The use of scientific and indigenous knowledge in agricultural land evaluation and soil fertility studies of Ezigeni and Ogagwini villages in KwaZulu-Natal, South Africa

Nkosinomusa Nomfundo Buthelezi

Submitted in fulfilment of the academic requirements for the degree of
Master of Science in the Discipline of Soil Science
School of Environmental Sciences
Faculty of Science and Agriculture
University of KwaZulu-Natal
Pietermaritzburg

March 2010

DECLARATION

I hereby certify that the research reported in this thesis is the result of my own investigation, except as acknowledged herein, and that it has not been submitted for a degree at any other university.

Signed:_________________________ Date:_____________________

Nkosinomusa N. Buthelezi

Signed:_________________________ Date:_____________________

Professor J.C. Hughes
(supervisor)

Signed:_________________________ Date:_____________________

Professor A.T. Modi
(co-supervisor)

ABSTRACT

In the past, the indigenous knowledge of soils of small-scale farmers in South Africa has been largely ignored in scientific research. Hence the use of scientific approaches to land evaluation has often failed to improve land use in rural areas where understanding of the prescriptive scientific logic is lacking. Despite this, it is clear that local people and small-scale farmers have knowledge of their lands based on soil and land characteristics that remain largely unknown to the scientific community. It is therefore important for researchers to understand farmers' knowledge of soil classification and management.

To address this issue, a study was conducted in the uMbumbulu area of KwaZulu-Natal to investigate the use of indigenous knowledge as well as farmers' perceptions and assessments of soil fertility. A preliminary questionnaire was designed to explore indigenous knowledge in a group interview that was conducted prior to the study. Another questionnaire was used to elicit indigenous knowledge from 59 randomly chosen homesteads representative of the population of Ezigeni and Ogagwini villages. Six homesteads were chosen for further detailed information on the cropping history, knowledge specific to the cultivated lands, detailed soil description and fertility. Soil samples were taken from these homesteads under different land uses (taro, fallow, veld and vegetable) at 0-30 and 30-60 cm depth for laboratory analysis. This was done to determine the effect of land use on soil physical and chemical properties and soil microbial activity. For scientific evaluation a general purpose free soil survey was conducted to produce land capability and suitability maps.

Farmers identified ten soil types using soil morphological characteristics, mainly soil colour and texture. These soil properties were also used in the farmers' land suitability assessment. In addition, slope position, natural vegetation and village location were used to indicate land suitability. The amount of topsoil was also used in land evaluation. However, slope position was considered the most important factor as it affects the pattern of soils and hence their suitability. Soils on the footslope were considered more suitable for crops than those found on the midslope and upslope. The yield difference observed between villages, which were higher in Ogagwini than Ezigeni, was also used as a criterion for evaluation. Farmers attributed these yield differences for various crops to the effect of soil type on productivity. In support, scientific evaluation found that Ezigeni village had a number of soils with a heavy textured, pedocutanic B horizon and hence a relatively shallow effective rooting depth. Moreover, the Ezigeni village land suitability was limited in places by poor drainage and stoniness. These limitations were rarely found for the Ogagwini village soils.

Farmers had a total of six comprehensive and well defined soil fertility indicators, namely crop yield, crop appearance, natural vegetation, soil texture, soil colour and presence of mesofauna. Results showed that farmers' fertility perceptions are more holistic than those of researchers. However, despite this, their assessment correlated with soil analysis. There was a close relationship between scientific and indigenous suitability evaluation for three commonly cultivated crops (taro, maize and dry beans). This was further substantiated by yield measurements which were significantly higher for Ogagwini as rated by both farmers and scientific evaluation as the more suitable. The significant agreements between the scientific and indigenous approaches imply that there are fundamental similarities between them. Recognizing this and subsequently integrating the two approaches will produce land use plans relevant and profitable for both small-scale farmers and scientists.

PREFACE

The experimental work described in this thesis was carried out in the School of Environmental Sciences, University of KwaZulu-Natal, Pietermaritzburg, from July 2008 to November 2009, under the supervision of Professor Jeffrey C. Hughes and Professor Albert T. Modi.

This study represents original work by the author and has not otherwise been submitted in any form for any degree or diploma to any tertiary institution. Where use has been made of the work of others it is duly acknowledged in the text.

DECLARATION – PLAGIARISM

I, Nkosinomusa Nomfundo Buthelezi, declare that:

1. The research reported in this thesis, except where otherwise indicated, is my original research.
2. This thesis has not been submitted for any degree or examination at any other university.
3. This thesis does not contain other persons' data, pictures, graphs or other information, unless specifically acknowledged as being sourced from other persons.
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Signed: …………………………………………………………

Date: …………………………………..

ACKNOWLEDGEMENTS

I would like to extend my gratitude to the following:

Firstly, God Almighty for helping me realize my potential and for always coming through for me.

Professor Jeff Hughes for constantly believing in me, guidance, encouragement, and for academic assistance towards the completion of the study.

Professor Albert Modi for help with the project design, advice and soil survey.

South Africa Netherlands Research Programme on Alternatives in Development under project 05/32 entitled: "The social agronomy of compound agriculture: A case study of the dynamics of commercialization", and the National Research Foundation, Pretoria for funding the project.

Ezemvelo Farmers Organisation members for their availability for the interviews.

Victor Bangamwabo for help with digitizing the maps.

Dr. Dorothea Smith for help with the microbial activity analysis.

Tad Dorasamy for assistance and advice with laboratory analysis.

Jo Buthelezi, Ayanda Mthalane, Simphiwe Ngcobo and Vusi Mbanjwa for help with field data collection.

Dr. Shaun Ramroop for statistical advice.

Charity Maphumulo, Karen Caister and Ncebo Zulu for their help in the interviews.

Phesheya Dlamini for help and advice on various aspects of the study.

Lastly, my beautiful daughter, Siphokazi Dlamini, for the inspiration to finish this thesis.

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CHAPTER ONE
INTRODUCTION

The exponential increase in world population density and the introduction of land reforms have caused an increase in agricultural land degradation, often through overgrazing and agricultural mismanagement. This increase has caused a significant decrease in the arable land available for agriculture and increased use of energy, irrigation overuse and high fertilizer application (Apai and Navanugraha, 2004). On the other hand, economic recession has led to a large increase in agricultural land use, especially in rural areas, because people cannot afford to buy food. As a result, the increased pressure on the land has caused serious concerns for long-term agricultural sustainability and food security.

To recover and secure agricultural sustainability in both subsistence and commercial farming, there is a need to reassess our land evaluation systems. Scientists should consider both the direct methods of an indigenous approach and the indirect methods of the scientific approach. The latter evaluates the land based on the soil and site properties that can influence a particular land use, while the former evaluates by trial and error where the evaluator grows the crop or makes a construction and observes the response (McRae and Burnham, 1981). Krupenikov (1992) recorded that the direct methods have been used since the Stone Age and hence are of significant value to the local people. This was corroborated by Sandor *et al.* (2006) who mentioned that these methods employ the knowledge that has been accumulated by local people and passed down over generations from their interaction with the environment. Numerous studies have investigated the potential of integrating the indigenous knowledge system with the scientific system for improved agricultural sustainability (Payton *et al.*, 2003; Oudwater and Martin, 2003; Adedipe *et al.*, 2004; Gowing *et al.*, 2004; Cervantes-Gutiérrez *et al.*, 2005). It is hence likely that they will have a positive impact when included in land evaluation methods.

Land evaluation involves land use planning which informs all decision making done for the sustainable use of land resources (Gowing *et al.*, 2004). This process can be carried out in three ways namely suitability, capability and value (McRae and Burnham, 1981). However, the method most used for agricultural purposes is a suitability study which evaluates the land for a defined use or practice (McRae and Burnham, 1981). Unfortunately, land evaluation processes have been done mainly through soil surveys which farmers may not fully understand and which exclude the social and cultural aspects. Brinkman and Smyth (1972) reported that these factors are essential when conducting and interpreting land evaluation because it allows people to contribute to land use planning. They further stated that the concept of land can be closely related to that of a cultural ecosystem which includes the influence of man on land attributes. Therefore, understanding and incorporating indigenous knowledge and indigenous farming and management practices in land evaluation will ensure proper land use and resource management in rural areas.

A high production demand requires an increase in agricultural productivity. To achieve such high productivity, farming practices implemented by both scientific and indigenous approaches should ensure good soil fertility management. Soil fertility is the capacity of the soil to support the population of crops above-ground and is thus essential to sustainable agriculture as well as food security (Watson *et al*., 2002). The implemented land management practices should not only improve soil fertility but also ensure sustainability to prevent resource base degradation. The importance of soil fertility has led to the development of suitable management strategies which provide sustained and profitable production such as crop rotation, shifting cultivation and intercropping (Manna and Singh, 2001). These practices have been utilized in both scientific and indigenous approaches as means of soil conservation and increasing soil fertility for many centuries. They have been observed to have beneficial effects on nutrient availability and soil biological, physical and chemical properties.

However, agricultural intensification, mainly following the scientific approach, has reduced crop diversity through monocropping often resulting in low soil fertility status (Apai and Navanugraha, 2004). In the indigenous approach, intensified agriculture has caused farmers to decrease the fallow period also causing a decrease in soil fertility (McAllister, 1992). The decreased soil fertility observed under monoculture is a result of nutrient and water depletion due to a constant demand for the same nutrients over a long period of time, as well as an increase in the pathogen population (Turkington *et al*., 2004). Sound management strategies can be derived from information provided by soil fertility analysis. Soil tests assist in fertilizer recommendation hence preventing under or over application of fertilizers. According to Beegle (1995) the increase in fertilizer application rate has led to a decreased plant response. This consequently causes the unavailability of some nutrients due to nutrient imbalance. Soil acidity is another major concern for soil fertility management because low soil pH limits the availability of most plant nutrients. High application of fertilizers, especially nitrogen fertilizers, can elevate soil acidity and therefore result in a similar effect on nutrient availability. Even though acidic soils can be ameliorated through the application of lime there are high costs involved, especially for commercial farmers who are cultivating very large land areas. The use of low input systems in the indigenous approach, mainly practiced in rural areas, has shown high productivity with minimal management costs (Rajasekeran, 1993; Barrera-Bassols and Zinck, 2003a).

It is unfortunate, however, that there is almost no literature referring to indigenous knowledge of soils in South Africa. As mentioned previously such ignorance has resulted in the use of scientific approaches to land evaluation. These have often failed to improve land use especially in rural areas where prescriptive logic is lacking. Despite this, it is clear that local people have knowledge of their soils and have been using it for generations. This research is therefore aimed to gain a preliminary understanding of a much undervalued aspect of soil science that will allow further sustainability of our soil resource. The study focuses on two villages in KwaZulu-Natal, Ezigeni and Ogagwini, and aims to:

(a) explore indigenous and scientific knowledge systems in terms of land evaluation;
(b) compare indigenous and scientific land evaluation; and
(c) test farmer fertility management and assessment systems using scientific methods.

CHAPTER TWO
SCIENTIFIC AND INDIGENOUS LAND EVALUATION AND MANAGEMENT OF SOILS

2.1 Indigenous knowledge

2.1.1 What is indigenous knowledge?

Indigenous knowledge refers to the knowledge that has been accumulated by local people over a number of generations through their direct interactions with the land and environment (Sandor *et al*., 2006). This knowledge has been studied since the nineteenth century following the perceived failure of scientific methodologies and interventions to improve subsistence farming. Scientists have since recognized the value and potential of farmers' knowledge to improve agricultural development. To develop research methodologies aimed at collecting and documenting indigenous soil knowledge, a new discipline termed 'ethnopedology' was introduced. Ethnopedology is a "hybrid discipline structured from the combination of natural and social sciences" (Barrera-Bassols and Zinck, 2003a). The documented knowledge includes local perceptions of soil classification, soil use and management (Sandor *et al*., 2006), which are used to increase the relevance of scientific interventions as well as their adoption by farmers (Sillitoe, 1998). The incorporation of indigenous knowledge brings the 'locally informed perspective' into development strategies hence increasing their potential in small-scale, subsistence farming (Crevello, 2004).

The long-term interaction of local people with their land and environment led to the establishment of a historically and culturally-constituted indigenous knowledge (Altieri and Trujillo, 1987; Purcell, 1998; Sandor *et al*., 2006). The survival of indigenous knowledge through adverse field conditions for many centuries has proven it to be time-tested knowledge compared to the more recent scientific knowledge (Norgaard, 1984; Purcell, 1998). However, the dynamic nature and oral transmission of indigenous knowledge (Beckford and Barker, 2007) makes it more vulnerable to change with each new generation. The 'ecological rationale' of indigenous knowledge allows for the implementation of ecologically correct systems for the partitioning of natural resources (Alteiri and Trujillo 1987). Erkossa and Ayele (2003) refer to indigenous knowledge as an insight that the local people have on their natural and social environment which they use to adapt to their local context. This shows that this is not just merely knowledge but it is a skill and heritage of everyday life (Sillitoe, 1998) that is used as a basis for decision making not only in agriculture but also in human and animal health (Beckford and Barker, 2007). Indigenous knowledge has subsequently become a key aspect of local communities (Ogen, 2006).

Purcell (1998) stated that culture is essential to the existence of indigenous knowledge. Indigenous knowledge therefore becomes location specific and dependent on social customs, ethnicity, age, gender and wealth as well as interactions between and within communities (WinklerPrins and Sandor, 2003). For example, Birmingham (2003) found that a farmer's knowledge followed a land tenure pattern i.e., the farmer was more familiar with the land belonging to him. In addition, Sillitoe (1998) mentioned that such dependency limits the accessibility and potential use of indigenous knowledge.

Engel-Di Mauro (2003) studied the effects of gender relations and social standing on local soil knowledge and management in SW Hungary and he found that gender had a direct influence on soil classification and soil management. Low soil pH and macronutrient levels were measured in male-controlled cash crops and very high amounts of phosphorus on female-controlled subsistence plots. For soil classification, women used general descriptions while men had much more specific knowledge because of their exposure to education and training. This showed a direct relationship between gender and soil knowledge and management. From the results, Engel-Di Mauro (2003) then recommended further research on the effect of social relations on soil and soil dynamics.

The effect of age was shown by Birmingham (2003) in a study on local knowledge of soils in Ivory Coast. He found that adults had a broader and more detailed understanding of indigenous knowledge than the youth. The reason for this variation as given by farmers was that young people retain information only when it is written down. This shows the effect of modern training and education on the conservation, relevance and value of indigenous knowledge (Habarurema and Steiner, 1997). A study by Akullo (2007) in Uganda also outlined that education and training have prejudiced peoples' outlook on indigenous knowledge.

Another limitation to the use of indigenous knowledge is the question of its reliability and long-term sustainability. Bellon (1995) argued that there is no adaptive or direct functional link between knowledge and management. He further mentioned that for indigenous knowledge to contribute to long-term agricultural sustainability there should be an established functional relationship between specific knowledge and a particular management practice. Developing research methodologies to address this problem still remains a challenge.

The loss of indigenous knowledge through generation succession and introduction of new crop varieties has caused much uncertainty and doubt for many subsistence farmers over the years. Alteiri and Trujillo (1987) noted that the replacement of indigenous crop varieties with new hybrids and adoption of modern technologies limit the relevance of indigenous knowledge. This results in the loss of knowledge of traditional cropping patterns and management practices. However, despite all these limitations, scientific research has shown the relevance and significance of indigenous knowledge (Richards, 1985; Sillitoe, 1998; Payton *et al*., 2003; Sandor *et al*., 2006; Akullo, 2007; Dlamini, 2007; He *et al*., 2007). It is therefore important to ensure the continued survival of indigenous knowledge.

Modification of indigenous knowledge to fit the scientific approach has caused much degradation of such knowledge. To counteract this, recent studies have moved towards integrating indigenous knowledge with scientific knowledge to achieve an efficient system understood by both farmers and scientists (Habarurema and Steiner, 1997; WinklerPrins, 1999; Cools *et al*., 2003; Gowing *et al*., 2004). Such integration will guarantee the conservation of indigenous knowledge as well as its impact on long-term sustainability.

2.1.2 Indigenous soil classification and land evaluation

The increasing value of indigenous soil knowledge to agricultural sustainability has resulted in the documentation of farmers' knowledge so as to understand how they perceive and classify their soils (Shrestha *et al*., 2004). Niemeijer and Mazzucato (2003) mentioned that this indigenous soil knowledge forms a benchmark for communication not only between farmers but also between soil scientists, development workers and extension workers when compared to scientific classifications such as FAO, USDA Soil Taxonomy and French soil classifications. The integrative nature of indigenous knowledge is reflected in local classification systems which describe soils as a mixture of properties which are then combined and modified to build up descriptive classes (Sillitoe, 1998).

Indigenous soil classification uses physical and perceptual dimensions (Ettema, 1994; Talawar and Rhoades, 1998). Cervantes-Gutiérrez *et al*. (2005) simplified this further and said local people use their knowledge to classify soils according to appearance, characteristics and productivity. Local soil classification is based on day-to-day surface observations which provide a true reflection of reality that are thus more reliable and viable for land use (Sillitoe, 1998; Eriksen and Ardón, 2003). Although this system does not consider soil genesis, it does consider the factors that influence land evaluation such as topography, microclimate and vegetation (Sillitoe, 1998).

The physical properties predominantly used by farmers are soil colour and texture and they are considered as the basis of indigenous soil classification (Barrera-Bassols and Zinck, 2003a). For example, farmers in Niger perceive black soils as the most fertile and heavier in texture and hence less susceptible to erosion, while light coloured soils are regarded as infertile and easily erodible. Furthermore, a study by Shrestha *et al*. (2004) showed that there are many other properties that farmers use to classify their soils. Among these are soil structure, consistency, workability, stone content, water infiltration, water retention and requirement as well as manure requirement. Cervantes-Gutiérrez *et al*. (2005) carried out a study in Mexico and illustrated how farmers use soil properties to classify their soils (Table 2.1). They found that farmers only use the topsoil properties which they combine to classify the soil into classes according to their agricultural suitability.

Table 2.1. Ethnolinguistic terminology used in Zoyatlán, Mexico for diagnostic soil features and designation of the distinct properties of topsoil (modified from Cervantes-Gutiérrez *et al*., 2005).

Soil type	**Soil features**			**Topsoil properties**		
	Soil depth	**Soil colour**	**Fertility**	**Texture**	**Consistency**	**Water retention**
Tlalcapochtic	Deep	Black	High	Not clayey, not sandy "nibarrosa ni arenosa"	Loose "suelta"	Cold soil "suelo frio"
Tlaltezoquit	Deep	Black, brown	High	Clayey "barrosa"	Very sticky "muy pegajoso"	Very cold soil "suelo muy frio"
Texalli	Moderate to shallow	Brown, red	Good	Sandy "arenosa"	Very loose "muy suelta"	Hot soil "suelo caliente"
Tlalchiltic	Moderate	Red	Low	Not clayey, not sandy "nibarrosa ni arenosa"	Loose "suelta"	Hot soil "suelo caliente"
Xalli	Moderate to shallow	Grey	Low	Sandy "arenosa"	Very loose "muy suelta"	Cold soil "suelo frio"
Tlalnextli	Deep	White, ashy	Very low	Sandy to loam "arenosa a suave"	Loose "suelta"	Cold soil "suelo frio"
Tepetatl	Very thin	Red, black	Very low	Sandy and clayey "arenosa y barrosa"	Loose to firm "suelta a dura"	Not specified

The interpretation of the soil names given by farmers allows for almost a total quantification of the differentiating properties between soil classes which makes it valuable for agronomic classification. The study also demonstrated that farmers were well informed of the effect of environmental factors on soil characteristics as this knowledge guided their classification of soil into different types regarding quality, suitability and management.

In addition, Ettema (1994) found that farmers in Nigeria used taste and smell for agricultural evaluation. Taste was used to determine salinity and acidity. Smell was used to evaluate whether the soil is 'good' or 'bad'. He also found that farmers used vegetation, suitability of the land for a certain crop production, degree of soil degradation and soil organisms. Farmers observed the growth of vegetation prior to planting as well the presence or absence of organisms to evaluate soil quality.

The indigenous evaluation approach is characterized by a descriptive classification so that the evaluation is not based on a clear soil and land classification (Talawar and Rhoades, 1998). Furthermore, local soil classification systems are mainly focused on local soil taxonomies which do not adequately reflect the logic behind land use decisions thus limiting the use of local soil knowledge for sustainable development (Niemeijer and Mazzucato, 2003). Local soil classification is not only about local soil taxonomies but also reflects cultural and socioeconomic aspects (Barrera-Bassols and Zinck, 2003a). Unfortunately, the use of a comparative approach in most ethnological studies has excluded these basic elements of indigenous knowledge hence leaving out the practical implementation of local soil knowledge during the production process (Barrera-Bassols *et al*., 2006). This has confirmed the need to achieve an integrated methodological approach which will overcome the differences between the indigenous and modern systems (Sillitoe, 1998; Talawar and Rhoades, 1998; WinklerPrins, 1999). An integrated approach has been increasingly proposed as a relevant methodology as it recognizes the importance of the cultural context in understanding farmers' knowledge of local soil classification (Barrera-Bassols and Zinck, 2003a).

Indigenous land evaluation plays a vital role in land use decision making and land management in rural areas (Zurayk *et al*., 2001). It enables subsistence farmers to match their production systems to soil types by providing fundamental information on soils as they appear on a landscape (Bacic *et al*., 2003). Low cost and relevant scales make traditional surveys used as part of indigenous land evaluation more easily accessible to farmers

(Habarurema and Steiner, 1997). Traditional surveys are available at large scale that gives detailed information at a village level hence giving more insight into land use and agricultural production (Niemeijer, 1995). This has given indigenous evaluation more value to the extent that it is used to supplement scientifically based systems and conventional mapping techniques (Krasilnikov and Tabor, 2003). Indigenous knowledge improves the relevance and accuracy of scientific surveys which otherwise would not benefit local people (Sillitoe, 1998).

2.1.3 Indigenous soil management

According to Talawar and Rhoades (1998) indigenous soil management is more concerned about managing natural processes (e.g. erosion, nitrification etc.) as indicated by the nature of visible agricultural variables than single components such as soil, plants and water resulting from these processes. Using indigenous knowledge, farmers have managed to develop sustainable land use management practices to improve subsistence farming.

2.1.3.1 Soil fertility

Soil fertility is the primary factor affecting agricultural sustainability. It is therefore necessary to explore how this factor is affected by land use management practices. A case study by Desbiez *et al*. (2004) showed that farmers prefer the term ‘field fitness’ rather than ‘soil fertility’ to describe soils’ ability to produce crops. They perceive soil fertility as a function of current and previous management regimes. This explains why soil fertility *per se* is not a primary factor in local evaluation (Greenland *et al*., 1994 cited by Talawar and Rhoades, 1998). In addition, Sillitoe (1998) mentioned that farmers treat soil fertility as a dynamic character of the soils which they improve through maximizing crop diversity. He further stated that farmers also take advantage of climatic and soil variations to enhance soil productivity and increase yields. As soil fertility indicators, farmers use soil colour, crop performance in terms of yield, vegetation and environmental factors. For example, soil colour provides a good measure of inherent soil fertility (Barrios and Trejo, 2003). Even so, crop production indicators used by farmers such as yield and crop appearance may not always be a true reflection of soil quality (Marenya *et al*., 2008). For example, high yield can be a result of favourable weather or improved seed (Marenya *et al*., 2008). Despite this, Payton *et al*. (2003) still promote these indicators as a basis for environmental management as they provide accurate indications of environmental conditions. According to Fairhead and Scoones

(2005), farmers' perception of soil fertility is both a soil and social criterion as it is based on moral, religious and mythical frameworks.

2.1.3.2 Indigenous land use practices

The main objective of indigenous land use practices is to increase agricultural diversity which plays a significant role in resource conservation and protection (Barrera-Bassols and Zinck, 2003a). These practices provide soil health hence maintaining soil fertility and productivity (Rajasekeran, 1993). Indigenous land use practices do not only ensure good management of the land but are also concerned with environmental management (Tikai and Kama, 2004).

(a) Shifting cultivation, crop rotation and intercropping

The use of these practices began when people were still hunter-gatherers and land management was mainly dependent on social dynamics. For example, the idea of fallowing is referred to in the Bible as people realized the benefit of "resting" the land (Leviticus 25: 3-5; Reeves, 1997).

However, as the population increased and the land became scarce, people moved towards other cropping practises such as crop rotation, shifting cultivation and intercropping. Crop rotation involves the planting of different crops in a recurring sequence (Watson *et al*., 2002) while intercropping refers to the planting of different crops simultaneously (Richards, 1985). Shifting cultivation has been defined by Dvořàk (1992) as the 'alternation of periods of cropping with relatively long periods of fallow'. The beneficial effects of these practices are evident in soil physical, chemical and biological properties which influence soil fertility and determine the extent of soil degradation. A high degree of intra-specific and inter-specific crop diversity associated with these cropping systems reduces resource competition and enhances growth and productivity (Richards, 1985).

A case study conducted by Pestalozzi (2000) in the High Andes of Peru showed how people have manipulated the agricultural potential of this highly elevated area (4000 to 4500m above sea level) that has a low nutrient status to achieve relatively high yields through sectoral fallowing. In this management practice the field is left to lie fallow for nine years to allow for a high accumulation of biomass. Farmers mentioned that in fallowing vegetation has an essential role in restoring soil fertility by increasing organic matter accumulation. This was confirmed by laboratory analyses which showed that soils had high nitrogen and phosphorus content (91 and 12.5 kg ha^{-1}, respectively).

Fallowing was soon followed by the introduction of rotations with forage legumes, as population densities increased further (Reeves, 1997). A similar shift in land management was observed in the former Transkei (currently known as the Eastern Cape), South Africa in the study by McAllister (1992). He recorded that this increase in population pressure had a significant effect on agriculture from the 1940s. The benefit of rotations has also been observed when alfalfa is included. This crop is deep-rooted and is thus able to exploit nutrients from subsoil horizons which are then added to the upper layer when it decomposes (Gray, 1998). The legume-based rotation is an effective and a profitable way of restoring lost nutrients, mainly N, and improving soil properties especially under conventional farming (Belay, 2001).

The effect of legumes on nutrient availability is evident under intercropping. Intercropping legumes with cereals has been reported to better exploit mobile resources such as nitrates and soil moisture (Richards, 1985). Increase in soil moisture creates a favourable environment for microorganisms resulting in higher activity and biomass. In addition, intercropping has been observed to have a role in garden soil conservation (McAllister, 1992). Both intercropping and crop rotation assist in replacing the nutrients removed from the soil during harvest hence establishing a balanced nutrient cycling mechanism to prevent fertility depletion and increasing the sustainability of production systems (Grant *et al*., 2002). This is mainly through high mineralization of organic matter as a result of high microbial activity under these cropping systems (Haynes, 1984; Crevello, 2004). These cropping systems also provide diversity in agriculture which to a large extent prevents competition (Richards, 1985).

Manna and Singh (2001) conducted a long-term study (38 years) in western India to investigate the effect of intercropping on soil properties. The study compared intercropping and monocropping which is the dominant practice under intensive agriculture. Coconut and vegetable plots were planted under monoculture. Alternately coconut was intercropped with guava, sapota, banana, custard apple and litchi. The results showed a significant increase in mineral nutrients and soil organic carbon under intercropping as compared to monocropping (Table 2.2). This was attributed to high microbial activity and hence high mineralization of organic matter which results in the high release of nutrients.

For example under monoculture at site A available N was 177.1 mg kg^{-1} which was almost doubled under intercropping (301.6 mg kg^{-1}). Organic carbon also increased from 4.1 g kg^{-1} under monoculture to 8.6 g kg^{-1} under intercropping. Biomass content was found to be 222 and 841 kg ha^{-1} under monocropping and intercropping, respectively. This is probably due to the residue that is incorporated into the soil over a long period of rotation resulting in the high organic matter content.

Table 2.2. Organic carbon, pH and available nutrients after monoculture and intercropping in western India (modified from Manna and Singh, 2001).

Field crop	pH (1: H_2O)	Organic C (g kg^{-1})	Available nutrients (mg kg^{-1})							
			N	P	K	S	Fe	Mn	Zn	Cu
Site A										
1. Coconut	7.45	4.1	177.1	11.1	177.2	19.1	12.2	15.5	3.9	3.3
2. Coconut + sapota	7.39	8.6	301.6	13.2	249.3	23.4	21.9	17.1	4.3	3.8
3. Vegetables	7.67	9.5	289.3	11.1	249.2	71.7	27.9	17.8	2.5	6.0
4. Coconut + guava	7.87	8.9	289.1	13.0	312.5	48.7	39.1	12.9	2.8	6.9
SEM ±	0.08	0.5	9.7	1.2	3.8	6.8	3.9	0.8	1.1	1.2
LSD (p = 0.05)	NS	1.1	20.7	NS	7.9	14.3	7.9	1.7	NS	2.3
Original levels	7.60	3.4	166.8	3.0	43.0	16.3	10.0	13.2	2.8	2.1
Site B										
5. Coconut	6.80	3.2	185.1	5.1	85.3	8.7	20.9	32.9	1.7	3.1
6. Coconut + guava	6.50	6.3	277.4	9.1	134.2	3.9	30.9	47.9	1.1	3.1
7. Coconut + banana	6.72	7.0	277.6	13.0	151.2	9.3	22.1	37.2	0.9	3.4
8. Coconut + custard	6.83	5.7	216.3	7.1	90.3	5.6	22.5	42.2	0.9	3.0
9. Coconut + sapota	6.55	7.6	283.2	10.3	144.6	3.0	23.8	37.7	1.8	3.9
10.Coconut + litchi	7.10	7.3	321.1	11.1	141.3	14.0	16.3	27.9	1.7	3.8
SEM ±	0.17	0.5	6.0	1.6	5.6	2.2	2.7	3.1	0.4	0.4
LSD (p = 0.05)	NS	0.9	12.7	3.2	11.2	4.3	5.5	6.5	NS	NS
Original levels	6.50	2.4	150.9	2.4	80.1	2.8	18.3	25.3	0.8	1.3

The effect of the above-mentioned indigenous cropping systems is not only on the management of soil properties but also on weed, pest and disease management. When these cropping systems are employed they act as a defence against the build-up of disease-causing organisms (Gray, 1998) and are important for weed management (Reznicek and Jost, 1998). Under intercropping, if the intercrops are effective and competitive, they can discourage weed growth by rapid establishment thereby overshadowing weeds (Richards, 1985). Intercrops can also fight weeds through allelopathy (i.e., releasing harmful organic substances to prevent weeds from growing close to them). Rotations allow for the control of parasitic organisms by changing their host as the crops are changed every season.

(b) Nutrient supply from inorganic and organic sources

Farmers treat organic matter as the primary source of soil fertility because they can easily manage it through management practices such as crop residues, mulching and domestic manure (Hoffmann *et al*., 2001; Barrios and Trejo, 2003; Niemeijer and Mazzucato, 2003). These practises minimise soil disturbance and are beneficial to environmental issues such as land degradation, climate change and water quality (Dumanski *et al.*, 2006). Farmers appreciate the holistic nature and interaction of factors affecting soil fertility such as nutrient status, soil structure, moisture content and soil fauna and flora (Fairhead and Scoones, 2005). These practices supply plant nutrients while improving other soil physical properties (Doanh and Taun, 2004). Fairhead and Scoones (2005) observed that some farmers use weeds as fertilizing intercrops which assist in the utilization of nutrient flushes at the beginning of the rainy season.

However, the insufficiency of organic amendments and low nutrient concentrations associated with them has led to the use of mineral fertilizers. Sanchez *et al*. (1997) recorded that organic input may be as low as 10 to 40 g N kg^{-1} compared to 200 to 460 g N kg^{-1} from inorganic fertilizers. However, the high costs and large volumes of water required for these fertilizers to be effective limit their use to more wealthy households (Briggs *et al*., 1998). In some instances it has also been mentioned that the use of mineral fertilizers increases salinity levels of the soils (Briggs *et al*., 1998). Sanchez *et al*. (1997) also mentioned that fertilizer recommendations are often made to cover large areas with a variety of soils hence making it difficult for farmers to know the best fertilizer for their particular fields. These concerns associated with the use of chemical fertilizers have caused some small-scale farmers to run experimental trials to evaluate their impact on soil properties as well as on the resultant yield (Tamang, 1993 cited by Talawar and Rhoades, 1998).

2.1.4 Indigenous soil and water conservation

Soil erosion is a major problem worldwide and it has a direct effect on soil conservation due to the huge soil losses associated with it. This loss of soil results in nutrient depletion and a decrease in soil fertility and productivity (Doanh and Tuan, 2004). An initiative was taken to provide awareness of global concern about natural resource degradation after the 1992 Earth Summit held in Brazil (Talawar and Rhodes, 1998). It was clear that scientists needed to incorporate farmers' experiential knowledge of soils to ensure sustainable and effective soil and water conservation planning (Vigiak *et al*., 2005). There are many techniques that farmers have developed using indigenous knowledge to prevent the loss of soil and water. The following case studies highlight some of these indigenous techniques of effective soil and water conservation that scientist have documented.

He *et al*. (2007) in a study of traditional farming methods for soil conservation done in the hilly Sichuan region of China found that farmers have developed management systems known as *tiaoshamiantu* and *biongoubeigou* for steep slopes. These erosion management techniques involve the use of an excellent traditional drainage system widely adapted to the sloping land. The farmers build level trenches that separate their fields and which serve to trap sediments during rainy seasons and intercept runoff directing it to hill-side ditches which are cleared at least once a year. The results showed a low net soil loss of 24.15 t ha^{-1} yr^{-1} under these slopeland management practices as compared to 105.8 t ha^{-1} yr^{-1} . This shows the efficiency of these traditional management systems in controlling soil erosion. Interviews showed that farmers had so much confidence in them because they are both cheap and practical ways of preventing soil erosion while allowing a good harvest.

Doanh and Taun (2004) in a case study conducted in Tay, Vietnam found that farmers used cropping systems such as intercropping and relay cropping to reduce erosion. In addition to these practices they have also developed land use systems that integrate silviculture, animal husbandry and fishery in the landscape. To combat lowland erosion, farmers were using mulching to protect the soil and conserve soil moisture. Farmers mentioned that mulching not only helps in soil moisture conservation but also enriches the soil with nutrients from plant residues hence improving soil fertility. On very steep slopes, farmers build stone lines to intercept runoff. Similarly, the study done in Okhombe, KwaZulu-Natal (South Africa) found that local people use stone lines in combination with indigenous grass plugs and stone packs (Plate 2.1) (Everson *et al*., 2007).

In Cebada Jichana and Dami Rancho in Cochabamba, Bolivia, farmers used Eucalyptus trees to prevent gully formation and to protect irrigation canals (Thiele and Terrazas, 1998). However, for already existing gullies farmers used stones to fill them up. Farmers also used deep infiltration ditches along contours to protect the soil from erosion. For water conservation traditional ox-drawn ploughs were used to make shallow ditches. This was also observed by Tengberg *et al*. (1998) in eastern Kenya where farmers dug a backslope trench to trap rainwater for use in their agricultural fields.

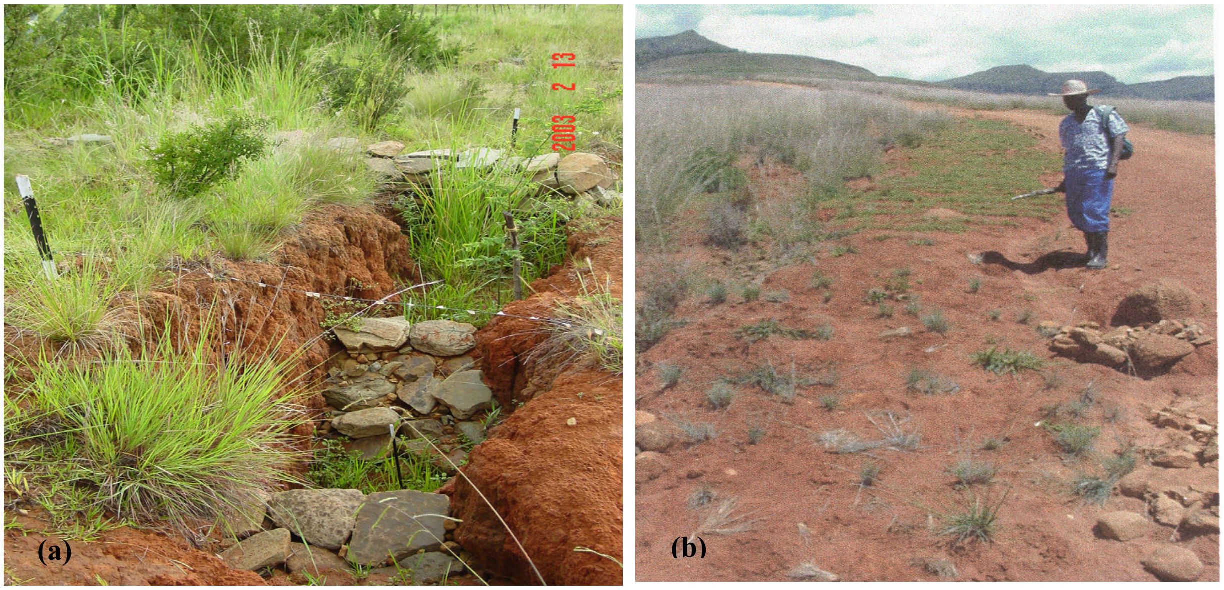

Plate 2.1. Techniques used by local people of Okhombe, KwaZulu-Natal to decrease the rate of soil erosion (a) stone packs and (b) indigenous grass (from Everson *et al*., 2007).

These case studies show the significant role played by indigenous knowledge in soil and water conservation. The advantages of applying indigenous conservation practices highlighted in the studies are their affordability and practicality. The various practices used in the study areas may be accredited to the differences in cultures and environmental conditions that influenced the farmers' knowledge. This, however, does not reflect any differences in the impact of indigenous knowledge across different cultures.

2.2 Scientific knowledge

The use of scientific knowledge was recognized during a "Period of Rapid Scientific Development (1800-1880)" after the introduction of scientific agriculture in the sixteenth century (Millar, 1955). Since then scientific knowledge has been applied in the study of soils and plant growth. This is the knowledge that is generated by scientific institutions such as universities and research institutes (Warren *et al*., 1991). It is therefore largely motivated by the values and cultures of Western civilization (Hammersmith, 2007).

Scientific knowledge is defined as "the product of an intellectual process of creating order out of disorder" (Cashman, 1991 cited by Stevenson, 1996), "through the help of empirical measures and abstract principles guiding it" (Agrawal, 1995). Unlike indigenous knowledge, scientific knowledge which is presented at a large scale can thus provide insights relevant in many different contexts (Agrawal, 1995). This shows that scientific knowledge relies only on information rather than context to provide meaning and understanding (Stevenson, 1996). For example, Fereyabend (1993) mentioned that scientific theories are measured by facts and experimental data. The theory can even be eliminated if not supported by data which are also produced based on ideational methodologies (Fereyabend, 1993).

However, despite these limitations scientific knowledge has made a vast contribution to agriculture. For instance, it provides the basis of land evaluation which is important in ensuring long-term natural resource sustainability. The following section discusses scientific land evaluation and its role in land use planning and management.

2.2.1 Scientific land evaluation

According to Ali *et al*. (2007) scientific land evaluation is considered a link to sustainable land management. This can be ascribed to the predictions it gives about long-term performance of the land which are then used in land use decision making (Bacic *et al*., 2003). Scientific soil surveys and soil mapping form the basis of scientific evaluation. They indicate soil properties and characterize soil units which are used to derive land use potential and response to management changes (Dent and Young, 1981). The choice of scale (1:5 000 (large-scale) to 1:200 000 (small-scale)) and type (i.e., free or rigid grid) of soil surveys are mainly dependent on the intended land use (Dent and Young, 1981). In a free survey, a surveyor can choose sites for profiles and samples whereas for a grid survey sampling is done based on a predetermined pattern following aerial photograph interpretation (Davidson, 1992). For practical applicability, the soil maps are usually supplemented with land capability and suitability maps (Krupenikov, 1992).

However, as much as capability and suitability maps have been used over many years, scientific evaluation has taken a shift towards more computerized methods. This is shown by the increasing use of geographical information systems (GIS) in the interpretation of soil properties for agricultural use and management (Barrera-Bassols *et al*., 2009). Through remote sensing, GIS has helped fill in gaps existing in scientific surveys and enabled their application for rural community land use management (Gowing *et al*., 2004).

In the South African context, GIS has played a great role in increasing the accuracy and value of land evaluation maps. This work was performed for the province of KwaZulu-Natal and is clearly reported by Camp (1999). The reason to incorporate GIS was to try to account for a wide diversity of natural resources resulting mainly from great variations in topography, climate and geology. This diversity had become a difficulty in the evaluation of site specific management. Using GIS the region was classified into agro-ecological zones (AEZ) and then further to Bioresource Groups and Units (BRU). Camp (1999) defines a BRU as an area with similar environmental factors which allow for uniform recommendations of land use and management. The BRU information provides suitability and capability potential of the area (e.g. crops that can be grown with their relative production levels). However, due to the continuous and unpredictable change of land use with time and space, land evaluation needs to be done repeatedly (Stewart, 1968). Therefore, BRU information can only be used as a benchmark when land evaluation is carried out in KwaZulu-Natal for farm planning.

The importance of laboratory analysis in scientific land evaluation cannot be overemphasized. Laboratory data provide support for recommendations and decisions made from a soil survey, especially regarding agronomic management (Dent and Young, 1981). The analysis is performed on the soil samples collected during a survey. For agricultural evaluation, soil samples are mainly analyzed for fertility, chemical properties (e.g. CEC, pH, organic carbon etc.), physical properties (e.g. particle size, aggregate stability etc.) and biological properties (e.g. microbial activity etc.). However, it is the fertility analysis which provides recommendations for fertilization and liming that is mostly used for farm management.

2.3 Soil fertility: Historical perspective

History is the essential component of science development which provides content to the theories science contains at any particular time (Fereyabend, 1993). It is therefore necessary to revisit the history of science in order to understand and be able to explain the currently observed behaviours and trends. This section aims to briefly review the history of soil fertility, how it has evolved over the centuries and how the developed theories have been used to understand soil behaviour. Agrawal (1995) described scientific knowledge as being built upon previous findings. The following historical review supports this statement as the existing scientific knowledge of soil fertility is based on many proposed earlier findings.

The period of rapid scientific development marked a significant stage in the study of plant growth. The attempts to understand the source of energy for plant growth started with the study by Theodore de Saussure in 1804. He found that plants acquired only nitrogen from the soil and carbon from the air. However, later studies by Thaer based on his humus theory were against Saussure's findings and argued that plants obtained carbon and other nutrients from the soil (Millar, 1955). From this statement it was then clear that soil fertility management should be based on the management of the soil humus balance (Feller and Manlay, 2001).

However, Thaers' humus theory did not hold for long as Von Liebig introduced the mineral theory in 1840. Liebig's studies were mainly focused on minerals (in the form of fertilizers), as they were then known as the only scientific method of maintaining soil fertility. Nevertheless, Grandeau in 1878 appreciated the role of humus in increasing the bioavailability of mineral elements. From his studies, Liebig derived a 'Law of the Minimum' which stated that "by the deficiency or absence of one necessary constituent, all the others being present, the soil is rendered barren for all those crops to the life of which that one constituent is indispensable" (Millar, 1955). These studies opened the route for recommendations on the use of fertilizers as a supplement for depleted minerals which are now widely used in agricultural institutes for advising farmers (Feller and Manlay, 2001).

As much as Liebig's theory was applauded and stole attention, its sustainability was still questionable. This led to the establishment of long-term field experiments at Rothamsted Experimental Station in the U.K by J.B Lawes in 1843. The study results showed that there was a greater increase in soil organic carbon when manure was added than when chemical fertilizers were added. In 1876, another set of long-term field experiments were set out in the Morrow Plots in Illinois, USA to investigate the effect of continuous cropping and soil amendments on soil properties and hence soil fertility. This study showed that fertilization increased soil fertility under rotation. In line with the Law of the Minimum, the study also demonstrated an average of 52% decrease in soil organic matter and soil fertility where no nutrient supplement was added. Boulaine (1989 cited by Feller and Manlay, 2001) also noted that the use of chemical fertilizers only accounted for less than 15% of the minerals taken up by the plants.

On the other hand, Feller and Manlay (2001) associated the use of chemical fertilizers with high rates of erosion leaving most of the land bare and unproductive. There was then a need for a sustainable alternative which would fulfill the Law of Minimum but yet not degrade natural resources. The Law of the Return which relied on the recycling of decomposed material to ensure organic flows for fertility maintenance gained favour, especially in organic farming (Feller and Manlay, 2001). This revived the role of humus in soil fertility establishment and caused a shift from the mineral theory. The role of humus in the biogeochemical cycle and C and N mineralization was shown to be the crucial driving element of the return (Feller and Manlay, 2001). The humus concept proved to have a holistic approach to soil fertility as compared to the reductionist approach of Liebig's mineral theory. This has caused Thaer's humus theory to regain popularity and value in sustainable farming as humus is the key factor in soil fertility.

The long-term field experiments (e.g. at Rothamsted and the Morrow Plots) provided the experimental data to evaluate sustainability of agricultural systems. This information is used in modern field trials as the basis for soil management and crop production (Millar, 1955). For example, the study by Paustian *et al*. (1992) recognized long-term field trials as a unique source of information on soil C dynamics and variations across a range of climatic and soil conditions as well as management regimes. Paustian *et al*. (1992) confirmed that these field trials provide the empirical data to evaluate the sustainability of agricultural systems. This was further emphasized by Rusmussen *et al*. (1998) and Richter *et al*. (2007) who argued that the information from the long-term field trials gives understanding of soil behaviour not only now but also for future predictions in agriculture. For instance, the Rothamsted trials showed that the intensive use of nitrogen fertilizers, especially ammonium and urea, exacerbates soil acidity (Goulding *et al*., 1998). In addition, de Ridder *et al*. (2004) noted that long-term field trials provide a good measure of fertility change as a result of soil processes influencing the nutrient status in the soil.

2.4 Integrating indigenous and scientific knowledge

Scientific studies have shown that there are similarities between indigenous and scientific knowledge systems (Ferguson and Messier, 1997; Huntington, 1998). According to Barrera-Bassols and Zinck (2003a) and Krasilnokov and Tabor (2003) this implies that these knowledge systems are both based on the same principles and goals. Abu-Lughod (1987) also noted that there has been a close interaction between the two systems since the 15^{th} century. However, there has been more emphasis on research into the differences between the two systems (Tsuji and Ho, 2002). These have been pointed out as epistemological (differences in knowledge attainment) and substantial (differences in subject matter) differences (Agrawal, 1995; Stevenson, 1996). In spite of these differences, the preceding discussion has suggested that there is a need for integration in order to achieve sustainability of agricultural systems. Often this is not easy to implement as scientific knowledge is not open to change (Briggs and Sharp, 2004). For successful integration, scientific knowledge must accept indigenous knowledge as being valid and not just as something to be preserved (Nadasdy, 1999; Briggs and Sharp, 2004). Another difficulty when integration attempts are made is communication which still remains a barrier to understanding and hence to incorporating local knowledge into scientific systems. The normally used qualitative methods such as questionnaires cannot always easily access the knowledge because of cross-cultural differences (Huntington, 1998). Even when the knowledge is acquired, translation decreases the value and meaning of indigenous knowledge and this also influences the contribution of this knowledge to development.

The advantages of integrating indigenous knowledge and scientific knowledge have been outlined in the scientific research (Sillitoe, 1998; Talawar and Rhoades, 1998; WinklerPrins, 1999; Payton *et al*., 2003; Oudwater and Martin, 2003). Hence, there have been a number of integration methodologies proposed (Payton *et al*., 2003; Sandor and Furbee, 1996; Habarurema and Steiner, 1997; Norton *et al*., 1998).) These include the use of qualitative database analysis and Geographical Information Systems (GIS) as an integration domain which was done by Payton *et al*. (2003) in the study conducted in East Africa and Bangladesh. Another methodology is the integration through the social learning approach which was done by Reed *et al*. (2007) in Kalahari, Botswana. Some other studies have used the comparison methodology to find possible correlations that can form the basis for integration (Birmingham 2003, Gray and Morrant, 2003; Oudwater and Martin, 2003). Such initiatives show that scientists have recognized that farmers hold valuable information about micro-scale variations within their environment (Cools *et al*., 2003). As much as scientific information can be very precise, its relevance to local people can be relatively low (Figure 2.1). Despite relatively low precision, local knowledge can be very relevant (Figure 2.1). This shows how both indigenous and scientific approaches will never be effective and sufficient as dichotomous entities but only as a unit.

Indigenous knowledge will provide scientists with insights into natural resource management valuable for local resource conservation (Krasilnokov and Tabor, 2003; Marenya *et al*., 2008). Having deeper insight, scientists will then be able to produce conventional surveys that can assist and enable them to make recommendations for a specific environment (Cools *et al*., 2003). The previous exclusion of indigenous knowledge has resulted in the failure of these scientific interventions in guiding rural land use decision making (Sillitoe, 1998; Barrera-Bassols and Zinck, 2003a, b). Such failure was recorded by Cleveland *et al*. (1995 cited by Norton *et al*., 1998) in Zuni, New Mexico where the introduction of agricultural systems to replace the beliefs and knowledge systems of local people led to land degradation.

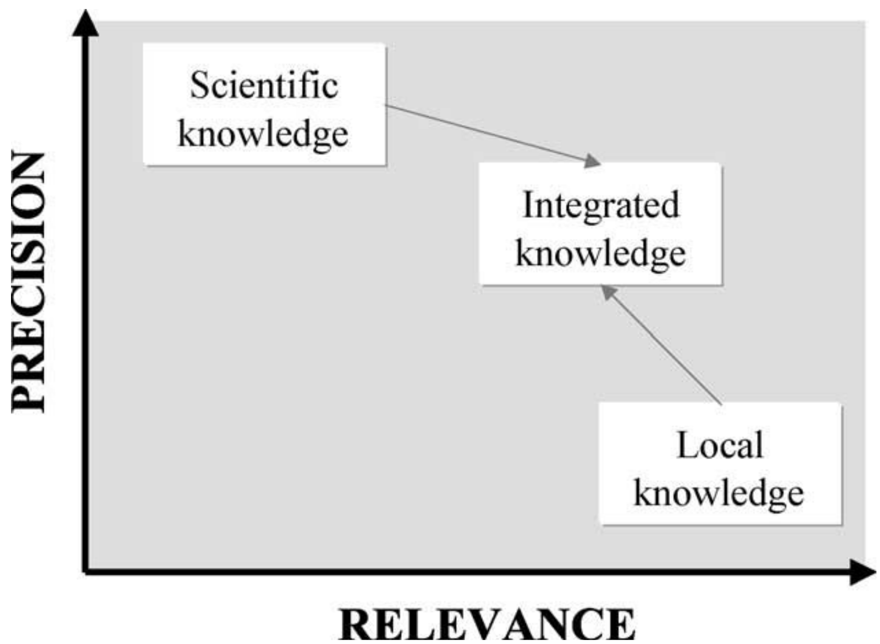

Figure 2.1. Schematic representation of the comparison between scientific and local knowledge systems (Cook *et al*., 1998 cited by Barrios and Trejo, 2003).

The relevance and adoption of soil surveys will ensure proper land use and management and hence low natural resource degradation and high agricultural sustainability. The integration can also be economically viable as detailed scale maps will be produced at low cost compared to the currently used remote sensing technology (Gowing *et al*., 2004). This will mean farmers can access survey information applicable at village level at a low cost. Moreover, the integrated knowledge will provide systems with a balance between empirical and prescriptive approaches.

2.5 Conclusion

Indigenous knowledge of soils shows the wisdom and experience of local people in living in harmony with nature. This is supported by some of the principles underlying modern science. Evaluation and management systems of the indigenous approach are mostly driven by the same key factors as those in the scientific approach. However, differences are noted in the ways both systems acquire knowledge. The scientific systems are formulated based on hypothetical facts and experimental data whereas indigenous systems are based on cultural and social factors driven by context. Such differences must not be overlooked if we intend a long and sustainable future for agriculture.

This review has shown that farmers have a comparative understanding of their environment accumulated over time. This is contrary to the limited understanding of land resource professionals derived from the scientific knowledge which has only existed for just a few centuries. However, indigenous knowledge has not added much value to large scale farming but, when integrated with scientific knowledge, can have a huge impact on agricultural land use. The integration of the different knowledge systems can provide consensus in terms of land use planning and management. This is because indigenous knowledge complements scientific knowledge and hence increases its contribution and impact, especially in rural areas. Also recognized in improving the relevance of scientific surveys is the inclusion of GIS in land evaluation systems. The relatively high cost of this tool, however, has limited its use only to trained personnel thereby sidelining the local people. It is therefore necessary to focus on integrating the two systems in order to sustain natural resources in a cost-effective way for both commercial and subsistence farming.

CHAPTER THREE
MATERIALS AND METHODS

3.1 Background

The study was conducted in two villages (Ezigeni and Ogagwini) of the uMbumbulu geographical area in KwaZulu-Natal (Figure 3.1).

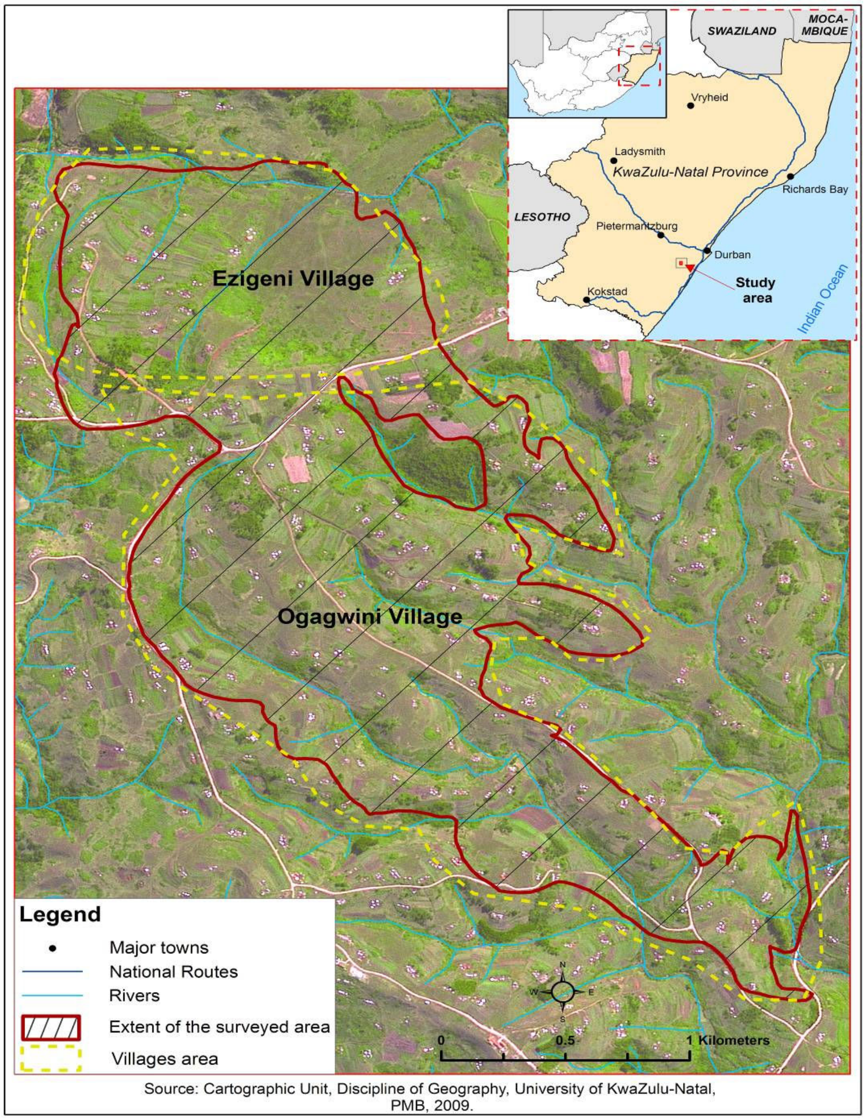

Figure 3.1. The location of Ezigeni and Ogagwini villages in KwaZulu-Natal.

The study site is located at 29° 59' 0" South, 30° 42' 0" East between 394 and 779m above sea level. The mean annual rainfall is 956mm with minimum and maximum temperatures of 18.2 to 25.2°C, respectively. Dominant vegetation is grassland, bush clump grassland and bush clump grassland with isolated forests (Camp, 1999). Only 22.9% of the 65.7% arable land has a high potential (Camp, 1999). This is attributed to the shallow depth and poor drainage of the soils. The BRU information (Camp, 1999) shows that the area is suitable for tomatoes, cabbages, sugarcane, maize and dry beans. Dry bean and maize require a maximum of 500 mm rainfall and 23^{o}C which falls within the climatic range of the BRU where the villages are located (Leibenberg, 2002; du Plessis, 2003). However, these climatic conditions are not adequate for *amadumbe* (taro) production which most of the farmers are currently planting in both villages. This is due to high water demand (1750 mm under dryland production) and a maximum of 27^{o}C (Kay, 1987), which exceeds the rainfall and temperature of the uMbumbulu area

3.2 Choice of study area

Members of the Ezemvelo Farmers Organization (EFO) reside in both Ezigeni and Ogagwini villages. This was the first South African subsistence farmer's organization certified to supply organic vegetables to supermarkets, after many years of growing indigenous crops such as maize and *amadumbe*. Farmers rely on indigenous systems such as crop rotation, crop residues and animal manure for soil fertility management. Primary crops cultivated for the market are *amadumbe*, sweet potatoes and potatoes. To ensure the continuing output of these farmers there was a need to assess the agricultural potential of their lands. The present study forms part of a larger South Africa-Netherlands research programme on alternatives in development (SANPAD) project with the objective to combine indigenous knowledge and scientific knowledge to investigate the potential of traditional crops in rural economic development.

3.3 Indigenous land evaluation

3.3.1 Household interviews

Interviews form part of the techniques used for participatory rural appraisal (Gowing *et al*., 2004). This technique was used to acquire soil indigenous knowledge (Appendix 1). For easy accessibility and accountability all respondents chosen were part of the EFO. These were randomly chosen and were representative of the population of both Ezigeni and Ogagwini villages. A questionnaire was produced for a preliminary group interview to test the farmers interest (Appendix 1(b)). Only 23 female farmers were present. Furthermore, this questionnaire was produced to test if the questions asked would be relevant and adequate to acquire the required information. This questionnaire was then upgraded to interview a total of

59 farmers individually from both villages to gain a general background of their indigenous agricultural land evaluation and management (Appendix 1(c)). Of the farmers interviewed only five were men. The questionnaire focused on local soil classification and its importance in land evaluation. To control for the lack of depth in farmers' responses, the interviews were open and hence there were follow-up questions in case the answer given was not satisfactory. The responses were sorted and fitted into single variables which were coded and statistically analysed.

Another questionnaire (Appendix 2) was produced to gather more detailed information on the deep understanding farmers have about their soils. To obtain this information, six (three from each village) of the 59 households were chosen. These were chosen based on the fact that their cultivated fields were characterised by generally comparable soil forms which were common for both Ezigeni and Ogagwini villages (i.e., Hutton and Oakleaf). Care was given to ensure that responses distinguished between indigenous knowledge and the practices taught by extension officers. The questionnaire required information on the cropping history, knowledge specific to the cultivated lands, and detailed soil description and fertility assessment.

3.4 Scientific land evaluation

3.4.1 Soil survey and mapping

A topographic map (1:10 000) was used as a base map. The soil survey was carried out through the free survey method (Dent and Young, 1981). The mapping unit boundaries were mainly determined by changes in topography with subsidiary indications from vegetation and parent material. Site properties (e.g. vegetation, position on the landscape) and soil properties were recorded at each mapping point. Auger points were taken from both villages and were georeferenced using GPS. Soil forms and families were classified according to the Soil Classification Working Group (1991). These data were then entered onto computer and delineated using ArcMap version 9.

Soils were classified for land suitability (for maize, taro and dry bean) and capability based mainly on soil form, depth and drainage. Depending on which of these were limiting, the soils would fall under one of the following suitability classes, namely very well suited (Sl), well-suited (S2), moderately suited (S3), poorly suited (S4), and not suited (N) for the specified use. For land capability, the land was rated in eight classes which include groups of capability units or sub-classes that have the same relative degree of limitation or potential (Davidson, 1992). These classes range from I to VIII in order of decreasing agricultural potential based on limiting factors that include erosion hazard (e), excess water (w), soil root zone (s) and climatic (c) limitations (Davidson, 1992).

3.4.2 Soil sampling and analysis

From the six homesteads chosen for detailed interview, a total of 24 representative soil samples were collected. Pairs of samples were taken from each homestead. Each pair consisted of sub-samples taken from 0-30cm and 30-60cm depth. The samples were collected from different management practices (i.e., fallow, veld, taro and vegetable production lands). However, not all six homesteads had all four land uses hence the total number of samples. The soils were analysed for pH, organic carbon, particle size distribution, fertility indicators and microbial activity.

Soil samples were air-dried and passed through a 2mm sieve before analysis. Soil pH was measured using a 1:2.5 ratio of soil:distilled water as well as a 1:2.5 ratio of soil:1M KCl. Particle size distribution was determined using the pipette method (Gee and Bauder, 1986). The potassium dichromate oxidation procedure was used to determine organic carbon (Walkley, 1947). For soil fertility, the samples were analyzed by the Soil Fertility Analytical Service at Cedara (Riekert and Bainbridge, 1998). For microbial analysis the soil samples were rewetted to 50% water holding capacity before carrying out microbial activity analysis. The 50% water holding capacity was calculated using texture and organic carbon (Smith, 1995; Smith *et al*., 2001). The samples were then incubated for four weeks to allow for the regeneration of microorganisms. They were then put in the refrigerator a day before the analysis. The analysis with two replications was done using the FDA (fluorescein diacetate) method (Schnürer and Rosswall, 1982).

3.4.3 Statistical analysis

The statistical analysis of the soil sample data was done using Genstat 11 by an analysis of variance. The least significant difference (LSD) was calculated at 5% level of significance. Farmers' responses were coded and grouped for a multivariate analysis using SPSS version 15. The status of indigenous knowledge was decided after comparing the similarities and differences in responses given by participants. These were represented by different codes which were entered into SPSS software.

3.5 Comparison methodology

Scientific and indigenous evaluation systems were compared based on the land suitability classifications. The information provided by the scientific suitability maps was compared to the vernacular suitability evaluation provided by the farmers. Farmers' fertility assessment was also compared with the scientific perception based on results of soil analysis. Yield was used as a quantifiable indicator to test the effect of fertility management practices implemented by Ezigeni and Ogagwini farmers. Yield measurements (in terms of harvested biomass) for maize, *amadumbe* and dry beans taken in the 2007/2008 growing season were used.

CHAPTER FOUR
RESULTS AND DISCUSSION

4.1 Household characteristics

The members of the EFO that participated in the study were involved in organic farming of mainly *amadumbe* (taro) and other crops such as dry beans, maize, potatoes, pumpkins and sweet potatoes. Farming is the livelihood for most of the households in uMbumbulu, hence food production is for both marketing and subsistence. Farmers only practice traditional farming, however, tractors are used for tilling the soil. Women are responsible for cultivation while the men are away working and only come home at weekends. Most households consisted of six to ten family members with a low level of education (Table 4.1).

Table 4.1. Household characteristics of EFO members interviewed from Ezigeni and Ogagwini villages.

Gender		***Education Level***	
males	5	not educated	6
females	54	grade 1 - 8	26
		grade 9 - 12	21
		higher education	6
Age		***Family size***	
< 30	15	1 - 5 members	11
31 - 45	15	6 - 10 members	31
46 - 55	13	> 10	11
>56	13		
Missing data	3		6

Table 4.1 shows that there were a comparable number of farmers across the age groups. The effect of gender was not investigated since there were very few males (5) compared to females (54). Table 4.2 shows that there was no significant effect of gender in the knowledge gathered. Most farmers had either grade eight or matriculation as the highest obtained level of education. The respondents with matriculation could not afford to go to institutions of higher learning hence these young people stay at home and are available to help in the fields. Even those that are still at school are taken to the fields during weekends and school vacations. Because of this exposure of young people to indigenous farming there was no significant effect of age and education on the knowledge elicited (Table 4.2). This is contrary to the results reported by Birmingham (2003) from Ivory Coast who found that older farmers had more detailed knowledge than younger farmers.

Table 4.2. Multivariate analysis showing the significance of age, gender and education level and their interactions on farmers' indigenous knowledge in Ezigeni and Ogagwini villages (n = 59).

Factors	F	DF	P
gender	0.18	1	0.894
age	0.457	1	0.237
level of education	1.163	4	0.345
gender* age	0.589	2	0.560
gender* education	0.456	1	0.504
age* education	0.602	8	0.770
gender* age*education	6.054	1	0.019

The combination of gender, age and education had a significant effect on status of knowledge (Table 4.2). Younger people because of their education are able to easily grasp the knowledge being passed onto them and may even be able to develop it and make it better.

4.2 Indigenous soil management

Farmers in both villages, with a few exceptions, own livestock and practice mixed cropping (Plate 4.1) and rotation systems (below-ground followed by above-ground type of crop) for fertility management.

Plate 4.1. Mixed cropping practice (beans, maize and taro) at Ezigeni village.

The area cultivated by farmers from both villages ranged from 0.6 to 4 ha. Respondents recommended frequent rotation in taro plots especially when planted in dark soils to avoid reduction in yield (Appendix 4). In a series of experiments by Asao *et al*. (2003) it was clear that such a decrease in yield can be attributed to a detrimental effect of taro root exudates. In the current study, farmers rotate taro with either maize or beans depending on the soil type and drainage in order to avoid this effect (Appendix 4). Farmers that have infertile soils in their fields had observed the positive response in yield when these soils are treated with large amounts of manure one or two months before planting (Appendix 4). Farmers use kraal manure, stubble mulch, and fallowing to replenish depleted nutrients (Appendix 3). However, the scarcity of these organic amendments has encouraged some of the farmers to try anaerobic composting suggested to them by an extension officer. Unfortunately, this alternative was not successful because of interference from pests (birds, wild hogs and soil organisms). Overall, despite similar management practices, farmers have observed that crops yield more when planted in Ogagwini soils and hence consider these soils more fertile than the soils of Ezigeni village (Appendix 4).

4.2.1 Indigenous soil classification

Farmers were only concerned with the topsoil as they use this part of the profile for their agricultural activities. This follows the trend which has been observed for all local classification systems (Sillitoe, 1998). Culture, which is an integral part of the farmers' belief in this region, does not allow digging as it is believed to anger the ancestral spirits. Subsoil is only seen when digging for a grave and hence is not important for the farmers' agricultural knowledge. This confirms the statement by Ettema (1994) that farmers' land evaluation focuses only on suitability of the land for production systems. As farmers were asked to critique the scientific approach they seemed to be concerned with the time and labour involved in this approach (Appendix 3). Hence their soil classification is based on descriptive characteristics rather than characteristics of the whole profile as it is in the scientific classification.

Farmers recognized ten soil types (Table 4.3). Farmers' classification was based on different soil morphological attributes but soil colour and texture were the key properties as they were said to relate to potential fertility and water retention. This is consistent with the results of Sandor and Furbee (1996) and Talawar and Rhoades (1998). These soil descriptive morphological properties are reflected in their soil taxonomy (Table 4.3). This shows that local soil classification is mainly concerned with land productivity (Ettema, 1994) as you can derive soil suitability from the soils' name.

Table 4.3. Local soil taxonomy used by farmers of Ezigeni and Ogagwini villages (n = 59)

Local name	Texture	Colour	Location	Uses
Ugadenzima	Clayey (*ubumba*)	Reddish black	Midslope	Agriculture
Idudusi	Loam (*uthambile*)	Black	Lower slope	Agriculture
Isibomvu	Clayey (*ubumba*)	Dark Red	Upslope	Agriculture
Udongwe	Clayey (*ubumba*)	Grey	Footslope	Agriculture
Umgogodi	Clayey (*ubumba*)	Grey	Footslope	Plastering
Isdaka	Clayey (*ubumba*)	Black	Footslope	Agriculture
Umgubane	gravelly (*ungamatshe*)	black or red	Upslope	Construction
Ugwadule	Clayey (*ubumba*)	black or red	Upslope	NS*
Isduli	Clayey (*ubumba*)	Black	Footslope	Agriculture
Ugedle	Sandy (*isihlabathi*)	Red	Upslope	Agriculture

* NS = Not specified

4.2.2 Land suitability assessment

In common with scientific evaluation, farmers recognized drainage and soil depth (referred to as the amount of topsoil) as limiting factors for land use. Farmers could not relate soil depth (as defined in scientific terms) to any production factor. They observed a low water holding capacity in red soils resulting in crop wilting especially under high temperatures. Poorly drained soils (e.g. *Isdaka*) mostly favoured the growth of taro. This is due to the large transpiring surfaces of taro and hence a huge demand for water (Mare, 2006). However, for other crops these soils were not "good" as perceived by the farmers because of their negative effect on yield. This was presumably due to waterlogging in these poorly drained soils that induces reducing conditions and hence oxygen depletion, low biological activity and nutrient availability (Schaetzl and Anderson, 2005).

In addition to colour and texture, farmers (58%) considered slope position as an essential factor affecting land suitability (Figure 4.1). Farmers preferred footslope soils for agriculture as these are regarded as more fertile when compared to upslope and midslope soils. They attribute this difference in fertility to removal and deposition of soil from upslope to downslope resulting in higher nutrient levels in footslope soils. Similar results were found by Barrera-Bassols and Zinck (2003b) in the study conducted in Mexico where farmers defined valley landscape soils as deep, multilayered and hence fertile.

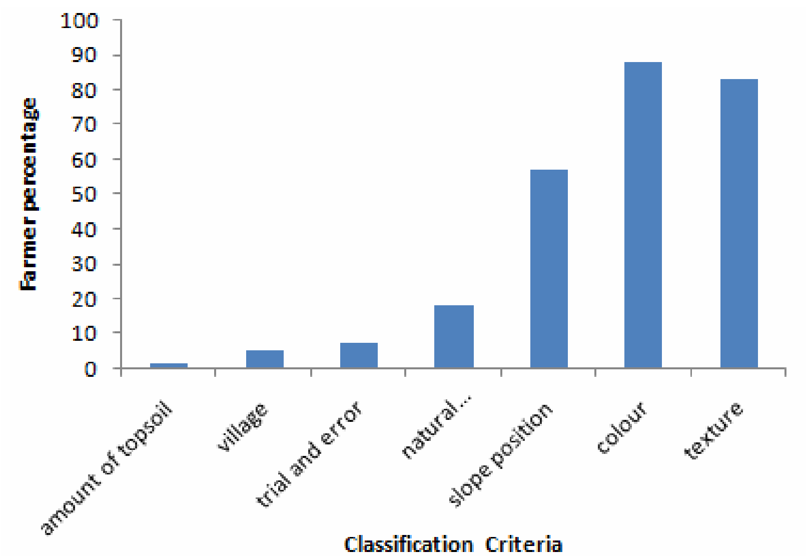

Figure 4.1. Factors considered for land suitability assessment ('natural…' refers to natural vegetation) by farmers of Ezigeni and Ogagwini villages.

Furthermore, farmers understood the role of slope position on soil erosion and hence on land suitability. They associated steep slopes with high soil erosion and such lands were not used for crop production. This factor is also considered in the scientific evaluation hence its use in the indigenous approach has shown high correlation between the two knowledge systems (Cools *et al*., 2003; Payton *et al*., 2003). According to the farmers, texture (described as soft, friable or hard) and "amount of topsoil" determined the extent of soil erosion. Sandy, shallow soils were regarded as the most susceptible to soil erosion as compared to heavy textured, deep soils. Farmers "preferred" any erosion event to occur during the early stages of growth because it is easier to replant than when it occurs during the later stages of crop development (Appendix 4). However, in both cases economic implications are inevitable. Farmers who cultivated on steep slopes used their indigenous knowledge and planted across the fields to avoid erosion. This practice of soil conservation was also reported for Transkei (South Africa) farmers who laid out their planting across the field (McAllister, 2002).

Twenty percent of farmers use natural vegetation focusing mainly on vegetative growth and species diversity. Consistent with a healthy soil ecosystem, farmers in these villages associated agriculturally suitable land with high species diversity (Mäder *et al*., 2002). Farmers were aware of the competition between the crops and weeds, and therefore the land is weeded just before planting and during the early stages of development. A small percentage of farmers used trial and error (8%), village (5%) and the amount of topsoil (2%)

for land suitability evaluation. In trial and error, farmers plant different crops on the same land alternately and the one that yields the best is the one grown thereafter on that particular land. This is an ancient criterion that has been identified by direct methods of indigenous knowledge evaluation (McRae and Burnham, 1981). Some farmer's land suitability evaluation was based on the differences they have observed between the soils from both villages, and hence they used villages as a classification criterion.

Farmers also had an understanding of the effect of soil type on land suitability for different crops (Table 4.4). The fertility status of the soils was derived from the responses given for Section 2 of Appendix 1(b). The effect of soil type has been observed by farmers in yield differences between the Ezigeni and Ogagwini villages. Higher yields have been observed for Ogagwini village. Farmers thus regard Ogagwini soils as more fertile because they do not demand large amounts of supplementary fertility inputs (Appendix 4). However, farmers did not have an explanation for these differences. Scientific evaluation showed that Ezigeni soils had many limitations to soil use which were rarely observed for the other village. These included soil depth, poor drainage and stoniness.

Table 4.4. Crop suitability according to Ezigeni and Ogagwini farmers (n = 59)

Local name	Fertility status*	Principal crops
Ugadenzima	Low to moderate	potatoes, maize, beans
Idudusi	High	maize, taro, beans
Isibomvu	Moderate to high	sweet potatoes, maize, beans
Udongwe	Moderate	beans, taro
Isdaka	Moderate to high	spinach, taro
Isduli	Low to moderate	taro, maize, beans
Ugedle	Low	potatoes, sweet potatoes

* Fertility status estimated from farmers responses

Despite deep soils (>120cm), a number of soils at Ezigeni were characterized by duplex character with a pedocutanic B horizon (Appendix 5) which has a heavy texture due to illuviation of clay from the overlying horizon (Soil Classification Working Group, 1991). As a result these soils have a shallow effective rooting depth. Moreover, some homesteads in both villages, but more especially in Ezigeni, cannot afford to pay for the tractor so their fields are tilled to the same depth every year resulting in the formation of a plough pan which further restricts root growth and hence decreases water and nutrient uptake (Rasmussen, 1999). Despite these differences between the villages, Table 4.3 shows that the soils in both villages are generally suitable for crop production. Farmers acknowledged that the soils in these villages had high clay contents. They recommend cultivating them when they are wet as they become very hard once they dry out and hence difficult to work.

4.3 Scientific land suitability assessment

A land capability map (Appendix 6) was produced to show the overall general potential of the study area. This map shows that most of the area has a high potential for arable use. This is in agreement with Camp (1999) who recorded that 65.7% of this BRU is arable. Capability class I had deep, well drained soils such as Hutton, Inanda, Oakleaf, and Clovelly with shallow and/or poorly drained soils such as Mispah and Willowbrook, for the non-arable classes VI and V, respectively. To show the potential of each village for specific agricultural uses suitability maps were produced (Appendices 7 to 12). Land suitability was rated for the three most commonly cultivated crops (taro, dry beans and maize).

Soil types mapped ranged from highly suitable, deep soils such as Hutton to the least suitable shallow soils i.e., Mispah and Glenrosa. Suitability maps for Ezigeni village (Appendices 7 to 9) show that a large part of this village has only limited agricultural potential. These limitations include soil depth (d), drainage (w), R (rockiness) and slope (Section 4.2.2). However, the extent of limitation from each of these physical constraints depended on the crop. Soil texture has an implication about long-term drainage conditions which together with soil depth affects rooting. For example, despite their depths, Valsrivier and Swartland were limited by a heavy textured, pedocutanic B horizon. Another example is the poor drainage of the Katspruit and Willowbrook soils. As a result only four out of the eleven classified soils were found highly suitable for crop production. Due to difficulties and high costs associated with fighting these limitations some areas remain permanently limited.

In contrast the Ogagwini suitability maps (Appendices 10 to 12) do not show many limitations to the production of dry beans, taro and maize, respectively. Of the six soil forms (Appendix 13) mapped for Ogagwini, four have moderate to high potential for agricultural production. This shows that Ogagwini village has a higher agricultural suitability compared to Ezigeni. This is similar to the farmers' suitability assessment for these villages. This shows that there are similarities between the farmers' decision on land use and that obtained by scientific evaluation and that these two systems share common principles and goals

(Krasilnokov and Tabor, 2003). Both systems have similar objectives which include ensuring proper use and management of soil resources for long-term sustainability and food security (Desbiez *et al*., 2004).

4.4 Farmer soil fertility indicators

Farmers in both villages had comprehensive and well defined indicators that they used to distinguish between productive and non-productive lands (Appendix 4 and 1(c)).Contrary to scientific assessment, farmers consider only morphological soil characteristics (Figure 4.2). They use a combination of indicators to rate the land as either 'good' or 'bad'. In scientific terms these lands will be either fertile or infertile, respectively.

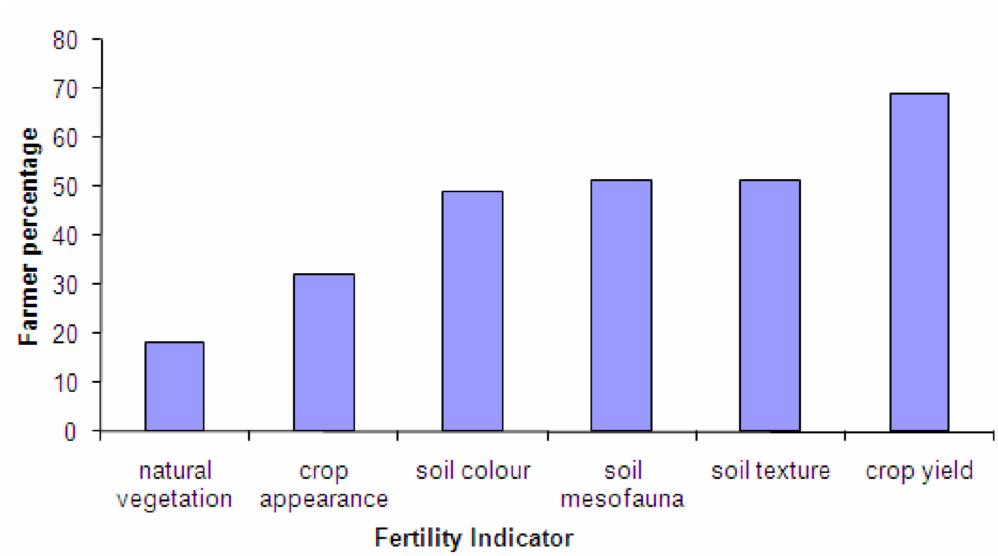

Figure 4.2. Local indicators identified by farmers in response to the questionnaire (Appendix 1) for fertility assessment of soils in Ezigeni and Ogagwini villages.

Soil colour was used with dark topsoils indicating higher fertility than lighter topsoils. For example, *Idudusi* is regarded as a good soil regardless of rain received. High fertility of dark soils may be attributed to higher organic matter content which is lower in lighter coloured topsoils (West and Post, 2002). This agrees with the known generally positive correlation between organic matter and soil fertility. Science has shown that high organic matter contents have generally beneficial effects on soil physical, chemical and biological properties (Manna and Singh, 2001). Dark colours are hence important indicators for fertility for both scientists and farmers even though the former will gain support from laboratory analysis. In this context soil texture referred to the 'feel' of the soil with 'soft' soils being a sign of the most fertile soils. Farmers further mentioned that 'soft' soils characterized by dark and deep characteristics give even greater yields.

Natural vegetation, especially weed growth and diversity observed before planting, also gave a statement about soil fertility in the villages of uMbumbulu. This is similar to the results obtained by Shaxson (1997 cited by Mairura *et al*., 2007) who found that in many sub-Saharan African countries farmers closely related soil quality to vegetation. In the current study, farmers used Blackjack (*Bidens pilosa* L.), *Amaranthus* species and '*ubhongabhonga (Ardisia crenata* Sims*) and 'isithenjane'* (*Cassia occidentalis* L) as indicators for highly fertile fields. Similary in Gachoka, Kenyan farmers were using these species to distinguish more fertile fields (Mairura *et al*., 2007). Fujisaka *et al*. (2000) also validated the use of weeds as soil quality indicators for fields of high agricultural potential. However, the presence of weeds may not always reflect soil conditions. For example, the growth of certain weed species may be a result of changes in cropping practice and soil management (Suarez *et al*., 2001). This shows that farmers may sometimes err in their fertility assessment.

Soil organisms are the other local indicator used for soil quality in Ezigeni and Ogagwini. The presence of soil mesofauna created an expectation of higher yield for the villagers. Farmers recognised earthworms as beneficial for soil fertility. This is in accordance with the findings of Murage *et al*. (2000) in a study conducted in Kenya. This is presumably because of the fundamental role of soil fauna in improving the soil structure and enhancing aeration, infiltration and water-holding capacity through excretion of their casts (Schaetzl and Anderson, 2005).

Amongst the indicators used by farmers, crop production factors are considered most reliable indicators of differences in soil fertility. These crop factors include crop appearance (crop colour and firmness) during the establishment stages, and crop yield, used by 35% and 72% of farmers, respectively. This shows that crop yield forms a benchmark for soil quality assessment in the indigenous approach (Gruver and Weil, 2006). Crop yield may not always reflect soil fertility conditions as it may also be affected by non-soil factors. As mentioned by Marenya *et al*. (2008) these non-soil factors may include management practices (e.g. seed type, time of planting etc.) and agroecological conditions (e.g. rainfall, pest incidence etc.). In cases where these factors have played a role in the measured yield (a likely common scenario) farmers will make a mistake in their fertility assessment.

However, despite this, it is clear that farmer fertility assessment is mainly concerned with food security which is highly dependent on land productivity. Mineral soil fertility did not inform any decision made by farmers on soil fertility assessment. However, this soil fertility component did have an indirect role in farmer fertility assessment. This role is evident when farmers use crop appearance (e.g. colour) as a fertility indicator. Crop colour is associated with the presence or absence of certain mineral elements. For example, yellowing of leaves has been shown by scientific research to be a symptom of nitrogen deficiency. Farmers did not use the term "fertility" but rather the ability of the land to produce. In the study by Desbiez *et al*. (2004) farmers were using the term 'soil fitness' instead of soil fertility. This term emphasizes the potential of the land, especially in terms of crop production as affected by soil management regimes and environmental factors (Desbiez *et al*., 2004). From this explanation it is clear that farmers in the current study also used 'soil fitness'. This differs from the reductionist approach of scientific researchers and it shows the more holistic view farmers have towards soil fertility.

4.5 Soil fertility analysis

Only two soil families (i.e., Hutton 2200 and Oakleaf 1210) were sampled from the six homesteads chosen for the detailed questionnaire. The following discussion is based on the assumption that these two soil forms would behave similarly under similar management. Both Hutton and Oakleaf are red or brown indicating good drainage, they are both very deep soils (>120cm) and both are formed from dolerite, the Hutton on *in-situ* rock; the Oakleaf on doleritic colluvium.

4.5.1 Plant nutrients and soil pH

Tables 4.5a and 4.6a show that the average soil pH (H_2O) was comparable across the two villages for both A (5.79 and 5.93) and B (6.07 and 6.00) horizons. There was a high acid saturation in all Ezigeni and Ogagwini soils. However, Ezigeni topsoils had a higher median average acid saturation value of 44% compared to 30% for Ogagwini topsoils. This inevitably results in a decrease in exchangeable basic cations (Foth and Ellis, 1997). Ogagwini soils therefore had higher plant nutrient levels than Ezigeni soils. For example, Ogagwini topsoils had an average available P content of 3.24 mg kg^{-1} compared to 1.88 mg P kg^{-1} in Ezigeni topsoils (Tables 4.5a and 4.6a) and the average effective cation exchange capacity (ECEC) of the soils from Ogagwini village was higher (5.09 and 5.03 $cmol_c$ kg^{-1} in the A and B horizon, respectively) than the soils from Ezigeni village (4.16 and 3.43 cmolc kg^{-1}, respectively). Calcium and P values were significantly different between homesteads ($p<0.05$). This may be due to past soil management (e.g. cultivation practices and addition of fertilizers) rather than intrinsic soil differences.

In addition to the effect of soil pH and acid saturation, N and Mg were significantly affected by land use ($p<0.05$). Although the overall nutrient levels were relatively low in the soils from both villages, there was moderately high N under cultivated land (i.e., taro and vegetable fields). This can probably be attributed to the N retained in cereals and vegetable residues, especially those from legumes, which are recycled during decomposition (Hartemink *et al*., 2000).

4.5.2 Soil organic carbon

Land use significantly affected ($p<0.05$) topsoil organic C (Tables 4.5a and 4.6a). The difference in organic C was significant between homesteads and between villages ($p<0.05$). The high organic C under vegetables at Ezigeni may have been provided by the residues left in the field and subsequently incorporated into the soils after harvesting (Ogle *et al*., 2005). The lower amount of organic C under taro in Ezigeni compared to Ogagwini may be due to differences in management, especially ploughing as this exposes previously inaccessible organic matter to microbial attack. Overall, the soils from Ezigeni village had higher organic C in both A and B horizons than the soils from Ogagwini village. This may be a reflection of the different soil textures as Ogagwini soils are generally sandier than those of Ezigeni allowing more rapid organic matter decomposition (Marhan and Scheu, 2005).

4.5.3 Soil particle size distribution

There was a relatively higher average amount of sand (48%) in the topsoils from Ogagwini village while the topsoils from Ezigeni showed high average silt content (42%) (Tables 4.5a and 4.6a). However, soils from both villages showed a comparable moderately high amount of clay (24% and 27% in topsoils; 30% and 35% in subsoils of Ezigeni and Ogagwini, respectively).

Table 4.5a. Soil chemical properties and particle size distribution of the A horizon of soils from Ezigeni village.

Homestead	Soil form and family	Land use	pH H_2O	pH KCl	N %	P mg kg^{-1}	K cmol$_c$ kg^{-1}	Ca cmol$_c$ kg^{-1}	Mg cmol$_c$ kg^{-1}	H cmol$_c$ kg^{-1}	ECEC cmol$_c$ kg^{-1}	Acid saturation %	Organic Carbon %	Clay %	Silt %	Sand %
F. Mkhize	Oa 1210	Veld	5.65	4.40	0.60	1.92	0.04	2.58	0.88	1.13	4.63	24	7.6	11	54	35
Mbili	Oa 1210	Fallow	6.01	4.44	0.33	1.08	0.01	0.94	0.50	1.51	2.96	51	5.9	21	44	28
Bhengu	Hu 2200	Fallow	5.83	4.35	0.29	1.85	0.04	0.97	0.30	1.30	2.61	50	5.3	27	40	33
Mbili	Oa 1210	Vegetables	5.79	4.16	0.28	3.09	0.08	1.70	0.86	2.62	5.25	50	5.1	31	40	29
Bhengu	Hu 2200	Vegetables	5.51	4.35	0.33	3.16	0.07	1.00	0.51	1.57	3.15	50	6.1	16	45	39
F. Mkhize	Oa 1210	Vegetables	5.77	4.58	0.41	1.08	0.06	2.17	0.59	0.74	3.56	21	8.1	20	48	32
Mbili	Oa 1210	Taro	5.97	4.15	0.23	0.97	0.05	3.98	1.77	1.15	6.94	16	2.7	43	22	34
		Mean	5.79	4.35	0.35	1.88	0.05	1.91	0.77	1.43	4.16	37	5.8	24	42	33
		Median	5.79	4.35	0.33	1.86	0.05	1.80	0.68	1.37	3.86	44	5.9	23	43	33

Table 4.5b. Soil chemical properties and particle size distribution of the B horizon of soils from Ezigeni village.

Homestead	Soil form and family	Land use	pH H_2O	pH KCl	N %	P mg kg^{-1}	K cmol$_c$ kg^{-1}	Ca cmol$_c$ kg^{-1}	Mg cmol$_c$ kg^{-1}	H cmol$_c$ kg^{-1}	ECEC cmol$_c$ kg^{-1}	Acid sat. %	Organic Carbon %	Clay %	Silt %	Sand %
F. Mkhize	Oa 1210	Veld	6.15	4.58	0.46	1.19	0.02	1.27	0.43	0.94	2.66	35	7.4	11	42	47
Mbili	Oa 1210	Fallow	6.25	4.49	0.33	1.04	0.01	1.14	0.57	0.98	2.70	36	3.9	19	39	42
Bhengu	Hu 2200	Fallow	6.27	4.53	0.26	1.09	0.02	1.34	0.62	0.62	2.60	24	3.0	43	40	17
Mbili	Oa 1210	Vegetables	6.00	4.25	0.29	2.08	0.06	1.58	0.81	2.25	4.69	48	4.5	35	36	29
Bhengu	Hu 2200	Vegetables	5.90	4.49	0.30	1.11	0.07	0.66	0.50	0.88	2.11	42	3.8	28	37	35
F. Mkhize	Oa 1210	Vegetables	6.13	4.62	0.43	1.11	0.06	1.76	0.51	0.66	2.98	22	6.3	18	43	39
Mbili	Oa 1210	Taro	5.80	4.08	0.18	0.97	0.04	2.89	1.54	1.77	6.24	28	2.5	56	14	30
		Mean	6.07	4.43	0.32	1.23	0.04	1.52	0.71	1.16	3.43	34	4.5	30	36	34
		Median	6.10	4.49	0.31	1.11	0.04	1.43	0.60	0.96	2.84	34	4.2	29	38	35

* ECE C- effetive cation exchange capacity (sum of bases + H)

Table 4.6a. Soil chemical properties and particle size distribution of the A horizon of soils from Ogagwini village.

Homestead	Soil form and family	Land use	pH		N	P	K	Ca	Mg	H	ECEC	Acid sat.	Organic Carbon	Clay	Silt	Sand
			H_2O	KCl	%	mg kg^{-1}	……cmol$_c$ kg^{-1}……					……%……				
Z. Mkhize	Hu 2200	Veld	5.75	4.24	0.25	2.83	0.05	2.55	1.83	1.12	5.56	20	3.6	33	22	45
Z. Mkhize	Hu 2200	Fallow	6.28	4.15	0.24	2.78	0.04	1.65	0.93	1.91	4.53	42	3.7	23	24	53
Gasa	Hu 2200	Fallow	5.92	4.40	0.34	3.30	0.06	2.60	1.30	1.09	5.05	22	4.9	19	23	58
Gasa	Hu 2200	Taro	5.98	4.45	0.22	1.06	0.02	2.37	1.24	0.97	4.61	21	3.8	42	34	24
Ngcamu	Hu 2200	Taro	5.73	4.08	0.29	6.25	0.06	0.50	0.22	4.91	5.69	86	4.1	19	23	58
		Mean	5.93	4.26	0.27	3.24	0.05	1.93	1.10	2.00	5.09	38	4.0	27	25	48
		Median	5.93	4.25	0.26	3.04	0.05	2.15	1.17	1.52	5.07	30	3.9	25	24	50

Table 4.6b. Soil chemical properties and particle size distribution of the B horizon of soils from Ogagwini village.

Homestead	Soil form and family	Land use	pH		N	P	K	Ca	Mg	H	ECEC	Acid sat.	Organic Carbon	Clay	Silt	Sand
			H_2O	KCl	%	mg kg^{-1}	……cmol$_c$ kg^{-1}……					……%……				
Z. Mkhize	Hu 2200	Veld	5.80	4.27	0.24	2.35	0.04	2.42	2.20	1.35	6.02	22	3.2	36	22	42
Z. Mkhize	Hu 2200	Fallow	6.08	4.22	0.20	4.44	0.03	2.11	1.43	1.77	5.33	33	3.3	38	16	46
Gasa	Hu 2200	Fallow	6.25	4.44	0.27	2.22	0.03	1.99	1.18	1.01	4.21	24	4.5	36	37	27
Gasa	Hu 2200	Taro	5.93	4.47	0.29	1.90	0.04	3.24	1.57	0.63	5.48	11	4.6	41	42	27
Ngcamu	Hu 2200	Taro	5.93	4.20	0.30	1.87	0.03	0.84	0.32	2.92	4.11	71	4.0	23	27	50
		Mean	6.00	4.32	0.26	2.56	0.03	2.12	1.34	1.54	5.03	32	3.9	35	29	38
		Median	5.96	4.30	0.27	2.29	0.03	2.12	1.39	1.44	5.18	28	4.0	36	28	40

* ECE C- effetive cation exchange capacity (sum of bases + H)

Tables 4.5 and 4.6 show higher amounts of organic C and less sand in soils of Ezigeni. However, the ECEC of the soils is, on average, lower than soils of Ogagwini. Soils in both villages have high acid saturation with correspondingly low amounts of exchangeable bases. It should be noted, however, that the average acid saturation values for Ogagwini is inflated by those of the Ngcamu homestead (86% and 71% in A and B horizon, respectively). If this value is omitted the mean acid saturation drops to 26% in the topsoil, compared to 37% in the Ezigeni topsoils. The same homestead has the highest available P value (6.25 mg kg^{-1}) but even this, and the generally higher P in Ogagwini soils, would be deficient for most crops (Johnston *et al*., 1991). The pH_{KCl} values are also similarly low in all soils from both villages. In general it appears from this dataset that the soils in the two villages are not very different in terms of their fertility parameters and that the most marked differences are most likely due to differences in management practices (Desbiez *et al*., 2004).

4.5.4 Soil microbial activity

Microbial activity was higher under veld and fallow than under vegetable and taro (Figure 4.3). A high microbial activity under veld is due to high organic matter turnover providing enough energy for microorganisms. Moreover, veld provides favourable undisturbed conditions for the development of microorganisms.

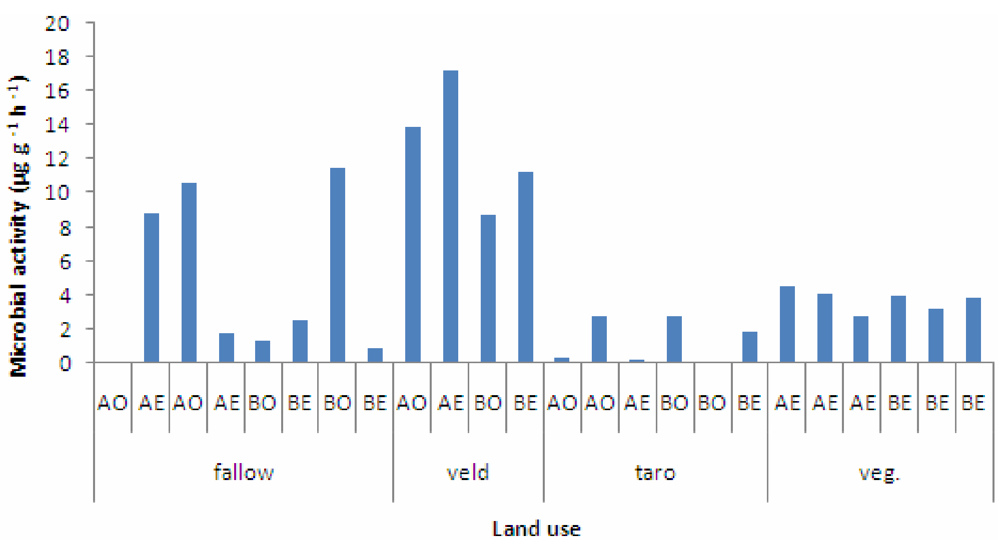

Figure 4.3. The effect of land use on microbial activity in A and B horizons of soils from Ezigeni (E) and Ogagwini (O) villages.

Low microbial activity under taro in Ezigeni soils may be due to very low organic matter. However, in Ogagwini soils under the same land use, the low microbial activity may be attributed to high clay content (42%). High clay content has been shown to decrease microbial activity by causing anaerobic conditions in inner parts of soil aggregates (Thomsen *et al.*, 1999).

4.6 Yield

Both scientific and farmer suitability evaluation found Ogagwini village to be more highly suitable for maize, taro and dry beans than Ezigeni. This was further confirmed by yield measurements. Figure 4.4 shows higher yields for Ogagwini village for all three crops. However, the highest average yield recorded for maize (3.7 Mg ha^{-1}) and taro (4.2 Mg ha^{-1}) is very low compared to optimum commercial yields of about 10 and 20 Mg ha^{-1} for these crops, respectively. This is probably a result of the low fertility of these soils as indicated by the analyses (Section 4.5).

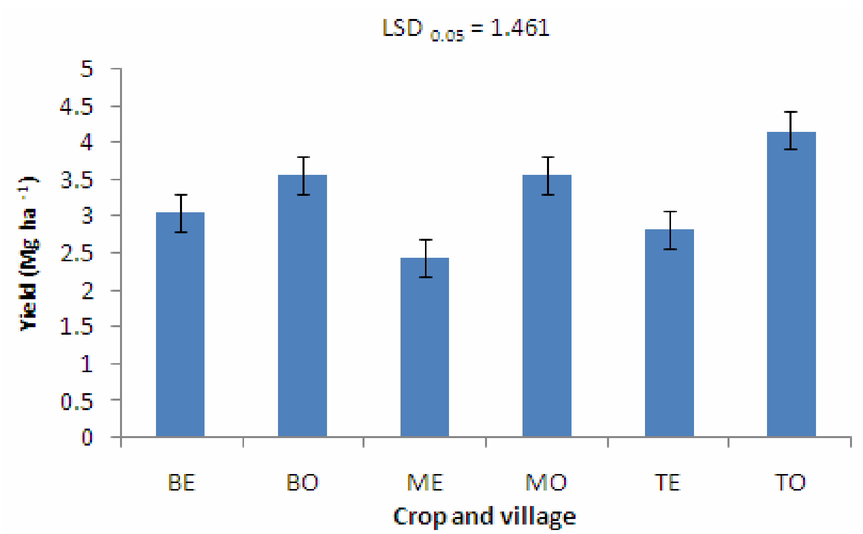

Figure 4.4. Means (± SE) for crop yield across locations ($p<0.05$). B – beans; M – maize; T – taro; E – Ezigeni village; O – Ogagwini village.

Especially important is likely to be the acid saturation which is higher than the critical acid saturation (20%) for maize in KwaZulu-Natal (Farina and Channon, 1991). Dry bean yield, however, was not affected by the acidity present in the soils of both villages. This is shown by high average yields of 3.1 Mg ha^{-1} and 3.6 Mg ha^{-1} recorded for Ezigeni and Ogagwini, respectively. This acid tolerance can be attributed to the chelation of Al in the rhizosphere by citric acid released from dry bean roots thus preventing the detrimental effects of Al. This Al exclusion mechanism was recorded by Miyasaka *et al.* (1991) in a study conducted to investigate the mechanism of aluminium tolerance in snapbeans.

The yield of maize, taro and dry beans was also significantly different among homesteads ($p<0.05$). Farmer Z. Mkhize and Farmer Mbili (from Ogagwini and Ezigeni village, respectively) had consistently higher yields for all three crops (Figure 4.5).

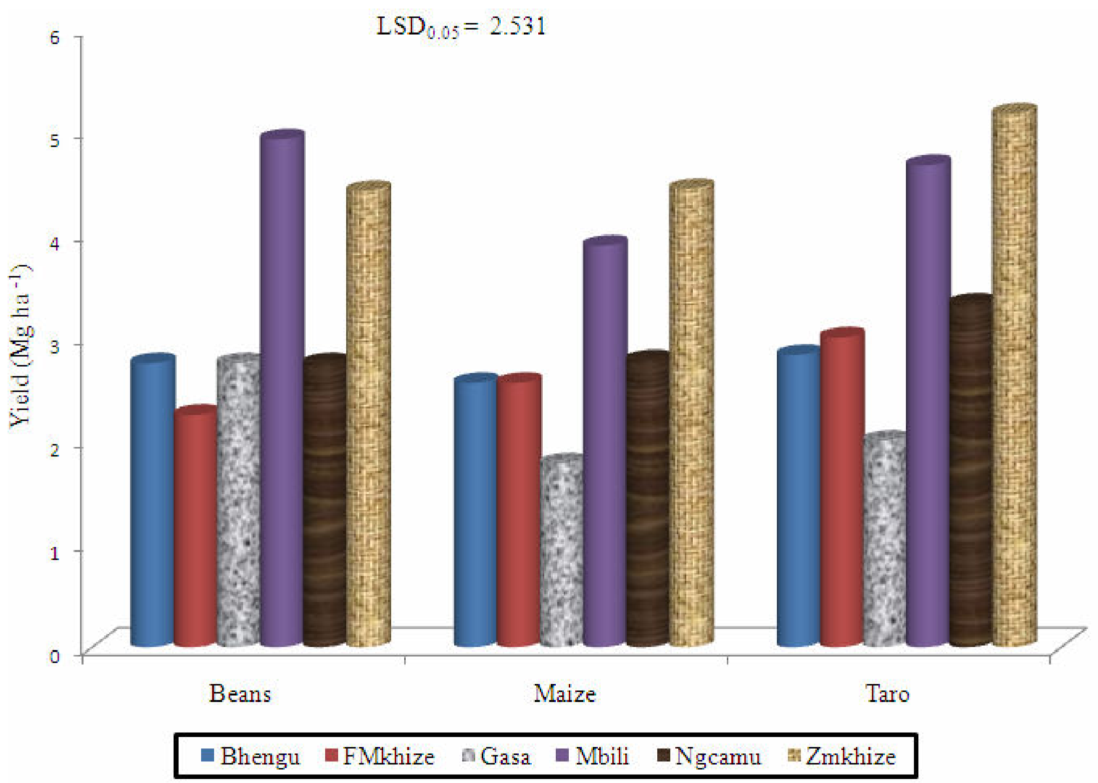

Figure 4.5. Means for yields of beans, maize and taro from six homesteads ($p<0.05$).

This shows that the yield is rather a reflection of management factors than inherent soil properties. These factors may include time of planting, weeding, availability of organic amendments, etc. For example, as much as kraal manure was widely used in both villages not all the homesteads own a herd of cattle. There was only one tractor to assist farmers till their soils at the beginning of the season. This had sometimes led to a delay in planting as farmers have to wait for their turn and the availability of a tractor driver.

CHAPTER FIVE
CONCLUSIONS

Farmers' soil indigenous knowledge is rather abstract when compared to the more commonly obtained scientific knowledge. This is more evident in farmers' soil classification which only takes into account the topsoil and ignores more detailed soil genesis which forms the basis of scientific classifications. This extends further to the way farmers perceive and assess soil fertility. Farmers' fertility indicators and soil taxonomy is based only on morphological soil properties and shows that farmers are more concerned with soil productivity and food security. As a result the farmers' approach is more holistic when compared to the reductionist approach of scientists. However, indigenous knowledge of soils in local communities is vitally important in improving the use and management of agricultural land. As much as this knowledge has not added much value to large scale farming, it can have a huge impact when integrated with scientific knowledge. It has the potential to enrich farmers with knowledge that is able to sustain their agricultural production and environment and hence deserves detailed attention.

Despite many differences between the scientific and indigenous approaches, results showed that there are many links between these two systems in terms of land evaluation. These range from determination of land use to management issues which are critical components of sustainable agriculture. Results showed that farmers' soil suitability evaluation and fertility perception corresponds with the scientific evaluation. This was shown by the correlation of farmers' perceptions with the soil testing results. However, the scientific data also showed that none of the sampled soils from either village is very fertile and that all have considerable constraints. Thus, while yields from Ogagwini are higher than from Ezigeni, all are low as predicted by the scientific fertility data. Only the acid tolerant dry beans yield satisfactorily and these yields are not very different between villages, a result again predicted by the similar fertility status of all the soils analysed. Therefore it is noteworthy that the soil properties (measured scientifically) follow and support the trend of the vernacular land suitability evaluation. The effect of management clearly plays the major role in whether farmers achieve a high yield rather than the village they reside in. This is clearly reflected by the good yields of Z. Mkhize and Mbili from Ogagwini and Ezigeni village, respectively, suggesting that they manage their soils more productively.

Moreover, the correlation was also found in the local indicators farmers use for soil fertility assessment. For example, soil colour, vegetation and soil mesofauna are used as fertility indicators in both systems. Furthermore, the soil suitability maps also support farmers' suitability assessment. This shows that although both the indigenous and scientific approaches use different methodologies they share same objectives. These agreements between the scientific and indigenous approaches imply that there are fundamental similarities between these two approaches. The inclusion of indigenous knowledge into scientific approaches will hence lead to the development of land use plans that are more relevant and profitable to small-scale farmers.

Results showed that land use had a significant effect on measured soil properties especially organic carbon and microbial activity. Hence, developing correct land use planning and helping farmers make informed land use decisions will ensure continued soil resource conservation. However, this cannot be achieved if scientists still perceive indigenous knowledge as just something to be preserved (Nadasdy, 1999; Briggs and Sharp, 2004). Moreover, indigenous knowledge may be discredited when it is tested with scientific knowledge as the point of reference. This shows that scientists do not believe that the former is able to stand alone and actually have a significant effect on land use and management. The integration process will thus require a change of perception and adoption of indigenous knowledge by scientists.

Overall the study has shown that farmers in Ezigeni and Ogagwini have a deep understanding of their land and environment based on indigenous knowledge. It is also clear that farmers have built up a vast store of indigenous knowledge that has been used for many generations. Hence, it is important to encourage the use of indigenous knowledge especially in small-scale farming where farmers cannot afford the techniques of the scientific approach. The previous methodology of scientists has often caused a huge loss of natural resources especially in rural areas (Cleveland *et al*., 1995 cited by Norton *et al*., 1998). However, recognizing the value of indigenous knowledge and not imposing complex scientific approaches on local people can improve land use and reduce resource degradation (Payton *et al*., 2003).

The current study only focused on soil agricultural uses. Given the fact that soil materials are not only used for agriculture but also for a variety of alternative uses, it is essential to understand the characteristics that make certain soils desirable or undesirable to local people for these uses. The indicated use of *Umgogodi* and *Umgubane* soils for plastering and construction, respectively, are examples mentioned in this study. Without such knowledge soils which are apparently of low agricultural value 'scientifically' may be destroyed or used for another purpose even though they are valued for a particular property by local people. It is therefore vital for future research to investigate the feasible methodologies for integration of all indigenous soils knowledge into the scientific approach. This will ensure the continued survival of indigenous knowledge and improve its role in preventing the loss of valuable soil material and assist in achieving sustainability of natural resources.

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APPENDICES

Appendix 1. Questionnaires

Appendix 1 (a). Preliminary questionnaire

Section A: Household Details and farming system

1. Name of household:
2. Gender:
   - ☐ Female
   - ☐ Male

3. Age: 25 – 30 years☐ ☐ 31 – 35 years ☐ 41 and above☐36 – 40 years

4. How many are you in the household?
   ☐ 1 – 5 people. ☐ 6 – 10 people. Other, specify…………………………………☐
5. Who is supporting the family financially?
   …………………………………………………………………………………….
6. Is farming your major source of income? ☐ Yes ☐ No

7. What are your other sources of income? ☐ Government subsidy
   ☐ Employment
   ☐ Donations

8. Is your farm organic or conventional? ……………………………………………

9. Do you use scientific or traditional methods? ....

10. Are you farming for marketing or subsistence?...

Section B Soil Classification

1. Do you classify your soils? Y☐ ☐ N
2. If yes, how do you classify them? (I.e. which of the following soil properties do you consider?)

Soil colour☐	Soil depth☐	Soil drainage☐
Soil texture☐	Topography☐	Soil erosion☐

Other, specify ……………………………………………………………………☐

3. Do you know the effects of topography on soils along a landscape? ☐Yes ☐ No

If yes, can you briefly tell those effects?
…………………………………………………………………………………………………
…………………………………………………………………………………………………..

4. Rank the classification categories in order of importance for the following factors. The factors are production, soil fertility and land degradation.

Appendix 1 (a). (continued)

Production					
Rank	Very important	Important	Undecided	Least important	Not important
Soil Colour					
Soil Texture					
Soil Depth					
Topography					
Drainage					
Distance from home					
Soil Fertility					
Rank	Very important	Important	Undecided	Least important	Not important
Soil Colour					
Soil Texture					
Soil Depth					
Topography					
Drainage					
Distance from home					
Soil Degradation					
Rank	Very important	Important	Undecided	Least important	Not important
Soil Colour					
Soil Texture					
Topography					
Drainage					
Distance from home					

Appendix 1 (b). General survey questionnaire **(**Zulu version**).**

Isahluko sokuqala

1. Igama nesibongo:
2. Ubulili: □ Owesifazane □ Owesilisa

3. Isikhundla ekhaya:

Ubaba	Umama	Umkhulu	Ugogo	Indodakazi	Indodana	Umzukulu	Isihlobo nje

4. Iminyaka: □ ≤ 30 years □ 31 – 45 years □ 46 – 55 years □ ≥ 56
≤ : engaphansi noma elingana
≥ : engaphezulu noma elingana
- : kuya

5. Izinga lemfundo

Awufundanga	Ufesitiya - ezingeni lesibili	Izinga lesihlanu – ezingeni lesithupha	Izinga lesikhombisa-kumatikuletsheni	Imfundo ephakeme

6.Nibangaki ekhaya?
Kunabantu □ 1 – 5 □ 6 – 10 □ enye inamba, isho…………………………………

Isahluko sesibili: Ukuhlukaniswa kwomhlaba

1. Niyawuhlukanisa yini umhlaba? □Yebo □ Cha
2. Uma niwuhlukanisa, niwuhlukanisa kanjani?..
3. Kubaluleke ngani ukuhlukanisa umhlaba uma ufuna ukuwusebenzisela lokhu okulandelayo?

Amadlelo	Ukutshala	Ukwakha	Okunye:

Appendix 1(b). (continued)

Isahluko sesithathu: Umhlabathi

1. Bala izinhlobo zenhlabathi ozaziyo ngamagama………………………………………………………………………
2. Niyiqamba kanjani imihlabathi? Nikusebenzisa yini lokhu okulandelayo?

Umbala	Isamaba somhlabathi	Izwakala kanjani	Ubumanzi	Okunye:

3. Nazi kanjani ukuthi umhlabathi unothile na? Bala izibinelo kulokhu okubaliwe ngezansi.

Colour	Depth	Texture	Crop appearance	Crop yield

Isahluko sesithathu: Ukunakekelwa kwesitshalo

1. Ngabe ukukhethwa komhlaba kuya ngehlobo yomhlabathi?

Yebo		Cha	

2. Uma kunjalo yimiphi imihlabathi emihle ekutshaleni ziphi izitshalo?

Igama lomhlabathi	Isitshalo esivuma khona

3. Yiziphi izindlela enisebanzisayo ukunakekela miphi imihlabathi?

Igama lomhlabathi	Ukushintshanisa izitshalo endaweni eyodwa			Ukutshala izitshalo ezahlukene endaweni eyodwa		
	Njalo	Ngezinye izikhathi	Awuwusebenzisi	Njalo	Ngezinye izikhathi	Awuwusebenzisi

Appendix 1(b). (continued)

4. Nibafaka kanjani omanyolo futhi nibafaka kangaki?

Igama lomhlabathi	Umquba (inhlobo……………………………)			Umanyolo (inhlobo……………………………)		
	Njalo	Ngezinye izikhathi	Awuwusebenzisi	Njalo	Ngezinye izikhathi	Awuwusebenzisi

Appendix 1 (c). General survey questionnaire (English version).

Section A: Household Details

1. Name of household:

2. Gender:

□ Female

□ Male

3. Age: □ 25 – 30 years □ 31 – 35 years □ 36 – 40 years □ 41 and above

4. How many are you in the household?

□ 1 – 5 people □ 6 – 10 people □ other, specify……………………………….

Section B: Land Classification

1. Do you classify the land? □ Y □ N
2. If yes, how is the classification done?..
....
3. What is the significance of land classification in land use (i.e. veld choice or grazing, crop production and construction of buildings)?...
....
....

Section C: Soil Perspective

1. How do you identify soils (i.e. which of the following soil properties do you consider?) and why?

□ Soil colour □ Soil depth
□ Soil moisture □ Soil texture

2. How do you determine soil fertility?

a. Do you use visual inspection? If yes, how?..
....
....
....

Appendix 1 (c). (continued)

b. Do you use physical measurements? If yes, how?..
....
....
....

c. Do you use crop performance (i.e. growth rate or output in terms of yield)?...
....
....

Section D: Crop production

1. Is crop production determined by soil type? If yes, which soils are good for which crops and why?..
....
....
....
....
....

2. Which management practices do you practice?

(i) □ Crop rotation
□ Intercropping

3. Do you use chemical fertilizers or kraal manure? If not why?..
....
....

1. Are these management practices associated with land classification or soil type? If yes, how?..
....
....

Appendix 2. Detailed survey questionnaire**.**

1. Personal Details

Name:
Age:
Gender:
Experience in farming:……………………………………………………………….

2. (a) Cropping history

2006/7………………………………………………………………………………
2007/8………..
2008/9………………………………………………………………………………

(b) General knowledge about the soil used for crop production
……………………………………………………………………………………………
……………………………………………………………………………………………

2. Soil description

(a) How would you determine soil characteristics relevant for crop production (theoretically and practically if possible), e.g.
Soil Depth……………………….……………………………………..…………………….

Colour………………………………………………………………………………..….……
……………………………………………………………………..………………………

Fertility…………………………………………………………………………………

(b) How do you then decide on which crop to plant?
……………………………………………………………………………………………
……………………………………………………………………………………………
……………………………………………………………………………………………

(c) Farmers critique of the scientific approach
……………………………………………………………………………………………
……………………………………………………………………………………………

Appendix 3. Farmers' responses to the detailed survey questionnaire.

Household / **Question**	**Mr & Mrs Mbili** No livestock	**Mrs Emelda Bhengu** Livestock	**Mrs Filda Mkhize** Livestock	**Mr Gasa** No livestock	**Mrs K Ngcamu** Livestock	**Mr Z. Mkhize** Livestock
1. Personal details	Upper Ezigeni	Upper Ezigeni	Upper Ezigeni	Upper Ogagwini	Upper Ogagwini	Upper Ogagwini
2.Cropping history, general knowledge about production soils	Basic crops, field outside the homestead has been fallow for the past season. Highly productive field in the past when used as the yields were great.	Basic crops, groundnut. Farmer recognized that subsoil compaction affected yield (taro & pumpkins) until tractor deep ploughed and loosened the subsoil.	Basic crops, variety of vegetables. Farmer has a good understanding of soils as she described them using colour, texture, structure, tillability and their potential w.r.t production.	Basic crops, groundnut; trees: banana, avocado, orange & peaches. Tried anaerobic composting for sometime with no luck, serious pest (bird, wild hog & soil organism) problem.	Basic crops; trees: lemon, avo, guava, peaches, orange. Half of fields on very steep slopes, hence, fallow as risk of tractor ploughing are too high & draught power is scarce.	Basic crops, chillies, groundnut cowpea; trees: banana, avocado, orange, peaches, pawpaw, mango & wattle
3. Soil description	Topsoil (0-80) good, dark black friable high OM 'Dudusi' throughout the fields except bottom field down the road. Subsoil 80-1.0m red low clay. Good understanding of	Reddish more productive soil with high clay and more weeds, black weak structure with fewer weeds. Crop yield used as indicator of fertility/soil's potential. Kraal manure and rotation	Big portion of these fields have a high biological activity with high population of earthworms (fertile) in the black thick (0-60/70) topsoil. As you soils changes from	Reddish brown (loamy) soil on the higher elevation with dark black soil at the bottom next to seasonal 'wetland'. Depth not considered as a	No particular system in place, planting determined by availability of tractor to plough. However those that are	Red heavy clay that needs to be worked when moist not wet or dry, labour intensive & strenuous. Low productivity

	soil & their potential, use of rotation system and presence of earthworms	system used to manage fertility. Generally high clay soils are wet most of the time	light to heavy type as you reach the bottom of the slope there's a seasonal wetland. Soil classified mainly by structure, tillability and colour	factor in production whilst colour is just for differentiating purposes. Txt & structure noticed during tillage	planted are rotated and manured. Only concerned with produce as an indicator of soil's capability. Red productive soils in one field.	especially when too hot. Crop yield is determines soil type i.t.o. sun intensity & relief/rain shadow.

Other responses: Farmers think that scientific approach is too tedious and requires too many details, although two farmers articulated the importance of this approach as water deficiency was identified and now the village has a pump engine for water extraction.

Appendix 4. Farmers' responses to the preliminary questionnaire.

Group interview at Mrs Thuli Mkhize's homestead, Ezigeni
10 January 2008 - 09h00

- A meeting with the members of Ezemvelo Farmers Organization (EFO) had been arranged by Professor A.T.Modi (Co-supervisor). The intention was to explore the indigenous knowledge of soils to complement the soil survey questionnaires of September.

- There were 23 women present, Nkosinomusa (author of the current study), Charity Maphumulo (PhD student/ ARC extension officer), Ncebo (completed honours student) and Karen Caister (PhD student)

- The interviews started with Charity and Nkosinomusa asking questions with Ncebo clarifying and assisting in the choice of Zulu words to use for the technical concepts on the questionnaire.

- A problem arose with the questionnaire (Appendix 1 - the questions about structure, colour and soil types were not being understood as people did not know what they meant). After consulting together, the researchers decided to use a round about method to probe for knowledge because we all knew that the knowledge was there, but we had not found the key for getting on the same page. We then started asking questions that were not direct from the questionnaire but started from a point of familiarity (for both us and the farmers)

In the new line of questioning we asked:

What crops are you growing? - Where do you grow them? rainfed maize, potatoes, peanuts, maize, beans, etc. We grow them around the homesteads in our fields.

Do you use monoculture or intercropping? - We do intercrop but not frequently because we have enough land and we avoid monoculture if at all possible. We have observed low yields and poor quality under continuous monoculture.

Which crops are you growing for the EFO? - *amadumbe*
When you grow *amadumbe* where do you prefer to grow them? in wet soil (the term given was engombile).

How do you grow the crops in the wet soil? , in the areas of wetness - *amadumbe* are immediately rotated with maize - the exception is when the soil is dry enough, you can rotate *amadumbe* with beans - but there must be no signs of wetness. If you rotate *amadumbe* with maize you get no problems with the soil.

What colour is the wet soil? any colour, but we get better yields from black soil than red soil - they seem unable to explain why.

Appendix 4. (continued)

Do the red and black soils have zulu names? (and Gogo clicked to what we had been trying to find out) Now we had people on the same wavelength: and the following information was offered: - from soil classification to soil uses from the older farmers, and other uses by the younger farmers.

Soil types identified by farmers and their uses

Gadenzima	Idudusi	Udongwe	Umgogodi
use - farming	**use** - farming	**use**- making pots	**use**: as plaster for inside kitchens
texture- crumbly friabl	**colou**r - black	planting water loving crops (e.g spinach)	it absorbs the smoke and
high infiltration	**loamy** - structureless	**source** - found near the 'cattle dip' s	doesn't discolour or get dirty quickly
		and in river valley	**texture**: heavy clay

Umgogodi soil is found as a horizontal layer under a black layer of topsoil. To access the soil, one digs through the top soil layer and then moves sideways (even though they know they can get more from digging deeper) because it is easier to dig that way. If an area is identified as having this umgogodi layer, it is not used for cultivation (arable land) because the top layer is hard and sometimes a little rocky and also the umgogodi soil is valuable for other uses.

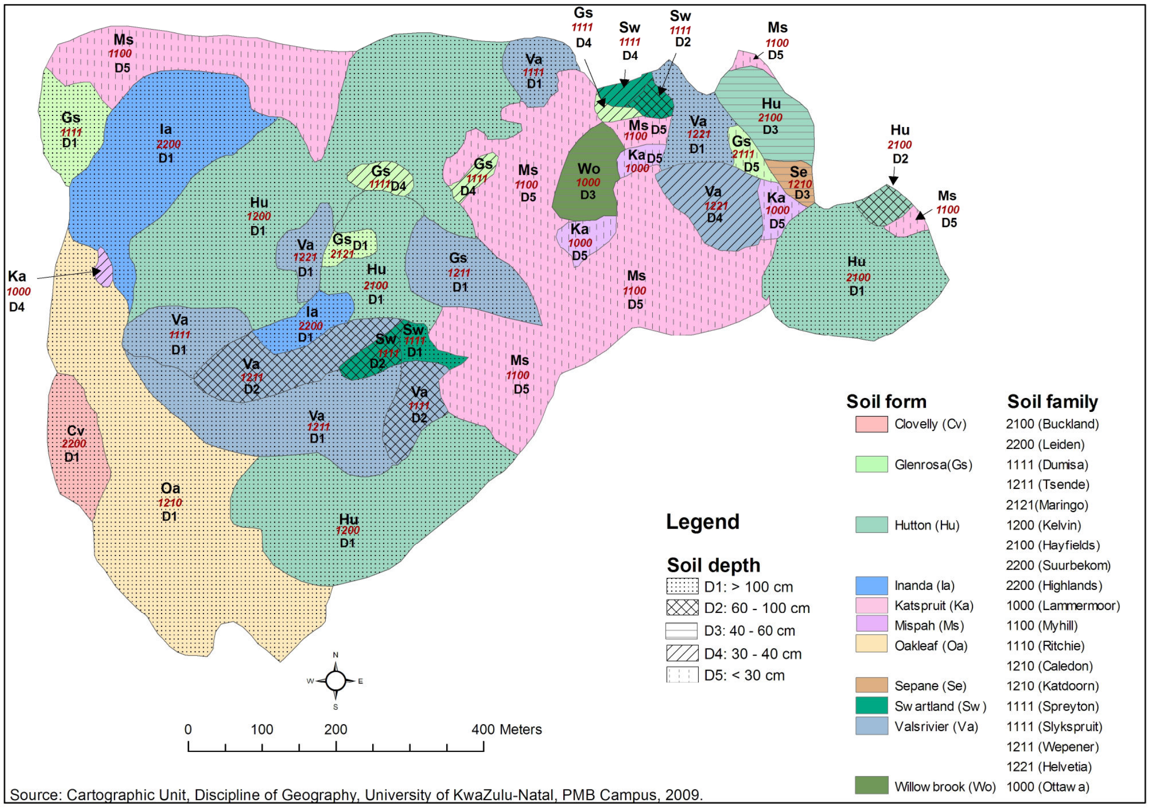
How do you identify soils suitable for cultivation? We know that the soil is fertile and suitable for planting if there is vigorous growth of '*ubhongabhonga* and *isithenjane*"- the dominant grass in this area. If '*uqadolo'* (black jack) is growing or there are soil organisms, especially earthworms, then we know that the soil is very fertile. We also use yield as an indicator of soil fertility.

Have any of you come from other areas? - if you have, were the soils different in those places? The group was unanimous in the belief/perception that in Ogagwini you can plant year after year without manure. The soils there are more fertile. In Ezigeni, you must use kraal manure.

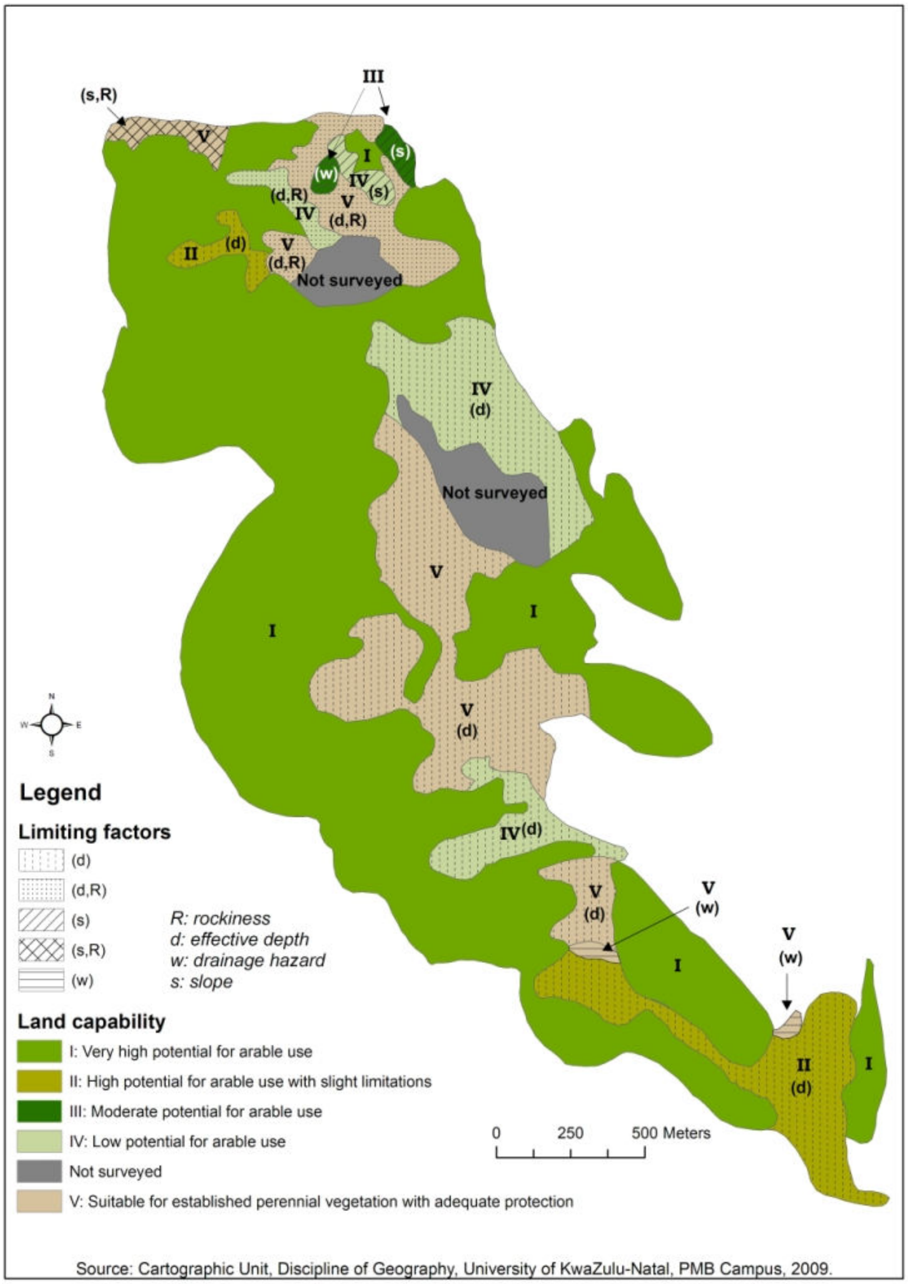
If your soil is not fertile, how would you reclaim it? - (Gogo answered) to reclaim soil, you must top dress the soil in spring with kraal manure - and leave it. You use as much as you have - the more you put in, the better the change in soil. You leave it on the surface and then plough and plant when normal planting should take place - about a month later.

Do you know the effect of topography on soils? – We have observed that high erosion in fields on steep slopes. This has been a serious problem when the erosion event occurred when the fields have been planted because then we would have to replant. However, it is easier to replant when the crops are still young than when they are old.

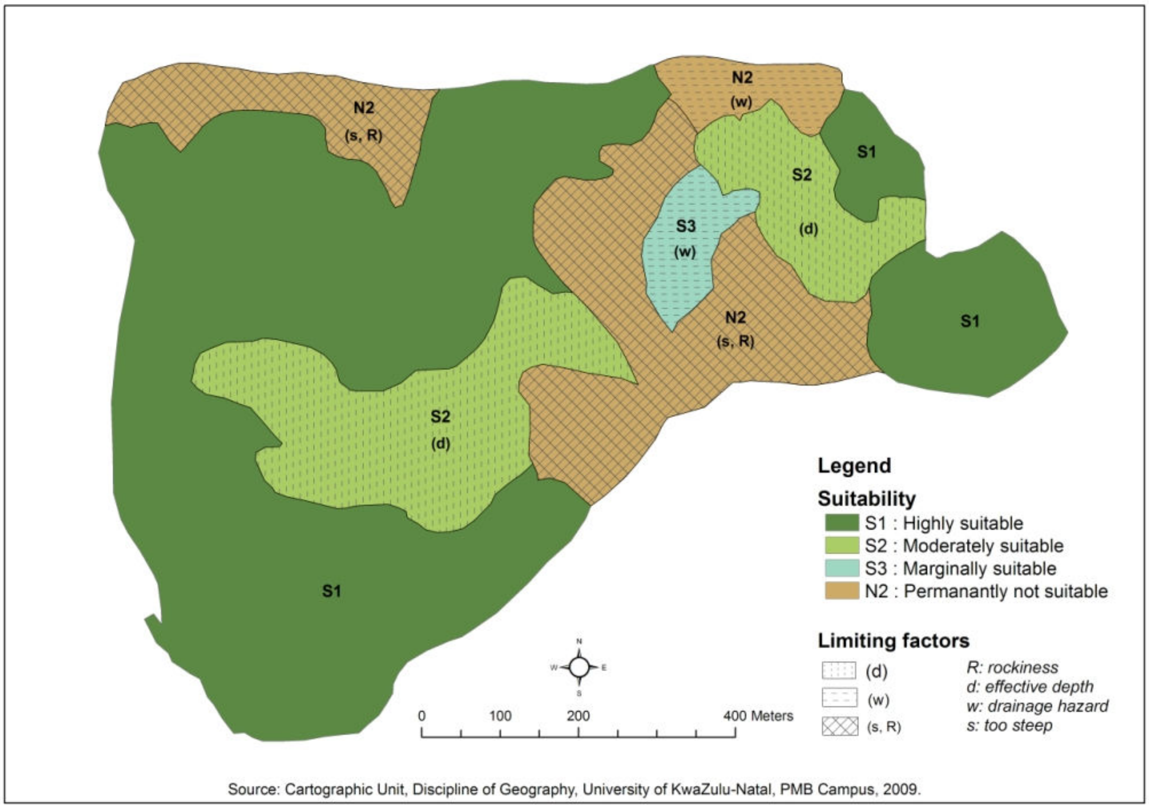
Appendix 5. Soil map of Ezigeni village



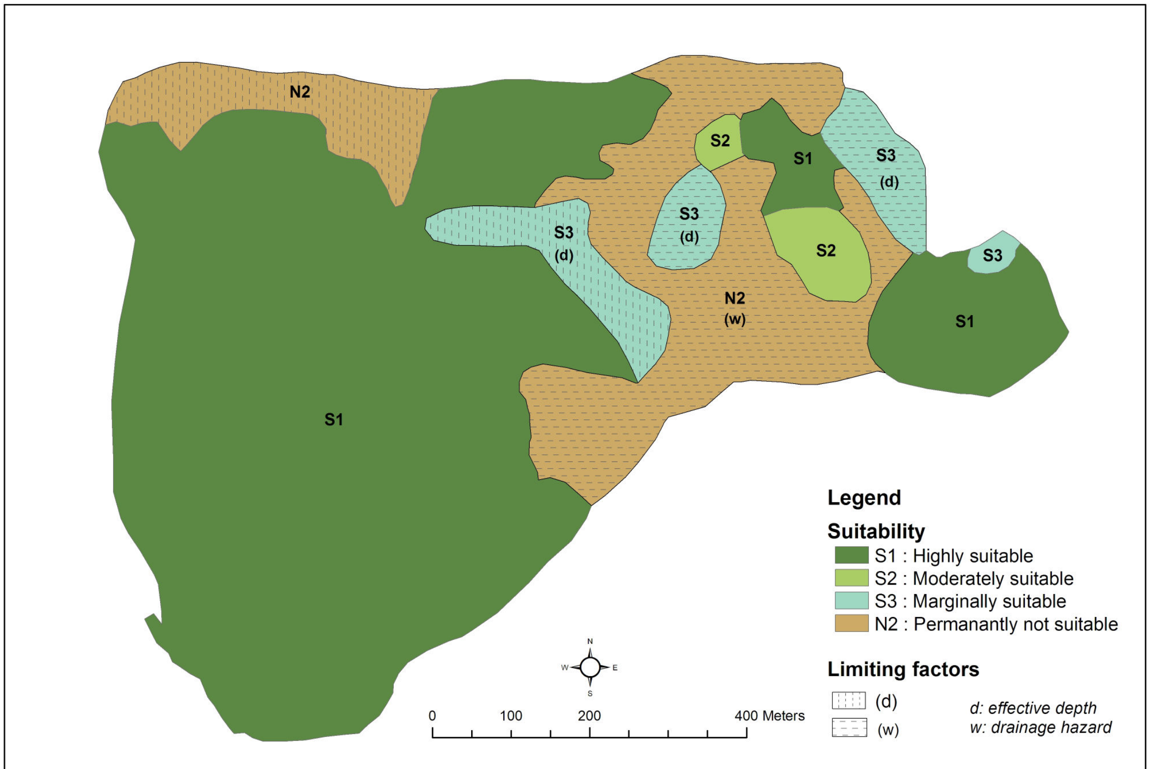
Appendix 6. Land capability map for Ezigeni and Ogagwini villages.



Appendix 7. Land suitability map for dry bean production in Ezigeni village.

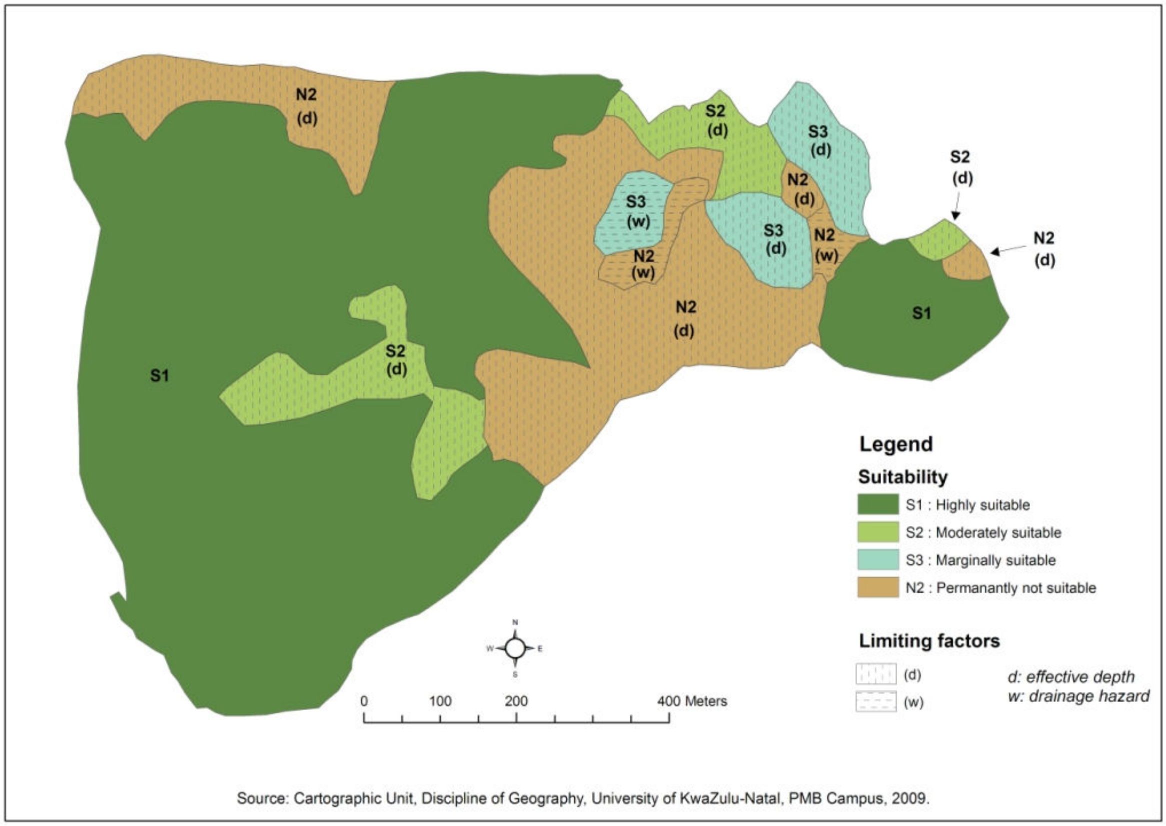


Appendix 8. Land suitability map for taro production in Ezigeni village.

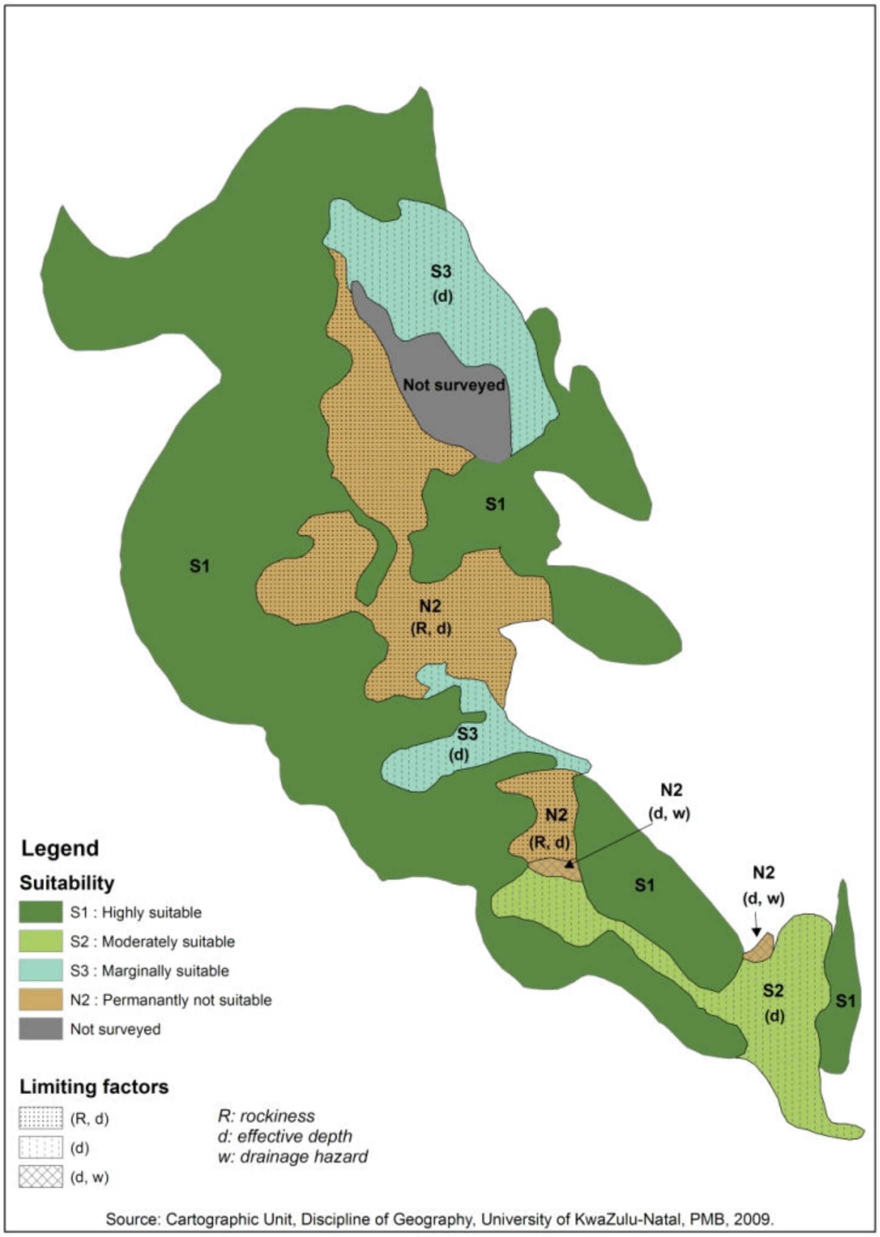


Source: Cartographic Unit, Discipline of Geography, University of KwaZulu-Natal, PMB Campus, 2009.

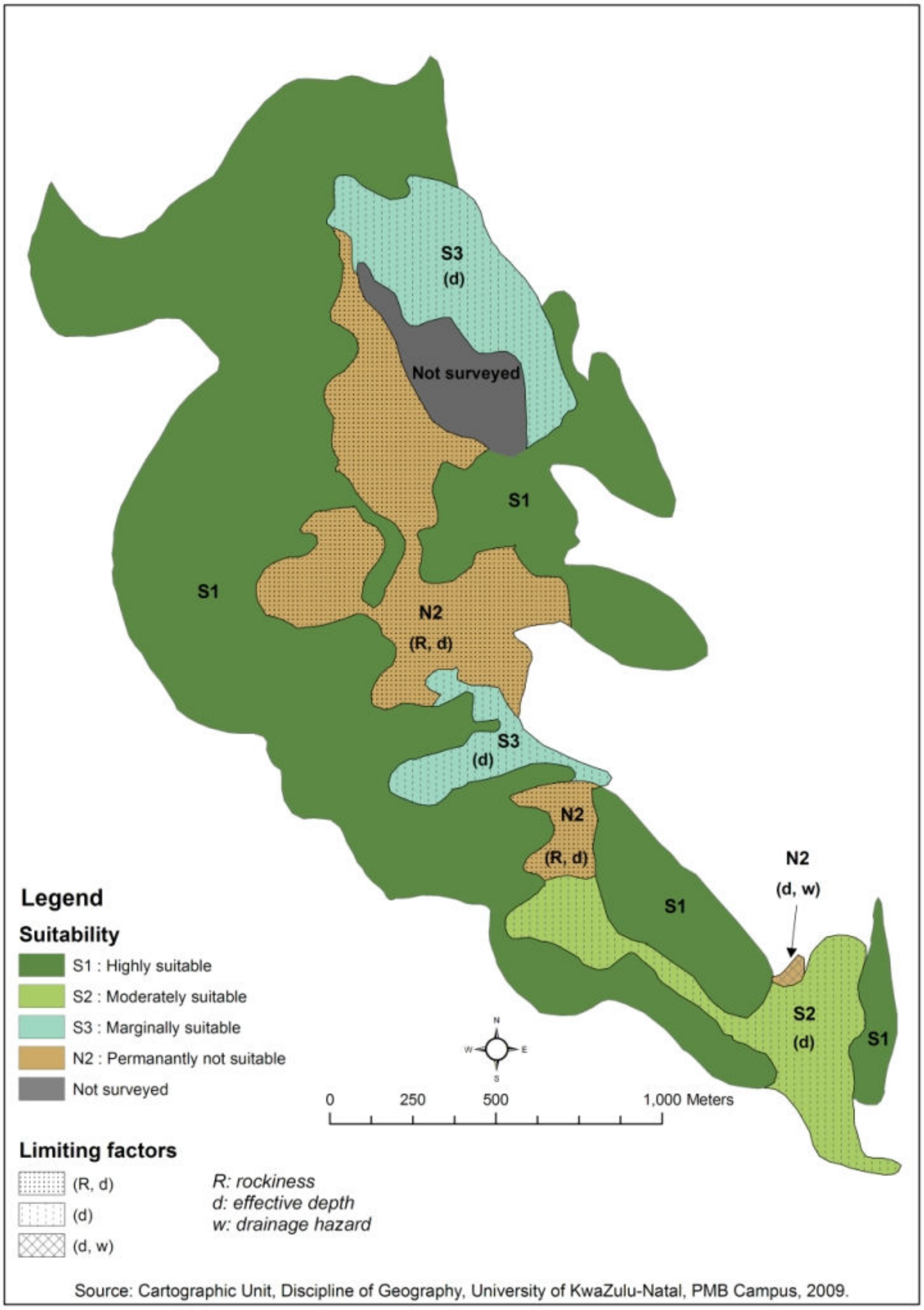
Appendix 9. Land suitability map for maize production in Ezigeni village.



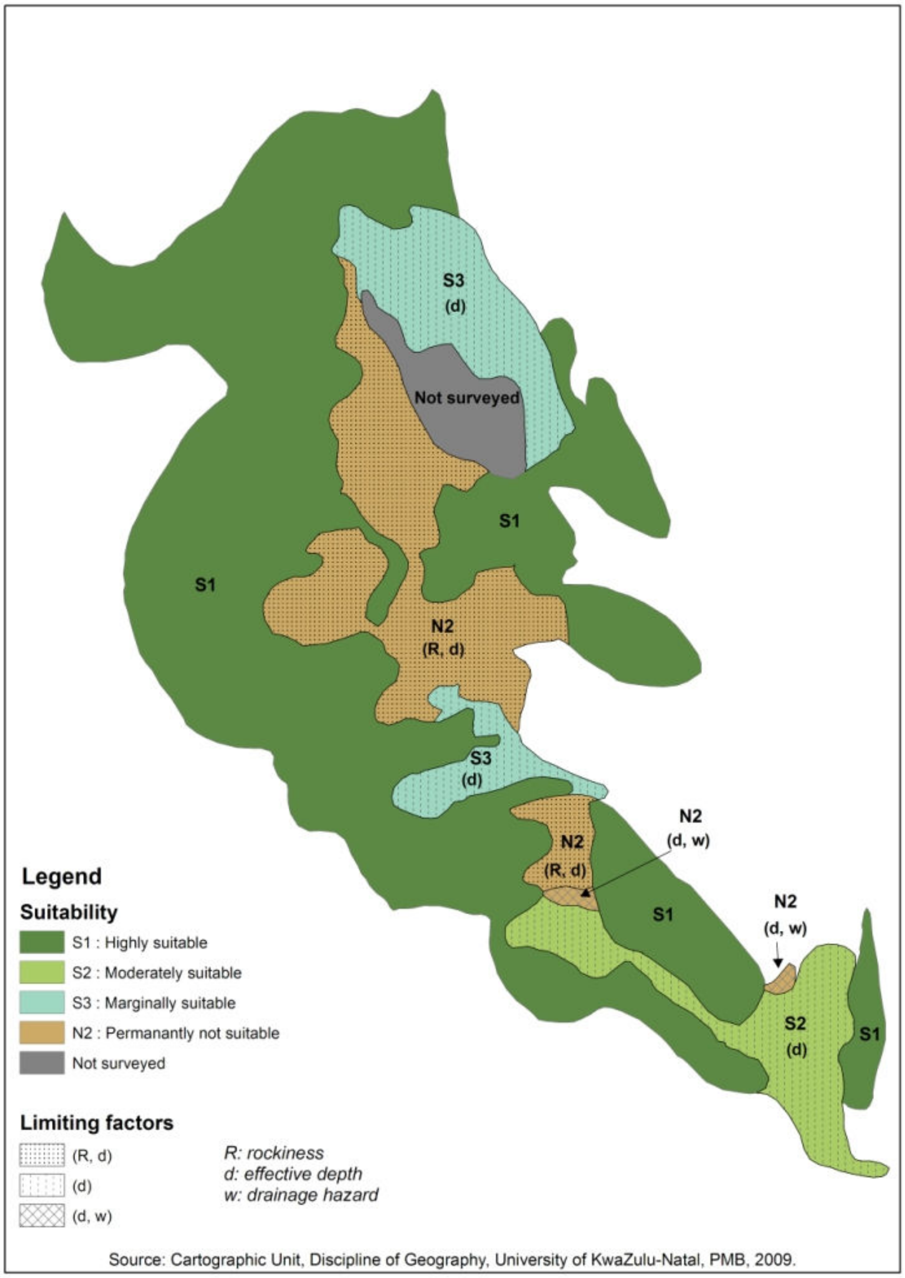
Appendix 10. Land suitability map for dry bean production in Ogagwini village.



Appendix 11. Land suitability map for taro production in Ogagwini village.



Appendix 12. Land suitability map for maize production in Ogagwini village.



Appendix 13. Soil map of Ogagwini village.