35	1
		36 - 40	2
		41 -45	1
		46 - 50	1

Height class 6 –10 had the highest mode with 11. Height classes are aggregated to the lower height classes. Dbh classes 16 – 20 and 21 – 25 had the same mode with 4 each. Frequency distribution seems to be evenly spread.

8.3.1.4 Height and dbh frequencies for Hilton

Frequency distribution for heights and dbh's is shown in table 39

Table 39: Dbh and height frequency distributions for locality of Hilton

Height frequencies		Dbh frequencies	
Class limit (m)	**Frequency**	**Class limit (cm)**	**Frequency**
0 - 5	2	5 – 10	5
6 - 10	12	11 – 15	7
11 - 14	2	16 – 20	2
		21 - 25	2

Height class limit 6 – 10 had the highest mode with 12. For the dbh class limit 11 – 15 was the mode with 7.

8.3.2 Relationship between dbh and height

Regression analysis was done on raw data, which is shown in appendix 11. The relationship of dbh and height in all four localities showed a linear relationship (Figure 54).

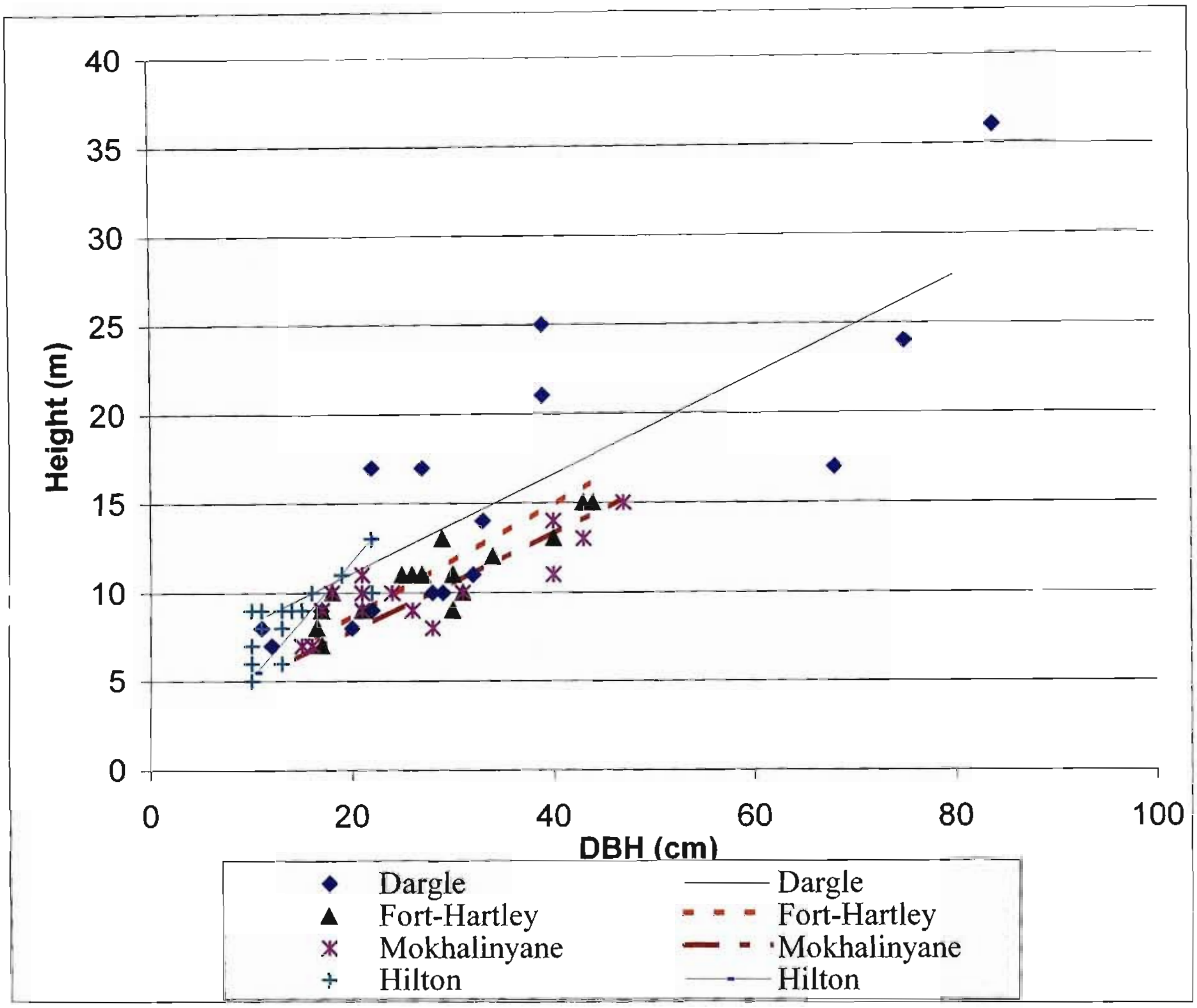


Figure 54: Dbh versus height for the four localities

Relationships as expressed by R^2 showed different degree of correlation and regressions were estimated from the equation Height = intercept + slope * dbh (Table 40).

Table 40: Coefficients of determination and regressed equations for the four localities

Locality	R^2	**Regressed equations**
Dargle	0.69	Y = 0.2764x + 5.5464
Fort-Hartley	0.77	Y = 0.3190x + 4.0901
Mokhalinyane	0.70	Y = 0.2764x + 2.2810
Hilton	0.63	Y = 0.625x - 0.75

Fort-Hartley indicated the highest relationship between the diameter at breast height and height at 77%. Mokhalinyane followed with 70%, then Dargle with 69%. Hilton was the last with 63%.

8.4 SEED MASS ASSESSMENT OF *C. AFRICANA*

Seed masses for the four localities are shown in Table 41 and the table shows respective altitude, annual rainfall and average annual temperature.

Table 41: Number of seeds per locality, altitude, mean annual rainfall and average annual temperature

Locality	Number of seeds (kg per ha)	Altitude (m)	Mean annual rainfall (mm)	Average annual temperature (°C)
Dargle	9 459	1 356	1 276	15.9
Fort-Hartley	10 717	1 400	754	14.7
Hilton	11 181	1 600	720	15.2
Mokhalinyane	12 446	1 613	589	15.2

Seeds for Dargle are the least numerous in a kilogram. This indicates that they are heaviest of all the localities. Correspondingly, they experience both the highest average annual temperature and rainfall and they are at the lowest altitude. Fort-Hartley is the second, and with similar pattern in all respects. Hilton is the third following the same sequence. Mokhalinyane is the fourth in all respects except in temperature, where they have similar average annual temperature of 15 °C with Hilton.

8.5 GERMINATION

8.5.1 *Celtis africana* seed and germination

The seed of *Celtis africana* is hard coated. Its colour is green when it is not ripe. Ripe seed ranges from yellow to brown or dark brown depending on the degree of ripeness. The radicle elongation is preceded by cotyledon expansion. Its germination is hypogeal i.e. the epicotyl grows in length while the hypocotyl remains short. Germination was taken to have occurred when the protruding epicotyl had reached about 2 mm.

8.5.2 Germination tests on *C. africana*

For all localities, at the termination of the experiment, cumulative germination was highest in treatments involving the partial opening by sand paper (manual-scarification) (Figure 55). They were followed by hot-water treatments except for Mokhalinyane locality, whereby acid treatment appeared second. Third, were acid treatments in all localities except Mokhalinyane. The controls emerged last in all localities. As a result manual-scarification had the greatest success on cumulative germination of *Celtis africana* in all localities. M. Underwood, (pers.comm Forestry Progrmme, UKZN, Pietermaritzburg, 2004) confirmed that the results on *Leucaena lencocaphala* have followed the same pattern. However, manual-scarification is time consuming. The trend for all four localities is shown in figure 55 and appendix 13.

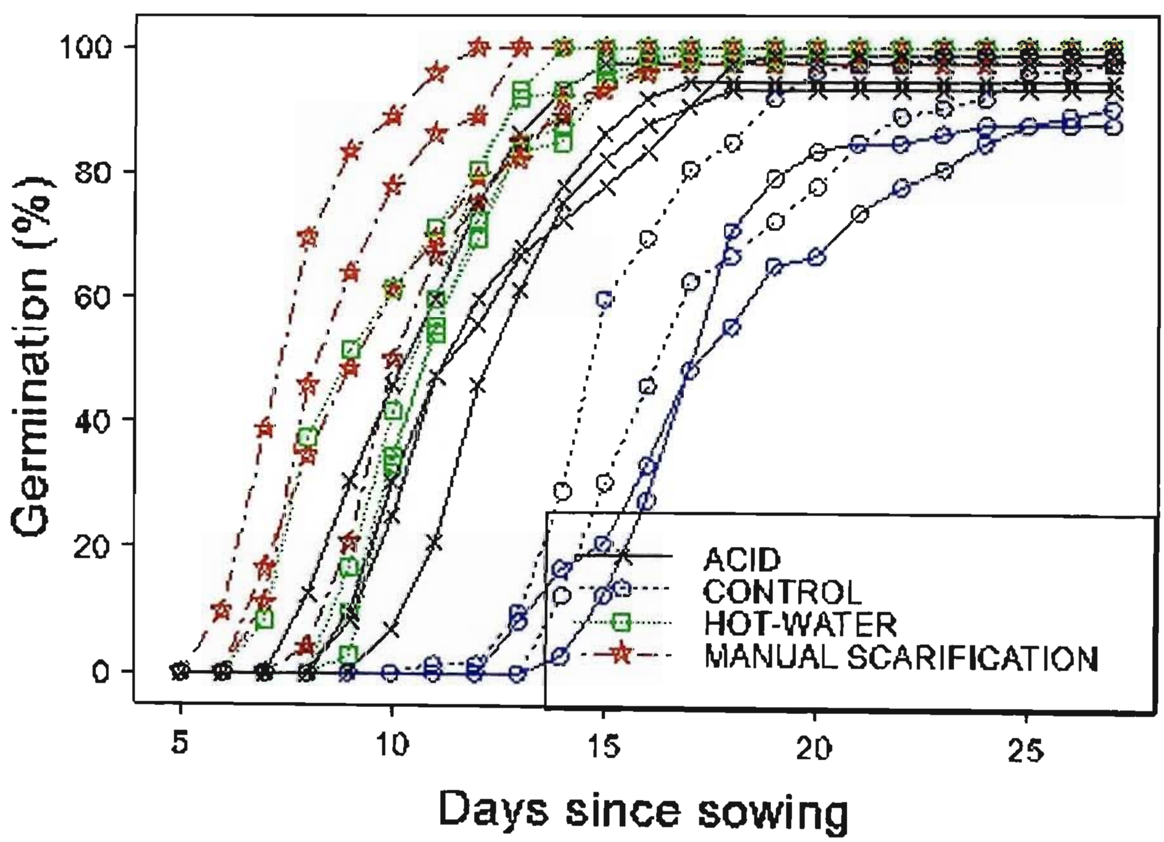


Figure 55: Germination percent versus days since sowing in four localities

The seed from Dargle took the shortest time of 24 days in all the treatments to complete the germination (Appendix 12). It was followed by seed from Hilton (25 days). In both Fort-Hartley and Mokhalinyane localities, germination was completed only in 28 days.

Dargle attained the highest germination percent in all treatments (Appendix 13). On average, the hot-water treatment had most counts of higher values in germination percent than other treatments. This could be due to naturalness of water with no harmful elements like in acids. Generally, the control showed the lowest germination energy as compared to other treatments (Appendix 13). All treatments achieved very high germination percent. Analysis of variance indicated that the effect of different seed treatments, tested at 5%, had no significant impact on germination percent (Table 42).

Table 42: Summary statistics of the analysis of variance on the variations caused by different germination treatments

Source of variation	**d.f.**	**s.s**	**m.s.**	**F**	**P**
Treatment	3	13.667	4.556	2.06	0.119
Residual	44	97.333	2.212		
Totals	47	111.000			

8.6 *C. AFRICANA* LEAF ASSESSMENT FOR COLOUR AND SIZES

For the four localities, leaf colours varied in crown of the same tree. Using Methuen Handbook of Colour (Korerup and Wanscher, 1967), the colours ranged between yellowish green through greyish green to dark and deep green. Raw data for leaf colours and leaf measurements are in appendix 14.

8.6.1 *C. africana* leaf colour

For Dargle, in December, 56% of the data, indicated that the leaves were deep green, 28% grayish green 11% dark green and 6% yellowish green. For Fort-Hartley, leaves with dark green colour amounted to 39%, with grayish green 33%, deep green 22% and yellowish green 6%. For Mokhalinyane, leaf colours ranged from deep green with 39%, grayish green with 33%, yellowish green with 17% and dark green with 11%. For Hilton, Dark green colour of the leaves amounted to39%, grayish green and deep green 28%.

8.6.2 *C. africana* leaf sizes

Leaves were measured as in section 5.5. Raw field data are shown in appendix 12. Means of lengths and widths per locality are shown in table 43.

Table 43: Mean leaf lengths and widths for the four localities

Locality	Length (cm)	Width (cm)
Dargle	64	39
Fort-Hartley	54	35
Mokhalinyane	51	33
Hilton	56	32

Dargle had the highest values for both mean lengths and widths with 64 cm and 39 cm respectively. Hilton ranked second in mean length with 56 cm while Fort-Hartley ranked second in mean width with 35 cm. Fort-Hartley ranked third in length measurement with 54 cm and Mokhalinyane was the last with 51 cm. In mean width Mokhalinyane was third with 33 cm and Hilton was the last with 32 cm.

Analysis of variance to test variations in lengths and widths was conducted. The results of the analysis for the lengths are shown in table 44 and those of the widths in table 45.

Table 44: Summary statistics of the analysis of variance on the variations of leaf lengths as affected by the locality.

Source of variation	d.f.	s.s.	m.s.	F	P
Locality	3	1708.0	569.3	2.43	0.073
Residual	68	15940.0	234.4		
Total	71	17648.0			

At 5% test the leaf lengths for the four localities did not show significant different with F - value of 0.073.

Table 45: Summary statistics of the analysis of variance on the variations of leaf widths as affected by the locality

Source of variation	d.f.	s.s.	m.s.	F	P
Locality	3	478.6	159.5	1.50	0.223
Residual	68	7236.7	106.4		
Total	71	7715.3			

The leaf widths did not show significant variation within localities tested at 5% level. The F-value was 0.223.

8.7 *C. AFRICANA* WOOD DENSITY ASSESSMENT

8.7.1 Comparison of wet and oven-dry wood densities

Means of wet and dry masses are shown in Table 46. Calculations and results are shown in section 7.7.1. Oven-dry density (d) was calculated by using formula (5.6.3) while wet density was determined by formula (5.6.5).

Table 46: Wood masses, moisture content and densities of *Celtis africana*

Locality	Wet mass (g)	Dry mass (g)	M.C. (%)	Wet density (kg/m^3)	Dry density (kg/m^3)
Dargle	0.69	0.61	13.11	590	520
Fort-Hartley	1.23	1.10	11.82	774	692
Mokhalinyane	0.76	0.68	11.76	817	731
Hilton	0.82	0.73	9	830	737

Considering the fact that the wood samples were obtained from the branches at man's height, and not from the stem, the results compared favourably with those of Dyer (unpublished), which whose density was 760 kg/m^3 at 10% moisture content.

In terms of moisture content Dargle had the highest value (13.11). It was followed by Fort-Hartley (11.82). Mokhalinyane was third (11.76), followed by Hilton (9%).

8.8 *C. AFRICANA* AS A MULTI-PURPOSE TREE

Wildlife normally feeds on foliage of *Celtis africana*. In like manner, domestic livestock (small and large stock) also browse the leaves and young shoots of the species earnestly (Figures 56 and 57). The leaves seem to be so enticing and palatable that the stocks insist, persistently, coming back even when they are chased away. This emphasises the need that potentials of *C. africana*, as a multi-purpose tree, should be explored. The routine browsing of the leaves by the wildlife without any noticeable or recorded inherent problems, overrides any possible ill effects.

Figure 56: Cattle feeding on *Celtis africana* foliage

Figure 57: Small stock browsing on *Celtis africana* foliage

8.9 PESTS AND DISEASES

Under Lesotho conditions, *Celtis africana* is generally attacked by many, as yet, unidentified pests and diseases. Mr D. P. Ambrose (pers. comm., National University of Lesotho, Roma, Lesotho 2004) mentioned that *C. africana* is predominantly attacked by mildew (*Uncinula necator*) and silver stripped hawk moth or cat's paw emperor moth (*Pseudobunea tyrrhena*).

8.9.1 Powdery mildew

The various types of powdery mildews are caused by distinct and different fungi (Large, 2003). All mildews belong to the family Erysipheae powdery mildew (Tubeuf, 1894).

Mildews mainly affect the leaves, tender growing shoots and fruits (Heald, 1943). On young leaves, the fungus appears as whitish patches. Severely infected leaves curl upward, become brittle with time, and fall prematurely.

8.9.2 Silver stripped hawk moth *Pseudobunea tyrrhena*

Silver stripped hawk moth belongs to the family *Saturniidae* in the order Lepidoptera. *Saturniidae* is a member of large group of silks, brahins, emperors and eggars constituting a super family, *Bombycoidea*. Emperor moth is pale purplish grey with a very conspicuous dark circular eyespot (Figure 58) surrounded by a white on each wing (Pinhey, 1975; Leftwich, 1977).

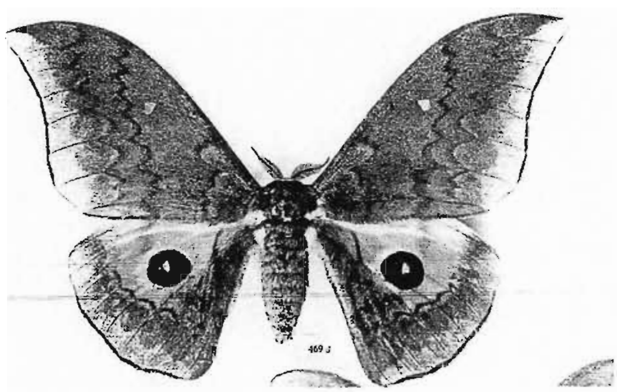


Figure 58: Silver stripped hawk moth *Pseudobunea tyrrhena* (Pinhey, 1972)

The catepillar is bright green with black rings. It pupates within a brown silky cocoon. Caterpillars of silk moths, emperors and hawkmoths *Bombycoidea* are vulnerable to predation, and they protect themselves in a variety of ways. Some are clothed with irritant hairs, others bear clusters of sharp spines, some are distasteful or even poisonous, and some may depend on camouflage (Leftwich, 1978). Mr D. P. Ambrose (pers. comm, National University of Lesotho, Roma, Lesotho 2004) explains that when the silver stripped hawk moth pupates, it burries itself in the ground and it can also mimic the tree in order to avoid the birds.

The moth larvae are herbivores (Leftwich, 1977). Females produce a sex pheromone that males can detect from long distances downwind. They (females) must first locate a plant, which will provide appropriate nutrition for the hatched larvae. This she senses by smell or sight, and confirms that it is a suitable species by receptors on the feet, antennae or tip of the abdomen. Finally, she lays eggs on part of the plant, which gives eggs and larvae the best chance of survival. The moth bears a large batch of whitish grey eggs (Figures 59 and 60).

Figure 59: Eggs of silver stripped moth born on *C. africana* leaf at Fort-Hartley

Figure 60: Leaves bearing eggs, larva and feeding scars made by both mildew and larvae of *Pseudobunea tyrrhena*

The larva of the Silver Stripped Hawk Emperor is green with yellowish-green lines and silvery markings (Figure 61). It has orange spiracles (Pinhey, 1972). The larvae feed on albizzia, celtis, *Ekebergia grumelia* and trema.

Figure 61: Larva of silver stripped moth

Cat's paw emperor is noted in Namibia, Cape Province, Natal Province, Northern Province, Mozambique, Zimbabwe, Malawi, Zambia, Equatorial East and West Africa.

8.10 CONCLUSIONS

Celtis africana in Lesotho is a true type to its species as compared to that of Dargle in KwaZulu-Natal. The recognised variations between the different strains are mainly due to climatic and edaphic conditions more than genotype. Strains in KwaZulu-Natal are on more favourable conditions than those in Lesotho. There is more rainfall and the growing season is longer than that of Lesotho. *Celtis africana* in Lesotho is exposed to higher altitudes, which are accompanied with harsh conditions of less annual rainfall and colder conditions. KwaZulu-Natal has more annual rainfall and warmer climate than Lesotho. It is a fact that raised temperatures do not necessarily increase the assimilation gain, as it might be assumed. An increase in temperature is accompanied by an increase in respiration (i.e. breathing), which is decidedly "temperature-controlled". As a result, the particular temperature-optimum, i.e. that temperature giving the highest assimilation performance for a given light intensity, is lower when the light is poor than when light is intense (Assmann, 1970). On comparative basis, in Lesotho, the temperatures giving the required assimilation performance, is of much duration than in KwaZulu-Natal. This is due to longer and colder winter periods.

As result more favourable conditions of longer growing periods, *Celtis africana* at Dargle gets more time for photosynthesis, which is the food making process for plants. This added advantage gives it more chance for building morphological organs. This is the reason why it significantly had more seed masses as shown in table 37. In like manner, it had high mean length and width sizes of leaves as shown in table 39. Equally *C. africana* at Dargle had the highest values in the two variables measured for height and diameter at breast height. Similarly, *Celtis africana* in KwaZulu-Natal is more widely distributed over large with no comparative geographical barriers like in Lesotho. The consequence of this is that pollen migration does not suffer any barrier in the form of long distance or mountainous topography. Consequently, the species is not easily susceptible to genetic drift as elicited by more vigour in seed germination tests (Appendix 13).

It is apparent that there are more tree species per unit of area in Kwazulu-Natal than in Lesotho (Table 35). This increased tree species diversity may be attributed to more favourable growing conditions for wider variety of other species and less human interruptions in the ecosystems.

The modes for both dbh and height classes for Dargle, had the highest values of 26 –30 for the former, and 15 – 18 for the latter (8.2.2). The common height mode for the three localities in Lesotho was 6 – 10. If this is not due to differences in age, it can reasonably be assumed that it is due to more favourable climatic conditions under which *Celtis africana* is growing under in KwaZulu-Natal.

Volume production per unit area is low when compared to that of commercial plantations (Table 35). Indication of higher volumes for Dargle and Mokhalinyane is counteracted by big range of variation, which is reflected by big standard deviations (Table 34). This shows that some trees are too big while others are too small. Generally, volume production is low in indigenous forests. Sargent and Bass (1992), support the assertion by stating that natural forests are blamed for low yields, which may be as low as 0.50 m^3 per hectare in contrast to industrial plantations, which may be in the order of 5-50 m^3 per hectare. However, the latter overlooks some social and environmental issues.

CHAPTER 9

CONLUSIONS AND RECOMMENDATIONS

9.1 CONCLUSIONS

In Lesotho, *Celtis africana* is not an exotic. It grows within its natural geophysical zones, which are, to a large extent, defined by physiography and climate. These two factors have most significant impact on its distribution, volume production and seed vigour.

9.1.1 Habitat and status of *C. africana* in Lesotho

On comparative basis, *Celtis africana* in South Africa is present in a wider variety of ecosystems. Of the many different habitats in South Africa, *C. africana* occurs mostly within the ecosystems that favour humid conditions. Along the coastal areas, where the precipitation is generally higher, *C. africana* is widely distributed and in the Coastal Forest and Thornveld, *C. africana* appears among trees, which are described as of general occurrence (50% or more). Not far away, in the Pondoland Coastal Plateau Sourveld the occurrence is less common and in both the 'Ngongoni Veld and the Dohne Sourveld it becomes a tree of less general occurrence. In the Natal Mist Belt 'Ngongoni Veld, though the altitude is high, (ranging from 900-1 350 m above sea level) the coastal element is so strong that *C. africana* is qualified as a tree of general occurrence. This qualifies it as a tree with great affinity for water. *Celtis africana*'s affinity for moist habitats can be equated with that of the willows and planes.

As Lesotho is further away from the coastal areas, it delineates the outer limits of *C. africana*, in particular. The lowest lying areas, which are the Lowlands, mark the start of the boundaries of Lesotho adjoining those of the South Africa. It follows, therefore, that at the zones where *C. africana* starts to diminish in South Africa, is where it begins to emerge in Lesotho.

Since a rise in altitude reflects a fall in temperature (3.6.5), the higher altitudes inland, further limit the occurrence *C. africana* in Lesotho. The impact of microclimate on distribution and influence of topography and elevation on plants, is supported by Ackerly *et al* (2001). The range of the Lowlands zone, which is ideal for successful growth is too narrow to allow the widespread of the species. These are the reasons why the species is so scarce and predominantly grows in the sheltered grooves and valleys. However, *C. africana* does grow into a sizable tree that can produce utilizable timber though it is within very narrow confines and under stressful climatic and edaphic conditions (Figure 62).

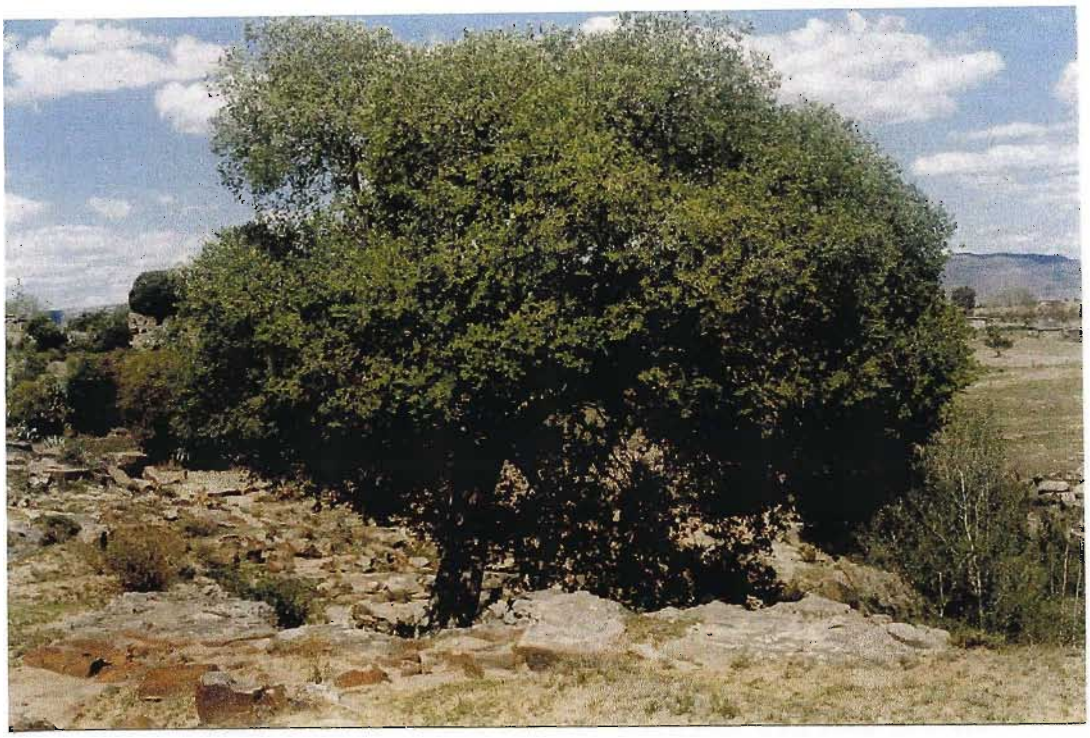


Figure 62: *Celtis africana* growing on very rough terrain in between stone rubbles at Mokhalinyane

Although many authors purport the idea that *C. africana* can survive in a wide and varied range of habitats, it prefers alluvial soils. In 2.3.1 it is mentioned that it survives and thrives well in sinkholes on dolomite formations and grows well on sandy soils by the coast and river-sides. The common aspect between dolomite and coastal plains is that, they may be characterized by either clastic or non-clastic sediments. Clastic sendiment consists of particles broken away physically from a parent rock. Non-clastic sediment consists of sediments formed of mineral compounds precipitated from chemical solution or from organic activity. These sediments are deposited in layers after being transported by streams, waves, currents, the wind or ice. Clastic sediments may be hydrogenic i.e. chemical precipitates which are compounds precipitated directly from water in which the ions are transported or biogenic in which organically derived sediments are created by the life processes of plants and animals. The ensuing carbonate sediments are normally calcium carbonate $CaCO_3$, derived from evaporite mineral calite, or Calcium-magnesium carbonate $CaMg(CO_3)_2$, derived from evaporite dolomite. This indicates that *C. africana* prefers soils reach in calcium, magnesium and carbon. It can be concluded that *Celtis africana* is a calcifuge and a water loving plant.

Under Lesotho conditions, *Celtis africana* is a climax species and it occupies a dominant position in the canopy. Most of tree associations identified with it in South African veld types bear similarities with those found in three localities in Lesotho. The common species in the localities in both Lesotho and KwaZulu-Natal are *Buddleja salviifolia, Leucosidea sericea, Hyparrhenia hirta, Olea africana, Acacia karroo, Halleria lucida. Grewia occidentalis* seems to be a close associate of *C. africana,* which in many cases have their branches interlaced. In many instances some authors mistake *G. occidentalis* for *C. africana* e.g. May (2000) and Staples and Hudson (1938). (P. Polaki 10th March, 2004 pers. comm.) states that seedlings of both species are not easy to distinguish when they are in a young seedling stage at a nursery. (L. Mongali 10th March, 2004 pers. comm.), Forestry Research seed collecter mentioned that all along they have been collecting *G. occidentalis* for that of *C. africana.*

On comparative basis seed dispersal of *C. africana* in Lesotho has been limited by diminished biodiversity. Birds and animals, which help to disperse its seeds have been reduced numbers which cannot effectively expand its distribution.

Celtis africana has been a tree noted for its many uses in Lesotho. Records show that it was once a valuable saw timber tree (May, 2004). May (2000) mentions that *Celtis africana* is the tallest indigenous tree recorded in Lesotho. The tree recorded was 22.4 m high with dbh of 108 cm. The species was used for making yokes, pick handles, chairs etc. other than being a valuable firewood. However, unabated timber utilization and periodic natural and man-made fires have converted the woody vegetation generally into grassland which have merged with the subalpine and alpine grasslands in the higher mountains (Mc. Vean, 1977). The resultant loss of vegetation accelerated both water and wind erosion.

Stressful conditions such as steep topography, adverse climatic conditions of extreme low temperatures and characteristic long spells during the dry seasons, have negatively influenced the production of tree biomass. Foliage of *Celtis africana* growing under Lesotho conditions is adapted to high evapotranspiration, cold temperatures and other restrictive conditions when compared to that of KwaZulu-Natal. Mean height and dbh for all localities in Lesotho are lower than those of Dargle in KwaZulu-Natal.

9.1.1.1 Genetic perspective of *C. africana* in Lesotho

In germination tests, the results for localities in Lesotho showed varied results. In many cases the results for localities in Lesotho indicated lower figures. Both germination percentage and vigour were highest in Dargle locality. Inferior results shown by *Celtis africana* in Lesotho, when compared to those of KwaZulu-Natal, may indicate that the species has been subjected to genetic variations. Brewer and Sing (1983) assert that extensive genetic variation in natural populations of most species is the rule. Therefore, for a species to survive over time, extensive genetic variation in a population is required. Genetic variation allows the species to change biologically so that it may compete successfully with changes in other species and to adapt to novel environments. Some of the genetic factors appear to affect populations of *Celtis africana* in Lesotho are selection, mutations and inbreeding. Small sized populations (like those of *C. africana* in Lesotho) are often the victims of genetic drift (Wright, 1976; Ridley 2000). Genetic drift is the random fixation of gene frequencies between generations (*Op cit*). It manifests an unusual behaviour to trees. Species may have abnormally short needles. One possibility is that, due to small population size in Lesotho, there might have been extensive inbreeding among trees. Extensively inbred trees normally incur inbreeding depression. *C. africana* is susceptible to the worst form of inbreeding, which is self-pollination, as it is hermaphrodite. Excessive inbreeding depression may ultimately lead to extinction. Again the species might have differentiated due to isolation. Isolation is the barrier to species migration (Wright, 1976) and for populations to differ genetically isolation is necessary. Species, which are far apart or occupy arid mountainous areas can easily become genetically differentiated as a result of selection.

In an exploitative harvesting, foresters normally opt for selecting only the best trees. Diameter limit, high value stems and species' preference are normally the dictating factors for selection (Wright, 1976; Zobel and Talbert, 1988; Young *et al.*, 2000). Selection of this kind results in what is termed dysgenic selection. Genetically, such an embarkation incurs serious genetic effects. Since only the best or vigorous trees are cut, the remaining ones are less vigorous and economically less desirable to reproduce a healthy crop. The same principle applies in cutting of indigenous trees for usual needs of fuelwoood, fencing materials, roofing etc. *Celtis africana* in Lesotho for quite along time has been subjected to cutting without gene renewal in the form of replanting. As a result it has suffered dysgenic effect.

9.1.2 *Celtis africana* as an agroforestry tree

Other than potentially being a tree for timber production with many industrial end uses, *Celtis africana* is browsed by both wildlife and domestic stock (both small and large livestock). Investigations indicate that the species has a high potential as livestock feed. As a result, under agroforestry systems, *C. africana* can fit in silvipastural system. Other than its nutritive importance, *Celtis africana* is an amenity tree in South Africa. Its outstanding beauty has made it to be declared a protected tree in South Africa. It is an excellent shade tree around the homesteads and it is very suitable in parks and along streets. However, *Celtis africana* is not without disadvantages. During the fall when it sheds its leaves it causes carelessness with scattered leaf litter (Figure 57). In its establishment there should be a thought on expenditure for upkeep and cleaning. Secondly, it has a tendency to develop surfacial roots (Figure 63). As result extra caution should be exercised when planting trees of *Celtis africana* not to place them too close to the fences or infrastructure. In many cases the roots unrubble the pavements. Its wood takes polish well and is widely used to fashion a variety of household articles.

Figure 63: Surfacial roots of *Celtis africana* planted too close to a fence and pavement.

9.1.3 Forestry literature on indigenous trees

Literature on indigenous species is very scarce and this is an indication that there is an urgent need for research and publications in the field of natural forests. Authors should realize the fact that different geographical localities may have different impacts on trees. They should always state the origin of their information and where it is applicable. The example is that the time of harvesting of seeds from Dargle should not be generalized for the whole of South Africa neither should they be generalized for KwaZulu-Natal.

9.1.4 Indigenous forests and plantation forestry

In both Lesotho and South Africa forestry sector is dominated by plantation forestry. There is little attention give to the research of indigenous species. In many countries there are controversies as to whether wood should be grown in plantations or under natural forest management. Each category has merits and demerits. Natural forests are blamed for low volume production (8.9) while plantation forestry may be disadvantageous where demands for alternative land use are high, where individual and community rights are not recognized and where state of biodiversity is adversely affected.

9.2 RECOMMENDATIONS

9.2.1 Awareness of the benefits of *Celtis africana*

Celtis africana is a tree with vast potentials for Lesotho. Its wood properties render it as a tree that can be utilized in small-scale industries. Kromhout (1967) states that, its wood is very useful, because of its medium weight and good workability. Also he mentions that furniture made from this wood is very attractive and it may be used to beautiful panels. Since its wood becomes pliable when soaked in water, it can be easily used to make artifacts. Growth of manufacture of artifacts in the country has a direct bearing on the promotion of tourist industry. In many parts of the world today, outdoor and tourism, show rising popularity. The major factors behind the persistent rise in use of outdoor recreation areas are the increase in population, higher income per capita and improved transport systems (Ts'ehlana, unpublished). Lesotho, with its weak economy, should always be aware of income generating opportunities. One such initiative could be foreign exchange earnings from tourism, which could be improved with tree establishments around recreational sites such as pic-nic sites, parks, nature reserves etc. The planting of beautiful trees like *Celtis africana* could be an excellent choice in such propositions.

Relevant information regarding the importance of *Celtis africana* should not be restricted to top people living in cities but should also be extended to the people living in the rural communities.

9.2.2 Improvement of management of indigenous trees

It should fall under the onus of a forester to establish and tend as well as to prescribe utilization of trees. As a result, trees either growing naturally or planted, should fall under the appropriate profession, that of the foresters. The situation in Lesotho, in regard to indigenous trees, may be modified to suit the existing traditional structures and forestry requirements. One way could be to subject indigenous trees to the relevant Ministry of Forestry and Land Reclamation with traditional leaders charged with the responsibility of overseers acting in full accordance with the Ministry's requirements. Alternatively, the Ministry may take full control of the indigenous trees and directly subject them to proper forest management principles.

9.2.2.1 Need for classification and research on indigenous forests

It is incumbent of the Ministry of Forestry and Land Reclamation to take stock of what is available of the indigenous trees in the country. This can only be feasible if natural vegetation is classified according to forest types. Proper classification can make it possible for the forests to be analyzed and recorded by species and parameters such as stems per hectare, area and volume. Such information is necessary when assessing the needs of the local communities. Community needs assessment can set a baseline for establishing demand and supply fundamentals for the country.

For the purposes of restoring *Celtis africana* to its original status as a valuable and important tree in the socio-economic fabric of Lesotho, intensive research efforts should be embarked upon. Basic data on growth rates, breeding systems and resilience to environmental stresses should be assessed for better management of *C. africana*. Viable and prospective geographic races should be selected for seed acquisition. In the same manner, proper provenances should be identified and certified seeds imported. However, local strains of *Celtis africana* are endemic, and there would be no need for species trials because it is already within its ecotonal zones. The element of adaptation, as it refers to the tree's performance over a full rotation in a new environment (Zobel and Talbert, 1984), is therefore not applicable.

9.2.3 Incorporation of *C. africana* in agroforestry programmes

It has been demonstrated that *Celtis africana* can be a multi-purpose tree. Since its foliage is eaten by livestock, *C. africana* has a potential of being incorporated into agroforetry systems, in particular silvipasture. It is, therefore, worth it to try and incorporate this species in agroforetry programmes in an effort to improve production and alleviate land competion. Nair (1996) describes the concept of agroforestry as deliberate growing of trees and shrubs, collectively called woody perennials, on the same unit of land as agricultural crops or animals, either in some form of spatial mixture or temporal sequence. In agroforestry systems there is significant interaction, ecological and economical, between the woody and the nonwoody components. Thus an agroforestry system normally involves two or more species of plants or plants and animals, at least one of which is a woody perennial. Additionally, all agroforestry systems are characterized by three basic sets of attributes, which are productivity (production of preferred commodities as well as productivity of the land's resources), sustainability (conservation of of the production potential of the resource base), and adoptability (acceptance of the practice by the farming community). Within the agroforestry systems, *Celtis africana* may fit in silvopasture, whereby woody perennials are incorporated with pasture or livestock. The prospects of agroforestry are as follows:

1. Trees can yield animal feeds through leaves, branches and fruits. The leaf litter can replenish the soil with nutrients as they fall and rot. Woody plants can provide fuelwood to the local communities.
2. The vegetation cover can provide shelter for the plants and animals. Most importantly, the vegetation cover can arrest soil erosion.
3. The leguminous pod-bearing trees can foster pasture growing underneath and improve soil fertility by of their rhizobial and mycorrhizal root systems as well as from the litter of their protein containing foliage.
4. Monocultures are avoided and, thus, total destruction by one type of disease or insects can be avoided.
5. Different crop types can explore different canopy and soil regimes for sunlight and nutrients. In this manner competition both above and underground can be avoided.

9.2.4 Tenure

A lack of land is a major concern in Lesotho. This situation leads to direct competition between forestry and agriculture, who are the main stakeholders in the land-use systems. Agriculture and forestry, other than having the problem of competition, are confronted with many similar problems (Figure 64). Lack of proper research in both fields restricts prospects for improvements and production in both fields but growing population (which is government problem) needs more food, fuelwood and building materials in order to address its basic needs. The rampant veld/range and forest fires adversely affect the two domains of production. The removal of forest cover by fires deprives agricultural land of its of its protective cover and render it susceptible to soil erosion. Both forest and agricultural plants are denied their symbiotic relationship. Illigal grazing is a common problem to both agriculture and forestry. In agriculture, overgrazing results from illegal grazing and overstocking and /or mismanagement of pastures. Forestry is mainly affected by illegal grazing. This point points out where agriculture and forestry are in conflict. The results of overgrazing are soil erosion.

In view of these serious socio-economic problems, forestry should diversify its list of priorities by incorporating, along with its traditional role, one also relating social forestry and agroforestry programmes at farm level. Of paramount importance is the fact that the merits of agroforestry systems are assessed not only in terms of quantities, but also on the extent to which the resource base is sustained and the practice is adopted by the local land-users.

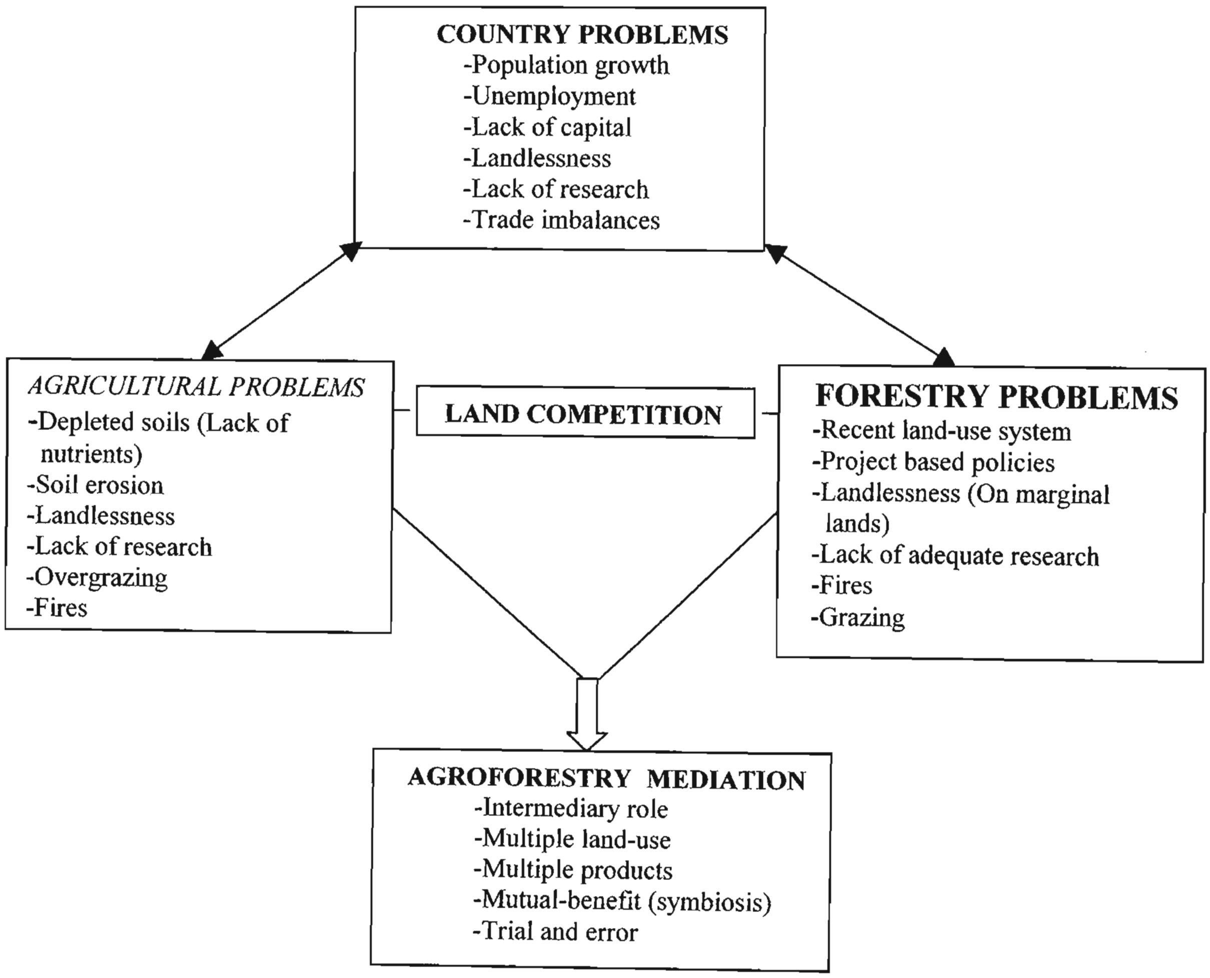


Figure 64: Interaction of country problems with those of forestry and agriculture

9.2.5 Forestry literature and education

Decision makers should relate new forestry issues to education. Material should be developed and curricula designed to address the importance and future role of indigenous trees in future land-use plans. Authors should be encouraged to bear the thought of education in mind when writing and publishing their books. Books should elicit the basic principle of " always move from known to unknown".

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APPENDICES NUMBERS 1 - 15

Appendix 1: Species which are found in association with *Celtis africana* in different Veldtypes (Acocks, 1953).

1. Coastal Forest and Thornveld.

Originally all coastal forest was supposed to be all forest but it is not today. It is recently an open thornveld with numerous and extensive patches of forests.The grasslveld is not pureand uniform but rather scrubby, full of tall herbs, shrubs and tall coarse grasses, showing how strong the successinalmovements towards forest is. The forest is mostly short (5-10 m high) but against the seaward –facing hills further inland it becomes taller and less tangled, being about 20 m high.It ranges from 450- 300 m above sealevel. It is evergreen except some of the largest trees in the dry seasons. The commonest trees of general occurrence (50% or more) including *C. africana*, are the following:

Millettia caffra	*Vepris lanceolata*
Ficus natalensis	*Rhus legati*
Kiggelaria africana	Combretum kraussi
Brachylaena discolor	*Acacia karroo* (at the margins)

2. Pondoland Coastal Plateau Sourveld.

This veld type occupies a plateau, at an elevation of 300- 450 m above the sea, rising steeply from the coast, and deeply broken and indented by forest-filled gorges. The escarpment is covered with the forests, which aretropical at the coast, but subtropical on the upper slopes and showing resemblance of Knysna Forest. The forests are mainly found in protected places, the escarpment, the gorges, and little valleys below krantzes. Trees, which are less generally occurring, *C. africana* included, are as follows:

Hippobiomas pauciflora	*Vepris undulata*
Brachylaena discolor	*Chaetacme aristata*
Podocarpus falcatus	*Ficus ingens*
Ficus sur	*Rhus chirindensis*

3. 'Ngongoni Veld.

This veld occupies a narrow and irregular belt of rolling country just above the Coastal Forest belt. It lies on the slopes of the escarpment of the lowest of the series of plateaux of which, South Africa is made up, and lying between ± 450 and 900 m above the sea. It is mainly dominated by 'Ngongoni (*Aristida junciformis*). Trees of less general occurrence including *C. africana* are as follows:

Syzygium cordatum	*Scolopia flanagani*
Olea capensis subsp. Macrocarpa	Cussonia spicta.
Trimeria grandifolia.	*Kiggelaria africana.*

4. Other Turf Thornveld.

This veld type is found where the norite forms hills, as it does in the southern strip of turfveld along the northern foot of the Magaliesburg, the vegetation is a dense, short bushveld, i.e. decidedly mixed, including species even of forest affinity such as *C. africana* and the following:

Acacia caffra.	*Ficus ingens.*
Cussonia paniculata	*Grewia flava.*
Euclea crispa subsp. Crispa.	*Rhus leptodictya*

5. Karroid Broken Veld.

In essence this is a Karroo veld dotted with dwarf trees and shrubs, and including varying amounts of grass and succulents. In this veld, *C. africana* is found in dominant grassy mountain scrub dotted with shrubs in association with the following:

Olea europaea subsp. africana.	*Aloe ferox.*
Grewia occidentalis	Cussonia paniculata
Rhus lucida.	*Kiggelaria africana.*
- erosa.	Maytenus undata.
Buddleja glomerata.	*Tarchonanthus camphorates.*

6. Mountain Renosterveld.

Celtis africana is found in this veld under the temperate and transitional forest, and scrub types of the veld. It falls under trees classified as of general occurrence. By " temperate forest " is meant the forest of relatively temperate habitats; although it includes a higher proportion of southern species than does the coastal forest, it is still essentially of tropical origin.

Podocarpus falcatus	*Calodendrum capense*
Cryptocarya woody.	*Maytenus acuminata var. acuminata.*
Pittosporum viridiflorum.	Ptaeroxylon obliquum.

7. The Dohne Sourveld.

The Dohne Sourveld lies at an altitude of 600-1 350 m above the sea level and is warmer and drier, receiving 650-1 000 mm of rain per annum, and no snow in winter except on the tops of the mountains. In this veld *C. africana* falls under trees of less general occurrence with the following:

Podocarpus latifolius.	Calodendrum capense
Ilex mitis.	*Heteromorpha trifoliate*
Scolopia mundii.	*Cussonia spicta.*
Kiggelaria africana.	*Maytenus peduncularis.*

8. Highland Sourveld to Cymbopogon-Themeda Veld Transition.

This veld type links the Cymbopogon-Themeda Veld with the Highland Sourveld in the highest and wettest part of Orange Free State, at altitudes ranging from 1 500-2 000 m above the sea level and a rainfall of 650-1 000 mm per annum. Principal species with Leucosidea sericea, becoming important at higher level, are found in association with *C. africana* together with the following:

Olea eoropaea subsp. africana.	*Kiggeleria africana.*
Rhus erosa.	*Buddleja salvifolia.*
Grewia occidentalis.	*Rhamnus prinoides.*

9. Natal Mist Belt 'Ngongoni Veld.

This is the transitional veld between the 'Ngongoni veld and the Highveld Sourveld lying at altitudes ranging from 900-1 350 m above the sea level and receiving 900-1 150 mm of rain per annum. In this veld, very little of the forest survives, except at the upper margin of the veld type where Podocarpus species are the dominants, but at lower levels they are scarce. The coastal forest element is so strong, however, that it might have been better to group it with the 'Ngongoni Veld. In this Veld *C. africana* together with the following species are of general occurrence:

Rapanea melanophloeos.	*Ficus natalensis.*
Cryptocarya woodii.	*Kiggelaria africana.*
Combretum kraussii.	*Podocarpus falcatus.*
Leucosidea sericea .	*Trema guineensis.*
Podocarpus hikelii.	*Scolopia mundii.*

10. Transitional Cymbopogon-Themeda Veld.

Transitional Cymbopogon-Themeda receives around 500 mm of rain annually. It runs down the middle of the Free State province in an irregular belt, deeply indented from the west by the drier valleys of tributaries of the

Vaal River, and from the east by wetter and sandier ridges. Had it not been that most of the rock in this belt is dolerite, the vegetation would be Cymbopogon-Themeda veld, but the heavy dolerite soil causes it rather to resemble the Turf Highland in being dominated by Themeda. The small escarpment, which bounds this veldtype on the west side has fairly rich thornveld flora, in which the following species (including *C. kraussiana*) are important:

Acacia karroo.	*Euclea laceolata.*
Olea africana.	*Ziphus mucronata.*
Buddleja salicifolia.	*Royena pallens.*
Grewia occidentalis.	*Cussonia spicta.*
Rhus lancea.	*Heteromorpha arborescens.*

11. Themeda-Festuca Alpine Veld.

This is the veld type of the Drakensberg above 1 850-2 150 m, receiving a rainfall ranging from 600 to over 1 900 mm per annum on the higher points. There was, and sometimes still is, scrub forest in sheltered kloofs, in which *Leucosidea sericea* and *C. kraussiana* are the dominants, along with the following:

Buddleja savifolia.	*Rhamnus prinoides.*
Buddleja corrugata.	*Myrsine africana.*
Olea africana.	*Cluytia pulchella.*
Rhus lucida.	*Polemannia grossu lariaefolia.*

12. The Northern tall grassveld.

This veld type is characterised by patches of Hyparrhenia. Otherwise, it is a sour veld completely dominated by *Tristachya hispida.* Typical species in the scrub forest in this veld, including C. kraussiana, are:

Acacia caffra.	*Acacia arabica var. kraussiana.*
Acacia karroo.	*Rubia petiolaris.*
Buddleja salicifolia.	*Halleria lucida.*
Cussonia spicata.	*Canthium ciliatum.*

Appendix 2: Vernicular and scientific names

Sesotho/venicular name	***Scientific name***
Cheche	*Leucosidea sericea*
Kolitsana	Rhus pyroidies
Lebelete	Salix mucronata
Lebetsa	*Halleria lucida*
Lehlahlabaroana	*Cliffortia ramosissima*
	" *indigofera*
Lehlaku	*Diospyros lycioides*
Lekhatsi	*Kiggelaria africana*
Lelothoane	*Buddleia salviiifolia*
Lelora	*Buddleja corrugata*
Lesika	*Grewia occidentalis*
Leoka	*Acacia karoo*
'Masa	*Osyris lanceolata*
Mofahlatoeba	*Melolobium microphyllum*
Mofifi	*Rhamnus prinoide*
Mohlakola	*Euclea crispa var. crispa*
Mohloare	*Olea africana*
Mohlomo	*Hyparrhenia hirta*
Mokhoamphiri	*Rhus undulata var, burchellii*
Molutu	*Celtis africana*
Monkhoane	*Heteromorpha arborescens*
Monyamafi	*Clutia pulchella*
Moopaqoma	*Pittosporum viridiflorum*
Morokapheleu	*Myrsine africana*
Mosinabelo	*Rhus gerrardii*
Motale	*Cassinoplsis ilicifolia*
Motsetse	*Cussonia paniculata*
Moqai	*Maytenus undata*
Phuku	*Ilex mitis*
Qoqolosi	*Scolopia mundii*
Ralikokotoana	*Euclea coriacea*
Seboku	*Themeda trianda*
Sefeamaeba	*Maytenus heterophylla*
Sekila	*Protea caffra*
Sehalahala	*Aster discoideus*
Seletjane	*Hermonnia depressa*
Serata-majoe	*Eragrostis caesia*
Thita-poho	*Eragrostis gummiflua*
Ts'aane	*Eragrostis racemosa*
Ts'inabelo	*Rhus erosa*

Appendix 3: The geological succecssion in Lesotho **(Bennie and Partners, 1972)**

Series	Formation (thickness)	Lithology.	Age.
Stormberg.		Intrusive kimberlite	Cretaceous
		Intrusive dykes and sills of dolirite, gabbro and basalt	Low Jurassic
	Drakensberg Beds (0 – 1500 m)	Basalt lava flows.	Low Jurassic
	Cave Sandstone (0 – 240 m)	Fine-grained buff sandstone, very occasionally bedded.	Low Jurassic
	Transition Beds (0 – 80 m)	Fine-grained red sandstone with some clay-shales and mudstone	Triassic
	Red Beds (15 – 260 m)	Buff red sandstone with thin clay-shale and mudstones.	Triassic
	Molteno Beds (15-150 m)	Coarse-grained white sandstones and grits, wit clay –shales and mudstones.	Triassic
Beaufort.	UpperBeaufortBeds (150 m)	Buff sandstone, with purple and red clay-shales and mudstone	Triassic

Appendix 4: Mean daily, average monthly and total annual evaporation (mm) (Russell, 1979)

Station	Jan	Feb	Mar	April	May	June	July	Aug	Sep	Oct	Nov	Dec	Total	Average
Butha-Buthe	230	197	178	125	110	84	97	139	181	212	215	245	2013	168
Letseng-laDraii	179	156	140	95	77	64	74	108	156	169	171	193	1582	132
Maseru	288	227	174	117	83	62	84	122	186	215	230	260	2040	171
Mokhotlong	225	184	176	121	114	100	102	158	193	225	211	211	2020	168
Oxbow	189	150	140	99	76	56	67	104	148	170	166	192	1557	130
Roma	280	218	139	95	84	60	75	107	165	207	155	225	1810	151
Thaba-Phatsoa	267	208	176	111	113	76	86	127	199	203	197	237	2000	167
Average	237	191	160	109	94	72	84	124	175	200	192	223	1861	155

Appendix 5: Extreme maximum temperatures (°C) at 7 stations (Russell, 1979)

Station.	**Nov.**	**Dec.**	**Jan.**	**Feb.**	**For the year**
Maseru.	34.9	37.5	39.4	35.3	39.4
Mohele's Hoek	35.7	35.4	38.5	35.0	38.5
Quthing.	33.5	39.0	36.0	34.0	39.0
Butha-Buthe	32.2	38.0	34.8	32.7	38.0
Roma.	35.0	34.0	35.5	33.5	35.5
Lekubane.	25.1	28.4	29.1	26.0	29.5
Letseng-la-Draai.	20.8	21.3	20.3	23.5	23.5

Appendix 6: Extreme minimum temperatures (^oC) at 7 stations (Russell, 1979)

Station.	**May.**	**Jun.**	**Jul.**	**Aug.**	**For the year**
Maseru.	-5.7	-8.4	-9.6	-7.0	-9.6
Mohale's Hoek	-6.2	-5.5	-4.8	-7.0	-7.0
Quthing	-4.0	-7.0	-6.0	-8.0	-8.0
Butha-Buthe.	-7.7	-8.4	-9.6	-12.8	-12.8
Roma.	-4.0	-9.0	-4.6	-6.5	-9.0
Lekubane.	-7.5	-6.9	-6.9	-9.4	-9.4
Letseng-la-Draai	-12.6	-20.4	-15.2	-16.6	-20.4

Appendix 7: Frost free days between average, last and first frost days by district, years of record and elevation (Russell, 1979)

District	Years of record	Elevation (m)	Extreme last frost	Average last frost	Average first frost	Extreme first frost	Frost free days between average last and first frost days
Leribe	29	1740	1st Dec.	14th Sep.	10th May.	7th Apr.	237
Teyateyaneng	28	1750	2nd Oct.	24th Aug.	2nd Jun.	5th Apr.	281
Maseru	29	1530	4th Oct	6th Sep.	18th May.	2nd Apr.	254
Wepener	27	1400	17th Dec.	3rd Oct.	1st May.	8th Apr.	209
Mafeteng	25	1610	13th Nov.	20th Sep.	19th May.	23rd Apr.	240
Mohale's Hoek	28	1600	1st Dec.	26th Sep.	11th May.	6th Apr.	226
Mokhotlong	21	2200	30th Nov.	13th Oct.	9th Mar.	19th Apr.	187
Thaba-tseka	11	2160	25th Dec.	21st Oct.	3rd May.	9th Apr.	193

Appendix 8: Basic land tenures under the Land Act of 1979

	PURPOSE	GRANTING AUTHORITY	DURATION	CHARGES PAYABLE	TRANSFERABILITY	INHERIBILITY	TERMINATION
ALLOCATION	Traditional uses, including both agricultural & mixed-purpose (residential/agricultural) holdings.	Land Committee	- to an individual for life or a shorter specified period; - to a legal person, for a limited or indefinite period	None	Cannot be sold	May be willed; in case of intestacy, to eldest son, or, if no son, to nominee of family.	By expiration fixed term, altermination for abuse ofholding as defined iregulations.
RURAL	For previous "registrable titles", for modernized agriculture; and for solely residential	Land Committee & commissioner of Lands; and if a lease is for industrial or commercial purposes, the Minister.	Not less than 10yrs, and subject to maximums that vary according to use.	Prescribed rents except residential leases rentfree	Can sell or mortgage with permIssion of Commissioner of Lands.	Same as allocation, unless lease is governed by written law.	by expiration offixed term; alsterminable for breach of termof lease.
LEASE	Residential, Commercial, and industrial purposes.	Urban Land Committee and Commissioner of Lands; and If lease is for Industrial or commercial Purposes, Minister.	Same as rural leases.	Prescribed rents (residential leases included) plus development charges where applicable.	same as rural leases.	same as rural leases.	Same as rural leases
LICENCE	Agricultural purposes.	Urban Land Committees and Commissioner of Lands	Not specified in Act, but presumably indefinite	Prescribed annual fee plus development charges where applicable.	Cannot be sold.	Not specified In Act, but generally not Inheritable.	Subject to terminatioat the will of the grantby three months notice.

Appendix 9 Distribution of woodlots by districts (Chakela, 1997)

District	Plantable area (ha).	Area (ha) planted Up to 1993/94.	Area (ha) Survived/ Actually Stocked.	*Area (ha) stocked with*			*Number of woodlots.*				Total no. of woodlots
				Eucalypts	*Pine*	Other	-10	-20	21-50	>50	
Maseru	3,95320.20	2478.40	1,590.65	534.20	927.15	129.30	68	89	22	3	114
Berea	1,188.30	1,111.70	807.75	508.75	288.70	10.30	50	63	3	2	68
Leribe	3,1186.25	3,064.80	1,798.75	1,241.05	495.20	65.50	38	56	14	7	77
Butha-Buthe	1,087.10	946.15	507.15	351.30	128.00	27.85	28	15	4	1	20
Mokhotlong	143.00	44.00	20.50	0.00	4.50	16.00	13	13	0	0	13
Thaba-Tseka	254.00	176.00	49.50	7.25	9.00	33.25	14	15	0	0	15
Qacha's Nek	461.40	211.00	34.30	1.50	29.10	3.70	23	23	0	0	23
Quthing	955.70	925.40	426.55	48.05	350.30	28.20	57	66	1	0	67
Mohale's –Hoek	688.75	484.10	441.25	160.40	263.05	17.80	24	40	10	1	51
Mafeteng	1,078.00	921.00	454.50	126.65	288.90	38.95	18	31	6	0	37
Total	12,995.70	10,362.55	6,130.90	2,979.15	2,783.90	370.85	333	411	60	14	485

Appendix 10: Tree ownership by choice of species (Green and Hall, 1989)

Tree type	**Number**	**Percent**	**Cummulative %**
Peach (*Prunus persica*)	413	45.8	45.8
Apple (*Malus pumila*)	48	5.3	51.2
Prune (*Prunus domestica*)	6	0.7	51.8
Pear (*Pyrus communis*)	9	1.0	52.8
Grape (*Vitis vinifera*)	15	1.7	54.5
Quince (*Cydonia oblonga*)	16	1.8	56.3
Apricot (*Prunus armniaca*)	82	9.1	65.4
Fig (*Ficus carica*)	3	9.1	65.4
Pine spp	50	5.5	71.3
Eucalypt spp	33	3.7	74.9
Wattle (*Acacia dealbata*)	26	2.9	77.8
Cypress (*Cuppressus arizonica*)	22	2.4	80.2
Poplar (*Populus canescence*)	82	9.1	89.3
Willow (*Salix babylonica*)	37	4.1	93.5
Locust (*Robinia pseudoacacia*)	7	0.8	94.2
Cedar (*Cedrus deodora*)	1	0.1	94.3
Cheche (*Leucosedea sericea*)	2	0.2	94.6
Pepper tree (*Schinus molle*)	6	0.7	95.2
Privet (*Ligustrum vulgare*)	1	0.1	95.3
Lelothoane (*Buddlea salviifolia*)	4	0.4	95.8
Mofifi (*Rhamnus prinoides*)	1	0.1	95.9
Mookane (*Crotalaria distans*)	1	0.1	96.0
Hedge (any)	1	0.1	96.1
Coco (*Cotoneaster frigida*)	1	0.1	96.2
Lehlaku (*Diospyros lycioides*)	2	0.2	96.4
Kolitsana (*Rhus pyroides*)	2	0.2	96.7
Mokhoamphiri (*Rhus undulata var. burchellii*)	6	0.7	97.4
Mosilabelo (*Rhus gerrardii*)	16	1.8	99.2
White stinkwood (*Celtis africana*)	1	0.1	99.3
Lekhala (*Agave americana*)	1	0.1	99.4
Mohloare (*Olea africana*)	1	0.1	99.5
Mohlakola (*Euclia crispa var. crispa*)	1	0.1	99.6
Melia azetarath	1	0.1	99.7
Other	3	0.3	100

Appendix 11: Raw data for dbh and height by plots

DARGLE

Plot 1			Plot 2		
Tree no	Dbh(cm)	Height(m)	Tree no	Dbh(cm)	Height(m)
1	17	09	1	22	17
2	22	09	2	11	08
3	28	10	3	12	07
4	29	10	4	39	25
5	32	11	5	27	17
6	33	14	6	84	36
7	39	21	7	20	08
8	68	17	8	75	24

FORT-HARTLEY

Plot 1			Plot 2		
Tree no	Dbh(cm)	Height(m)	Tree no	Dbh(cm)	Height(m)
1	17	07	1	21	09
2	16	08	2	25	11
3	17	09	3	26	11
4	18	10	4	27	11
5	30	09	5	31	10
6	29	13	6	30	11
7	34	12	7	40	13
8	43	15	8	44	15

MOKHALINYANE

Plot 1			Plot 2		
Tree no	Dbh(cm)	Height(m)	Tree no	Dbh(cm)	Height(m)
1	17	09	1	15	07
2	21	10	2	16	07
3	21	11	3	18	10
4	28	08	4	21	09
5	31	10	5	24	10
6	40	14	6	26	09
7	47	15	7	40	11
8	17	09	8	43	13

HILTON

Plot 1			Plot 2		
Tree no	Dbh(cm)	Height(m)	Tree no	Dbh(cm)	Height(m)
1	10	05	1	11	08
2	10	06	2	11	09
3	10	07	3	13	08
4	10	09	4	13	09
5	13	06	5	14	09
6	15	09	6	22	10
7	16	10	7	22	13
8	19	11	8	10	05

Appendix 12: Germination periods by different treatments since sowing to first germination and period completed after first germination

Locality	Treatment	Days since sowing to 1st day of germination	Days to complete germination since 1st germination	Total number of days to complete germination since sowing
Dargle	Manual-scar.	6	7	13
	Hot-water	7	9	16
	Acid	9	11	20
	Control	11	15	24
Fort-Hartley	Manul-scar.	7	11	18
	Hot-water	9	8	17
	Acid	9	9	18
	Control	14	14	28
Mokhalinyane	Manul-scar.	7	7	14
	Hot-water	9	9	18
	Acid	8	8	16
	Control	13	15	28
Hilton	Manul-scar.	8	9	17
	Hot-water	9	12	21
	Acid	10	9	19
	Control	14	11	25

Appendix 13: Results of germination variables per treatment and locality

Locality	**Treatment**	**Germination (%)**	**Germination energy**	**Germination value**
Dargle	Acid	99	97	44
Fort-Hartley	Acid	94	86	43
Mokhalinyane	Acid	97	93	50
Hilton	Acid	93	88	39
Dargle	Control	99	92	33
Fort-Hartley	Control	97	89	33
Mokhalinyane	Control	90	78	25
Hilton	Control	88	79	23
Dargle	Hot-water	100	93	56
Fort-Hartley	Hot-water	99	92	55
Mokhalinyane	Hot-water	100	85	51
Hilton	Hot-water	99	83	50
Dargle	Manual-scarification	100	83	73
Fort-Hartley	Manual-scarification	97	79	55
Mokhalinyane	Manual-scarification	100	86	64
Hilton	Manual-scarification	97	85	49

Appendix 14: Leaf measurements and colour interpretations

DARGLE				FORT-HARTLEY			
Length	Width	Book ref. No.	COLOUR	Length	Width	Book ref. No.	COLOUR
76	30	30 ED	Deep green	80	59	28 F5	Dark green
77	47	29 E6	Grayish green	62	36	28 F6	Dark green
70	38	30 E8	Deep green	57	36	28 F8	Dark green
40	29	30 E8	Deep green	48	33	28 E7	Dark green
50	29	29 E7	Grayish green	80	60	29 E8	Deep green
83	52	29 E7	Grayish green	50	34	29 F6	Dark green
38	28	30 E8	Deep green	48	26	29 E6	Grayish green
65	47	30 E7	Yellowish green	36	34	29 E8	Deep green
73	27	30 E8	Deep green	51	31	30 D6	Grayish green
70	40	29 E8	Deep green	29	16	29 E6	Grayish green
72	53	29 F8	Dark green	42	20	30 D6	Grayish green
49	47	29 E7	Grayish green	53	34	29 D6	Grayish green
75	42	29 F6	Dark green	42	28	29 F5	Dark green
70	34	29 E5	Grayish green	55	45	30 E7	Yellowish green
80	49	29 E8	Deep green	77	51	29 ED	Deep green
82	45	29 D7	Deep green	48	20	30 ED	Deep green
39	32	29 E8	Deep green	60	35	29 E8	Dark green
43	32	30 E8	Deep green	60	34	29 E6	Grayish green

MOKHALINYANE				HILTON			
Length	Width	Book ref. No.	COLOUR	Length	Width	Book ref. No.	COLOUR
75	44	30 E8	Deep green	40	29	28 F5	Dark green
38	25	29 E6	Grayish green	50	40	28 F6	Dark green
81	45	30 D6	Grayish green	57	40	28 F8	Dark green
53	25	30 E8	Deep green	85	50	28 F7	Dark green
61	36	29 E7	Grayish green	59	28	29 E8	Deep green
45	30	29 E7	Grayish green	50	33	29 F6	Dark green
77	51	30 E7	Yellowish green	40	23	29 E6	Grayish green
38	20	30 E7	Deep green	70	40	29 E8	Deep green
60	29	30 E8	Deep green	40	24	30 D6	Grayish green
40	24	29 E8	Deep green	65	50	29 E6	Grayish green
52	29	29 F8	Dark green	61	43	30 D6	Grayish green
44	21	29 E7	Grayish green	61	37	29 D6	Grayish green
90	47	29 F6	Dark green	52	25	29 F5	Dark green
56	41	29 E5	Grayish green	53	31	30 E7	Grayish green
43	20	29 E8	Deep green	40	26	29 ED	Deep green
63	37	29 D7	Deep green	21	16	30 ED	Deep green
53	35	29 E7	Deep green	38	38	29 E8	Deep green
45	23	30 E7	Yellowish green	30	21	28 F7	Dark green

Appendix 15: Raw data for wet and oven-dry weight, volume and moisture content

Locality	Tree no.	Sample	Wet weight	Dry weight	Volume	% MC
Dargle	1	a	0.71	0.55	1.36	29.09
		b	0.74	0.65	1.24	13.85
	2	a	0.60	0.55	1.05	9.09
		b	0.74	0.63	1.15	17.46
	3	a	0.58	0.54	0.90	7.41
		b	0.75	0.70	1.19	7.14
	4	a	0.76	0.67	1.22	13.43
		b	0.73	0.63	1.18	15.87
Fort-Hartley	1	a	1.37	1.21	1.67	13.22
		b	1.41	1.26	1.75	11.90
	2	a	1.16	0.99	1.51	17.17
		b	1.08	0.97	1.42	11.34
	3	a	1.26	1.14	1.67	10.53
		b	1.15	1.04	1.43	10.58
	4	a	1.17	1.09	1.66	7.34
		b	1.15	1.02	1.63	12.75
Mokhalinyane	1	a	0.62	0.55	0.81	12.73
		b	0.83	0.74	0.99	12.16
	2	a	0.80	0.71	0.91	12.68
		b	0.72	0.64	0.84	12.50
	3	a	0.84	0.75	1.07	12.00
		b	0.78	0.70	0.96	11.43
	4	a	0.71	0.64	0.90	10.94
		b	0.94	0.84	1.03	11.90
Hilton	1	a	0.83	0.74	0.94	12.16
		b	0.84	0.75	0.97	12.00
	2	a	0.76	0.70	1.03	8.57
		b	0.72	0.64	0.97	12.50
	3	a	0.81	0.75	0.99	8.00
		b	0.78	0.70	0.94	11.43
	4	a	0.85	0.75	1.05	13.33
		b	0.76	0.68	0.97	11.76