APPLICATION OF SOIL INDIGENOUS KNOWLEDGE IN RURAL COMMUNITIES OF EASTERN SOUTH AFRICA

Nkosinomusa Nomfundo Buthelezi

BSc. (Soil Science); **BSc Hons** (Soil Science); **MSc.** (Soil Science)

Submitted in fulfilment of the academic requirements for the degree of **Doctor of Philosophy**

Discipline of Soil Science

School of Agricultural, Earth and Environmental Sciences

College of Agriculture, Engineering and Science

University of KwaZulu-Natal

Pietermaritzburg

2018

DECLARATION

I, Nkosinomusa Nomfundo Buthelezi, hereby declare that:

The research reported in this thesis, except where otherwise indicated, is my own original work. This thesis has not been submitted previously for degree or examination purposes at any other university. This thesis does not contain other persons' data, pictures, graphs or any other information unless specifically acknowledged as being sourced from other persons. This thesis does not contain other persons' writing, unless specifically acknowledged and cited. In the event where other written sources are quoted:

1. The words are paraphrased, and the general information used has been cited and referenced.

2. Where words or phrases have been taken as they are and inserted into this document, the writing has been placed within quotation marks and referenced.

This thesis does not contain text, graphics or tables copied and pasted from the Internet, unless the source is specifically acknowledged in the text and reference section.

Signed:

___________________ Date: 06 November 2018

Nkosinomusa Nomfundo Buthelezi

As the candidate's supervisor I have/~~have not~~ approved this dissertation for submission.

Signed:

Prof J.C. Hughes Date:____________________

As the candidate's co-supervisor I have/~~have not~~ approved this dissertation for submission.

Signed: Date:__________________

Prof P. Muchaonyerwa

As the candidate's co-supervisor I have/~~have not~~ approved this dissertation for submission.

Signed: Date:__________________

Prof A.T. Modi

As the candidate's co-supervisor I have/~~have not~~ approved this dissertation for submission.

Signed Date:

____

Dr K.F. Caister

ACKNOWLEDGEMENTS

Firstly, I would like to thank God Almighty for giving me the potential and ability to finish this project.

Prof Jeffrey Hughes for continued advice, support, patience and immense knowledge.

Prof Pardon Muchaonyerwa for support and advice as well as encouragement in times when I felt like giving up.

Prof Albert Modi for introducing me to this interesting subject of indigenous knowledge as well as advice and support.

Dr Karen Caister for support, advice and immense knowledge of qualitative research methods.

The National Research Foundation [REF. NO. TTK1205280913], University of Limpopo and Soil Science Department, University of KwaZulu-Natal for funding this work.

Mr Tad Dorasamy and Mr Pradeep Suthan for their technical assistance.

Mr Jothan Buthelezi and Ms Tezi Nala for help with sample preparation.

Mr Jon McCosh, Mr M Malinga, for their assistance with the identification of some of the study sites as well as setting up preliminary community meetings.

The Central Analytical Facility (University of Stellenbosch) and the KwaZulu-Natal Department of Agriculture & Rural Development (Cedara) for assistance with soil analysis.

Mr Dumisani Mashele for help with GIS analysis and interpretation.

The people of Zalaze, Ntshiqo, Potshini and Khokhwane villages for their willingness and cooperation to assist in all aspects of this work.

Zuzile Molefe for friendship, encouragement and inspiration. You made me believe in myself in times when I did not.

My loving husband (Sabelo Dube) for continued support, love, encouragement and inspiration to finish this project.

My lovely daughters (Siphokazi, Slindokuhle and Zobuhle) for inspiration to finish this project.

Lastly, my mother (Busisiwe Mhlongo) for continued support and encouragement.

ABSTRACT

This study investigated ethnopedological knowledge related to classification, fertility and non-agricultural uses of soil in four villages in KwaZulu-Natal and the Eastern Cape, South Africa. Ethnographic methods elicited general soil indigenous knowledge. Ethnopedologic techniques gathered understanding of soil taxonomy, mapping and fertility, and selection and use of healing, cosmetic and geophagic soils. Local assessments of soil fertility and mapping were compared to scientific approaches. Soil samples were analysed for physicochemical properties. Soils used for non-agricultural purposes were analysed by X-ray diffraction and X-ray fluorescence spectrometry.

Local classifications were based on observable soil morphological properties. Soil maps produced by farmers in areas with distinct geomorphic units closely correlated with scientific maps; on a floodplain the correlation was poor. Farmers assessed soil fertility using both crop and soil variables. There was poor correlation between farmers' fertility classes and laboratory data. Farmers understood soil-crop associations which formed the basis for their soil suitability assessment and have developed specific soil use and management practices.

Two soil types were identified for non-agricultural uses. Ukhethe, used for agriculture, was also used for geophagy; ibomvu for sun protection, healing and cosmetics. Geophagic soils were mainly saprolite from Leptosols. They were mostly fine-grained, had bright Munsell hues, contained mica, kaolinite, quartz and iron oxides, and elements such as Cu, Zn, Co and Pb. Ibomvu occurred in Ferralsols and was red to dark-red. Despite low sun protection factors, critical wavelengths >370 nm, the presence of TiO2 and high Fe2O3 explained its sun protection ability. The soil was fine grained, had low pH and exchangeable bases, and contained kaolinite that possibly explained its healing role.

These communities applied their pedological knowledge to soil use and management. There were diverse non-agricultural uses and possible land use conflicts where a soil has more than one use. Farmers classified soils at levels that could be incorporated as higher categories in the current South African system. Farmer fertility assessment could benefit from laboratory data. Soil suitability classification systems should be used to assess both agricultural and non- agricultural uses. Valuing all local uses of soil will ensure fair and relevant land use planning.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF APPENDICES

Chapter 1: General introduction

Pedological wisdom of rural people has informed soil use and management systems for many generations. To document and understand this knowledge relating to local approaches to soil perceptions, appraisal, classification, use and management, a relatively new discipline called ethnopedology was introduced in the late 1800s. Ethnopedological studies have revealed that rural people are innate pedologists (Barrera-Bassols, 2016). They have acquired pedological knowledge by experience and trial and error providing them with a long-term perspective on land use and management otherwise not available (WinklerPrins and Sandor, 2003). Existence of diverse soil uses (both agricultural and non-agricultural) in rural communities are informed and sustained by rural peoples' understanding of soils and their properties. It is thus imperative that soil indigenous knowledge be explored to understand ways in which it has been, and is being, applied by people in rural societies.

Ethnopedological studies have made a significant contribution in this regard. However, the studies have mainly been from Latin America, some parts of Africa and Asia with only a few in Europe and the Pacific area (Barrera-Bassols and Zinck, 2003; Capra et al., 2015). The majority of the studies have largely been ethnographic (most attention paid to indigenous terminology of soils) or comparative (correlation of the local classification with scientific taxonomies). Despite being informative, these studies did not adequately capture the essence of rural people's pedological wisdom leading to a shift towards an integral approach (Barrera-Bassols and Zinck, 2003). Soil investigations based on this approach go beyond local soil classifications to understanding local soil theories (including complex concepts about soil processes) underlining adaptation to dynamic soil circumstances and, moreover, informing soil use and management (Niemeijer and Mazzucato, 2003). This requires knowledge of local perceptions and beliefs about soils which are fundamental to the use and management of soils in rural communities.

Most ethnopedological studies have focused on agricultural uses of soils with little attention given to non-agricultural uses (Cabral et al., 2015). This has been likely perpetuated by the need to understand indigenous knowledge with respect to food security and also the bias of common scientific land capability and suitability classifications which were mostly designed for arable soils. Uses of soil as raw materials (e.g. cosmetic, healing, construction and geophagic practices) have not been well studied. Similar to agriculture, alternative uses of soils reflect multifaceted pedological contexts and a long association between humans and the Earth

(Limpitlaw, 2010). Thus, understanding ethnopedological knowledge associated with non-agricultural uses of soils is necessary to achieve sustainable and unbiased soil use and management.

Despite the significant contribution of Africa to ethnopedological studies, there has been little effort to document and understand pedological knowledge of rural communities in South Africa, especially those along the eastern seaboard. This thesis is thus aimed at contributing to the progress of ethnopedology in the South African context. There is a need to fully understand realities of local people as well as local theories through which the ethnopedological wisdom is produced and developed. To ensure full potential of this knowledge is realised, ethnopedological findings have to be linked with scientific findings through contrast and finding synergies between these. The study employs an integrated multidisciplinary approach with an aim to investigate the application of soil indigenous knowledge in various soil use and management systems. It was guided by four main questions, viz

(1) How is ethnopedological knowledge used to describe and adapt to the dynamic environments of rural people in eastern South Africa?
(2) How do rural people perceive, classify, use and manage soils in two ethnic groups of South Africa?
(3) What are local theories behind local soil perceptions, classification and use?
(4) How do local perceptions and classification of soil correspond to scientific findings?

The following overall objectives; were achieved to answer outlined questions. These were to investigate:

- farmers' local classification systems, their spatial knowledge and ability to map the distribution of different soils;
- whether local soil maps correlate with conventional, scientific soil maps;
- farmer-defined soil fertility indicators and if farmers can develop viable and sustainable soil-cropping systems without laboratory data;
- how farmers' perceptions of soil fertility correspond to laboratory measurements;
- ethnopedological knowledge related to uses of soils for healing, cosmetic and geophagy practices and

- the physicochemical and mineralogical properties of soils used for geophagy, healing, sunscreen and cosmetics in order to ascertain possible explanations for their claimed roles and implications for local users.

The thesis is structured as follows:

Chapter 2: A literature review on ethnopedological perspectives of soil use and management.

Chapter 3: Presents and discusses results on indigenous knowledge of soil classification in four selected villages of eastern South Africa.

Chapter 4: Presents and discusses results on farmer perceptions and laboratory measurements of soil fertility in four selected villages of eastern South Africa.

Chapter 5: Presents and discusses results on indigenous knowledge and characterisation of some geophagic and healing/cosmetic soil materials from KwaZulu-Natal, South Africa.

Chapter 6: General discussion, conclusions and recommendations for future work.

Note: Results in Chapter 3 have been published in Geoderma. The article is entitled "Indigenous soil classification in four villages of eastern South Africa".

Chapter 2: Ethnopedological perspectives of soil use and management: a review

2.1 Introduction

Ethnopedology is a relatively new discipline that aims to document and understand local approaches to soil perceptions, appraisal, classification, use and management (Barrera-Bassols and Zinck, 2003). Local people have acquired this knowledge by experience and testing over many generations providing a long-term perspective on land use and management that is otherwise not available (WinklerPrins and Sandor, 2003). Local soil knowledge enables local people to capture both temporal and spatial dynamics of soils, particularly with respect to land use (Sandor and Furbee, 1996). Local people are thus able to adapt techniques to their prevailing situations and have become experts of their local environment and innate pedologists (Barrera-Bassols, 2016). They can easily and comparatively assess their land use systems at least at a local scale (Cools et al., 2003). This reveals a detailed understanding of the local complex ecology that underpins the sustainable management of resources. Good understanding of the soil resource is therefore fundamental to sound land use and management (Gowing et al., 2004).

Ethnopedological studies have significantly increased as researchers acknowledge their important contribution. These have mainly been from Latin America, some parts of Africa and Asia with a few in Europe and the Pacific areas (Barrera-Bassols and Zinck, 2003; Capra et al., 2015). The initial view of early ethnopedological studies was the correctness of scientific methods and how they were used to validate local knowledge through correlation and comparison with scientific understanding (Barrera-Bassols and Zinck, 2003). However, recent work has shown the value of local soil knowledge and the potential for its integration with scientific knowledge to obtain sustainable solutions towards environmental and natural resource challenges. This shift has encouraged researchers to make efforts to understand local soil knowledge in its context i.e., considering socio-economic, historical and cultural aspects (WinklerPrins, 1999). Local perceptions about soil are informed by soil theories and concepts framed within the local context. Niemeijer and Mazzucato (2003) thus argue that in order to better understand the outward attributes of local soil knowledge (e.g. local soil taxonomies), researchers must pay attention to concepts, perceptions and beliefs which they refer to as the "frame of reference of soil knowledge". This aspect reveals the pedological wisdom of local people and its application in soil use and management.

This review provides an account of how indigenous soil knowledge has been used to sustain rural livelihoods of diverse cultures around the world. It focuses on the application of the empirical wisdom of local people in relation to agriculture, i.e., soil properties and soil classification, land use and soil management and also examines some alternative uses of soils such as geophagy and pharmaceutical uses. The review uses examples from cultures of Africa, Latin America and Asia that have made a significant contribution to ethnopedological studies.

2.2 Soil indigenous knowledge

"The history of soil other than of its genesis (a concern of pedology) is a history of its perceptions and the consequences of its use" (Showers, 2006). For millennia, there has been a continued interaction between humans and soil. This interaction of humans with soil (as the product of pedogenesis) led to a significant history of exploration and discovery, experimentation and classification (Showers, 2006). Humans have left and continue to leave permanent imprints on the soil suggesting that soils' history is a function of both natural and human influences. Inevitably, what happens with soils and societies is not only a matter of biogeochemistry but also of culture (McNeill and Winiwarter, 2006). Therefore, what people understand and/or misunderstand about soils is a necessary part of any history of the link between soil and society (McNeill and Winiwarter, 2006). Local soil theories, perceptions and beliefs relating to how people use and manage the soil are fundamental reflections of this link. Scientific approaches can provide necessary evaluation of prevailing soil perceptions and theories that may be explained by intricate soil processes of which rural people are not aware.

Soil properties or lack of them create certain perceptions and beliefs and thus decisions on whether to conserve or abandon a particular soil (McNeill and Winiwater, 2006; Showers, 2006). For millennia, people have recognised the value of soil and thus used it for many purposes including agriculture, construction, healing and ritual purposes. The lack of soil analytical data in rural communities means that farmers often have to entirely depend on their understanding of observable soil properties such as colour, texture and consistence in order to communicate, classify and assess suitability for many uses. The understanding of the relevance of these properties in relation to soil use reveals the pedological wisdom of local people. Although the pedology of local people is largely dependent on the framework of soil classification, it does provide a plausible basis for soil use and management. However, for long-term sustainability of soil, particularly local agricultural soils, knowledge of analytical data is considered to be a valuable addition to pedological assessment.

Soil information forms the basis for sustainable agricultural land use planning and development. For researchers this information is derived from soil survey and accompanying soil analyses which are often not understood by farmers (Braimoh, 2002), thus making soil indigenous knowledge (SIK) fundamental to farmer-level land use planning. WinklerPrins (1999) defines SIK as "the knowledge of soil properties and management possessed by people living in a particular environment for some period of time". Experience and observations as well as systematic experimentation have enriched local communities with a dynamic knowledge base that provides them with a long-term perspective on particular soil-plant systems (Showers, 2006). Similar to all knowledge systems, SIK is thus able to adapt to ever-changing conditions.

Early ethnopedological studies were largely ethnographic, i.e., most attention was paid to indigenous terminology of soils (Barrera-Bassols et al., 2006; Krasilnikov and Tabor, 2010). These studies, however, did not account for how local people name and classify their soils, i.e., the principles behind the classification. Following this came a comparative approach that correlated the local classifications with scientific taxonomies. Although this approach did highlight differences and similarities between the systems, it disregarded the symbolic meanings and values fundamental to the practical implementation of SIK (Barrera-Bassols et al., 2006). Establishing links between local and scientific soil types is important as they show potential synergism for solving problems related to soil and land management (Barrera-Bassols and Zinck, 2003). However, beyond this there should be an attempt to understand why such differences exist, the level at which people classify their soils and the extent to which local perceptions and beliefs affect soil use and management. It is also important to note that despite using similar characteristics (e.g. soil colour, texture and consistence) to assess soils, scientific and indigenous definitions and perceptions of soils often compare poorly (Sikana, 1993; Talawar and Rhoades, 1998). As Niemeijer and Mazzucato (2003) convincingly demonstrate, behind indigenous soil taxonomies are farmers' theories of soil (including complex concepts about soil processes) which when captured by research can provide valuable insights into how farmers deal with their dynamic soil circumstances. To capture the essence of farmers' pedological wisdom there was then a shift towards an integral approach (Barrera-Bassols et al., 2006).

Such an integral approach is holistic in that it seeks to understand natural resource management schemes in the light of local social, cultural, economic and ecological contexts (Barrera-Bassols et al., 2006). Theories that indigenous people have about their soil and land resources are thus based on a complex interaction between beliefs (K*osmos*), knowledge (C*orpus*) and practise (P*raxis*) (K-C-P) which provides both theoretical and practical benefits (Barrera-Bassols and Zinck, 2003; Barrera-Bassols and Toledo, 2005). Consequently, integrative studies of the K-C-P model have become a useful means to obtain a detailed understanding of complex local realities and soil use and management (Barrera-Bassols and Toledo, 2005; Barrera-Bassols et al., 2006). However, it is worth noting that the *beliefs* aspect of indigenous knowledge (IK) is seldom explored in ethnopedological studies (Barrera-Bassols and Toledo, 2005; Barrera-Bassols et al., 2006).

2.3 Soil classification

Soils have been and remain crucial to the existence of human societies and due to their wide variability have been the subject of classification in order to group 'like' soils together. The Chinese book, *Yugong* (2 500 BP) is one of the earliest known soil classification systems where soils were grouped into nine classes based on soil colour, texture and hydrological features. Other examples of early soil classifications are those by Theophrastus, a Greek botanist (370-287 BC) and Marcus Porcius, a Roman lawyer (234-149 BC) (Krasilnikov et al., 2009). They named soils based on observable properties such as clay, sandy, salty, hard, mottled, friable, etc. Ancient soil classifications were thus largely pedological using morphological properties of soils. Most pre-scientific soil classification studies are to be found in Africa, Latin America and Asian countries (Barrera-Bassols and Zinck, 2003). Early work by Dokuchaev (1883) resulted in significant advancements in soil pedology that led to the use of soil genesis as a conceptual basis for soil classification. This consequently led to the development of intricate scientific classification systems largely based on knowledge of pedogenesis. Soil types were thus largely defined by the principles underlying the classification. Commonly the ancient classification systems are now largely ignored and are increasingly being replaced by scientific classification systems, especially in developed countries. It is noteworthy that these scientific classification systems are still often based on the quantitative differentiation of morphological properties and are aimed at agricultural uses of soils (Talawar and Rhoades, 1998). However, they differ from ancient indigenous classification systems in terms of the priority given to these in relation to soil genesis. It can, however, be argued that most, if not all, scientific soil classification systems have evolved from and still have a very strong imprint of the indigenous soil classification approach. Some have even adopted soil folk names (e.g. Slavonin names such as *chernozem*, *solonetz* and *gley* in the scientific Russian soil classification).

The influence of soil forming factors as well as pedogenic processes on the development of soils forms an integral part of scientific classification systems. Differences in the degree of influence of the soil forming factors as well as their combinations are reflected by the existence of an infinitely large number of different soils. Scientific classification systems group soils with similar properties to allow some generalization and exchange of information on soils found in different areas. Many countries, such as the USA (whose Soil Taxonomy (Soil Survey Staff, 2014) is often presented as an internationally useable classification), Australia, Brazil, Canada, China, France and South Africa, have produced their own soil classifications based on the arguable premise that particular local conditions require a national classification. More recently the Food and Agriculture Organization of the United Nations (FAO) has suggested an international classification known as the World Reference Base for Soil Resources (IUSS Working Group WRB, 2014) which attempts to bring uniformity to soil classification terminology, although national interests remain strong in many countries.

Despite the wide use of these systems in making and interpreting soil surveys as well as their use as communication tools among soil scientists, there still remains the most problematic decision on which properties of soils to use to determine and identify soil classes (Nortcliff, 2006). Moreover, with an apparent current emphasis on generalization and the development of a common classification system, small-scale spatial variations may be overlooked. Highly detailed classifications (e.g. soil phase level) can, however, deal with this apparent shortcoming. Unfortunately, these come at very high costs that farmers often cannot afford. Although this does not suggest a fault in the classification, such information may be redundant given that farmers are well equipped to understand these variations at their level of classification.

2.3.1 Indigenous soil classification systems

An indigenous classification system classifies soils based on experience often gained over many generations. Such long-term interaction with soils enables farmers to develop vernacular soil taxonomies. Vernacular soil names are either nominal or consist of descriptive names based on certain soil properties that aim to provide a basis for land use (Krasilnikov and Tabor, 2003). Through trial and error, farmers have learnt the implications of soil morphology on soil behaviour and consequently its use and management. Their taxonomy reflects SIK that is then interpreted into land use. Consequently, farmers' soil classification is user-oriented. The fact that soil underpins food production (Buol et al., 2003) has led to a bias towards the classification of soil for agricultural uses. As a result studies on indigenous soil classification have often only focused on farming communities (Crane, 2001; Barrera-Bassols et al., 2006, 2009; Ngailo and Nortcliff, 2007; Breuning-Madsen et al., 2010; Nwankwo et al., 2011; Estrada-Medina et al., 2013; Abdulrashid and Yaro, 2014). This gives the impression that indigenous soil classification is only concerned with agricultural soils. Notwithstanding the significance of these studies in understanding ways in which communities establish soil-crop systems, similar attention should be given to non-arable soils that are classified and used by rural communities. Some examples of agricultural soil classification include productive soils of well drained plains called *"tsa'a pepeuo"* and poorly-drained soils of inland valleys called *"tsa'a ngui"* from west Cameroon, (eusoils.jrc.ec.europa.eu/Library/Maps/ Africa Atlas/Download/49); fertile and poor soils of Ethiopia known as *reguid* and *rekik*, respectively (Corbeels et al., 2000) as well as productive *turbaya/hancin kare* soil from Nigeria (Abdulrashid and Yaro, 2014). In places, soils considered as not suitable for agriculture and used as construction materials are also classified using indigenous classification systems. For example, the *ile gamo* (a silver grey, clay-rich residual from micaceous shales) in Nigeria; *rakar* in India, which are strongly weathered cemented soils, and central Mexico's cemented layer of volcanic soil known as *tepetates*.

Despite the main emphasis being on morphological properties, communities often do acknowledge soil-landscape relationships and this understanding is reflected in their local classification. Krasilnikov and Tabor (2010) give examples from Central Asia (*akum* – white loose sands without vegetation and *karakum* – black sands with a fragmented turf layer on the surface), north Africa where people distinguish between desert environments (*erg* – sandy desert usually located in depressions, *feh* – soil of clayey-stony desert, *regh* – a stony gravel desert, and *serir* – stony desert of lowland regions) and in east Africa where soils of dryland savanna landscapes are known as *miombo* soils.

2.3.2 Criteria for indigenous soil classification systems

Colour and texture are the most frequently used criteria for indigenous soil classification systems. Barrera-Bassols and Zinck (1998) showed that of the total of 62 ethnic groups in 25 countries in Africa (west, east and south), Latin America and Asia, more than 95% used colour and texture, about 56% used consistence and soil moisture while relatively few used properties such as fertility and workability. The use of colour is not surprising as it is the most evident soil property that can be observed easily in the field. Soil names are often derived directly from the observed colour of the soil. For example, Japanese name the dark volcanic ash soil, *kuroboku* meaning "black as ink" (Krasilnikov and Tabor, 2010). In West Africa, Ghanaian *nete kokoo* are well-drained brown/red soils, Nigerian *ille funfun* are bleached, coarse sandy soils and in Burkina Faso the *zi-sabille* are black soils (Bonsu, 2004). Ngailo and Nortcliff (2007) reported black, well drained- *ibushi* and *itogolo*- grey, imperfectly drained soils from Tanzania, East Africa. In -South Africa (KwaZulu-Natal), *isibomvu* is used for well-drained, red agricultural soils (Buthelezi et al., 2013). Similarly, the Xicrins people of Brazil use colour to classify soils into four classes, viz *aka* - white soils, *kamrek* - red soils, *ngra* - yellow soils and *tuk* - black soils (Cooper et al., 2005). In addition, metaphorical names are sometimes used to indicate soil colour as in the Russian "*podzol*" that refers to the whitish-grey ash-colour beneath the topsoil that is exposed at the surface after ploughing (Krasilnikov and Tabor, 2010). The use of soil colour has been scientifically related to soil physicochemical and drainage status of the soil, both important with respect to soil use and management. Similarly, the use of this property in indigenous soil classifications has revealed the same understanding. For example, farming communities have associated darker soils with good fertility; grey soils with low-lying areas and poor drainage and red soils with poor fertility and frequent droughtiness (Mairura et al., 2007; Buthelezi et al., 2013; Abdulrashid and Yaro, 2014; Nath et al., 2015).

Texture is also an important property, which largely affects soil behaviour through its influence on soil hydraulic, physical and chemical properties. Most societies classify soils into three major groups i.e., sands, loams and clays depending on their particle size distribution. Vernacular soil names indicating these include *anwea* – sandy soils of Ghana, *yanrin* and *bole* – Nigerian sandy and clay soils, respectively (Bonsu, 2004) and *udongwe* – South African (KwaZulu-Natal) clay soils (Buthelezi et al., 2013). For farming communities the use of texture is perceived in terms of its influence on soil water holding capacity and ease of tillage. Sandy soils are associated with low water holding capacity, high infiltration rate and generally poor fertility. Clay soils, on the other hand, often have physical constraints of workability, especially those with shrink/swell properties. They are subjected to periodic saturation due to low infiltration making them difficult to plough. These are often not preferred for agriculture despite their good chemical fertility. Almost worldwide, loams are considered best for cultivation (Krasilnikov and Tabor, 2010). Some of the names used for these soils include *tierra baya* (Mexico), *idudusi*, *ovunguvungu* (South Africa Nguni people), *alaadun* (Nigerian

Yoruba people), and in various Latin American countries *lima or limos* are used (Krasilnikov et al., 2009).

Indigenous soil classification systems are simpler than scientific ones and reflect the observed reality encountered by local people (Sillitoe, 1998). Focusing primarily on the morphological properties of interest to land use and management, they provide detailed and relevant soil information that can be directly applied to day-to-day soil use decisions. Since local people have precise information on these local specific variations, indigenous soil classification can thus contribute to the identification of properties of interest with respect to soil use and management (Krasilnikov and Tabor, 2003).

The simplicity and flexibility of the indigenous classification systems are important features for farmer-level of soil use. Distinctions between soils are determined by the classifier's perceptions, assumptions and needs as these are often not hierarchical schemes (Showers, 2006). This allows people to relate soils to one another in any way that seems appropriate to their needs (Sillitoe, 1998). Indigenous soil classifications allow people to accommodate for any significant changes in soil type by modifying their descriptor terms; so soil here may be "some of this and less of that" whereas a soil over there may be "less of this and more of that" (Sillitoe, 1998). Even though this strengthens the application and improves the relevance of SIK at the local scale, it remains largely place-specific with limited potential for transfer over broader geographic areas.

On the other hand, scientific classifications (e.g. Soil Taxonomy, South African soil classification) are often too rigid as soils have to be placed in "closed" categories with no room for intergrades. The introduction of qualifiers in the WRB system (IUSS Working Group WRB, 2014) has given some flexibility to the scientific classification. Indigenous soil classification systems still provide useful information with a potential to improve the relevance of technical soil maps, especially in developing areas. They ensure that the inventory and development of local resources is culturally relevant (Krasilnikov and Tabor, 2010). Moreover, they assist effective communication between scientists and non-scientists that will ensure understanding of soil properties relevant to correct soil use and management.

2.4 Soil quality management

2.4.1 Fertility

Soil fertility is one of the most important factors that determines the ability of the soil to produce crops. Failure to maintain the balance between nutrient inputs and harvest removal has led to soil fertility depletion, especially in Africa (Murage et al., 2000). Poor soil fertility results in low per capita food production and hence is a major constraint to long-term food security. To assess soil fertility, scientists rely on laboratory analysis of critical properties (e.g. exchangeable cations, pH, acid saturation, organic carbon amongst others) from which they are able to make recommendations. However, this information is often not accessible to rural communities, and uses scientific terminology that may not be understood by local soil users. This is a major concern for many rural communities since food security is highly dependent on soil productivity. Rural communities have thus developed reliable and locally adapted methods to assess and manage soil fertility to ensure sustained soil productivity. They have for centuries used their experience and observations to produce a number of soil fertility indicators as well as soil fertility management practices.

Agricultural production is the primary concern behind understanding as well as assessing soil quality in rural communities. Crop yield and crop appearance are consequently major local soil fertility indicators (Gruver and Weil, 2007; Mairura et al., 2007; Buthelezi et al., 2013; Berazneva et al., 2016). Although these do not reflect precise nutrient content, local knowledge of soil fertility is still very critical due to low availability or absence of chemical fertilisers and soil analysis information. Moreover, most rural communities still produce crops under rainfed conditions in which soils are vulnerable to losses due to factors such as topography, over-intensive use of the land. Other local indicators of soil fertility include the natural vegetation as well as soil factors that affect plant growth such as drainage, colour, texture, stoniness and the presence of soil organisms (Shaxson, 1999; Corbeels et al., 2000; Moges and Hoden, 2007; Odendo et al., 2010; Buthelezi et al., 2013; Bezabih et al., 2016). The use of a range of properties by local farmers shows that they view soil fertility as a multi-faceted concept that is not limited to nutrient status (Talawar and Rhoades, 1998; Corbeels et al., 2000). This is similar to the scientific approach to soil fertility assessment. However, disregarding absolute nutrient status may result in chemically poor soils and consequently compromised crop yields. An indication of some nutrient deficiencies by the qualitative indicators used by farmers is not adequate to give accurate fertiliser/lime recommendations. The provision of a complete soil fertility assessment is thus important for the two (i.e., scientific and indigenous) approaches to complement each other in order to overcome their respective shortcomings. This creates an urgent need to make soil analysis data available in user-friendly formats and language that can be easily understood by all farmers. Moreover, other management constraints that may offset the benefit of laboratory data will need to be considered.

Although, farmer soil fertility assessment is qualitative, studies have shown that it has a good correlation with laboratory data of soil chemical and physical properties. For example, Birmingham (2003) reported a low cation exchange capacity (CEC) of 2.0 $cmol_c\ kg^{-1}$ for *bossay dodo pepe* (white, sandy soils) that farmers in Bete, Cote d'Ivoire, considered least desirable for crop production. The author also found the highest organic matter content (2.45%) in a bottomland soil (*paplay*) which was distinguished from other bottomland soils as forming because of water and sediment movement downslope. In central Kenya, Mairura et al. (2007) investigated how fertility classes determined by farmers based on local indicators compared with chemical and physical characteristics measured in the laboratory. They found that soils in the high fertility class had a CEC of 5.8 $cmol_c\ kg^{-1}$ compared to those categorised as having low fertility, which had a CEC of 3.8 $cmol_c\ kg^{-1}$. Correlations were also reported for soil organic carbon that was 33.6 and 24.3 $mg\ kg^{-1}$ for high and low fertility classes, respectively. Similarly, Buthelezi et al. (2013) in KwaZulu-Natal, South Africa reported a relatively high effective CEC (mean of 5.0 $cmol_c\ kg^{-1}$) for soils locally considered fertile, in comparison to those that were not (mean of 3.8 $cmol_c\ kg^{-1}$). Kuldip et al. (2011) also found that laboratory analysis of soil properties correlated with traditional soil characterisation by the *Nyishis* of Arunachal, Pradesh, India. In Ghana, Dawoe et al. (2012) reported higher levels of N, P, K and organic matter in farmer-perceived fertile (0.27%, 3.12 ppm, 136.1 ppm and 2.90%, respectively) compared to infertile sites (0.13%, 2.10 ppm, 90.4 ppm and 1.93%, respectively). These studies show that although local soil fertility assessment is largely empirical, it can be supported by sound scientific theory. Despite the reported significant differences between farmer-perceived fertile and infertile soils, it is evident that overall studied soils (irrespective of perceived fertility status) had relatively poor chemical fertility. This further emphasizes the need for laboratory data to ensure that farmers do not only effectively assess but are also able to adequately enhance and manage soil fertility.

Nonetheless, local knowledge of soil fertility has enabled farmers in rural communities to develop sound soil fertility management strategies. Some of the common practices of indigenous soil fertility management include crop rotation, crop residue application and manuring. These have been reported to improve soil fertility but due to increasing population pressure and subsequent land shortages, some farmers have been forced to abandon some of these techniques, especially fallowing (Corbeels et al., 2000). All these methods are not only locally relevant but also economically feasible and can be easily implemented. For example, Misra et al. (2008) reported a study in Garhwal, Himalayas where farmers use soil fauna such as earthworms, ants and arthropods to maintain soil fertility. They revive soil fauna biodiversity mainly through two traditional methods, i.e., application of farmyard manure and using mixed cropping and crop rotation. Mixed cropping is locally known as *borahnaja*, which means that food sufficiency and security can only be achieved through highly diversified cropping systems (i.e., at least 12 different crops per year). Cultivated crops included paddy rice, millet and pulses (produced between April and October, Kharif season) as well as wheat, barley, mustard, lentils and peas produced in winter. Misra et al. (2008) also observed that farmers placed more emphasis on leguminous crops, which they believe to enhance and maintain soil fertility. Although they could not provide any substantial explanation of this benefit, farmers had observed a general increase in the productivity of crops grown subsequently with less application of farmyard manure.

2.4.2 Soil and water conservation

Land degradation and the subsequent reduction in food production are major concerns for soil quality and long-term agricultural sustainability. These are largely due to runoff and soil erosion, which not only result in soil loss but also reduce plant-available water and soil nutrient levels. Although issues of land degradation are of concern worldwide, conservation of both soil and water has proven a crucial component of agricultural systems especially in semi-arid regions in the developing countries of Africa and south-east Asia. This has consequently resulted in a long history of external interventions towards achieving soil and water conservation in these regions (Reij, 1991). These have mainly focused on the mechanical conservation of soil through soil bunds, ridging, and contour ploughing (Scoones, 1996). Examples include large scale terracing in the Machakos district in Kenya, contour bunding in Zimbabwe (Scoones, 1996) and terracing in Ethiopia (Engdawork and Bork, 2014). Such major engineering schemes have often proved unsustainable and unpopular in rural settings. This is mainly because they were largely based on rainfall and crop water requirement but gave only limited consideration to social, economic and technical constraints experienced by local users. Exclusion of local people from the process meant that the techniques were poorly executed and maintained (Scoones, 1996). Despite terracing being a common indigenous soil conservation technique in these regions, its upscaling to use of modern complicated tools and inclusion of irrigation presented a challenge for most traditional users in the communities. This resulted in low adoption of such technical soil and water conservation measures, as they tended to be labour intensive, costly and to have a more long-term effect compared to original indigenous practices designed for local conditions. Consequently, the top-down approach employed by these interventions became their major downfall and the main factor contributing to their limited success (Reij, 1991; Bewket, 2007). For example, standard contour ridges imposed during the colonial era in Zimbabwe were designed with the purpose of conserving soil by diverting water away from the field to the watercourse. However, this seemed inappropriate to farmers in drier areas where these have been adjusted and adapted from soil conservation to water harvesting (Scoones, 1996). Observation of the failures of these external interventions has led to the acknowledgement of the potential role of local people in ensuring effective land management.

Farmers have developed ecologically sound practices to ensure adaptation and survival in otherwise challenging environments. These technologies have evolved incrementally and reflect a cumulative response to a range of temporal influences (Scoones, 1996). Unlike conventional techniques, indigenous soil and water conservation techniques (Reij, 1991) are flexible which is an important attribute given the spatial variability of soil and topography (Scoones, 1996). This shows the "adaptive performance" of ethno-engineering as illustrated in cases from Zimbabwe and Ethiopia (Scoones, 1996). In both these cases, the techniques have evolved over time through trial and error allowing farmers to adapt to their prevailing conditions. The nature of these techniques largely ensures the minimisation of risk, which is the governing principle of African farming. As a result, they do not only ensure survival from season to season but also give ways of conserving the long-term productivity of soils.

Indigenous soil management techniques have been developed based on IK without any external intervention. Reij (1991) showed that terracing and manuring are the most common practices in Africa. Terracing is mostly practiced in countries with an average annual rainfall greater than 1 000 mm (e.g. Kenya, Ethiopia, Tanzania), while manuring seems to dominate in countries with an average annual rainfall of about 800 mm (e.g. Togo, Ghana, Mali). Some old records of terracing exist in Mexico, China and Yemen where this technique has been practiced for about 2 000, 4 500 and 6 000 years, respectively.

A number of studies have been conducted to document and evaluate the efficacy of using specific terracing technologies in soil and water conservation and promoting crop productivity (Mati, 2006; Amsalu and de Graaf, 2006; Wakindiki et al., 2007; Ajibade, 2008; Denison and Wotshela, 2009; Ahaneku, 2010). It is evident from these studies that the ultimate goals of indigenous techniques are to (i) prevent soil particle detachment and conserve water in situ; (ii) halt the transportation of soil particles by either reducing the runoff flow velocity or slope length and gradient; and (iii) safely dispose of excess runoff from the cultivated fields.

Tekwa et al. (2010) studied a number of indigenous soil and water conservation techniques used by local communities in the Mudi area, Nigeria. Their aim was to assess the effectiveness of these practices on the sustainable crop production of six villages (Digil, Duda, Hurida, Humbu, Gella and Yewa). Using the Likert scaling test (Norman, 2010) they showed that the indigenous techniques were relevant and specific to particular village conditions and hence were effective in conserving soil and water which consequently improved crop production. For example, they found hillslope terraces to be most effective in Gella and Duda villages, which were both located on steeply sloping ground (20 -22%). In the more gently sloping areas (<10%) where Digil, Yewa and Hurida villages were situated, vegetation barriers were most effective due to the groundcover of mostly trees and shrubs. This study reflects the integrated effect of these techniques on erosion, infiltration and soil nutrient levels, which results in effective soil and water conservation. The choice of which technology to use and its application was largely dependent on the prevailing local conditions as shown by Tekwa et al. (2010).

It is clear that indigenous soil and water conservation technology is crucial in rural agriculture given the often low adoption rates and/or failure of newer, highly mechanised equipment often introduced via a top-down approach. Indigenous soil and water conservation techniques display ethno-engineering technology that underpins farmer-based innovation. They are adapted to local conditions as well as farmers' needs and are thus relevant and highly effective.

The previous sections have considered ethnopedology as applied in agricultural systems including the value of indigenous pedological knowledge in producing relevant soil classifications to aid soil management and ethno-engineering approaches to soil and water conservation techniques. Indigenous knowledge of soil and land management has clearly provided solutions to an array of local problems. Nonetheless, indigenous practices are not without challenges. For example, the majority of terrace farms remain under rainfed conditions and lack irrigation (Chapagain and Raizada, 2017). Furthermore, they still rely on simple tools, limited animal draft power and relatively abundant household labour (Mountjoy and Gliessman, 1988; Varisco, 1991). As a result they have been mostly less productive when compared to farms with appropriate mechanization and irrigation (Chapagain and Raizada, 2017). External interventions aimed at improving the efficacy of these and other indigenous soil water conservation techniques thus have potential to bring much needed solutions for rural communities. Appropriate methodology is, however, necessary to ensure inclusion of intended users to produce and implement locally relevant and sustainable techniques.

2.5 Soils: non-agricultural uses

Most ethnopedological studies have only focused on the production potential of agricultural soils, while much less attention has been given to non-agricultural soils and their possible uses (Cabral et al., 2015). This is unfortunate because it results in the disregard of soils with low agricultural potential but considered by users as suitable for other uses. Similar to agriculture, alternative uses of soil reflect a long association between humans and the Earth (Limpitlaw, 2010). There is great diversity of non-agricultural soil and land uses throughout the world. Thus, understanding ethnopedological knowledge associated with non-agricultural uses of soils is necessary to achieve sustainable and unbiased land use and management. These include the use of soils as raw materials for construction and tools (e.g. traditional pots), healing, cosmetic and geophagy practices. This section focuses on the less commonly documented uses of soils including geophagy, healing, and sunscreen, their history and perceptions as well as some of the implications associated with them.

2.5.1 Geophagy

Geophagy is a cross-cultural phenomenon of deliberate ingestion of earthy material (Hunter, 1973). It is noteworthy, however, that this practice is common in tribal and traditional societies (Lar et al., 2015). Geophagy dates to about 300 BC when first mentioned by Hypocrates, the Greek physician, following his observation of ingestion of earthy material amongst pregnant women. Subsequently, Aristotle observed that soil was also ingested for therapeutic and religious purposes. In general, geophagy was then perceived as a deviant and irrational behaviour (Engberg, 1995). In the early 19th century, geophagy was mainly associated with black African races, and later then spread to other countries through migration (Hunter, 1973). Modern geophagy has been reported worldwide e.g. northern Europe, the Mediterranean countries, Africa, East Asia, North and South America, Australia and the Pacific Islands (Hunter, 1973).

Only those soils that have certain properties such as colour, softness, flavour and plasticity are eaten (Laufer, 1930; Henry et al., 2013). Geophagic materials have a range of textures and consistencies. Fine-grained clays seem to be the most preferred due to their smoothness and sour taste.

One of the most obvious questions which after centuries remains to be fully understood is why do people eat soil? Four major suggestions have been made i.e., nutritional and health factors, pathological dimensions, psychological reactions or sociocultural factors. Within these, three hypotheses have been put forward namely nutrient deficiency (supplements for deficient nutrient elements, particularly iron and zinc), protection (medicinal value generally as an antidiarrheal as well as detoxifying certain plant species) and lastly that it is a culturally promoted and generationally diffused practice (Hunter, 1973; Vermeer and Frate, 1979; Engberg, 1995; Abrahams, 1997; Geissler et al., 1999; Henry et al., 2013). Consequently, Henry et al. (2013) categorised geophagists into four groups, *viz*. those defined by gender (women), age (young children), physical status (pregnant women) and social status (people exposed to nutrient deficiencies). Nearly all the reported cases of geophagy are among women, especially those that are pregnant, and young children (Geissler et al., 1999; Woywodt and Kiss, 2002; Ngozi, 2008; Kawai et al., 2009; Al-Rmalli et al., 2010; Diko and Diko, 2013). However, none of the suggested reasons for geophagy has been proven and it is likely that the rationale differs from society to society.

When the composition of geophagic materials is considered most studies on their physicochemical properties have reported the dominance of kaolinite and quartz, and that they tend to have a low pH, low electrical conductivity and a silty texture (Ekosse and Obi, 2015; Okunlola and Owoyemi, 2015). Given the wide variation of environmental conditions under which these materials are encountered, it is especially necessary to understand their properties and their consequent implications for human health.

2.5.2 Healing and pharmacology

The relationship between soil and human health has existed for thousands of years (Brevik and Hartemink, 2010) and a wide range of natural materials have been used to treat both minor ailments and chronic problems. For example, enriched mineral kaolin has been used to counter various poisons when taken internally with water. Possibly the most astounding results from the use of clay were reported in the late 1800s when a Dr Kuhne began administering it to treat soldiers of the Sarbian armies suffering from cholera. There was a decrease in the mortality rate from 44% to 3% (Musafir and Chazot, 2006). Clay pastes have been used on stubborn septic wounds and they helped deodorize, protect from irritation and heal (Musafir and Chazot, 2006). Such studies suggest that clay has a range of properties that are effective against various bacterial diseases.

The soil-human health relationship was initially based on casual observations without detailed scientific investigation (Brevik and Sauer, 2015) which only began in earnest in the early 19th century. Recently, isolation of antibiotic compounds from soil organisms has been achieved in the USA (Brevik and Sauer, 2015; http://m.bbc.co.uk/news/health-30657486). There have been many studies on the interrelationships between soil and human health covering a variety of aspects such as the transfer of nutrients from soils to people (Oliver, 1997; Abrahams, 2002; Taylor et al., 2010), the effect of soil heavy metals and other trace elements (Senesil et al., 1999; Brevik, 2009; Lopes et al., 2017) and the link between soil organisms and human health (Pepper et al., 2009; Brevik and Sauer, 2015).

The crucial properties of healing clays are their colloidal dimension and high surface area that are associated with optimal rheological characteristics and/or sorption capacities (López-Galindo and Viseras, 2004; Abdulrashid and Yaro, 2014). These are dependent on the structural, chemical and textural properties of the particular clay mineral. As a result, different clay minerals, especially kaolinite and smectites, are used extensively in the production of medicines.

Clays are used medically both externally and internally. Internal uses includes drinking clay (Wilson, 2003), which is generally administered to provide relief from gastrointestinal distress (Droy-Lefaix and Tateo, 2006) and geophagy (Section 2.5.1). The external application is for open cuts and wounds, where the clay adsorbs the toxins from the skin, and provides heat to stimulate circulation for rheumatism treatment (Carretero et al., 2006). This curative power of clays has been variously attributed to absorption capacities, CEC, and extremely fine particle size, which play a significant role in the removal of secretions, toxins, oils and contaminants from the skin (Williams and Haydel, 2010). Pusch (2015) reported that a clay paste applied to a hand wound led to healing within two days. The sticky paste helped stop bleeding and formed a scab that protected the wound from microbial attack and thus prevented infection (Pusch, 2015). Clay minerals (e.g. kaolin) have an ability to exert a soft antiseptic action by producing a water-poor medium unfavourable to bacterial growth (Carretero and Pozo, 2010). Smectite has also been reported to clean and refresh the skin surface as well as to help heal topical blemishes and is thus effective in dermatology (Pusch, 2015).

Although research on healing clays has focused mainly on the physical properties of clay minerals (Williams and Haydel, 2010) the healing processes can occur through various pathways. For example, less attention has been given to the geochemical mechanisms controlling antibacterial properties of clays despite the generally known property of metallic ions having strong inhibitory and bactericidal effects on a broad spectrum of bacteria (Williams and Haydel, 2010). In these clays, the healing is largely a function of chemical attack on the human pathogens and they are referred to as “antibacterial clays” as opposed to the “healing clays” discussed earlier. These clays do not kill by physical associations between clay and bacterial cells as was demonstrated by Williams et al. (2011). Rather it is the ability of antibacterial clays to buffer the intracellular pH and oxidation state that leads to conditions that improve Fe^{2+} solubility that seems to be key to their healing potential (Williams et al., 2011; Morrison et al., 2014). A clay mineral (CsAgO2) found in France are amongst a few clays proven to have antibacterial properties with the ability to kill bacteria while promoting skin growth (Williams et al., 2011). Williams and Haydel (2010) outline the methodology for evaluating the antibacterial activity of clays.

2.5.3 Cosmetics

Soil materials, especially various clays, are widely used in the manufacture and use of cosmetics. Clays have good sorbing properties for various substances including greases and toxins (Choy et al., 2007; Carretero and Pozo, 2010). Furthermore, clays are able to give the skin opacity, remove shine and cover blemishes subsequently facilitating skin cleansing, beauty and detoxification as well as ion exchange with the skin (Carretero, 2002). In addition, clays have been shown to offer ultra-violet (UV) radiation protection (Dlova et al., 2013; Madikizela et al., 2017). There is considerable literature on the use of clay minerals as active ingredients in cosmetic formulations (Carretero, 2002; Lopez-Galindo and Viseras, 2004; Carretero et al., 2006). These studies show that clay minerals such as kaolinite, smectite (e.g. montmorillonite), talc, and rutile are suitable to provide protection against external physical and chemical agents due to their ability to adhere to skin forming a film. However, these studies have focused mostly on isolated clay minerals found in modern commercial products while little attention has been given to clays used traditionally for cosmetics in many rural communities. The clays used by the communities are integral to traditional methods of beautification built on SIK. Matike et al.

(2010) have documented the extent to which clays are used in rural communities in Africa (Table 2.1).

Table 2.1 shows that clays are widely used amongst African communities. These are largely identified by their colour with red and white most commonly used.

Table 2.1 Types of clays used for cosmetic application by traditional African tribes (Matike et al., 2010).

Traditional name	Colour	Tribe and country where the clay is used	Region
Nzu	White	Igbo (Nigeria)	West Africa
Edo	Yellow	Igbo (Nigeria)	
Uli/Uri	Black	Igbo (Nigeria)	
Munuku	White	Igbo (Nigeria)	
Kalaba chalk	White	Cameroon	Central Africa
Thriga	Red	Masaai and Kikuyu (Kenya)	Eastern Africa
Ortijze	Red	Himba (Namibia)	Southern Africa
Musiro	White	Iiha de Mozambique	
Ikota	White	Xhosa (South Africa)	
Ingceke	White	Xhosa, Pondo (South Africa)	
Umthoba	Yellow	Xhosa, Pondo (South Africa)	
Ingxwala	Red	Xhosa (South Africa)	
Umdiki	Red	Xhosa (South Africa)	
Imbola	Red	Pondo (South Africa)	
Ibomvu	Red	Zulu (South Africa)	
Umcako	White	Zulu (South Africa)	
Letsoku	Red	Pedi (South Africa)	
Luvhundi	NS*	Venda (South Africa)	

*NS - not specified

It should be noted that the same clay type maybe given different names in different communities. For example, red clay is referred to as *ibomvu* and *imbola* by Zulu and Xhosa ethnic groups, respectively. Thus, different rural communities use similar clay types. For example, in the Eastern Cape of South Africa, a Pondo bride is smeared with red clay (*imbola*) before meeting her husband on her wedding day so as to cleanse and lighten her skin (Matike et al., 2010). Similarly, in the Zulu ethnic group, a teenage girl is smeared with red clay during the ritual known as *umemulo* (initiation to womanhood). The use of clay in this ritual is mainly for beautification purposes.

There is also evidence of the use of both white and red clays for cosmetic purposes in northern Africa. For example, Egyptian women used red clay to enhance beauty of certain parts of their bodies (Chaudhri and Jain, 2009). Similarly, women from East and West Africa also use clays to decorate their bodies during funerals and certain rituals (Burt, 1982). The Himba of Namibia apply *ortijze* (red clay) daily to rid their body of dirt and bad smell (Troeng, 1995). It has also been recorded that indigenous African tribes use clays for sun protection (Reed, 2007).

The exploitation of these properties of clays suggests that people are aware of their ability to cleanse, purify and protect the skin. The use of an inherent property such as colour (specifically red and white) is intriguing, especially considering the implied mineralogy and its possible effect on common uses of these clays. Trial and error seem to provide indigenous communities with valuable lessons regarding use and behaviour of these clays. The use of clays in cosmetics, as well as the extent of UV protection, depends on the clay's mineralogical and chemical composition (Matike et al., 2010). This emphasizes the importance of ascertaining cosmetic components of traditionally used clays by conducting research on their properties to establish a possible relationship between IK and scientific evidence. A few studies have investigated the chemical and mineral composition of clays used in traditional cosmetics. Most of these studies are from South Africa and report on the efficacy of red clays in cosmetic application. South African red clays (*ibomvu/imbola*) have been reported to have low pH, fine-grained particle size distribution, and are dominated by kaolinite and hematite with significant amounts of titanium oxide (Matike et al., 2010; Dlova et al., 2013; Madikizela et al., 2017). These properties can explain the potential of the red clays to act as sunscreens. For example, Hoang-Minh et al. (2010) and Dušenkova et al. (2015) showed that a high amount of iron in the form of hematite reduced UV-transmission, significantly increasing the UV-protection value of clays. Despite the commonly reported low sun protection factor (<5) these clays give a broad spectrum protection against solar UV radiation (Dlova et al., 2013; Ng′etich et al., 2014; Rifkin et al., 2015; Madikizela et al., 2017). Furthermore, the high titanium oxide content contributes significantly to the healing and cosmetic roles of the clays. These have largely been attributed to their nanometre particle size as well as a high refractive index that are crucial for healing (Yamamoto, 2001) and sunblock (Smijs and Pavel, 2011), respectively. Minerals with high refractive index can be used as effective solar protectors (Carretero and Pozo, 2010). Traditional clays can thus provide some sun protection as they contain active ingredients that serve as effective cosmetic components. Unfortunately, these have received little attention from researchers despite forming a significant part of indigenous soil use.

Similar to agricultural uses, this section shows that the pedological wisdom of rural people forms the basis for selection of soil material for non-agricultural uses. An understanding of soil morphological properties (e.g. colour and texture) remains the criterion for soil suitability. The use of common classification criteria for both agricultural and non-agricultural soils suggests a possibility for land use conflict. However, a lack of studies focusing on the parallel investigation of agricultural and non-agricultural uses has created a gap that may exacerbate soil suitability bias towards the former and that may result in land use conflicts where the latter may be locally preferred.

2.6 Conclusions

Soil indigenous knowledge constitutes complex local pedological wisdom acquired through long-term observations and experiences by rural communities. Soil is an integral part of human livelihoods from agriculture to its interaction with human health. Knowledge of soil morphological properties gained through trial and error is fundamental to the application of SIK. Rural people are able to use soil morphological properties to identify, distinguish and make land use decisions about soil materials. This knowledge is key to indigenous soil classifications that have formed the basis for most advanced modern soil classification. Indigenous soil classification systems remain simple and flexible and are easily adapted to local conditions. The emphasis on individual properties of interest to land use can contribute in the development of the multiple criteria for a soil phase. They can thus complement often rigid scientific soil classification systems.

The pedological wisdom of rural people is fundamental to soil use and management in many communities. The review has shown that SIK has significantly contributed to the development of a sound farmer soil fertility evaluation approach as well as soil water conservation strategies. Farmer soil fertility evaluation, however, remains largely one-dimensional as it disregards absolute soil fertility status. Addition of laboratory data to the farmer fertility evaluation will provide accurate fertiliser recommendations thus ensuring optimum crop yields and sustained livelihoods. Furthermore, SIK has proven important in soil and water conservation and the development of effective innovations such as terraces. These systems, however, have limited productivity due to low inputs and lack of sufficient labour. Implementing locally appropriate and relevant interventions could result in the advancement of such local techniques to systems that are more productive.

Non-agricultural uses of soils are also largely governed by knowledge of soil morphological properties. The physicochemical and mineralogical characterisation of soils used for cosmetics, healing, and geophagy are consistent with these functional roles. Geophagic soils have variable compositions due to varied sources and provenance. Healing clays have been associated with occurrence of kaolinite and smectite as well as general physicochemical properties. This focus has largely ignored the chemical mechanisms explaining the curative properties of some clays. Cosmetic clays used in traditional beautification methods have played a significant role in many rural communities with limited access to commercial products. Such clays have specific cosmetic components that can provide possible explanations for their traditional use. However, these have not received much attention with only a few studies from Africa, particularly South Africa. This gap has led to biased soil suitability classifications that are largely aimed at agricultural potential with less or no regard for soils that have less agricultural potential but which are suitable for other non-agricultural uses significant to rural people. It is thus imperative that this knowledge is learned and understood to inform comprehensive and less biased soil suitability classifications

Many rural people are pedologists. Their knowledge and understanding of morphological properties is a plausible base for soil use and management at least at field-level. Soil indigenous knowledge has the potential to provide an adequate description of complex and dynamic environments and the experiences of farmers and rural people in general. It seems that SIK should be considered to be a complementary set of knowledge with valuable additions from the local experiences vital for improving the relevance of scientific knowledge to rural peoples' needs. In the same way, scientific knowledge can contribute to improving some of the indigenous soil management approaches. However, methodology for such integrations should be well balanced to ensure that both stakeholders are equally involved, otherwise excellent interventions will continue to add to the recorded failures of scientific approaches in rural communities. It is thus imperative for ethnopedological research to consider land-user perceptions of soil use and management in the broadest terms.

In the light of evident gaps and research needs, the current study undertook an integrated approach to investigate ethnopedological information in selected villages of South Africa. It appreciates both limits and synergies that exist between the two epistemologies (i.e., indigenous and scientific approach). Literature has shown that rural people are well qualified to define their own problems and are knowledgeable about their soils. The study thus goes beyond a descriptive approach (i.e., soil classifications) to investigate local soil theories related to these with the main focus on the land use practices and management of soil resources. It explores how ethnopedological wisdom has been applied to adapt to changing social realities. This appreciates the cultural context in which rural people engage symbolically and practically with soils. Overall, the study explored the role of ethnopedological knowledge of rural people in soil use and management that is crucial to long-term sustainability.

Chapter 3: Indigenous soil classification in four villages of eastern South Africa

3.1 Introduction

Conventional soil survey data are often presented in a format that is not user-friendly, and are thus commonly undervalued, and underutilized by non-specialists in making land use and management decisions (Grealish et al., 2015). Despite having advanced the understanding and classification of soils worldwide, internationally recognized classification systems such as Soil Taxonomy (Soil Survey Staff, 2014) and the World Reference Base (IUSS Working Group WRB, 2014), as well as national systems (e.g. South African; Soil Classification Working Group (SCWG), 1991), are general purpose and use specialized terminology and language to classify and name soils. Their utilisation thus requires considerable expertise and experience (Fitzpatrick, 2013). In order to improve the local relevance and impact of soil survey data, the knowledge of local land users needs to be considered (Sillitoe, 1998).

Local soil knowledge is widely recognized for its practical value and contribution to rational and sustainable soil management (Barrera-Bassols and Zinck, 2000; Niemeijer and Mazzucato, 2003; Nath et al., 2015). It has been demonstrated in many countries and across many ethnic groups that integration of local soil knowledge in participatory soil surveys helps to address practical issues and provides culturally acceptable solutions appropriate to local contexts (Barrera-Bassols et al., 2009). Some studies have found poor correlations between local and scientific classifications (Schuler et al., 2006; Barrera-Bassols et al., 2009) while others have reported good correlations (Payton et al., 2003; Oliver et al., 2010). Such variation has often been attributed to differences in landscape structure in the areas studied.

Many rural people are pedologists (Barrera-Bassols, 2016) in that their knowledge and understanding of soil morphological properties has proven to be a solid base for soil use and management, at least at field-scale. Taxonomies of local vernacular classification systems are developed based on descriptive morphological soil characteristics important to the user (Sandor and Furbee, 1996; Habarurema and Steiner, 1997; Corbeels et al., 2000; Krasilnikov et al., 2009). Key soil morphological properties, such as colour and texture, are the main criteria for classification most commonly reported (Ettema, 1994; Shah, 1995; Talawar and Rhoades, 1998; Barrera-Bassols and Zinck, 2003; Sillitoe et al., 2004). Distinctions between soils are determined by the classifier's perceptions, assumptions and needs, as these are often not hierarchical schemes (Showers, 2006). This allows people to relate soils to one another in any way that seems appropriate to their needs (Sillitoe, 1998). Local soil classification thus goes beyond soil nomenclature and has formed the basis for local soil-crop systems.

Ethnopedological knowledge has the potential to provide an adequate description of complex and dynamic environments and the experiences of farmers and rural people in general (Niemeijer and Mazzucato, 2003). Soil indigenous knowledge should thus be considered as a complementary set of knowledge with valuable additions from the local experiences vital for improving the relevance of scientific knowledge to rural peoples' needs. Ethnopedological research must therefore consider land-user perceptions of soil use and management in the broadest terms. To capture the essence of farmers' pedological wisdom there is a need for an integrated approach (Barrera-Bassols et al., 2006).

Many ethnopedological studies have, however, been mainly descriptive and focused in Latin America, Africa and Asia with few in Europe and the Pacific areas (Barrera-Bassols and Zinck, 2003; Capra et al., 2015). Despite Africa's significant contribution to ethnopedological studies, very few of these have come from South Africa despite its broad linguistic and ethnic diversity (Nethononda and Odhiambo, 2011; Buthelezi et al., 2013; Manyevere et al., 2014). While land use planning decisions make use of the South African soil classification system, soil knowledge of indigenous people is ignored, with negative effects on local relevance of such decisions. This study aimed to explore indigenous knowledge related to soil classification systems and criteria used by the Zulu and Xhosa ethnic groups in eastern South Africa and the level at which they classify their soils. To achieve this the soils in the study areas were identified and mapped using both local and scientific (SCWG and WRB) classifications and the spatial coincidence between them measured. Another main aspect of the study was to investigate if the local classification schemes could be integrated with the current scientific classifications to produce a system for use at the local farmer level.

3.2 Study site

The study was conducted at Potshini and Khokhwane villages (Figure 3.1) in KwaZulu-Natal (KZN) (predominantly Zulu ethnic group) and in Ntshiqo and Zalaze villages (Figure 3.2) in the Eastern Cape (EC) (predominantly Xhosa ethnic group) Provinces of South Africa (SA). Zulus and Xhosas were chosen because they are two of the three major ethnic groups unique to SA.

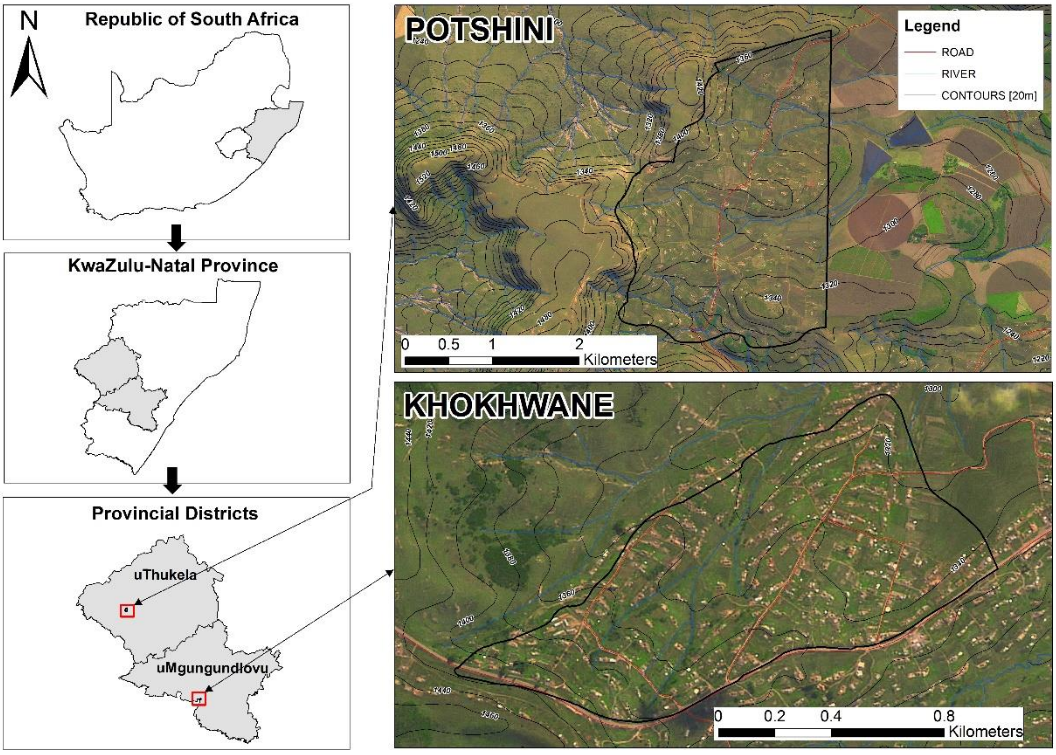


Figure 3.1 KwaZulu-Natal study sites.

Potshini (28.8145ºS, 29.3679ºE) is located in the foothills of the Drakensberg Mountains, north-western KZN at about 1 300 m.a.s.l. The mean annual rainfall is 700 mm and maximum and minimum mean annual temperatures are 34ºC and -4ºC, respectively (Kongo et al., 2010). The underlying geology is characterised by a horizontal succession of Permo-Triassic fine-grained sandstone that alternates with shale, siltstone and mudstone of the Beaufort and Ecca Groups of the Karoo Supergroup (Dlamini and Chaplot, 2012). The natural vegetation is classified as Northern KwaZulu-Natal Moist Grassland (Mucina and Rutherford, 2006). The village is predominantly a smallholder farming area (mainly crop production and unimproved grazing).

Khokhwane (29.7014°S, 30.1039°E) is located in central KZN about 53 km north of Pietermaritzburg at about 1 300 m.a.s.l. Shale of the Ecca Group dominates the underlying geology and the vegetation in the area is characterised by Moist Midlands Mistbelt (Camp and Hardy, 1999). The area receives an average annual rainfall of 750 mm with maximum and minimum average annual temperatures of 22.8°C and 9°C, respectively. Similar to Potshini, this area is mainly used for small-scale agricultural production.

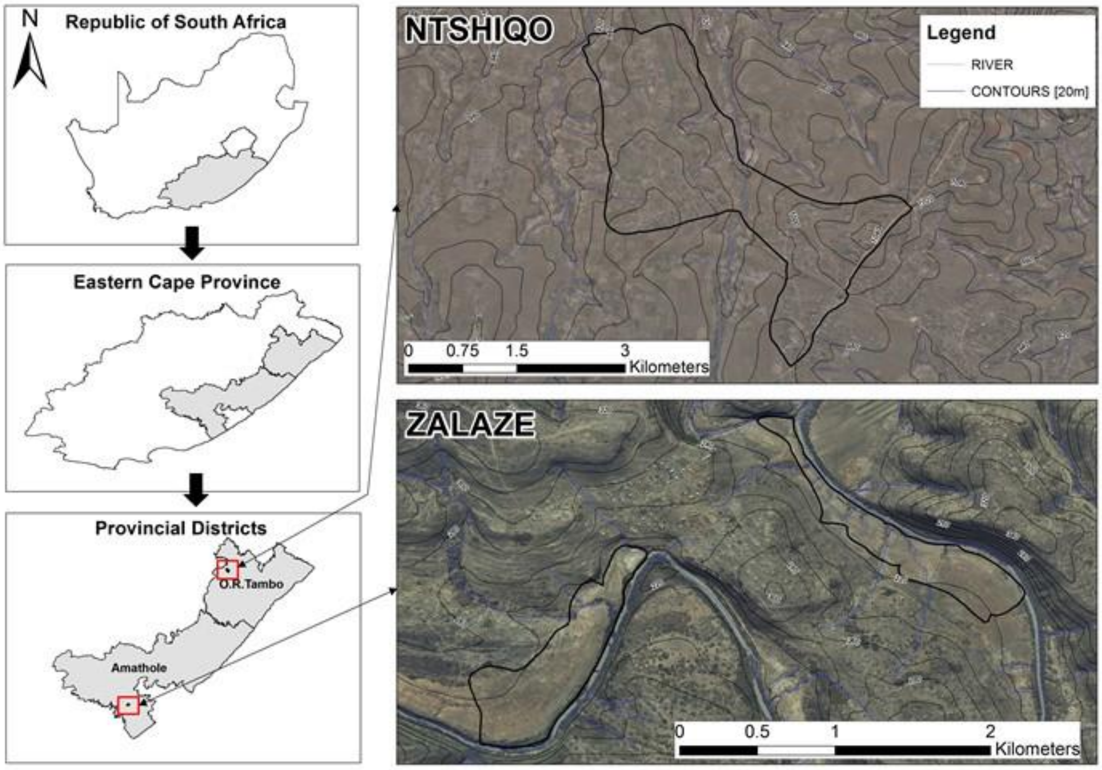


Figure 3.2 Eastern Cape study sites.

Ntshiqo (31.2774°S, 28.7068° E) is located in the wild coast region of the EC about 47 km north-west of Mthatha at about 945 m.a.s.l. The area receives an average annual rainfall of 749 mm and has maximum and minimum mean annual temperatures of 26.5°C and 3.2°C, respectively (Calmeyer and Muruven, 2014). The area is underlain by sandstone of the Beaufort Group with post Karoo dolerite intrusions. Mthatha Moist Grassland (Mucina et al., 2000) dominates the vegetation. Small-scale agricultural production constitutes the main land use in the area.

Zalaze (33.0332°S, 27.0544°E) is located on the coastal plateau of the Keiskamma River catchment near Peddie at 1 080 m.a.s.l. The area is characterised by semi-arid climate with an average annual rainfall of 450 mm and maximum and minimum mean annual temperatures of 26.8^{o}C and 7.6^{o}C, respectively (Mhangara et al., 2012). The underlying geology is dominated by fine-grained mudstones of the Beaufort Group. The natural vegetation is Eastern Thorn Bushveld (Mucina et al., 2000) with livestock and subsistence cropping as predominant land uses (Kiguli et al., 1999).

3.3 Methodology

This research uses a mixed methods approach for generating knowledge. The field investigation followed an iterative process involving a progression of questioning from a broad descriptive approach to a more detailed analysis. Different ethnographic techniques including questionnaires, free listing, interviews, transect walks and participatory mapping were used to explore local soil knowledge (Oudwater and Martin, 2003). A technical soil survey was carried out using a free survey method (Dent and Young, 1981). A cartographic threshold based on the concept of soil consociation was used to quantify the spatial correlation between locally developed and scientific soil maps (Barrera-Bassols et al., 2006).

For the qualitative aspect of this research, a representative respondent group was purposefully selected from the four villages. Fifty randomly selected farmers were identified and interviewed from each of the four villages generating an initial respondent group of 200 farmers.

3.3.1 Indigenous knowledge data collection

The structured questionnaire (Appendix 1) was administered to all 200 respondents to obtain a general overview of local soil knowledge. The questionnaire included a free listing exercise as the core inquiry into local soil terminology used and data on local soil fertility perceptions (Chapter 4).

In the next iteration, semi-structured interviews (Appendix 2) were coupled with transect walks to obtain more detailed information on soils. The transect walks were field-based and determined by the number of farmers-identified soil types. For these, forty farmers (10 from each group of 50) were chosen on the basis of their level of soil knowledge and practical experience shown during the questionnaire stage or on recommendation of other farmers. This group was expected to have greater understanding of local soils compared to the average farmer. Information collected included ethnopedological information such as detailed descriptions of soil properties for each soil type provided during free listing, as well as soil fertility assessment and management (Chapter 4). Each farmer was only asked about soils with which they were familiar i.e., soils they cultivated in their own fields. Both household questionnaires and interviews were conducted at each individuals' houses. All semi-interviews were audio recorded and open ended questions from these were analysed informally using themes developed from word-based techniques, viz. word repetition and key indigenous terms (Ryan and Bernard, 2003). Words occurring a lot often are seen as salient in the minds of respondents and useful in understanding what people say (Ryan and Bernard, 2003). Words or synonyms that farmers used a lot were noted and later used to identify recurring themes related to questions asked. Audio recordings were also revisited for clarity of understanding during data analysis.

3.3.2 Participatory soil mapping

The final step in the iterative process was to select 20 individuals from the group of 40 (five from each village). In Potshini and Khokhwane five males and five females were involved in mapping. In Ntshiqo and Zalaze seven males and three females were chosen. These farmers had proven to have a detailed knowledge and understanding of the local soils in the previous interviews. By this time, a level of trust and cooperation had been established and farmers were able to compile local maps of soil classifications representing the four villages, allowing the researcher to 'see' the landscape as the farmers experienced it. Each group of five formulated a mapping team and were provided with an aerial photograph to map boundaries of soil types within their village using similar approaches as Oudwater and Martin (2003) and Gowing et al. (2004). Discussion was followed by georeferenced transect walks. These covered the whole extent of each studied village and were guided by the farmers who followed their perceived local soil distribution. They were aimed at confirming soil boundaries as well as acquiring more details of farmers' soil categories through local-specific, detailed soil descriptions. Each mapping team then created a local soil map which was subsequently digitized using ArcGIS 10.1 (ESRI, 2012).

3.3.3 Comparison of local and scientific maps

A technical soil survey was carried out at 1:10 000 using a free survey method (Dent and Young, 1981). Scientific maps were prepared according to the South African classification system (SCWG, 1991) and the World Reference Base (IUSS Working Group WRB, 2014). The scientific maps were then incorporated into GIS to determine and quantify the degree of spatial correlation between the local maps and those of the scientific systems. Spatial correlation was done at the lowest category of the South African classification, i.e., the soil family. Key reference group, principal and supplementary qualifiers were used for spatial correlation with the WRB. The GIS comparison was done through the intersection of the mapping units on each pair of maps and using the common area covered by both as an analysis mask. The analysis was first done using general summary statistics that provided an overview of the range and distribution of soil map units, and this was followed by the analysis of intersections between local and scientific soil maps. The results of the spatial correlations were used to explain similarities and differences between the scientific and participatory soil surveys. Spatial correlation was considered strong when the local soil class occupied 75% or more of the scientific soil cartographic unit; otherwise spatial correlation was considered to be moderate (50 -74%) or weak (Barrera-Bassols et al., 2006).

3.4 Results

The profile of farmers in four villages is shown in Table 3.1. According to results from structured questionnaires, except for Zalaze, women are mostly responsible for farming activities. Surveyed farmers are predominantly adults, particularly of old age from 41 to above 60 years. The higher proportion of farmers are either married or widowed and have been involved in farming for more than 20 years.

The largest group of farmers had either no formal or primary education with a sizeable proportions having secondary education. Khokhwane farmers did not farm large areas as most owned an average of 1 - 4 ha fields. Farmers in other villages, however, cultivated the largest fields of more than 8 ha. All farmers tended to use family labour to carry out their faming activities.

Table 3.1 Socioeconomic characteristics of farmers in study sites (n=50).

Variables	%			
	Khokhwane	**Potshini**	**Ntshiqo**	**Zalaze**
Gender				
Female	74	72	82	46
Male	26	28	28	54
Marital status				
Single	26	16	6	16
Married	34	42	70	56
Divorced	0	0	4	0
Widowed	40	42	20	28
Age				
< 30	0	0	4	2
31 - 40	8	10	16	2
41 - 60	38	38	52	42
> 60	54	52	28	54
Economic Activities				
Farming	70	68	94	94
Employment	28	0	2	2
Both	2	32	4	4
Education level				
No formal education	36	34	18	14
Primary education	38	40	40	56
Secondary education	22	22	38	24
Tertiary education	4	4	4	6
Farming scope				
1 – 4 ha	98	46	18	26
4.5 – 8 ha	0	0	2	8
> 8 ha	2	54	80	66
Farming duration				
< 5 years	4	4	2	0
5 - 10 years	4	8	2	6
11 - 20 years	4	4	4	6
> 20 years	88	84	92	88
Labour				
Family	98	100	98	100
Hired	2	0	2	0
Both	0	0	0	0

3.4.1 Local soil classification

Farmers identified soil types distributed across the study sites as follows: Potshini (9), Khokhwane (6), Ntshiqo (4) and Zalaze (3). Farmers mostly used similar words or phrases and soils are described using the combination of these in Tables 3.1 to 3.3. Colour, texture, stoniness, drainage and consistence were primary criteria for distinguishing between soil types in all villages. However, the order of importance differed between villages with more emphasis placed on colour and texture in Ntshiqo and Zalaze, respectively. Potshini and Khokhwane did not put any particular emphasis on a single soil property as the criteria were dependent on the landscape structure, which differed within these villages. All farmers considered other property-dependent variables as well as perceptual property attributes (e.g. crop suitability and manure requirement) as additional criteria. Both topsoil and subsoil horizons were considered in the local classification systems. However, Ntshiqo and Zalaze farmers only considered the latter if it occurred close to the surface and presented certain limitations to the overall agricultural potential of the soil.

The soil nomenclature was based either on an exclusive property or on a combination of soil properties. Soil colour, texture and drainage were exclusively used in local taxonomy. For example, all soils from Ntshiqo (e.g. *obomvu* - red; *omhlophe* – white) were named based on their colour while the most exclusive use of texture was observed in Zalaze (e.g. *ovunguvungu* - loam), Khokhwane (e.g. *udongwe* - clayey) and Potshini (e.g. *itshetshe* - sandy). The exclusive use of drainage was only observed in Khokhwane and Potshini (e.g. *isidaka* – poorly drained, muddy). A combination of soil properties was used for example in Khokhwane where *ugadenzima* referred to soil that was clayey, very hard and sticky i.e., a combination of texture and consistence.

The classification system in the KZN villages was nominal but in Ntshiqo and Zalaze, it was hierarchical with two levels. The higher category consisted of mutually exclusive main soil types based on primary classification criteria, i.e. colour (e.g. *obomvu* - Ntshiqo village); texture and stoniness (*ovunguvungu* - Zalaze village). Soil classes based on the higher category were then subdivided into subclasses constituting the lower category based on defined properties of significance with respect to soil use and management. The lower category was thus more specific than the higher category. A large number of descriptors or adjectives were used as suffixes to specify a particular subclass for the lower category. The differentiae used seemed to indicate limitations for soil use mostly associated with the subsoil. One of the common suffixes used in Ntshiqo was related to stoniness that in this context referred to all coarse fragments (*uhlalutye* or *amatye*) as well as iron concretions commonly encountered in this village and locally referred to as *irhexe*.

Table 3.2 Description of attributes used to recognize soil types in Khokhwane.

	Soil type				
	Ugadenzima	*Isidaka*	*Idudusi*	*Ukhethe*	*Ubumba*
Classifying attributes					
Horizon	Topsoil	Topsoil	Topsoil	Subsoil	Subsoil
Texture	Clayey	Sandy to clayey (clay content < underlying horizon)	Loamy*	Sandy (with high proportion of coarse fragments)	Clayey *(clay content > overlying horizon)
Colour	Greyish to whitish when dry; dark when wet	Very dark; black	Black; dark reddish	Reddish and blackish	Greyish matrix with yellow and red mottles
Structure	Well developed; strong	NA#	Structureless to weak	NA	Well developed; strong
Consistence					
Dry	Hard*	Loose to hard	Loose to soft	Hard, loose to friable*	Hard
Wet	Very firm; very sticky and very plastic	Sticky and plastic	Friable; non to slightly sticky	Friable; non-sticky and non-plastic	Very sticky and very plastic
Stoniness	None	None	None	Abundant*	None
Other	In depressions and low-lying valleys; sometimes cracks when dry	Often waterlogged; on low-lying landscape positions; cracks when dry; difficult to plough	Often very deep; easily workable; higher landscape position	Mixture of soil and weathering rock; can be continuous hard rock; soft and hard types recognised; dominated high landscape positions, convex slopes	On low-lying landscape positions; not easy to till; often cracks when dry
Property attributes					
Internal drainage	Poorly drained	Poorly drained*	Well drained	Well drained	Somewhat to poorly drained
Moisture condition	Moist	Moist	Often moist	Dry	Moist
Drying rate	Fast	Very slow	Slow	Fast	Fast
Wetting rate	Slow	Fast	Slow	Fast	Slow
Manure requirement	Very high	High	Low	High	Very high
Flooding	Seasonally	Frequently	None	None	Seasonally

*Major classification criteria; #NA - not applicable

Table 3.3 Description of attributes used to recognise soil types[#] in Potshini.

	Soil type	
Classifying attributes	*Isibomvu*	*Itshetshe*
Horizon	Topsoil and subsoil	Topsoil
Texture	Loamy	Sandy to powdery* (silty)
Colour	Reddish to red*	Reddish, brownish, yellowish and whitish
Structure	Weak to moderate	Structureless to weak
Consistence		
Dry	Loose to soft	Loose
Wet	Friable; non to slightly sticky	Friable; non-sticky and non-plastic
Stoniness	None to many	Few
Other	Have both red topsoil and dark topsoil (higher elevations on mountainous areas) variants	On depositional parts of the landscape; can have signs of wetness at shallow depth
Property attributes		
Internal drainage	Well drained	Well drained
Moisture condition	Often moist	Dry
Drying rate	Slow	Fast
Wetting rate	Slow	Fast
Manure requirement	Low	High
Flooding	None	None

[#] Including *isidaka* and *ubumba* described in Table 3.1; *Major classification criteria

For example, *obomvu-onerhexe* meaning a red soil dominated by concretions and often signs of wetness at some depth below the subsoil. The other descriptive suffixes included *obudongwe*, a soil with a significantly high clay content, particularly associated with *omnyama* – a black soil found in lower lying areas in Eastern Cape study sites (Table 3.4).

At Zalaze, on the Keiskamma floodplain, farmers recognized the continuum of soil texture from coarsest closest to the river to finest furthest from the river. This was reflected as farmers introduced subclasses related to stoniness (locally referred to as *grabile* and *uhlalutye* – gravel and stones) and colour. For example, stoniness was used for soils furthest from the riverbank and at the bottom of the slope (e.g. *udongwe olunohlalutye*).

Table 3.4 Description of attributes used to recognise soil types# in Ntshiqo and Zalaze.

Classifying attributes	Soil type			
	Omnyama	*Isanti*	*Omhlophe*	*Ovunguvungu*
Horizon	Topsoil	Topsoil	Topsoil	Topsoil
Texture	Clayey	Sandy*	Sandy to clayey*	Loamy*
Colour	Black*	Brownish to whitish	Whitish*	Darkish to yellowish to reddish
Structure	strong	ND$	ND	weak to moderate
Consistence				
Dry	Hard*	Loose	Loose to hard	Loose to soft
Wet	Very firm, very sticky and very plastic	Non-sticky and Non-plastic		Friable; non-sticky
Stoniness	None	Few	None, few	None
Other	Occur in low-lying positions	Can refer to soils with light coloured, bleached sandy soil (locally described as *isiganga*) or pure river sand. On low-lying landscape positions - floodplains and river terraces	Usually on lower parts of sloping fields; not easy to till when clayey	Mixture of *isanti* (sand) and *umhlaba* (soil); has equal proportions of sand to "soil"; very easy to till
Property attributes				
Internal drainage	Well drained	Well drained	Somewhat poorly drained	Well drained
Moisture condition	Dry	Dry	Dry	Often moist
Drying rate	Fast	Fast	Fast	Slow
Wetting rate	Slow	Fast	Slow	Slow
Manure requirement	Moderate	High	High	Low
Flooding	None	None	Seasonally	None

Including *obomvu* and *udongwe* similar to *isibomvu* and *ubumba*, respectively, described in Table 3.1; *Major classification criteria; $ND – not defined

Furthermore, sandy soils closest to the river had a descriptor relating to their whitish, bleached colour (e.g. *isanti* o*mhlophe*) and loamy soils on well-drained slopes had a colour descriptor relating to their red colour (e.g. *ovunguvungu obomvu*).

Farmers also recognized vertical textural differences. For example, farmers described some soils as having a loose, sandy topsoil over a very heavy textured subsoil. It was interesting to note that Zalaze farmers changed the order of importance of the criteria as they moved upslope. Colour became the major criterion at the higher level of classification while texture formed the subclass (e.g. *obomvu* similar to *isibomvu* in Table 3.2). Both Ntshiqo and Zalaze farmers used the subdivisions only if there was a need to indicate a certain limitation. As a result, they were only considered in the agricultural fields where people have close contact with the soils and have come to understand the influence of specific properties on soil behaviour.

3.4.2 Local soil mapping

Farmers in all villages were able to map the spatial distribution of soil (Appendices 3, 6, 9 and 12) and seemed more confident in mapping the soils from their agricultural fields as well as areas close to their homesteads than more distant areas. They mainly used soil colour and landscape position to determine the soil distribution pattern, especially for areas outside their agricultural fields. Farmers associated landscape position to erosion-deposition processes as well as drainage differences. The other properties used as classification criteria were largely neglected during the mapping process in all villages except for Zalaze where soil texture remained the main factor of spatial analysis. Soils closest to the river were mapped as *isanti* (higher proportion of sand) and those further away were mapped as either *ovunguvungu* (loamy- equal proportion of sand and 'soil') or as *obomvu*. An understanding of the relationship between soils and landforms thus seemed to guide recognized soil patterns. For example, Potshini farmers associated *isibomvu* (with dark topsoil) with high lying steep slopes, *itshetshe* on lower lying areas followed by *isidaka* on footslopes. Ntshiqo farmers identified a similar pattern where *obomvu* was mapped in higher lying landscape positions with *omhlophe* associated with lower lying, valley landscape units. In Khokhwane, *ukhethe* was mapped consistently on upslope, convex slopes while *idudusi* and *ugadenzima* were associated with lower lying slope positions. The farmers were able to recognize their homesteads as well as agricultural fields from the aerial photograph and these were then used as reference points in determining the extent of some soil classes. Noteworthy was the fact that not all the locally identified soils were represented on the participatory maps, particularly soils based on the subsoil (i.e., *udongwe* and *ubumba*).

3.4.3 Comparing local and scientific soil maps

The maps produced using the SCWG (1991) and the WRB (IUSS Working Group, WRB, 2014) systems are given in Appendices 4, 7, 10 and 13, and Appendices 5, 8, 11 and 14, respectively. Scientific classification according to the SCWG (1991) identified a total of 44 soil families distributed across all study sites. The highest number of soil families were identified at Potshini (15) followed by Ntshiqo and Khokhwane with 13 and 10 soil families, respectively. Only six soil families were identified at Zalaze village. All the villages, except Zalaze, showed a general catenary association of soils. For example, at Potshini a range from well-drained upland (e.g. Hutton form), to somewhat poorly drained lower midslope (e.g. Avalon form) and poorly drained footslope (e.g. Katspruit and Kroonstad forms), was observed. Correlations between the SCWG (1991) classification and the Soil Groups of the WRB (IUSS Working Group, WRB, 2014) were done following Fey (2010) and are given in Tables 3.5 to 3.8.

Strong correlations largely reflected taxonomic consistence between scientific and local soil classes. Correlation with the SCWG yielded a total of 19 strongly correlated pairs, 22 moderately correlated pairs and 79 weakly correlated pairs across all villages (Tables 3.5 to 3.8). Potshini and Ntshiqo had the most weakly correlated pairs (26 and 22, respectively).

Table 3.5 Correlation of Khokhwane local soil classes with the South African classification (SCWG, 1991) and World Reference Base (IUSS Working Group, WRB, 2014).

		Correlation	
	Local classification	**SCWG**	**WRB**
		Pn 2200 (100%)	
Strong correlation	*Isidaka*	Ka 1000 (92%)	Gleysol (92%)
	Ugadenzima	Va 1121 (100%)	Cutanic Luvisol (100%)
		Va 2121 (100%)	
	Ukhethe	Ms 2100 (100%)	Lithic Leptosol (100%)
		Sw 2111 (100%)	Leptic Luvisol (100%)
Moderate correlation	*Idudusi*	Cv 2200 (68%)	Gleyic Luvisol (70%)
	Ugadenzima	Se 2210 (70%)	Leptic Cambisol (60%)
	Ukhethe	Gs 1111 (60%)	
Weak correlation	*Idudusi*	Gs 1111 (19%)	Leptic Cambisol (19%)
		Ka 1000 (8%)	Gleysol (8%)
		Se 2210 (25%)	Gleyic Luvisol (25%)
	Isidaka	Cv 2200 (10%)	Acric Ferralsol (7%)
		Gf 2200 (4%)	
	Ugadenzima	Gf 2200 (3%)	Acric Ferralsol (5%)
		Gs 1111 (21%)	Leptic Cambisol (21%)
		Cv 2200 (8%)	
	Ukhethe	Cv 2200 (14%)	Acric Ferralsol (8%)
		Gf 2200 (3%)	Gleyic Luvisol (5%)
		Se 2210 (6%)	Acric Ferralsol (7%)

Table 3.6 Correlation of Potshini local soil classes with the South African classification (SCWG, 1991) and World Reference Base (IUSS Working Group, WRB, 2014).

		Correlation	
	Local classification	**SCWG**	**WRB**
Strong correlation	*Isibomvu*	Hu 2200 (99%)	Cutanic Acrisol (79%)
	Itshetshe	Av 2200 (84%)	Xanthic Ferralsol (92%)
		Ct 2200 (95%)	Leptic Cambisol (79%)
		Gs 1211 (79%)	Cutanic Lixisol (99%)
		Oa 1120 (81%)	
		Oa 1210 (95%)	
Moderate correlation	*Isibomvu**	Bo 2110 (72%)	Ferralic Nitisol (74%)
	Isibomvu	Sd 1210 (74%)	Acric Ferralsol (61%)
		Va 1211 (51%)	Haplic Luvisol (68%)
			Cutanic Luvisol (72%)
	Itshetshe	Tu 1120 (71%)	Endogleyic Arenosol (71%)
		Ka 1000 (67%)	Gleysol (67%)
		Oa 1220 (71%)	Haplic Cambisol (69%)
		Cv 2200 (73%)	
		Gf 2200 (54%)	
Weak correlation	*Isibomvu*	Av 2200 (16%)	Cutanic Acrisol (12%)
		Cv 2200 (25%)	Xanthic Ferralsol (3%)
		Gf 2200 (45%)	Haplic Cambisol (23%)
		Gs 1111 (40%)	Gleysol (4%)
		Ka 1000 (4%)	
		Oa 1120 (11%)	
		Oa 1210 (5%)	
		Oa 1220 (23%)	
	*Isibomvu**	Bo 2110 (26%)	Acric Ferralsol (0%)
			Cutanic Luvisol (26%)
	Isidaka	Ct 2200 (5%)	Cutanic Acrisol (8%)
		Cv 2200 (2%)	Endogleyic Arenosol (29%)
		Gs 1111 (11%)	Leptic Cambisol (6%)
		Ka 1000 (27%)	Acric Ferralsol (1%)
		Oa 1120 (9%)	Xanthic Ferralsol (4%)
		Oa 1220 (6%)	Gleysol (27%)
		Sd 1210 (1%)	Cutanic Lixisol (1%)
		Tu 1120 (29%)	Haplic Luvisol (31%)
		Va 1211 (24%)	Ferralic Nitisol (1%)
	Itshetshe	Gs 1111 (44%)	Acric Ferralsol (38%)
		Hu 2200 (1%)	Ferralic Nitisol (25%)
		Sd 1210 (25%)	
		Va 1211 (25%)	
	Ukhethe	Gs 1111 (4%)	Haplic Cambisol (2%)
		Gs 1211 (21%)	Leptic Cambisol (21%)
		Ka 1000 (3%)	Gleysol (3%)
		Oa 1220 (1%)	

**Isibomvu* variant with dark topsoil (higher elevations on mountainous areas)

Table 3.7 Correlation of Ntshiqo local soil classes with the South African classification (SCWG, 1991) and World Reference Base (IUSS Working Group, WRB, 2014).

		Correlation	
	Local classification	**SCWG**	**WRB**
Strong correlation	*Obomvu*	Gs 2111 (81%)	Haplic Ferralsol (82%)
		Hu 2100 (82%)	Acric Ferralsol (85%)
		Hu 2200 (85%)	Gleyic Cambisol (93%)
	Omhlophe	Gs 2121 (93%)	Albic Stagnosol (78%)
		Kd 1000 (78%)	
Moderate correlation	*Obomvu*	Bv 2100 (57%)	Plinthic Ferralsol (57%)
	Omhlophe	Lo 1000 (63%)	Albic Plinthosol (63%)
	Ontsundu	Av 2100 (64%)	Xanthic Ferralsol (64%)
		Cf 2100 (74%)	Leptic Cambisol (74%)
		Gs 1111 (68%)	Leptic Cambisol (66%)
		Ka 1000 (69%)	Gleyisol (69%)
		Va 1211 (59%)	Cutanic Luvisol (59%)
		Oa 1210 (73%)	
Weak correlation	*Obomvu*	Av 2100 (29%)	Gleyic Cambisol (7%)
		Cf 2100 (26%)	Haplic Cambisol (14%)
		Gs 1111 (11%)	Leptic Cambisol (26%)
		Gs 2121 (7%)	Xanthic Ferralsol (29%)
		Kd 1000 (14%)	Cutanic Luvisol (30%)
		Lo 1000 (12%)	Albic Plinthosol (12%)
		Oa 1210 (3%)	Albic Stagnosol (14%)
		Va 1211 (30%)	
	Omhlophe	Av 2100 (7%)	Leptic Cambisol (20%)
		Bv 2100 (6%)	Acric Ferralsol (5%)
		Gs 1111 (21%)	Haplic Ferralsol (1%)
		Hu 2100 (1%)	Plinthic Ferralsol (6%)
		Hu 2200 (5%)	Xanthic Ferralsol (7%)
		Ka 1000 (31%)	Gleyisol (31%)
		Oa 1210 (24%)	Cutanic Luvisol (11%)
		Va 1211 (11%)	
	Onsundu	Bv 2100 (37%)	
		Gs 2111 (19%)	Acric Ferralsol (10%)
		Hu 2100 (17%)	Haplic Ferralsol (17%)
		Hu 2200 (10%)	Plinthic Ferralsol (37%)
		Kd 1000 (7%)	Albic Plinthosol (25%)
		Lo 1000 (25%)	Albic Stagnosol (7%)

Table 3.8 Correlation of Zalaze local soil classes with the South African classification (SCWG, 1991) and World Reference Base (IUSS Working Group, WRB, 2014).

		Correlation	
	Local classification	**SCWG**	**WRB**
Strong correlation	*Isanti emhlophe + umhlaba*	Tu 2110 (90%)	Endogleyic Arenosol (90%)
		Oa 2110 (80%)	
Moderate correlation	*Obomvu - isanti encane*	Va 1211 (64%)	Cutanic Lixisol (58%)
		Cv 2100 (51%)	Ferralic Arenosol (51%)
	Omnyama onohlalutye + dongwe	Oa 1210 (51%)	
Weak correlation	*Obomvu onohlalutye*	Va 1211 (20%)	Cutanic Lixisol (18%)
	Ovunguvungu - omnyama	Oa 1110 (40%)	Haplic Arenosol (37%)
		Tu 2110 (8%)	Endogleyic Arenosol (8%)
		Oa 1210 (1%)	
		Oa 2110 (2%)	
	Ovunguvungu - onsundu	Oa 1110 (26%)	Haplic Arenosol (24%)
		Va 1211 (8%)	Cutanic Lixisol (7%)
		Oa 1210 (2%)	
	Isanti emhlophe + umhlaba	Oa 1110 (1%)	Haplic Arenosol (1%)
	Isanti emhlophe yomlambo	Cv 2100 (49%)	Ferralic Arenosol (49%)
		Oa 2110 (18%)	Cutanic Lixisol (2%)
		Oa 1110 (14%)	Haplic Arenosol (13%)
	Obomvu - isanti encane	Oa 1110 (9%)	Haplic Arenosol (8%)
		Tu 2110 (2%)	Endogleyic Arenosol (2%)
	Omnyama onohlalutye + dongwe	Oa 1110 (2%)	Haplic Arenosol (5%)
		Va 1211 (1%)	Cutanic Lixisol (1%)
	Ovunguvungu - obomvu	Oa 1210 (45%)	Haplic Arenosol (12%)
		Va 1211 (6%)	Cutanic Lixisol (5%)
		Oa 1110 (9%)	

Zalaze village had the least number (2) of strongly correlated pairs compared to other villages. When the correlation was done using the WRB, the total number of strongly correlated classes was 13, moderately correlated pairs (18) and weakly correlated pairs (63). Similar to the SCWG correlations, Potshini and Ntshiqo had the most number of weakly correlated pairs and Zalaze the least number (1) of strongly correlated pairs.

3.5 Discussion

3.5.1 Local soil classification criteria

Findings of this work support the view that farmers are "innate pedologists" (Barrera-Bassols, 2016). Although the local classification is not concerned with pedogenesis (Pereira et al., 2017) it does embrace its product (i.e., the morphology). The listing process supported by transect walks and field observations provided detailed information on the criteria and principles underlying local soil classification systems at the study sites. The farmers used their understanding of key morphological properties such as colour, texture and consistence to give detailed descriptions of soil types. Similar results have been reported in other ethnopedological studies (Gowing et al., 2004; Douangsavanh et al., 2006; Buthelezi et al., 2013). Soil colour, one of the major properties used to distinguish between soil types by the farmers in the study areas, was associated with in-field and village-level variation in drainage with red (well drained) soils being on the higher lying areas and yellowish, whitish and grey soils (e.g. o*mhlophe* and moister variants of *itshetshe*) on the lower parts. The exclusive use of colour in soils considered to lack physical limitations (i.e., red soils at Potshini - *isibomvu* and at Ntshiqo - *obomvu*) can be related to the high iron content inherited from dolerite intrusions common in these villages.

Although soil texture was used at all the study sites, it was overwhelmingly important at Zalaze where classification was only carried out on floodplain soils. Floodplain soils develop on sediments from various sources and thus are often highly heterogeneous. This explains the significance of texture in the Zalaze local classification compared to other villages where mostly upland soils were classified. In this village, soil classification was largely defined by the proportion of sand present in the soil. This could be attributed to the general increase of small-scale variations on the footslope associated with continuous additions of runoff and subsurface flow from upslope (Southwell and Thoms, 2006). Zalaze farmers recognized vertical texture contrast in some soils that are characterised by a significant increase of clay in the subsoil and as a result are considered by local farmers as having low agricultural potential. The clayey B-horizon in these soils is known to present an impediment to both water and root growth (Fey, 2010). Nonetheless, Zalaze farmers had realised that deep disking helped break the hard subsoil thus allowing roots to grow deep enough to access the "nourishment" in the clay soil below the less "rich" sandy soil. The change from texture to colour as they moved upslope away from the floodplain shows the flexibility of the system to capture changes in local soil-landscape associations.

Unsurprisingly, farmers considered stoniness a common suffix at the second level of classification in areas that were characterised by highly dissected, upland topography and rock outcrops (parts of Khokhwane) and prominence of iron concretions (Ntshiqo) both contributing to the significance of the coarse fraction in relation to land use potential. Stoniness is one of the key constraints for prime agricultural land due to its influence on soil water dynamics (Novák and Kňava, 2012). Moreover, stoniness limits soil workability. Consistence seemed to be most relevant to farmers when clayey and lithic soils occurred. They specified the differing behaviour of clayey soils upon wetting and drying (e.g. *ugadenzima* and *udongwe* soils - very sticky and difficult to plough when too dry or too wet). Field observations and interviews revealed that farmers thus considered clayey (especially expanding clay) soils as having poor workability. This can be due to the effect of clay content and type on soil consistence and thus soil tilth. *Ukhethe* (lithic soil) was dominated by fresh or partly weathered rock. Consistence (particularly, firm and hard) of these soils thus presents a constraint for crop growth which is of primary interest to the farmers. As a result, farmers in the present study classified *ukhethe* using both stoniness (higher category) and consistence (lower category). Drainage was used to classify soils defined by permanent or seasonal waterlogging. For these soils, poor drainage overrides other properties with respect to land use potential.

The use of these key morphological soil properties is explicitly descriptive of the limitations (or lack thereof) for land use. Farmers used (exclusively or in combination) morphological properties that are key to soil behaviour and management which thus influence the soils’ use potential. Consistent with other similar studies (Gowing et al., 2004; Nwankwo et al., 2011; Buthelezi et al., 2013; Barrera-Bassols, 2016), farmers in this study based their classification mainly on the topsoil, which they considered an indicator of the arable potential of the soil. The farmers’ knowledge of their soils is based on experiment, with trial and error giving them more confidence in classifying the soils they farm than those on areas further from their homestead.

3.5.2 Local vs. scientific soil maps

Soil-relief relationships considered in both local and scientific soil mapping can explain observed spatial coincidence (or lack thereof) between local and scientific maps. Good spatial correlation in villages located in upland areas (Khokhwane, Potshini and Ntshiqo) can be explained by occurrence of distinct geomorphic units associated with specific local soil classes thus making them more comparable to the scientific classification. Gobin et al. (1998, 2000, 2001) in Nigeria, Cools et al. (2003) in Syria, Payton et al. (2003) in Bangladesh, Hillyer et al. (2006) in Namibia, and Barrera-Bassols et al. (2009) in Mexico, have also reported relatively good correlation between local and scientific soil classes for areas with similar landscapes. In these areas it seemed that the key diagnostic criteria for both local and scientific classification overlapped. For example, upland soils mostly on old stable landscapes (Hu 2200 - Acric Ferralsol) scientifically associated with good drainage as well as reddening due to residual accumulation of iron coincided well with red soils (*isibomvu* and *obomvu*) locally classified based on colour. Soils in lower lying positions or depressions also strongly correlated with local soil classes as both classes are defined using drainage. The influence of slope position on the drainage and thus morphology of these soils (*omhlophe* (white) - Kd 1000 (Albic Stagnosol) and *isidaka* (muddy) - Ka 1000 (Gleysol)) is reflected in both classification systems through the emphasis on surface bleaching commonly associated with footslopes (and/or depressions) where these soils occur. These slope positions are associated with high water table inducing gleying and consequently low chroma matrix colours. The similar emphasis of both systems on either a characteristic topsoil or subsoil also yielded strong and moderate correlations. For example, Bonheim 2110 with a melanic topsoil and red cutanic subsoil (SCWG, 1991) coincided with i*sibomvu* (dark-coloured variant) at Potshini. Strong correlation was also achieved for *ukhethe* with Mispah 2100 (Lithic Leptosol) (Table 3.5) indicating soil depth as the main similarity between the two systems.

The difference in soil depth considered by local and scientific classifications was the main reason for poor spatial correlation observed, particularly in Khokhwane, Potshini and Ntshiqo. For example, weak correlations were found mostly in soils with heavier textured subsoils, as the concept of duplex soils is either unfamiliar to local farmers or not considered in local mapping. Farmers only considered the subsoil in soils with a shallow A-horizon or when it was exposed by erosion. This illustrates that local classification systems are use-oriented and thus directly related to present land use and management. In addition, the weak correlations could also be explained by the generalization of the local soil classes with less attention paid to field-plot variations captured by the SCWG classification during transect walks, as reflected by the high number of soil families mapped. The lower level of the South African classification, i.e. family, proved to be complex and too elaborate in comparison to the simpler and more general local soil classes. However, the low number of recorded weak correlations between the WRB and local classifications suggests similarities between the two systems. Although not necessarily based on subsoil, local soil classification in the four villages follows Fey (2010) grouping of South African soils. The local soil classes are fewer and broader explaining the better correlation with the WRB (significantly lower number of weakly correlated pairs) compared to the SCWG. This shows that these farmers classify at higher levels than soil form and family. These could thus be incorporated as a category higher than the soil form in the current South African classification.

Notably, however, there were somewhat questionable cases of strong and/or moderate correlations of local soil classes (e.g. *itshetshe* – Potshini and *onsundu* - Ntshiqo) with taxonomically different scientific soil classes (Tables3.6 and 3.7). This may imply less correlation between the topsoils and subsoils of the areas covered by these locally recognised soils (i.e. duplex and plinthic soils). Furthermore, *onsundu* was mapped in an area with an uneven topography that was not captured by farmers as it was mostly found in areas outside the agricultural fields with which they were unfamiliar. Similarly, although *itshetshe* covered the largest extent of Potshini village most of it occurred outside the cultivated lands. Although farmers in both villages did recognize differences between individual soil types, these differences were not spatially mapped as they were not significant with regard to land use. As a result, Potshini farmers generally did not pay attention to variations within local soils considered less productive (e.g. *itshetshe*) unless found in cultivated fields.

Lack of clear geomorphic units resulted in generally poor correlations in Zalaze on an active floodplain of the Keiskamma River. Surface textural differences imposed by floodplain sedimentation patterns took precedence in the local soil classification. Sillitoe et al. (2004) found similar results on the Jamuna floodplain in Bangladesh. Although similar properties were used in the classification of the scientific soil classes, the emphasis was more on the subsoil. For example, the presence of luvic/non-luvic and red/non-red B-horizons in Oakleaf soil families. Moreover, classification at higher level may not adequately capture dynamic changes of topsoil characteristics. It is thus probable that better correlations could be obtained by considering individual topsoil properties (i.e. at the soil phase level than at the higher levels of the soil classification), particularly on active landscapes (Barrera-Bassols, 2016).

The poor correlations thus reflect differences in the criteria used by farmers and scientists (Sikana, 1993; Habarurema and Steiner, 1997; Niemeijer and Mazzucato, 2003; Sillitoe et al., 2004; Schuler et al., 2006). While local classification systems use descriptive, usually apparent characteristics, mainly surface soil colour, scientific soil classification uses soil categories based on both visual properties and quantitative laboratory data. The two systems use different pedological units, since the profile concept (considered in the scientific classification) does not seem to exist in the local classifications as the emphasis was mainly on the cultivated topsoil (Sillitoe, 1998; Sillitoe et al., 2004). Nonetheless, strong correlations show that areas with stable landscapes could be adequately classified and mapped with both local and scientific classification systems. Although there are linguistic differences in the local soil nomenclatures, farmers used similar morphological properties suggesting that there is a possibility to develop a general local classification system for South Africa that can form part of the existing soil database. In active landscapes, local classifications tend to put more emphasis on individual soil properties rather than in higher taxonomic classes. Thus, local classifications better capture the dynamic nature of topsoils in these environments that is significant for land use and management.

3.6 Conclusions

Farmers of the Zulu and Xhosa ethnic groups of South Africa have comprehensive understanding of pedological features, i.e. soil morphological properties used as the basis for soil classification. Local nomenclature thus reflected micro-scale variations in key topsoil properties, particularly colour and texture, and carries with it important local soil theories. Farmers' choice of primary classification criteria was determined by the local environmental setting that determined the nature of the soil properties. As a result, farmers' soil terminology was mostly different both within ethnic groups and across villages. There were fundamental similarities between local and scientific soil maps resulting in strong correlations between the classification systems. These relate to the field soil description criteria as well as consideration of soil-landscape relationships in the delineation of soil units. Consequently, local soil units correlated fairly well with scientific soil units, particularly in upland, stable landscapes. The soil-landscape relationship, however, differed between a floodplain and adjacent upland areas.

The progression and reordering of the classification criteria from the floodplain to the upland area showed the flexibility and simplicity of the local classification system. Farmers also classified soils at higher levels than the two-tier system of the South African classification and so these could be incorporated as higher categories in the current South African classification system. Local soil classifications were flexible with regards to the taxonomic level used thus enabling them to better capture spatial variations in soils on both stable and dynamic landscapes. This strength of local classifications should be used to complement scientific, general-purpose soil maps. Key soil morphological properties reflected in the local nomenclature can be used as inputs to generate soil data in a user-friendly and practical format. This will ensure that the value of soil survey data increases in relevance and practicality.

Chapter 4: Farmer perceptions and laboratory measurements of soil fertility in four villages of eastern South Africa

4.1 Introduction

Soil fertility depletion is a major threat to sustainable agriculture, especially in sub-Saharan Africa (Sanchez et al., 1997; Tully et al., 2015). The maintenance and improvement of soil fertility has been the main challenge to meet high production demand in arable agriculture (Dalal et al., 1991). For rural communities, local knowledge has provided an in-depth understanding of their soils that for centuries has informed their local soil fertility perceptions and sustainable land-use decisions. Local knowledge of soil management has thus evolved and become increasingly recognized for its importance to sustainable land management (Nath et al., 2015). Farmers have acquired this knowledge through long-term, intimate interaction with their natural environment.

Despite not having the ability to know precise nutrient content, farmers assess soil fertility using their collective experience (Niemeijer and Mazzucato, 2003). Previous studies have reported the use of a number of local fertility indicators (e.g. crop performance, crop yield, earthworms, soil colour, soil texture and soil depth) that capture the spatial variability of soil fertility (Corbeels et al., 2000; Moges and Holden, 2007; Odendo et al., 2010; Buthelezi et al., 2013). Farmers perceive soil fertility in a holistic manner as an integration of quantitative aspects (i.e., physical, chemical and biological properties) as well as current and past management regimes (Nath et al., 2015). Using these indicators farmers are able to monitor soil fertility changes between and within their fields and thus can provide valuable insight into soil quality and its variability in space and time (Ericksen and Ardón, 2003, Ramisch, 2005).

Local farmer perceptions and their assessment of soil fertility can differ from scientific approaches resulting in differences in perceived problems and solutions required (Desbiez et al., 2004). Unsurprisingly, local perceptions of soil do not always correspond with scientific analysis largely due to broader contextual concerns within which the former are often framed. Local perceptions and benefits of local knowledge should then be assessed in the context of each region for effective soil resource management (Tesfahunegn et al., 2011). Moreover, soil analysis comes at high costs that most small-scale farmers cannot afford due to common financial constraints. Scientists thus need to gain understanding of these local perceptions and use participatory research approaches in collaboration with farmers to provide sustainable solutions. Research has shown the significance of farmers' knowledge and perceptions of soils in developing relevant technologies and management interventions (Neimeijer and Mazzucato, 2003; Desbiez et al., 2004; Shrestha et al., 2004; Berazneva et al., 2016). Sandor and Furbee (1996) demonstrated that farmer's knowledge of soil physical properties largely influenced soil management (e.g. plant density, seedbed preparation and crop selection). Evident from these studies is the availability and relevance of context-specific knowledge of farmers that is crucial in adapting researchers' understanding of soil biophysical processes to local conditions.

Unfortunately, there is minimal understanding of local soil fertility perceptions by small-scale, resource-poor, local farmers in South Africa. This study therefore aimed to investigate farmer perceptions and assessment of soil fertility in selected rural communities in eastern South Africa. The specific objectives were to investigate (i) farmer defined soil fertility indicators; (ii) if farmers can develop viable and sustainable soil-cropping systems without laboratory data; and (iii) how farmers' perceptions of soil fertility correspond to laboratory soil measurements.

4.2 Methodology

4.2.1 Site description

The location and description of the four villages used in this study were given in Section 3.2.1.

4.2.2 Questionnaire survey and in-depth interviews

Detailed information of the ethnographic techniques used was given in Section 3.2.2. The structured questionnaire (Appendix 1) included aspects on recognition of soil fertility status, common fertility indicators, common crops grown, as well as local soil types. This was followed by interviews (Appendix 2) that covered information on farmers' perceptions of soil fertility assessment and management (e.g. local soil fertility indicators, soil-crop management practices and any other related aspects). Lastly, farmers (10 from each village) were taken on in-field transect walks during which each one of them was asked to delineate their own fields into three possible fertility categories (i.e., good, moderate and poor).

4.2.3 Soil sampling and analysis

Soil samples were taken from 0-20 cm in plots representing the three soil fertility classes demarcated by farmers using their own descriptive indicators. Four subsamples were taken from each class to make a composite sample that was then thoroughly mixed, air dried, crushed and passed through a 2 mm sieve prior to analysis. Samples were analysed for pH, exchangeable bases, acid saturation, organic carbon and particle size distribution (Manson and Roberts, 2000).

4.2.4 Data analysis

Qualitative data collected was coded and subjected to descriptive analysis using SPSS version 24 (IBM Corp, 2016). Statistically significant differences between perceived soil fertility classes were analysed using the analysis of variance (ANOVA) in Genstat (version 14, VSN International, UK, 2011). Mean separation was done using Fisher's LSD test at $p < 0.05$. Means of the three soil fertility categories from each village were compared using contrast analysis in ANOVA.

4.3 Results

4.3.1 Local indicators of soil fertility

Most farmers (91%, n=200) in the villages recognized different levels of soil fertility. Vernacular names, such as "*ukutyeba*" (Xhosa) and "*ukuvunda*" (Zulu) – literally meaning 'being fat', were used to describe good soil fertility. Farmers used multiple qualitative descriptors to distinguish these soils from those perceived as less fertile. Soils perceived as having poor fertility were said to be "tired" as most of their "fat" or nourishment would have been exhausted. When asked to elaborate on the interpretation of these concepts of soil, farmers then introduced multiple qualitative descriptors to distinguish between *umhlaba otyebileyo*/*ovundile* (fertile productive soils) from those perceived as less fertile (*umhlaba ongatyebanga/ongavundanga*). These descriptors were mostly associated with the topsoil, the layer commonly considered in both local soil classification (Chapter 3) and soil fertility evaluation. Based on the frequency of use of each descriptor, these were summarised to formulate fewer major soil quality indicators. The resulting categories included crop performance (crop yield, crop appearance and overall crop health and vigour), weeds, soil fauna, ease of tillage, consistence (both wet and dry), soil colour, soil depth and stoniness (i.e., hard rock, plinthite, abundant stones) as common criteria for soil quality assessment. Table 4.1 gives a description of these in relation to fertile and infertile soils.

Table 4.1 Descriptive terms for major soil fertility indicators for the two extremes of fertility identified by farmers in the four villages.

Soil quality indicator	**Descriptions**	
	Fertile (healthy) soil	**Infertile (unhealthy) soil**
Crop appearance	Darkish green, strong seedlings, good crop, tall, large stalks, vigorous	Poor, stunted growth, yellow, small cobs, light green, poor stands
Nutrient deficiency	Happy crop, well-nourished crop, solid and uniformly coloured leaf, no spots, firm seedlings	Yellow, spots on leaves, purple, leaf discolouration, stripping
Topsoil colour	Dark, black, brownish, dark red	Light coloured, whitish
Consistence	Soft, friable, loose, non-sticky	Hard, very hard, very firm, sticky, very sticky
Drainage	Water does not stand, water enters the soil quickly, takes a lot of water	Holds water for longer periods, ponding, does not drain
Ease of tillage	Easy, smooth, good tilth, crumbles	Requires a lot of effort, difficult, better when wet
Water retention	Always moist, remains moist even when there is not much rainfall, holds moisture for long	Dries up quickly, too wet, too dry, loses moisture fast, droughty
Earthworms	Many, abundant earthworm casts, big, seen when ploughing	Absent, few

Crop performance took precedence as most farmers in all villages (97% Zulu farmers, n=100 and 73% Xhosa farmers, n=100) mentioned it. In terms of crop appearance, farmers observed seedling emergence and establishment, leaf colour and time of tasselling in a maize (*Zea mays*) field.

The yield parameters farmers considered included characteristics such as the number and size of cobs per stalk as well as how the seeds fill up the cob. According to farmers, a fertile soil makes the crop “happy” and gives it sufficient nourishment. It is defined by farmers as a “good soil” that is able to enhance crop growth and give good yields. As a result, all the seeds planted will emerge and grow fast, the leaves will be healthy i.e., dark green and big, and the maize will tassel on time and give big cobs with a large number of seeds.

Although the soil fertility status was largely based on crop yield (55%; n=200), soil properties were also used as indicators (45%, n=200). These properties are reflected in the local soil names (Table 4.2). The choice of soil properties used as fertility indicators differed with local soil types. Consistence and drainage were key indicators for soils such as *ugadenzima* (Khokhwane), *isidaka* (Potshini) and *udongwe* (Zalaze). These were perceived as less fertile mainly due to their very hard, dry consistence and highly sticky, wet consistence. High manure requirement for *ugadenzima* was also mentioned as an indicator of poor soil physical condition. Moreover, *omhlophe* of Ntshiqo village was perceived as less fertile due to a sandy texture as well as poor drainage.

Table 4.2 Local soil types identified by farmers in the four villages from the Eastern Cape (EC) and KwaZulu-Natal (KZN).

Soil type	Translation	Province
Obomvu/Isibomvu	Red soil	EC/KZN
Ugadenzima/Udongwe/Ubumba	Clayey soil	EC/KZN
Idudusi/Ovunguvungu	Loamy soil	EC/KZN
Isidaka	Sandy with clay (poorly drained)	KZN
Itshetshe	Sandy, powdery	KZN
Omhlophe	Sandy, white (poorly drained)	EC
Ukhethe	Stony	KZN
Onsundu	Brownish	EC
Omnyama	Black	EC
Isanti	Sand	EC

Soils such as *idudusi* (loam), *obomvu/isibomvu* (red) and *ovunguvungu* (loam) from Khokhwane, Nthsiqo/Potshini and Zalaze, respectively, were perceived as highly fertile in part due to their soft, spongy and less sticky wet consistence improving their ease of tillage and allowing for good seedling emergence and root growth.

Weeds and soil fauna were also associated with soil fertility. According to farmers, a highly fertile soil has abundant weeds. Growth of natural vegetation prior to planting, i.e., soils with dense, green natural vegetation, was associated with fertile soils. Zulu farmers had the highest mention of natural vegetation (57%, n=100) and gave some examples of weeds associated with both fertile and infertile soils. Occurring on fertile soils were weeds such as blackjack (*Bidens pilosa* L.), Devils Fig (*Solanum torvum*), Amaranth (*Amaranthus hybridus*), heart pea (*Cardiospermum grandiflorum*), and rapoko grass (*Eleusine indica*), while weeds such as Jimsonweed (*Datura stramonium*) and strand buffelsgras (*Stenotaphrum secundatum*) generally indicated an infertile soil. Farmers also reported more earthworms in fertile soils than those considered less fertile.

Topsoil colour was used mainly in Potshini and Ntshiqo. Some Potshini farmers considered fertile soils to have darker reddish colours, while the infertile soils had very bright red colours. When described using a Munsell Colour Chart, fertile *isibomvu* were 2.5YR 3/4 (dark reddish brown) and infertile *isibomvu* were 2.5YR 5/8 (red). The light (white) soil of Ntshiqo was also generally considered as infertile compared to red soils.

In addition to crop performance, stoniness was the major fertility indicator in areas with shallow, lithic contact and/or plinthic character. Soils with a high percentage of coarse fragments (either as a mixture of weathering rock and soil, plinthite or stones) were considered least fertile. For example, according to Khokhwane farmers, *ukhethe* (lithic soil) "does not have enough soil", i.e., shallow soil depth, as the topsoil overlies hard or weathering rock. In the cultivated floodplains of Zalaze village, soils affected by large deposits of coarse fragments, either buried or still at the surface, were considered less fertile.

Farmers also acknowledged the role of non-edaphic factors such as planting date, weeding, crop variety and rainfall form, intensity and seasonal variability as affecting soils' productivity. For example, *isidaka* in Potshini was considered productive only under moderate rainfall and early planting in the first week of November. According to farmers, this soil "does not produce anything" if there had been previous intense rain events as it becomes waterlogged. *Obomvu* (red soil) at Ntshiqo is fertile but only gives good yields when planted early to avoid the effect of cutworm. In addition, these, mainly apedal, red soils have been observed by farmers to give poor yields when there is insufficient rainfall.

4.3.2 Soil-crop suitability

Crop allocation in all four villages was affected by soil type and consequent perceived soil fertility status. Maize, beans (*Phaseolus vulgaris*) and potatoes (*Solanum tuberosum*) were the most commonly grown crops in all the villages. Most farmers attributed this choice of crops to soils (71%, n=200), while other reasons given were consumption (49%, n=200) and profit (31%, n=200). Home gardens were dominated by vegetables such as cabbage (*Brassica oleracea*), spinach (*Spinacia oleracea*), onion (*Allium cepa*) and butternut (*Cucurbita moschata*). The production of these crops was mainly for home consumption and sometimes for sale at local markets. Red (*isibomvu/obomvu*) and loamy (*idudusi/ovunguvungu*) soils were ranked higher than all the other soils for the production of these common crops.

Despite not being considered to have high suitability for the commonly grown crops, *ugadenzima*, *omhlophe* and *isidaka* were also often used for agriculture due to lack of better arable land. Farmers ranked these soils as either second or third due to limitations such as waterlogging and very hard, dry consistence. For example, farmers indicated that *ugadenzim*a has high moisture retention, hence after rains it is difficult to till and the crops die. For this reason, clayey soils (e.g. *ugadenzima* and *udongwe*) were not preferred for tubers such as potatoes but considered as highly suitable for leafy vegetables. *Ukhethe* was also used for agricultural purposes in cases where there was no other alternative.

When asked whether soil fertility is increasing or declining, most farmers (90%, n=40) indicated that soil fertility is declining. This perception was attributed to a number of factors, including climate change, no fallowing and continuous cultivation (particularly in the main fields) as well as late planting related to observed changes in climate. According to farmers, evidence of climate change included observed increasing frequency of drought, unpredictable rainfall patterns and increasing temperatures. Other factors not related to soil fertility were also mentioned to have led to decreased gross production. These included lack of labour and resources as well as loss of interest in cultivation. According to farmers, most of the fields are now left idle as most young people either are now in school or employed in cities. This has resulted in a decrease in production over the years. Farmers identified the decrease in soil fertility through factors such as reduced crop yields, less green (more unhealthy) crops, and infestation of certain weeds. A few farmers could not rate whether soil fertility was declining or increasing as they said this depended on how an individual manages their fields.

4.3.3 Local knowledge of soil fertility and management

During the interviews, it was evident that farmers focus more resources and intensive management on the perceived good, commonly fertile soils (*idudusi*, *isibomvu* and *obomvu*) due to expected satisfactory outputs. For example, these soils were deliberately planted first and weeded more often compared to the perceived bad soils. According to farmers this ensures that perceived good soils are cultivated in case their resources get depleted before planting has been completed. Farmers also mentioned that fertile soils tended to have many weeds and hence weeding required more time. The overall management of the crops during the growing season, especially in the home gardens, was also largely influenced by the perceived fertility.

The use of manure was common in all the villages and was largely determined by the perceived fertility. For example, perceived bad soils (*ugadenzima*, *itshetshe*, *udongwe* and *omhlophe*) were given a lot of manure as farmers believe that it helps soften the big clods and alleviates drainage and soil moisture constraints associated with these soils thus improving their fertility and subsequent crop yield. Although there was no standard quantity of manure applied to these soils it was evident from farmers' responses that they added more wheelbarrow loads, compared to perceived fertile soils. This application of manure was said to improve both the physical soil condition as well as its fertility.

Soil management differed between home gardens and main fields. Most farmers practiced crop rotation (84%, n=200) and intercropping (66%, n=200) for soil management in home gardens with the main fields largely put under maize monoculture. Some farmers also used fallowing (47%, n=200) and application of crop residues (31%, n=200). In Khokhwane, maize, beans and potatoes are intercropped and rotated annually. When asked why they rotate these crops, farmers indicated that when they do not change the crop the soil gets "tired" and does not produce good yields. They further mentioned that the soils get "old" and fail to support crops if the same crop is repeated over many consecutive cropping seasons. They observed an increase in yield after rotation. Some mentioned that they also rotate the crop varieties. In addition to these practices, farmers largely relied on the use of kraal manure, which was generally perceived to be more effective than chemical fertilisers. Farmers mentioned that kraal manure stays in the soil for up to five years, unlike chemical fertilisers that have to be applied often.

Nonetheless, both synthetic fertilisers and kraal manure were used as soil fertility supplements. However, the former were largely applied in distant fields rather than home gardens on which kraal manure was used. Farmers have acquired knowledge of fertiliser use mainly from agricultural extension officers as well as from fellow farmers. Financial constraints were also mentioned as factors resulting in the low use of commercial fertilisers.

In addition to specific soil properties, field management in both ethnic groups was also determined by the local hydrology and elevational changes within the fields. For example, field areas on lower slopes where water collects were managed differently from those on higher areas. The former mostly consisted of clayey soils and the latter of lighter textured soils. These differences largely determined crop-site allocation as farmers always matched the crops with specific soil microenvironments. For example, farmers with *ugadenzima* on sloping lands allocated potatoes to higher lying areas and maize as well as leafy vegetables to the lower parts.

4.3.4 Farmers' fertility assessment vs measured soil fertility

Table 4.3 relates farmer soil fertility perceptions to laboratory measurements of some physicochemical properties. Particle size distribution was similar in all perceived soil fertility categories in all villages with no significant differences in clay, silt or sand. Soil pH did not differ significantly between the fertility categories in all villages. However, fertile plots at Khokhwane had relatively higher average soil pH compared to moderate and poor plots (Table 4.3). Extractable P ($p < 0.001$) and exchangeable Ca ($p < 0.05$) were only significant in Khokhwane. Only Khokhwane and Potshini showed significant differences in the effective cation exchange capacity (ECEC) of perceived soil fertility classes. In Khokhwane the good soil fertility category had significantly higher ECEC compared to both moderate and poor categories.

The moderate category soils at Potshini had significantly higher ECEC compared to good and poor categories. Soils at Potshini had a moderate amount of organic carbon (1.3-1.5%). Soils from the other villages had low to very low amounts of organic carbon (0.50 – 0.97%).

Physicochemical properties of locally preferred good agricultural soils in comparison to those least preferred are shown in Table 4.4. Except in Zalaze, both good and bad agricultural soils had similar low pH. At Khokhwane and Potshini the good soils (*idudusi* and *isibomvu*, respectively) had significantly higher acid saturation compared to the least preferred bad agricultural soils.

Only Mg was found to be significantly higher in the least preferred bad agricultural soils from both Khokhwane and Zalaze. There were no significant differences in exchangeable cations in soils from the other villages. The least preferred agricultural soil at Zalaze (*udongwe olunohlalutye)* had significantly higher ECEC than the preferred good soil. All exchangeable cations of preferred agricultural soils from other villages were comparable to those of the least preferred soils. Except for the sand and clay fractions at Potshini, the particle size distribution of good and bad soils from all villages were not significantly different. *Itshetshe* (least preferred soil at Potshini) had significantly higher sand and lower clay than the most preferred soil

Table 4.3 Average soil properties of farmer-identified soil fertility categories in the four villages.

Village and farmers subjective fertility classes	Acid sat.	OC*	pH (KCl)	Ca	Mg	K	ECEC#	P	Sand (2.0 – 0.02mm)	Silt (0.02 – 0.002mm)	Clay (<0.002)
	(%)			($cmol_c\ kg^{-1}$)				($mg\ kg^{-1}$)	(%)		
Khokhwane											
Good (n=14)	23.6a	0.74	3.92	3.19b	2.57	0.82	8.17b	30.5b	20.6	46.4	31.9
Moderate (n=6)	48.8b	0.94	3.86	2.17ab	1.59	0.31	5.52a	10.3a	20.8	43.2	34.8
Poor (n=11)	34.5ab	0.95	3.72	1.07a	1.57	0.58	6.39ab	15.1a	21.7	46.4	36.6
Potshini											
Good (n=13)	10.5	1.50	4.23	1.44	2.94b	0.57	5.36a	16.8	53.0	26.6	20.4
Moderate (n=9)	22.1	1.31	3.98	1.21	1.87a	0.25	8.95b	12.6	43.9	30.1	26.1
Poor (n=8)	17.1	1.31	4.44	1.22	2.16ab	0.41	4.53a	6.18	57.7	26.0	16.3
Ntshiqo											
Good (n=22)	2.89	0.780	4.55	1.50	3.15	0.33	5.07	6.09	47.7	31.4	17.8
Moderate (n=14)	2.06	0.970	5.14	1.56	2.80	0.59	5.02	7.36	55.2	33.6	13.5
Poor (n=6)	1.50	0.870	5.16	1.45	2.42	0.33	4.27	12.6	50.3	34.4	16.1
Zalaze											
Good (n=21)	0.520	0.500a	7.11	6.80	2.27	2.0	11.0	99.8	40.0	16.8b	31.3
Moderate (n=9)	0.560	0.660b	7.27	8.18	3.05	1.9	13.1	75.0	39.7	10.5a	32.1
Poor (n=8)	0.170	0.500a	7.28	8.09	2.93	1.8	12.8	96.0	38.8	14.5ab	30.5

* OC – organic carbon; # ECEC – effective cation exchange capacity. Means followed by different letters in the same column for each village are significantly different at $p < 0.05$; no letters means no significant difference

Table 4.4 Physicochemical properties of locally perceived good and bad soils in the four villages.

Village	Local soil	Acid sat.	OC$	pH (KCl)	Ca	Mg	K	ECEC@	P	Sand (2.0 – 0.02mm)	Silt (0.02 – 0.002mm)	Clay (<0.002mm)
		%			(cmol$_c$ kg^{-1})				(mg kg^{-1})	%		
Khokhwane	*Idudusi** (n=14)	35.4	0.78	3.91	2.73	1.42	0.76	7.04	22.4	22.7	44.3	33.0
	Ugadenzima# (n=7)	23.2	0.95	3.82	2.06	3.43	0.45	7.40	22.0	18.0	47.1	35.0
	p-value	0.04	ns	ns	ns	<0.001	ns	ns	ns	ns	ns	ns
Potshini	*Isibomvu** (n=7)	28.9	1.6	4.05	1.19	2.11	0.54	6.70	10.8	38.1	31.1	30.8
	Itsheshe# (n=9)	8.22	1.4	4.48	1.44	2.59	0.43	5.67	9.62	57.3	24.9	17.7
	p-value	0.002	ns	ns	ns	ns	ns	ns	ns	<0.001	ns	0.01
Ntshiqo	*Obomvu** (n=6)	2.08	0.58	4.55	1.22	3.00	0.33	4.63	4.70	45.8	35.7	18.5
	Onerhexe# (n=6)	3.92	0.55	4.76	1.10	1.99	0.35	3.54	10.0	56.7	29.3	14.0
	p-value	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns
Zalaze	*Ovunguvungu** (n=6)	0.620	0.50	7.11	6.82	2.30	1.9	11.0	97.2	40.8	56.5	64.1
	Udongwe# (n=4)	0.00	0.50	7.74	8.53	3.88	2.0	14.5	146	35.3	73.3	83.0
	p-value	ns	ns	0.02	ns	0.01	ns	0.04	ns	ns	ns	ns

$ OC – organic carbon; @ ECEC – effective cation exchange capacity. *- perceived good soil and preferred for agriculture; # - perceived bad soil and not preferred for agriculture; ns – not significant.

4.4 Discussion

Farmers in all the villages had similar perceptions regarding soil fertility. The concepts of *ukutjeba* or *ukuvunda* reflect the farmers' understanding of soil fertility. Farmers understood that soil should be able to provide sufficient nourishment and support for the growing crop. As a result these concepts encompass more than just nourishment (nutrient status) but a wide range of soil properties as well as constraints such as lack of labour, weeding, and rainfall levels that have resulted in crop yield decline. Farmers have well-defined and comprehensive local indicators commonly used to assess the current fertility of their soils. These are visually observable and identifiable characteristics such as crop performance (i.e., crop yield and crop growth), stoniness, soil colour, soil workability, drainage and natural vegetation. The use of these indicators is common in similar studies across the African continent and elsewhere (Irungu et al., 1996; Onduru et al., 2002; Dezbies et al., 2004; Gruver and Weil, 2007; Mairura et al., 2007; Dawoe et al., 2012). The local fertility indicators, particularly crop performance, are important attributes of crop production and thus are often used by farmers for soil fertility assessment (Stocking and Murnaghan, 2001). Farmer soil fertility assessment is thus mainly concerned with soil productivity and thus food security.

The relationship between crop performance (especially crop yield) and soil quality is complex. Chemical attributes not immediately reflected in the growing crop and thus crop yield may lead to misperceptions of soil fertility by farmers (Barrera-Bassols, 2016). Moreover, crop yield is a reflection of both soil condition and biophysical factors and thus may not always be a good qualitative indicator of soil fertility. The use of crop yield as the main indicator may in part explain the lack of correlation between the chemical attributes and farmer perceived soil fertility (Table 4.3). Moreover, the fact that the perception of crop yield decrease in the four villages was linked to a number of non-edaphic factors (some of which had no direct link with soil fertility) suggests that soil fertility goes beyond availability of adequate "fat" in the soil.

On the other hand, the local indicators related to soil conditions can provide reliable soil fertility assessment. For example, farmers associated darker colours, abundant weeds and mesofauna, a friable consistence and lack of stones with fertile soils as all are a manifestation of the higher capacity of the soil to support optimal crop productivity. Darker soil colour is generally associated with higher organic matter and thus higher nutrient availability and water retention. For example, at Potshini the perceived good soils were darker and locally were considered to have good fertility and had relatively higher organic carbon (Table 4.3). Soil organic matter contributes positively to soil physicochemical and biological properties (e.g. cation exchange capacity, moisture retention and soil structure) thus promoting crop growth. Moreover, Table 4.3 shows low total exchangeable bases in red soils compared to dark coloured, loam soils considered by farmers as fertile and preferred for agriculture. Red apedal soils are often associated with intense weathering and thus are enriched with Fe (and Al) and have higher acidity, which inhibits crop growth due to limited basic nutrients (He et al., 2004). High acidity in these types of soils results in fixation of P and high Al and Mn toxicities with adverse effects on the availability of soil nutrients (Sanchez and Uehara, 1980). Farmers, however, did not base their evaluation of these red soils on their chemical fertility but rather on their available water content, especially during dry seasons. Although red soils are often considered to have high agricultural potential, particularly under irrigation, they are likely to become droughty due to mid-summer drought (Fey, 2010). Implements available at farmers' disposal may not be able to deal with such shortcomings as their soil fertility perception was related to soil water dynamics under prevailing local climate changes, a factor not often included in a routine scientific evaluation. Such additional information could complement the laboratory data.

Farmers also associated fertile soils with friable consistence and loam texture (i.e., *idudusi* and *ovunguvungu*), both known favourable properties for crop growth (Brady and Weil, 2014). Such properties are consistent with fertile soils characterised by organic matter, good physical condition and adequate soil moisture. Earthworms also prefer loamy soils with a sufficient food supply for their feeding and burrowing activities. The use of this biological indicator for good soil fertility was thus not surprising since mesofauna are regarded as the most representative organisms studied as indicators of soil health (Lavelle and Spain, 2001). Mesofauna are responsible for a number of functions such as decomposition of organic matter, and nutrient cycling in the soil that result in the improvement of soil properties and thus soil fertility (Cardoso et al., 2013). Similarly, many and a high diversity of weeds were reported in these perceived fertile plots compared to less fertile plots. This is consistent with productive soils (Mäder et al., 2002), which are able to support the growth of diverse plant communities.

In relation to soil quality variation, differences in the composition of weed communities have also been found to result from differences in soil. The use of weed species in the current study can thus provide a reliable empirical basis for subjective soil fertility assessment as they are most likely a result of management rather than inherent soil properties. For example, weeds associated with poor soil health were either very resilient (*S. secundatum*) or have exploited the soil nutrients thus affecting its fertility (e.g. *D. stramonium*). *Datura stramonium* is very competitive and can make the soil almost infertile (Flowerdew, 2012). It exploits the soil for nutrients, (particularly P) and water that the growing crop requires resulting in insufficient supply to the crop and inevitably poor crop growth and yield. This suggests that fields infested by such weeds had not been well managed and most likely had lost nutrients to this weed thus affecting the potential of the soil to support the intended land use. On the other hand, weeds such as *A. hybridus* and *B. pilosa* have been associated with fertile fields (Matthews, 1982). Presence of these weeds (particularly *Amaranthus*) may indicate high exchangeable bases and good physical soil condition. The presence of this weed in the farmers' plots was most likely an indication of the latter since the soils had low exchangeable bases (Tables 4.3 and 4.4). The use of weeds as unambiguous indicators of fertility, however, remains limited as their presence may reflect management practices rather than soil conditions (Corbeels et al., 2000).

Results showed that infertile or perceived bad soils are characterised by certain limitations resulting in a poor or not ideal balance of physical, biological and chemical properties. This is evident in the fertility indicators used to categorize these soils i.e., poor crop growth and crop yield, presence of aggressive and invasive weeds, shallowness, poor drainage, hard and sticky consistence and lack of earthworms. For example, hard and sticky consistence affected the ease of tillage as well as production of crops such as potatoes in soils such as *ugadenzima* and *udongwe*. Poor drainage in soils such as *isidaka* and *omhlophe* prevented cultivation of most commonly grown arable crops such as maize and dry beans that are adapted to well-drained soils. This suggests that farmers were able to use their local indicators to establish soil-crop associations and crop suitability. For example, soils not associated with any limitations to crop growth (e.g. *idudusi and ovunguvungu*) consistently had high perceived crop suitability. These local types of soils were either associated with depositional landscapes (*ovunguvungu*) and/or were deep (*idudusi*). Such characteristics are consistent with soils having high exchangeable bases and/or deep effective rooting depth. Both *ovunguvungu* and *idudusi* had high average exchangeable bases of 11.13 and 7.04 $cmol_c\ kg^{-1}$, respectively. Other studies from Burkina Faso (Dialla, 1993; Ericsksen and Ardón, 2003), Rwanda (Habarurema and Steiner, 1997) and Costa Rica (Winowiecki et al., 2014) have also found similar results where farmers had knowledge of land evaluation and management guided by knowledge of local soil types. This was reflected in the local taxonomy that is descriptive and utilitarian and encompasses local perceptions about individual soils (Tables 3.1, 3.2 and 3.3 in Section 3.3).

The use of physical indicators such as stoniness and soil texture was mainly in relation to their influence on soil hydrology and "amount" of soil available to support the growing crop. Stoniness presents a limitation to crop production as it influences a soils' effective depth or volume and moisture retention. It was thus expected that farmers would associate stony soils with infertility. For example, in fields characterised by *obomvu-onerhexe* and *ukhethe*, the farmers' fertility classes were based on effective depth affected by the presence of plinthite in the former and hard or weathering rock in the latter. Similarly, poor drainage and hard and sticky consistence result in physically poor soils. According to farmers, heavy textured soils (*ugadenzima* and *udongwe*) as well as soils in depressions and lower lying areas (*isidaka* and *omhlophe*) are generally perceived as bad soils mainly due to their poor ease of tillage as well as becoming overly wet for longer periods after rains or too dry in dry seasons. All these indicators are largely influenced by soil texture with clayey soils having more tillage challenges due to their small particle size. Table 4.4 shows an average clay percentage of 35% and 83% for *ugadenzima* and *udongwe*, respectively. *Isidaka* and *omhlophe* are subject to seasonal or permanent waterlogging that results in the depletion of oxygen and reducing conditions commonly with associated Mn and Fe toxicity.

The local fertility indicators were evidently more important to farmers than absolute fertility levels. This can explain the general lack of correlation between measured chemical properties and the soil fertility assessment given by farmers (Tables 4.3 and 4.4). This is contrary to similar studies that found good agreement between the two assessments (Murage et al., 2000; Desbiez et al., 2004; Moges and Holden, 2007; Yeshaneh, 2015; Berazneva et al., 2016). Differences in perceptions of soil quality may result in differences in evaluations of whether a plot has 'good' or 'bad' soil quality. Local concepts of what makes good or bad soil fertility are more complex than measured individual physicochemical properties and thus the measured properties were of little value in farmer fertility assessment that focuses on the overall soil health. This was further supported by common similarities in the physicochemical properties between locally perceived good and preferred agricultural soils and those perceived as bad and least preferred (Table 4.4). In a few cases where there were significant differences (acid saturation, Mg and ECEC) between preferred and least preferred agricultural soils, the latter were chemically better than the former but were limited by other observed hydro-physical properties that resulted in production constraints. For example, the soil fertility classes of *ugadenzima*, *udongwe*, *omhlophe* and *isidaka* were largely determined by internal drainage, drying rate, manure requirement and ease of tillage. As a result, manure requirement in *ugadenzima* was also not based on chemical assessment but aimed at correcting physical condition. Similar to Mairura et al. (2007), indicators used thus highlight the value of considering the visual and morphological soil characteristics used by farmers as key criteria in soil characterisation.

Nonetheless, local farmer soil fertility assessment did indirectly consider some chemical attributes of the soil. For example, they perceived yellowing of leaves as a sign of bad soil fertility. Yellowing of leaves is a symptom mostly associated with nitrogen deficiency. This suggests that farmers were able to recognize that something was wrong in the soil. Despite not having understanding of chemical fertility, farmers associated this observation with inadequate nourishment or "fat" in the soil and that it had to be managed either through the application of manure or the addition of plant residues. This represents some overlap with the scientific evaluation of fertility as the local system revealed what could be indicated by laboratory data. However, farmers would still not be able to estimate accurate fertiliser or manure requirements necessary to address nutrient deficiencies. For example, the exclusion of laboratory data in farmer soil fertility evaluation may have resulted in the inadequate supplementation and enhancement of soil nutrients shown by generally low exchangeable cations in all fertility categories (Table 4.3). Laboratory data can thus provide accurate information based on current soil nutrient requirements leading to increased crop yields.

Despite the general lack of correlation, a few Khokhwane and Potshini subjective fertility classes correlated with their objective measurements suggesting that the local indicators used are consistent with laboratory-measured proxies for soil fertility. For example, Khokhwane and Potshini farmers' fertile plots had higher total exchangeable bases compared to the less fertile plots. In Potshini this could be explained by relatively higher organic matter and clay content in fertile and moderately fertile plots compared to poor plots. The use of colour can thus be a relatively good qualitative indicator of current soil fertility in Potshini. This agreement may also suggest that the Zulu farmers in the studied villages are better at estimating soil fertility than the Xhosa farmers at Ntshiqo and Zalaze.

There seemed to be a relationship between farmers' fertility assessment and farm practices such as crop management, resource allocation, time of planting as well as general cropping systems. This is consistent with the findings of Desbiez et al. (2004) and Bwambale (2015) from Nepal and Central Rwanda, respectively. To some extent, farmers manage fertile and infertile soils differently. Farmers acknowledge the ability of fertile soils to adequately support crop growth and use less manure compared to perceived infertile soils. Fertile soils have a minimum requirement of soil amendments for optimal soil productivity as they can retain nutrients. However, the local farmers' decisions of investing more of their limited resources in fertile fields leaves those perceived as less fertile subject to poor management despite some evidence of efforts to improve them e.g. addition of manure to clayey or soils of poor fertility. This apparent lack of proper management and poor resource investment in poorer soils may render additional laboratory data a waste as they may not be considered or applied on these soils. Moreover, other management constraints such as labour problems and weeding contribute to the observed decrease in crop yields may offset the estimated yield increases that could be achieved with the application of scientific results.

Farmers in all villages practiced crop rotation and mixed cropping and reported an increase in soil fertility under these cropping systems. This observation by farmers is not surprising as their rotation involved leguminous crops that are known for their contribution to soil fertility via biological nitrogen fixation (Graham and Vance, 2003). Both crop rotation and intercropping are commonly practiced to optimize nutrient uptake, suppress soil-borne diseases and improve crop yield per unit area (Hiddink et al., 2010).

4.5 Conclusions

Farmers' perception of soil fertility largely related more to a set of observable physical indicators than absolute fertility status resulting in poor correlation between farmer fertility assessment and laboratory data. Soils perceived as poor or least preferred by farmers had soil fertility problems related to field indicators rather than actual measured fertility parameters. Farmers understand that soil fertility is a function of a complex interaction between soil and other factors such as micro- and macrotopography, climate, land use and management. They considered a wide range of indicators both edaphic and non-edaphic (especially those influencing important soil processes) to assess current soil fertility. To develop viable and sustainable soil/cropping systems, local farmer soil fertility evaluation would benefit from laboratory data that provide accurate fertiliser/lime recommendations necessary for optimizing crop yield. However, local management constraints such as labour problems and weeding have potential to counteract the benefits of scientific results and have to be considered for complete soil fertility evaluation. Local farmer perceptions of soil fertility had an impact on farmers' soil use and management decisions. Although crop allocation was mainly determined by the existing perceived suitability of the soil, farmers also took measures to improve less productive soils. Understanding local fertility perceptions will thus provide a necessary departure point towards developing effective and relevant technologies for soil fertility assessment in small-scale systems with the aim of improving adoption of integrated soil management interventions.

Chapter 5: Indigenous knowledge of some geophagic and healing/cosmetic soil materials from KwaZulu-Natal, South Africa and their characterisation

5.1 Introduction

In addition to agriculture, soil has provided raw material for making, producing and manufacturing various goods and services. Literature has considerable evidence of functional applications of soils that are largely attributed to their variable structural and chemical properties (Carretero and Pozo, 2010). Common functional uses of soils in South Africa include topical application for cosmetics, sunscreen, healing and human geophagy.

The use of clays in cosmetic practices surrounding initiation, birth and marriage is common in many indigenous African communities e.g. Zulu and Xhosa ethnic groups of South Africa (Matike et al., 2010; Morekhure-Mphahlele et al., 2017), Ovahimba tribe of Namibia (Molefe, 2015) and suggests local understanding of their properties. Matike et al. (2010) provide a comprehensive review of many more African tribes. The physical properties of clayey soils such as viscosity and consistency are vital, as cosmetic products must be smooth, adhesive and without grittiness (Ngomo et al., 2014). The physicochemical properties of natural clays thus play a crucial role in their cosmetic suitability (Carretero, 2002; Lopez-Galindo and Viseras, 2004). Preferred natural materials thus commonly have a silty or clayey texture (Matike et al., 2011). Morekhure-Mphahlele et al. (2017) indicated the possible role of factors such as the subjective (qualitative) texture experience during skin application in determining the suitability of clayey soils for cosmetic purposes. This was based on the finding that there was high compositional variability (even in samples sourced from similar locations) suggesting that the actual application may not be specific with respect to clay composition.

Cosmetic application of clayey soils may also have played a role in the ability of prehistoric humans to adapt to environmental circumstances (Rifkin et al., 2015). This understanding of cosmetic use may have led to the innovation of the habitual use of clayey soils for protection from the sun which may have emerged as a response to changing ultra-violet (UV) exposure rates due to climate change (Blome et al., 2012). As for cosmetic use, clay particle size and chemical composition are of great importance regarding UV-reflection and UV-absorption functions, respectively (Hoang-Minh, 2006). Besides being commonly known for its symbolic application, soil (particularly red ochre – clay stained by iron oxides) has the ability to limit the harmful effects of excessive exposure to UV light through its light reflection and scattering properties (Hoang-Minh et al., 2010). Besides cosmetic purposes, other non-agricultural uses of soil material include use for healing purposes.

The use of clays for healing has been reported in many communities around the world. This use of soils for healing is based either on beneficial effects discovered after trial and error (Mahaney et al., 2000) or on a clinical-biological basis (Droy-Lefaix and Tateo, 2006). Healing clays are known to contain iron oxides that have powerful astringent and styptic effects that halt haemorrhaging and that have antiseptic properties (Velo, 1984). As a result, mineralogical and chemical analyses have shown preference for specific red, clayey soils in prehistoric and current topical healing applications (Velo, 1984). While healing materials relate more to external injuries, other materials are ingested for a variety of reasons (geophagy), including the possible supply of mineral elements, as a means to reduce psychological cravings, as part of cultural practise (Ferrell, 2008).

Geophagy has been recorded in numerous African traditional communities (Gichumbi et al., 2012; Diko and Ekosse, 2014; Ekosse et al., 2017). It refers to the consumption of non-food substances, mainly clays (Young, 2010). This deliberate ingestion of soils has been mostly reported for pregnant women and children up to adolescence (Abrahams and Parsons, 1997; Geissler et al., 1999; Al-Rmalli et al., 2010; Songca et al., 2010). The ingested soil material is generally selected based on colour and texture as the main criteria (Nchito et al., 2004; Ngole et al., 2010). Preference for red soil has been reported in many communities and associated with prevention and alleviation of symptoms of Fe deficiency due to its inferred high Fe content (Harvey et al., 2000). Diko and Diko (2013) reported a preference for soil with high content of clay-sized particles with little or no sand grains as it is said to "melt easily" in the mouth. Ethnographic interviews have shown that people mostly ingest soils due to craving, lack of appetite, and anaemia (Geissler et al., 1999; Diko and Diko, 2013). Geophagy has also been associated with advantages relating to mineral supplementation. Some geophagic materials have been reported to provide elements such as Fe, Cu, Mg, Se, Zn, and I (Abrahams et al., 2006; Rifkin, 2012). There are, however, diverse perceptions regarding this practice. This is particularly because of the association of geophagy with both positive and negative effects on human health.

These effects of geophagy may vary depending on the physicochemical properties, mineralogy and geochemistry of the soil. As a result some studies have been undertaken in South Africa to characterise geophagic materials in order to understand possible implications for geophagists (George and Ndip, 1997; Ekosse and Ngole, 2012; Diko and Diko, 2013; Sumbele et al., 2014). Similarly, physicochemical characterisation of healing and cosmetic clayey soils is important as it may provide insight concerning selection and curative properties. There have also been a few studies aimed at investigating healing and cosmetic clayey soils in South Africa (Matike et al., 2010; Mpako et al., 2011; Dlova et al., 2013). However, most of the work on these non-agricultural uses of soils has been done in the Eastern Cape, Free State and Limpopo Provinces with little done in KwaZulu-Natal (KZN) (Saathoff et al., 2002; Msibi, 2014; Morekhure-Maphahlele et al., 2017). This is unfortunate given the reported variation in soils used for these non-agricultural uses as well as their prominence in KZN (undocumented personal communication and observation). According to Ferrell (2008), variations in different soils are largely due to their origin as well as their complex mineral composition. This study will thus expand the current understanding of these materials in less studied geophagic, cosmetic and healing soils of KZN. The aim of the study was to investigate the physicochemical and mineralogical properties of geophagic materials and their possible implications for the health of geophagic individuals. Moreover, the study characterised healing, sunscreen and cosmetic soils to establish possible explanations for their properties.

5.2 Methodology

5.2.1 Study sites and sample collection

Potshini and Khokhwane villages (Section 3.2.1) were chosen as the main sites following the preliminary questionnaires (Appendix 1) that revealed the use of soil for geophagy, cosmetic and healing. To obtain detailed information on these practices, in-depth interviews with knowledgeable and willing individuals who were identified during the questionnaire stage were conducted. Only eight geophagists were willing to provide information about the habit of ingesting soil as many did not wish to disclose or be openly associated with it. This was the main limitation as most individuals locally known to be ingesting soil were not comfortable to be interviewed or denied being actively involved in the practice. Ten participants who either used or were knowledgeable about the use of soils for healing, cosmetic and sunscreen purposes were also interviewed. Information gathered included criteria for selection of soils used, desired properties, possible mechanisms through which soils perform the claimed role, and the locations of soils. Geophagists were also asked to provide information on the amounts eaten, collection and preparation of ingested soil as well as possible reasons for eating soils. Similarly, participants were asked to provide information on healing and cosmetic soils e.g. preparation and method of application.

Five samples used for geophagy were collected from Potshini (samples G1 to G5) and two from Khokhwane (samples G6 and G7) (Figure 5.1).

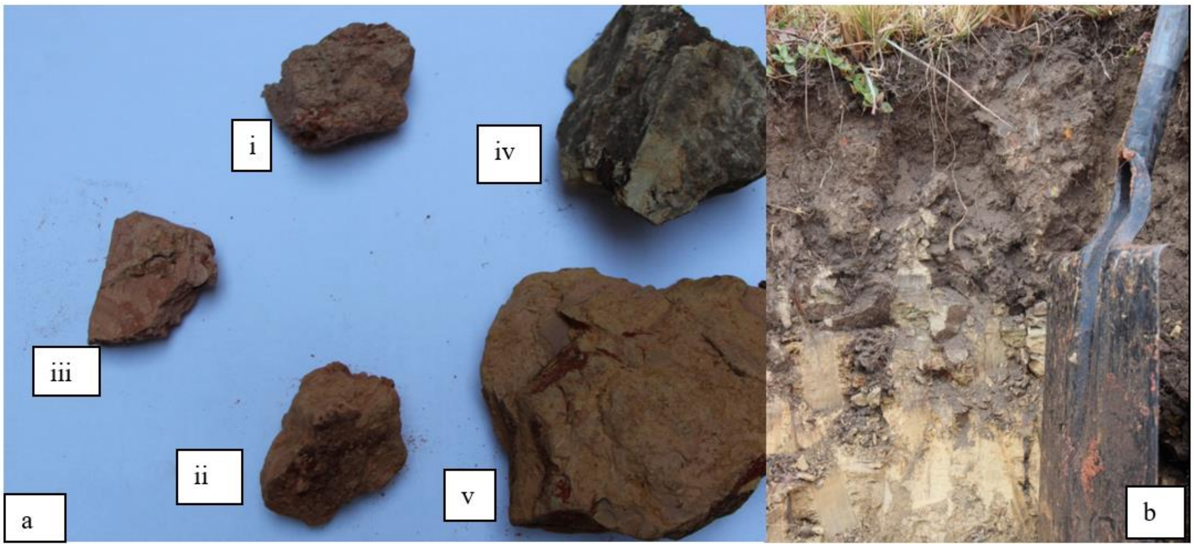


Figure 5.1 (a) Examples of some geophagic materials from Potshini (i, ii and iii) and Khokhwane (iv and v) and (b) geophagic site (Glenrosa –SCWG, 1991; Leptosol- IUSS Working Group, WRB, 2014) located in Khokhwane.

One type of soil material consumed is locally referred to as *ukhethe* (Table 3.1). All the samples were collected from below the solum. They were collected from the unconsolidated material of oxidic soils-Ferralsols (i, ii and iii from Potshini) or from less weathered rock or bedrock of lithic soils-Leptosols (iv and v from Khokhwane) (Figure 5.1).

The preliminary questionnaires in Potshini and Khokhwane villages revealed that a soil type (locally known as *ibomvu*) is used for healing, cosmetic and sunscreen purposes. Other respondents referred to the Potshini healing/cosmetic sample (Figure 5.2a) as *umadilika.*

One healing/cosmetic/sunscreen (*ibomvu*) sample was thus collected from each of the two villages. In addition, two more healing soils were obtained from two randomly selected rural locations near Louwsburg (27.5762ºS, 31.2798ºE) and Nkandla (28.6223ºS, 31.0894ºE) in northern KZN (Figure 5.2). These locations were chosen because of the prominent use of *ibomvu* for both healing and cosmetic purposes (Michael Malinga and Sphindile Sbiya - personal communication).

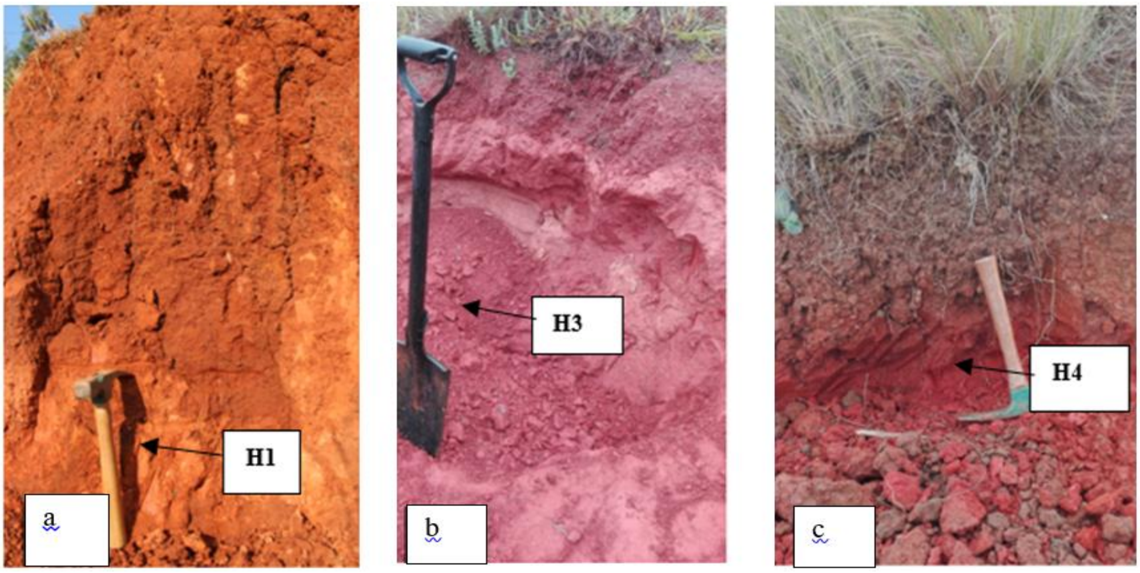


Figure 5.2 Oxidic soils (Ferralsols) at (a) Potshini, (b) Louwsburg and (c) Nkandla from which healing materials (H1, H3 and H4, respectively) were collected.

All healing/cosmetic samples were soil materials from varying depths. A non-healing red soil was collected as a comparison sample for each of the healing/cosmetic soils from Potshini and Khokhwane. These were red agricultural soils that participants identified as undesirable for healing and cosmetic purposes.

Both geophagic and healing/cosmetic samples were collected with the assistance of local soil users who identified the sample locations on condition that the actual locations were not divulged. Upon identification by the local user, the material was removed using a geological pick or knife. All samples were air-dried, ground and sieved to pass a 2 mm mesh prior to laboratory analysis.

5.2.2 Analysis

All the samples were analysed for pH (measured using 1:2.5 ratio of soil:1M KCl), exchangeable Ca, Mg and exchangeable acidity (extracted with 1M KCl) and exchangeable K, Zn, Cu and Mn (extracted with ammonium bicarbonate) (Manson and Roberts, 2000). Particle size distribution (PSD) was determined using the pipette method (Gee and Bauder, 1986). Powder X-ray diffraction (XRD) of bulk samples was carried out using a PANalytical Empyrean Diffractometer operated at 40 kV and 30 mA, with monochromated Co-Kα radiation. The XRD peaks were interpreted using X'PertHighscore plus software. Both major and trace elements were determined using X-ray fluorescence spectrometry (XRF). Two of the healing soils (H1 and H2), that were also used for cosmetic purposes and their comparison, non-healing samples (C1 and C2), from Khokhwane and Potshini were also analysed by the in vitro SPF testing procedure in their natural state (Diffey and Robson, 1989) on an Optometrics SPF 290 Analyser (Optometrics Corporation, Ayer, MA, USA) to estimate their UV protection efficiency.

5.3 Results

5.3.1 Geophagic materials

5.3.1.1 Geophagy in Potshini and Khokhwane

Questionnaires revealed that 74% (n=50) and 35% (n=50) of participants mentioned geophagy as one of the non-agricultural uses of soils in Potshini and Khokhwane, respectively. However, according to participants this was perceived as an aberrant behaviour and rarely openly practised. As a result, only five geophagists were willing to give details of the geophagy practice in Potshini and only three were identified from Khokhwane. All the identified and interviewed geophagists were females of childbearing age. These individuals collected the soil themselves and ate it as found or after sun drying. When asked why they ingest soil, geophagists (n=8) gave a number of reasons including desirable sour taste (88%), craving (75%), pregnancy (54%), and smell (50%). It was difficult to estimate the amount eaten as geophagists could not recall how much they eat at a time. However, some gave indications using a 250 mL cup. Some would consume a quarter to a full cup from once daily (50%) to once a week (25%) or not often (25%). The geophagists interviewed preferred soils that had a soft and smooth feel in the mouth.

5.3.1.2 Physicochemical properties

All geophagic samples were not "true" soil materials but less weathered, easily disaggregated rock often found at the base of soil profiles developed by in situ weathering. The physicochemical properties of the geophagic samples from Potshini (G1-G5) and Khokhwane (G6 and G7) are given in Table 5.1. All the samples were loams with silt content being at least 50% for three Potshini samples (G1, G3 and G4), 42% for one (G5) and, similar to both Khokhwane samples, G2 had less than 30%. Khokhwane samples had greater sand content of 71.4% (G6) and 60.8% (G7) compared to clay (12-15%) and silt (17-24%). Both medium and coarse sand were higher in Khokhwane samples (G6 and G7) compared to the Potshini samples.

Contrary to the other Potshini samples, G2 had a significantly higher sand fraction.

Table 5.1 Physicochemical properties of the geophagic samples from Potshini (G1 – G5) and Khokhwane (G6 and G7).

Parameter	Geophagic samples						
	G1	G2	G3	G4	G5	G6	G7
pH (KCl)	3.68	3.65	3.81	3.85	3.81	3.75	3.91
Exch. Acidity ($cmol_c$ kg^{-1})	4.52	5.00	4.63	5.35	7.90	2.71	3.40
K ($cmol_c$ kg^{-1})	0.33	0.36	0.33	0.28	0.33	0.53	0.27
Ca ($cmol_c$ kg^{-1})	1.6	0.79	1.23	0.85	0.33	1.3	0.87
Mg ($cmol_c$ kg^{-1})	2.71	1.88	2.03	2.87	1.13	2.65	1.97
Zn (mg kg^{-1})	1.4	0.57	0.49	0.43	0.21	0.37	0.93
Mn (mg kg^{-1})	24.8	59.6	85.4	21.5	6.45	17.6	37.1
Cu (mg kg^{-1})	1.0	0.96	1.1	1.8	0.64	0.55	0.82
Clay (<0.002 mm) (%)	34.3	25.2	47.3	17.7	19.3	12.1	15.4
Silt (0.05 - 0.002 mm) (%)	57.4	27.1	49.5	57.0	42.3	16.5	23.9
Very fine sand (0.1 - 0.05 mm) (%)	5.50	3.80	1.80	14.3	12.9	4.90	3.20
Fine sand (0.25 – 0.1 mm) (%)	2.50	5.40	1.00	8.00	9.20	8.00	7.50
Medium sand (0.5 - 0.25 mm) (%)	0.300	7.00	0.100	2.60	4.8	10.8	11.0
Coarse sand (2.0 - 0.5 mm) (%)	0.00	31.5	0.3000	0.400	11.5	47.7	39.0
Texture	silty clay loam	sandy clay loam	silty clay loam	silt loam	loam	sandy loam	sandy loam
Munsell notation	2.5YR 6/6	2.5YR 3/4	5YR 6/6	7.5YR 5/8	10YR 7/8	10YR 6/4	10YR 6/8
Munsell colour	light red	dark reddish brown	reddish yellow	strong brown	yellow	light yellowish brown	brownish yellow

Of the five samples from Potshini, one had red coloration, one yellow and three were brownish, similar to the two from Khokhwane (Table 5.1). Both samples from Khokhwane had a hue of 10YR. All samples were characterised by a strongly acidic pH. Across both villages, all geophagic samples had higher Mg (ranging from 1.13 - 2.71 $cmol_c$ kg^{-1} in different samples) compared to lower Ca (0.33 - 1.63 $cmol_c$ kg^{-1}) and potassium (0.27- 0.53 $cmol_c$ kg^{-1}).

5.3.1.3 Mineralogical composition

The mineralogy of the geophagic materials is given in Table 5.2 and the original XRD traces are given in Appendix 15. All geophagic materials consisted of both clay and non-clay minerals.

Table 5.2 Minerals identified (X) in the geophagic samples from Potshini (G1 – G5) and Khokhwane (G6 and G7).

	Geophagic samples						
Mineral	G1	G2	G3	G4	G5	G6	G7
14 Å		X			X		
Anatase	X	X	X				
Goethite							X
Hematite			X	X			
Kaolinite			X	X	X	X	X
K-feldspar	X					X	
Magnetite				X			
Mica/illite	X	X	X	X	X	X	X
Quartz	X	X	X	X	X	X	X

All geophagic samples contained mica and quartz. Except for G1 and G2, the rest also contained kaolinite. Samples G2 and G5 contained a 14 Å mineral. Anatase was recorded for samples G1, G2 and G3 whilst magnetite was only found in sample G4. Samples G1 and G6 contained K-feldspar, and G7, goethite. Hematite was found in samples G3 and G4.

5.3.1.4 Elemental composition

Silica (SiO_2; 60-70%), Al_2O_3 (16-21%) and Fe_2O_3 (4-9%) made up the greatest percentage of the major elements of the geophagic materials (Table 5.3).

Table 5.3 Major element composition (%) of the geophagic samples from Potshini (G1 – G5) and Khokhwane (G6 and G7).

Oxide	Geophagic samples						
	G1	G2	G3	G4	G5	G6	G7
SiO_2	62.49	61.31	59.97	59.83	69.70	62.78	59.39
Al_2O_3	20.22	20.57	21.57	19.10	16.04	19.46	19.60
Fe_2O_3	6.83	5.90	7.24	7.99	4.18	5.71	8.75
CaO	0.04	0.03	0.06	0.05	0.07	0.06	0.06
MgO	0.60	0.96	0.48	1.0	0.77	1.2	1.01
K_2O	2.13	3.40	2.10	3.68	3.12	3.75	3.18
Na_2O	0.04	0.03	0.04	0.05	0.03	0.05	0.06
MnO	0.03	0.1	0.07	0.1	0.05	0.03	0.06
TiO_2	0.83	0.92	0.91	0.79	0.79	0.87	0.78
P_2O_5	0.06	0.04	0.04	0.2	0.03	0.07	0.1
LOI*	7.15	6.81	7.62	7.48	4.93	6.35	6.85
Sum of conc.	100.36	100.07	100.09	100.26	99.71	100.30	99.87

* LOI - loss on ignition

All geophagic samples generally had low alkali and alkaline earth oxides except for K_2O (2.10% - 3.75%) with CaO and Na_2O <0.5% and MgO <1.5%. Concentrations of TiO_2 and P_2O_5 were <1.0%. Loss on ignition was lowest in G5 and highest in G3.

Selected trace elements in the geophagic samples are presented in Table 5.4. Complete results are presented in Appendix 16. The discussion that follows focuses on Co, Cu and Zn, considered as essential nutrients for humans, as well as Pb and Ni that are associated with toxicity (Campbell and Morrison, 1963)

Table 5.4 Selected trace element composition (mg kg^{-1}) of the geophagic samples from Potshini (G1 – G5) and Khokhwane (G6 and G7).

	Geophagic samples						
Trace element	G1	G2	G3	G4	G5	G6	G7
Ba	322.16	510.05	404.76	643.71	603.67	546.28	616.90
Co	12.19	16.99	33.43	16.94	13.99	7.820	14.53
Cu	48.84	38.46	34.12	27.82	14.90	36.01	36.56
Ni	35.55	224.06	19.45	23.53	15.92	21.88	35.28
Pb	21.40	40.38	32.45	37.79	18.57	21.08	51.10
Zn	81.34	73.87	40.68	80.51	56.88	103.72	124.4

Samples had variable concentrations of trace elements, especially Zn which was higher in Khokhwane (G6 and G7) compared to all Potshini samples. Sample G2 had markedly higher Ni while sample G7 had the highest Pb content. All samples generally had high Ba.

5.3.2 Healing/cosmetic soils

5.3.2.1 Use of soils for healing and/or cosmetic purposes

Preliminary questionnaires revealed that the red soil commonly known as *ibomvu* is widely used in cultural rituals associated with female traditional initiations (60%, n=200) and clan identification (64%, n=200. The initiation tradition known as *umemulo* (ceremony to signify that a girl is now entering womanhood) is very significant as it indicates a moment when the young girls are welcomed into adulthood. In-depth interviews revealed that the use of the *ibomvu* during the girl initiation is largely for cosmetic purposes. During this process, a girl is secluded for a certain period while being covered with the red soil that supposedly cleanses and lightens her skin prior to the actual ceremony.

According to the respondents, the clan identification ceremony involves face scarification or cutting of the small index finger performed mostly on infants of surnames such as Zuma, Mchunu and Zondi. Individuals with these surnames are distinguished from other clans by these forms of scarification. According to participants, the red soil paste is applied onto the cut to facilitate healing and prevent infection of the scars. The participants mentioned that the wound dries and heals faster when *ibomvu* is applied to it. A few mentioned that the same red soil is used during the infant skin-peeling period as well as for spiritual healing. The interviews further revealed that *ibomvu* is only used for topical application.

In addition, participants indicated that *ibomvu* has recently become a common sun protectant, particularly for women. This behaviour was, however, not initially positively received due to the long-term association of *ibomvu* with cultural rituals. According to the participants the red soil is mixed with water and smeared on the face on hot days to provide sun protection. Unfortunately, for all the mentioned uses of *ibomvu*, participants could not provide any estimation of the amount used. *Ibomvu* is dug from deeply weathered oxidic soils (Ferralsols) from sites that in most cases were located in remote areas outside residential areas. When asked how they discovered the potential of *ibomvu* in healing and cosmetic functions, participants mentioned that this knowledge has been passed down through generations and hence could not provide further explanations.

5.3.2.2 Physicochemical properties

The healing soils had a pH ranging from 3.91 to 4.21 (Table 5.5). Both H1 and H2 had a pH comparable to their respective comparison samples (C1 and C2).

Table 5.5 Physicochemical properties of healing soils from Potshini (H1), Khokhwane (H2), Louwsburg (H3) and Nkandla (H4). C1 and C2 are the non-healing samples from Potshini and Khokhwane, respectively.

Parameter	Healing soils				Non-healing soils	
	H1	H2	H3	H4	C1	C2
$pH_{(KCl)}$	3.91	4.09	4.05	4.21	3.88	4.05
Exch.acidity ($cmol_c\ kg^{-1}$)	0.990	1.99	1.64	1.34	2.38	1.48
K ($cmol_c\ kg^{-1}$)	0.23	0.080	0.21	0.040	0.19	0.22
Ca ($cmol_c\ kg^{-1}$)	0.57	0.72	0.66	0.46	1.7	1.3
Mg ($cmol_c\ kg^{-1}$)	0.65	0.80	4.7	0.69	1.2	0.63
Zn (mg kg^{-1})	1.3	0.0	1.5	0.10	4.0	0. 11
Mn (mg kg^{-1})	127	133	81.5	0.2000	0.98	9.57
Cu (mg kg^{-1})	4.81	3.78	3.33	1.25	2.36	0.950
Clay (<0.002 mm) (%)	32.6	35.9	14.6	33.1	41.0	54.3
Silt (0.05– 0.002 mm) (%)	61.2	51.4	66.1	62.1	26.4	28.9
Very fine sand (0.1– 0.05 mm) (%)	3.10	6.00	13.7	3.10	16.9	4.40
Fine sand (0.25 – 0.1 mm) (%)	2.7	4.9	4.9	1.4	14	3.3
Medium sand (0.5 – 0.25 mm) (%)	0.40	1.3	0.30	0.30	1.6	1.8
Coarse sand (2 – 0.5 mm) (%)	0.0	0.50	0.40	0.0	0.0	7.3
Texture	silty clay loam	silty clay loam	silt loam	silty clay loam	clay loam	clay
Munsell notation	2.5YR 4/8	5YR 4/6	5YR 3/6	2.5YR 3/6	5YR 2/4	5YR 4/6
Munsell colour	reddish brown	dark reddish brown	dark reddish brown	dark reddish brown	reddish brown	very dark reddish brown

All healing soils had low exchangeable cations (Table 5.5). Comparison samples had higher Ca than all the healing soils. All the healing soils had high silt contents between 51 and 66%. Sample H3 had the lowest clay content (15%) while the other three healing clays had clay contents ranging from 33% to 36%. Comparison samples had higher clay content (>40%) and lower silt (<30%) compared to healing soils. All soils had reddish brown colours with four having darker hues.

5.2.2.3 Mineralogical composition

All healing and comparison samples had both kaolinite and quartz (Table 5.6; Appendix 17). Only the comparison samples contained a 14 Å mineral and K-feldspar.

Table 5.6 Minerals identified in the healing clay samples from Potshini (H1), Khokhwane (H2), Louwsburg (H3) and Nkandla (H4). C1 and C2 are the non-healing samples from Potshini and Khokhwane, respectively.

	Healing soils				Non-healing soils	
Mineral	H1	H2	H3	H4	C1	C2
14 Å					X	X
Anatase		X	X		X	X
Gibbsite		X		X	X	X
Goethite	X			X		
Hematite		X	X		X	X
Kaolinite	X	X	X	X	X	X
K-feldspar					X	X
Mica/illite						X
Quartz	X	X	X	X	X	X

Hematite and traces of anatase occurred in healing samples H2 and H3 as well as in both comparison samples. Samples H2 and H4 had gibbsite which was also present in both comparison samples. Goethite only occurred in samples H1 and H4.

5.3.2.3 Elemental composition

Healing soils had higher quantities of Al_2O_3 (22-29%) and Fe_2O_3 (11-18%) compared to comparison samples (C1 and C2) with about 17% and 8% Al_2O_3 and Fe_2O_3, respectively (Table 5.7). Higher quantities of SiO_2 were recorded for the comparison samples of about 66%, while healing samples had a lower range of 39%-46%.

Table 5.7 Major element composition (%) of the healing soil samples from Potshini (H1), Khokhwane (H2), Louwsburg (H3) and Nkandla (H4). C1 and C2 are the non-healing samples from Potshini and Khokhwane, respectively.

	Healing soils				Non-healing soils	
Oxide	H1	H2	H3	H4	C1	C2
SiO_2	38.74	45.85	38.54	43.97	66.63	65.87
Al_2O_3	28.96	27.46	28.12	22.14	16.58	15.90
Fe_2O_3	17.4	11.1	18.4	20.4	8.17	8.20
CaO	0.02	0.03	0.02	0.03	0.03	0.03
MgO	0.49	0.24	0.18	0.73	0.13	0.21
K_2O	0.06	1	0.5	0.09	0.29	0.29
Na_2O	0.01	0.02	0.03	0.03	0.03	bdl$^{\#}$
MnO	0.2	0.05	0.06	0.3	0.02	0.02
TiO_2	2.01	1.34	1.27	2.28	1.15	1.21
P_2O_5	0.09	0.04	0.05	0.04	0.07	0.07
LOI*	12.3	13.0	13.3	11.8	8.52	8.80
Sum of conc.	100.35	100.29	100.43	101.07	101.65	100.61

* LOI - loss on ignition; # bdl – below detection limit

Except for H2 (K_2O >1.0%), all samples, including the comparison samples, had low (<1.0%) amounts of K, Ca, Mg, Na, Mn and P. Healing soils had the highest LOI (mean of 12%) compared to about 8% in the comparison samples. Titanium oxide was similar between healing soils and comparison samples. However, the highest (≥2%) was recorded for H1 and H4 with all other samples having <1.4%.

All healing soils, except for H2 showed consistently high V, Co, Ni and Cu compared to the comparison samples (Table 5.8). Complete results of trace elements are presented in Appendix 18. The highest V, Cr and Ni was found in H3. Except for H4, healing samples had lower Zn compared to the comparison samples.

Table 5.8 Selected trace element composition (mg kg^{-1}) of the healing soil samples from Potshini (H1), Khokhwane (H2), Louwsburg (H3) and Nkandla (H4). C1 and C2 are the non-healing samples from Potshini and Khokhwane, respectively.

	Healing soils				Non-healing soils	
Trace element	H1	H2	H3	H4	C1	C2
Ba	72.23	277.9	104.9	500.5	78.15	72.08
Co	65.80	15.50	22.59	141.2	27.40	27.46
Cr	173.6	194.2	304.8	249.8	203.0	201.9
Cu	144.2	44.08	98.55	108.4	56.40	52.16
Ni	102.9	43.75	128.9	86.06	66.64	65.01
Pb	2.98	35.9	10.1	13.5	17.0	17.9
V	236.8	210.4	254.8	204.7	176.1	170.6
Zn	63.11	47.64	60.05	73.19	72.40	75.69

Sample H2 had the lowest concentrations of Co, Ni, Cu and Zn but the highest amount of Pb compared to all the other samples. The highest concentration of Co and Ba was recorded for sample H4. The trace element contents of the two comparison samples (C1 and C2) were very similar to each other.

5.3.2.4 UV-protection characteristics

All the samples had low SPF values (Table 5.9).

Table 5.9 Sun protection characterisation of the healing soil samples from Potshini (H1) and Khokhwane (H2). C1 and C2 are the non-healing samples from Potshini and Khokhwane, respectively.

	Healing soils		Non-healing soils	
Parameter	H1	H2	C1	C2
Sun protection factor	2.5	1.8	1.9	2.0
UVA/UVB* ratio	1.1	0.9	1.0	0.9
Critical wavelength (nm)	390.0	389.2	389.6	388.3

* - UVA – long-wave ultraviolet A (320-400nm);
UVB – medium-wave ultraviolet B (280-320nm)

Healing soils had SPF values similar to the comparison samples. Similarly, both UVA/UVB ratio and critical wavelengths were also similar between the cosmetic samples and comparison samples.

5.4 Discussion

5.4.1 Geophagic materials

Current findings on geophagic soil properties were relatively consistent with the effects reported or desired by local geophagists. This supports the argument that geophagy is practical folk wisdom and environmentally adaptive behaviour (Henry and Kwong, 2003). For example, interviewed geophagists were women and thus subject to blood loss via pregnancy and menstruation causing iron deficiency (Campbell and Morrison, 1963). Consuming soil could have thus been a physiologic response to iron deficiency. Although variable, the reddish colours indicative of iron in the geophagic materials may support the micronutrient supplementation hypothesis that may induce craving in geophagic individuals. The colours reported for geophagic materials reflect the influence of iron oxides (Tables 5.2 and 5.3), indicated by the Munsell colour notation (Table 5.1). The preference for yellowish/reddish or brown colours in geophagic materials has been reported in other studies in South Africa (Ngole et al., 2010; Olowoyo and Macheka, 2013; Ekosse and Obi, 2015) and Cameroon (Diko and Ekosse, 2014; Ekosse and Obi, 2015). This may be attributed to the general association of geophagy with low levels of haemoglobin (Young, 2010), which suggests possible iron supplementation by ingested material (Abrahams and Parsons, 1997). Geophagic materials had a notably high (up to 9%) Fe_2O_3 (Table 5.3) and thus may provide sufficient iron supplementation to geophagic individuals, especially those who ingest soil during pregnancy. Particle size distribution showed a high silt concentration compared to both clay and sand in all the samples. This supports the generally reported textural preference given by interviewed geophagic individuals. The results are consistent with results from other parts of South Africa where people also preferred soft or powdery material without significant grittiness (Diko and Ekosse, 2013; Sumbele et al., 2014; Ekosse et al., 2017).

The pH largely affects the taste of geophagic materials. The geophagic materials had acidic pH, which also explains the low exchangeable bases. Acidic pH in geophagic materials has been reported in other parts of South Africa (Ngole et al., 2010) and Cameroon (Diko and Ekosse, 2014). Depletion of mobile chemical elements generally leads to acidic soil conditions. The acidic nature of the geophagic samples imparts a sour taste (Diko and Ekosse, 2014) which improves desirability by most of the geophagists (88%). The low pH can also explain the possible solubility and absorption of Fe by geophagic individuals. Higher pH ranges have also been reported for geophagic materials from Swaziland i.e., 5.0 – 7.1 (Ngole et al., 2010; measured in KCl) and South Africa 4.90 – 8.29 (Sumbele et al., 2014; method not given). The differences in pH of the geophagic materials may be due to the extent of weathering as well as their mineralogy. Lower soil pH may, however, result in higher concentrations of potentially toxic heavy metals such as Ni, Cu, Zn and Pb as shown in Table 5.4, which are released upon ingestion (Olowoyo and Macheka, 2013).

Contrary to the commonly reported dominance of quartz with kaolinite (Young, 2010; Gichumbi et al., 2012; Ekosse and Obi, 2015; Okunlola and Owoyemi, 2015), all the present samples also contained mica or illite, while samples G1 and G2 apparently did not contain kaolinite. This is similar to Ekosse et al. (2017) and Sumbele et al. (2014) who also reported quartz, feldspars and mica with only minor amounts of kaolinite in their samples. The differences in the mineralogy of geophagic materials may be attributed to differences in provenance as well as extent of weathering. Traces of kaolinite in samples may help explain the earthy smell indicated by some geophagists as a reason for ingesting soils. This mineral is known to give an earthy smell when dampened with water (Raymond and Johnson, 2017). Despite a general association of muscovite with advanced weathering (Lal, 2006), there seems to be incomplete weathering of the mica, suggesting less intense weathering conditions. The occurrence of mica or illite in the samples could give the samples a smoother feel and counteract the grittier feel of the quartz.

The highest of the major elements in all samples was SiO_2 followed by Al_2O_3 and Fe_2O_3. This trend is consistent with a number of studies done on geophagic materials from different regions (Ekosse et al., 2017; Ekosse and Ngole, 2012; Sumbele et al., 2014). Silica can benefit geophagists as it is known to help grow and maintain strong bones as well as playing a role in the formation of connective tissues such as ligaments and tendons (Jugdaohsingh et al., 2015). Samples with excess quartz (>50%), however, have an undesirable gritty feel and may negatively affect the dental enamel of geophagic individuals (Ekosse et al., 2017). The preference for soft and smooth soils for geophagy suggests that geophagists were aware of, or irritated by, the effect of coarser particle fractions in the soil. All geophagic samples had higher K_2O and MgO concentrations compared to the other alkaline earth oxides. This is attributed to the mica and feldspar components in the samples. In addition to muscovite, samples G1 and G6 contained K-feldspar that further contributed to their K_2O levels. Illite and muscovite retain K locked up in their interlayer and it is thus not easily released. As a result, despite the high concentration of K, its availability to the geophagists is limited. This is further supported by the very low extractable K (<0.5 $cmol_c\ kg^{-1}$) reported for most geophagic materials (Table 5.1).

Furthermore, these clay minerals can also limit the availability of subsequently released K. These clay minerals may result in severe hypokalemic myopathy (metabolic muscle weakness disorder) by binding available K in the intestine when ingested (Ukaonu et al., 2003). The high levels of MgO recorded could suggest that illite is most likely the form in which mica occurs in these geophagic samples. Low Ca/Mg ratios (Table 5.1), however, can also be explained by preferential leaching of Mg as geophagic materials were collected at depths below felsic solums (Shaw et al., 2001). Loss on ignition was generally low in all the samples indicating the low content of water and organic constituents. The low concentrations of CaO and Na_2O suggest that the samples are dominated by non-expanding clays together with low amounts of plagioclase feldspars and this is confirmed by the XRD data (Table 5.3).

The geophagic samples had variable mean trace element concentrations. However, they had noticeably high amounts of essential elements such as Cu, Zn and Co. Lead was also high, particularly in sample G7. The essential trace elements play a significant role in structural and protective physiological roles (Prashanth et al., 2015). For example, Zn supports normal growth and development during pregnancy and adolescence. Geophagic individuals will thus benefit from eating these geophagic materials as the release of essential elements from the soils is likely to occur at low pH similar to that of the stomach. The risk of geophagic individuals being exposed to heavy metals is dependent on the amount of soil ingested per day and the bioavailability of the metal (Ekosse et al., 2017). Individuals who ingested soil daily were likely to be at risk of accumulating toxic levels of heavy metals. For example, concentrations of Pb recorded in this study showed that individuals ingesting geophagic samples G2, G3, G4 and G7 are more at risk of accumulating high concentrations of Pb with more daily intake. Health risks may include cardiovascular, renal, gastro-intestinal and haematological effects (Mahurpawar, 2015). High Ba concentrations were indicative of a felsic source as well as presence of K-feldspars. However, the solubility of this element is low as it tends to be adsorbed on Mn and Fe oxides. This may then counteract the potential adverse effect on geophagic individuals given the potential toxicity of this element to humans. Substitution of K in mica by Ba may also account for the high concentrations of Ba in all the geophagic samples. The overall mineralogical and chemical composition of the geophagic samples suggests that they are of felsic, sedimentary origin.

5.4.2 Healing and cosmetic soils

The use of soil for healing and cosmetic purposes seems to have a cultural origin as it was mainly associated with common rituals. However, it was evident from the interviews that the use of soils, particularly *ibomvu*, was more than symbolic as it also had functional roles (i.e., healing and cosmetic). Walking long distances to collect the soil, as well as specific selection of *ibomvu* instead of any of the other soils suggests that participants were aware of the healing and cosmetic functions of this soil, despite not being able to provide explanations. Chemical and mineralogical analysis of the red soil (*ibomvu*) provided useful insight into the possible mechanisms or explanations of its described multipurpose functional roles. The low pH recorded for *ibomvu* can be related to intense leaching and weathering. According to Nagoba and Pichare (2016) most pathogenic bacteria grow best in neutral and slightly neutral pH. The acidic nature of the clays enables them to provide defence mechanisms against bacteria by creating an unfavourable environment for bacterial growth. Similar acidic pH has been recorded for other South African healing and cosmetic clays (Matike et al., 2011; Madikizela et al., 2017). The abundance of kaolinite (Table 5.6; Appendix 17) can explain the low exchangeable bases in the clays. Kaolinite has little or no isomorphous substitution and charges within the structural unit are balanced resulting in low cation exchange capacity (López-Galindo et al., 2007). It is commonly used as an excipient in pharmaceutical preparations to enhance organoleptic characteristics (Carretero and Pozo, 2010; Khurana et al., 2015). It is also exhibits a very high affinity and good retention capacity for proteins such as bovine serum albumin (Duarte-Silva et al., 2014) important in pharmacokinetics (Chen et al., 2008). Reddish colours recorded for the soils are indicative of iron oxide such as hematite that was confirmed by the XRD analysis (Table 5.6). The presence of hematite and goethite is consistent with the red hue due to the greater pigmenting power of the former iron oxide. The natural colouring of the clays makes them more appealing to the users as they facilitate painting of bright and colourful decorative patterns on the body (Matike et al., 2011). This may explain the mentioned recent increase in the use of *ibomvu* for casual cosmetic and sun protection, a use not related to rituals. The soils had high silt and clay fractions with very low coarse sand fractions compared to the comparison samples. The fine particle size of these fractions, particularly the clay, may explain why these soils are used for topical application on wounds. Such fine particle size and the presence of kaolinite allow for absorption of secretions, toxins and contaminants (Carretero, 2002; Williams et al., 2009). This may support the claim made by local users that when *ibomvu* is applied to a wound it dries and heals faster. Moreover, this particle size distribution is consistent with cosmetic mixtures that should be smooth, non-gritty and non-abrasive (Veniale et al., 2007). According to Dlova et al. (2013) the higher proportion of smaller particles in red clays improves their light scattering and absorption ability that is fundamental for sun protection. The recorded critical wavelength for the soils (>370 nm) supports this claim and qualifies *ibomvu* as a broad-spectrum protectant (Moyal and Fourtanier, 2008).

Kaolinite being a major component of the healing/cosmetic samples supports their functional use for healing, sunscreen and cosmetic purposes. Dlova et al. (2013) and Madikizela et al. (2017) also found similar mineralogy in cosmetic clays from other parts of South Africa. Kaolinite is one of the clay minerals commonly used in pharmacy and cosmetics (López-Galindo et al., 2007). Despite having a relatively low specific surface area, kaolinite can adsorb proteins, bacteria and viruses (López-Galindo et al., 2007) and thus act as a dermatological protector (Carretero, 2002; Willimans and Haydel, 2010; Eigbike et al., 2013). It is also used in pharmaceutical preparations including being a diluent and binder, thickening and anticaking agent (Carretero and Pozo, 2009). The dominance of kaolinite in the healing clays can be attributed to kaolinization indicated by increases in LOI values compared to the comparison samples (Table 5.7).

The soils had Al_2O_3, Fe_2O_3 and SiO_2 as the main major elemental oxides (Table 5.7). This is consistent with results from South Africa (Madikizela et al., 2017) and Tunisia (Khiari et al., 2014). These oxides are evidence for the presence of iron-based minerals, kaolinite as well as quartz as confirmed by the XRD results (Table 5.4). The effectiveness of Fe-rich clays in healing severe skin infections has been documented (Haydel et al., 2008). Moreover, Londono et al. (2017) recently showed that Al toxicity plays an integral role in the antibacterial action of kaolin-rich clays. This suggests that the *ibomvu* samples may possibly have antibacterial properties. High quantities of silica have been associated with greater risk to human health due to the possible carcinogenicity of quartz particles (Khiari et al., 2014). High quantities of this oxide in the samples thus may be a cause for concern. High TiO_2 with low concentrations of the alkaline oxides are likely a result of intense weathering and thus the dominance of non-expanding clay minerals. Moreover, the occurrence of high TiO_2 content (averaging 1.73%) may contribute significantly to the healing and cosmetic roles of the soils. This could support the claim by interviewed participants that the soils have important roles in both functions. According to Yamamoto (2001) TiO_2 has a nanometre particle size that may be important for antibacterial activity important in the healing process. Moreover, TiO_2 is one of the active ingredients used in commercial physical sunblock (Elmarzugi et al., 2013) due to its high refractive index (Judin, 1993). According to Carretero and Pozo (2010) minerals with a high refractive index can be used as solar protectors. The occurrence of this oxide in the clays thus suggests their significant efficacy in UV-protection despite their low SPF. The high average LOI (12.62%) of the healing/cosmetic clays compared to comparison samples (8.66%) is consistent with clay dominated by kaolinite which has a LOI of about 13% (Newman, 1987).

Cobalt is usually associated with Ni and high concentrations of these elements can be explained by the presence of high quantities of iron oxides in the samples. According to Kim et al. (2006) iron oxides can adsorb larger amounts of Co than clay minerals. This is further confirmed by the highest concentration of Co found in sample H4, which contained goethite (Table 5.6). Topical exposure to these two elements has been associated with dermatitis since they can penetrate the skin (Agency for Toxic Substances and Disease Registry, 2004). Individuals using samples H1, H3 and H4 are particularly at risk as they contain very high concentrations of one or both of these elements. There was, however, no local evidence of such effects on the interviewed local users. This could be explained by the fact that the use of *ibomvu* is only occasional and/or seasonal and such effects may only be experienced with constant continual application.

The low SPF values of the soils (Table 5.9) are consistent with soils used for sunscreen in Durban (Dlova et al., 2013), Bizana (Madikizela et al., 2017), and De Hoop (Rifkin et al., 2015) in South Africa, as well as from Bomet, Kenya (Ng'etich et al., 2014). All these authors reported SPF values less than five, which classifies them in the low SPF category (Cosmetic, Toiletry and Fragrance Association, 2004). Despite having low SPF, the cosmetic clays do provide some degree of both UVA and UVB protection. A number of parameters including grain size distribution and chemical composition determine the UV-protection ability of clays (Hoang-Minh et al., 2010). In addition to their critical wavelength, both H1 and H2 had higher Fe_2O_3 and more kaolinite compared to the comparison samples. Hoang-Minh et al. (2010) and Dušencova et al. (2015) showed that high Fe content (particularly in the form of hematite) significantly affects the UV-protection value of clays by reducing UV-transmission levels. Hence, both H1 and H2 are likely to have more potential for UV-protection than the comparison samples.

5.5 Conclusions

Geophagic materials were saprolitic or unconsolidated materials below the C-horizon. Physicochemical analysis revealed that geophagic materials are varied with respect to particle size distribution but were mostly dominated by fine-grained fractions. Colours of geophagic soils varied but they predominantly had bright Munsell hues suggesting the presence of iron-bearing minerals. Mineralogical analysis showed that the geophagic soils were mainly composed of muscovite and kaolinite, with quartz as the major non-clay constituent. The quartz may pose a threat to human dental enamel. Geophagic materials had essential elements that may benefit the geophagic individuals. However, the presence of heavy metals in geophagic materials may affect the health of geophagic individuals in the long-term.

Only one soil type (i.e., *ibomvu*) was used for healing, cosmetic and sunscreen purposes. The critical wavelength (>370 nm), and presence of TiO_2 and high Fe_2O_3 explained the claimed UV-protection ability. Physicochemical and mineralogical analyses revealed an acidic pH, low exchangeable bases, dominant fine-grained particles (high clay and silt) and kaolinite that may possibly explain these roles.

The different mineralogical and chemical compositions of the healing/cosmetic and geophagic materials were important in ascertaining possible explanations for their functional uses. Despite only relying on macro-morphology as well as trial and error, these findings suggest that local users do appreciate the differences in the soils and thus have, over time, learnt their functional uses. For example, the use of *ibomvu* was initially in rituals and so mostly symbolic, while now its observed benefits in terms of healing, cosmetic or sunscreen has broadened its application to casual use.

Chapter 6: General discussion, conclusions and recommendations for future work

6.1 Introduction

People in rural communities have used soils for centuries as either raw material or for agricultural purposes. Only recently has this knowledge been explored through the relatively new discipline of ethnopedology that seeks to document and provide understanding of indigenous perceptions, classification, appraisal, use and management of soils (Barrera-Bassols and Zinck, 2003). However, not enough effort has been made to conduct ethnopedological studies in Southern Africa, particularly, South Africa. The aim of this thesis was thus to investigate the application of ethnopedological knowledge in agriculture and non-agricultural uses of soils amongst two of the main ethnic groups indigenous to South Africa. The following questions were answered;

(1) How is ethnopedological knowledge used to describe and adapt to the dynamic environments of rural people in eastern South Africa?

(2) How do rural people perceived, classify, use and manage soils in two ethnic groups of South Africa?

(3) What are local theories behind local soil perceptions, classification and use?

(4) How do local perceptions and classification of soil correspond to scientific findings?

6.2 Soil classification and mapping

Local people in the four villages have detailed, practical ethnopedological knowledge that is integral to their agricultural and non-agricultural uses of soil. This knowledge is evident in the local soil classifications that are use-oriented and which have been developed over long periods. The Zulu ethnic group (Khokhwane and Potshini villages) classification system is nominal whilst that of the Xhosa ethnic group (Ntshiqo and Zalaze villages) is hierarchical with two levels. The nomenclatures of both local soil classifications are not based on random taxonomy but are structured in terms that infer the potential of the soil classes for local land uses. As a result, specific soil properties such as texture (*itshetshe*; *udongwe*), colour (*isibomvu*), consistence (*ugadenzima*), stoniness (*ukhethe*) and drainage (*isidaka; omhlophe*) are used to define soil classes at all levels of the classification. The use of these morphological properties as the basis for local soil classification is consistent with what informs categories of scientific soil classification systems. These morphological properties are an expression of soil forming factors and processes (Jenny, 1941) not directly considered in the local classification systems. However, despite the general lack of knowledge of soil forming factors, local classification did consider topography as a major factor contributing to some observed soil properties. This factor was considered in the light of its contribution to erosion-deposition processes and soil drainage conditions. This knowledge seemed to also influence soil suitability and local fertility perceptions. For example, soils on lower parts of sloping fields (e.g. *ugadenzima, isidaka, omhlophe*) were perceived as less fertile mostly due to somewhat poor drainage and/or clayey texture. Consequently, the local soil maps in areas with distinct geomorphic units had strong correlation with the scientific soil maps. Some existing differences between the local and scientific classification systems did yield weak correlations. For example, scientific soil classes mainly based on diagnostic horizons that were distinctly different from the topsoil, which was the layer that was most often considered by farmers, resulted in poor correlations.

The nominal nature of the local classification systems led to the development of very broad soil classes with no clear evidence of taxonomic chops within the properties used as the basis for classification. Farmers classified soils at a level higher than the current two-tier (soil form and family) taxonomic classification of South Africa. For example, in the SCWG (1991) diagnostic horizons are based on a set of quantitatively defined properties with generally narrow limits resulting in a wide range of different soil classes (forms). On the other hand, the local soil classifications have adopted more general soil classes more comparable to Fey (2010) groupings of South African soils. The two ethnic groups studied used similar soil classification criteria and largely similar local soil classes, despite linguistic differences. Their soil nomenclature, however, reflects key morphological properties and by implication reflects soil genesis sufficient to become the highest category of a national classification system. The local classification systems thus have potential to formulate official soil groupings at a level higher than that of the soil form. Having such an addition will make soil survey data more user-friendly and locally relevant.

The soil profile concept does not exist in the local classification systems in any of the villages. As a result, local soil classes could refer to either the whole vertical section of the soil from the surface to its pedological depth or a layer within this vertical cross section. For example, *obomvu*, and *isibomvu* referred to the former, while *ukhethe* mostly specifically referred to the latter. Despite this observation the local classifications were mostly based on the topsoil rather than the subsoil. The latter was only considered in cases where it was distinctly contrary to the topsoil morphology to such an extent that it presented a limitation to the soil's potential and/or was used for non-agricultural purposes. The local classifications considered local variations in the topsoil such as texture variations brought about by depositional processes as well as the local management of soils by farmers.

Although local classification seems to not have advanced as much as scientific classifications over time, it is effective in identifying real differences between soils, especially those significant to their potential use. This was supported by the strong correlations between the two systems whenever soils without significant differences between their top and subsoils (*isibomvu/obomvu* –oxidic soil- Ferralsol) or those based on the diagnostic horizons (e.g. *ukhethe*-lithic soil- Leptosol) were classified. Despite the lack of understanding and direct consideration of pedogenesis in the local classification systems, there seemed to be a full embrace of its effect on the recognised soil classes and their behaviour. The ability of local people as pedologists is thus evident in the application of this ethnopedological understanding of soil diversity in making land-use and management decisions. Using their ethnopedological knowledge local people have thus been able to develop local land evaluation systems. The recognition of major morphological properties and long-term adaptation through trial and error informed soil suitability evaluations. Rural people were thus able to associate certain local soil classes with either agricultural or non-agricultural uses.

6.3 Soil fertility and land use

Regarding agriculture, local small-scale farmers were most concerned with the overall productivity of the soil and thus food security. This was reflected by the broad perception of soil fertility presented by farmers. Local concepts used to describe good soil fertility (i.e., *ukuvunda* or *ukutyeba*) both literally translate to “fat” and “strong”. The former was further explained as referring to the internal nourishment whilst the latter reflected the physical status of the soil. According to local fertility perceptions, *idudusi* and *ovunguvungu* were commonly associated with good soil fertility. Local fertility perception was focused on the observable properties as reflected by the local fertility indicators used e.g. crop performance, stoniness, texture, soil colour, ease of tillage, drainage and natural vegetation. These are mostly the same as the classification criteria adopted by the local soil classification systems in the four villages further emphasizing the use-orientation and practical nature of these systems. From the local soil taxonomy farmers are able to make sound land-use decisions suggesting that the local classifications are informed by land-use requirements.

The almost exclusive consideration of the macro-morphological properties for the local soil fertility assessment has both positive and negative aspects. The emphasis on these properties mainly focuses on the physical ability of the soil to support a growing crop. For example, in fields characterised by *obomvu-onerhexe* and *ukhethe*, the farmers' fertility classes were based on effective depth as influenced by the presence of plinthite in the former and hard or weathering rock in the latter. Similarly, poor drainage and hard and sticky consistence result in physically poor soils. According to farmers, heavy-textured soils (*ugadenzima* and *udongwe*) are generally perceived as bad soils mainly due to their difficulty of tillage as well as becoming too wet for long periods after rain or too dry in dry seasons. According to Fey (2010) these would correlate with duplex soils whose agricultural potential is related to the high clay enrichment in the subsoils. Moreover, soils such as *obomvu*, *isibomvu* and *idudusi* were perceived as highly fertile and had high suitability rating mainly due to lack of physical or drainage constraints. These relate to the oxidic soil group of Fey (2010). These soils are characterised by deep weathering and generally considered to have good agricultural potential. Estrada-Medina et al. (2013) found that Mayan farmers (Mexico) consider similar key soil properties to evaluate soil use suitability. It was interesting to note, however, that either individual chemical fertility attributes measured in the laboratory did not differ between local soil classes or the one perceived by farmers to have bad fertility recorded better results. Furthermore, there was generally no correspondence between locally perceived fertility categories and measured laboratory data. Despite indicating serious production constraints, local fertility assessment ignores the absolute fertility status resulting in chemically poor soils. For example, soils in Khokhwane and Potshini are characterised by very high acid saturation that adversely affects crop production. Even in cases where local soil fertility classes identify chemically related indicators (such as nitrogen deficiency mostly associated with yellowing of leaves), farmers still do not know the fertiliser or lime requirements needed to achieve adequate nutrient levels. Laboratory results thus have the potential to complement the local fertility assessment in order to increase crop yields.

A close relationship exists between perceived fertility and local soil management as well as soil-crop associations. Local management dynamics may thus counteract the expected benefits of laboratory data. For example, management constraints such as lack of labour may result in poor/lack of weeding eventually resulting in compromised crop growth and yield. Moreover, apedal soils (e.g. *obomvu*, *isibomvu*) locally perceived as good agricultural soils are, according to farmers, only productive when there is sufficient rain. This means that in dry seasons these soils become too droughty and less productive irrespective of their fertility status. This observation may not be part of a routine scientific fertility assessment. Other problems relate to planting dates that have been affected by the observed changes in climate (i.e., rainfall patterns, drought, increasing temperatures). Farmers have to adjust their farming activities in the light of the unpredictable cropping seasons. Such information is also not necessarily captured by a technical fertility assessment but does play a significant role in the productivity of the soils. Local and technical soil fertility assessments can thus complement each other to achieve complete and locally relevant soil fertility evaluation.

6.4 Non-agricultural uses of soils

In addition to agricultural uses of soil, local people also acknowledged other functional uses of soils e.g. geophagy, healing, cosmetic and sunscreen. The association of certain soils with specific uses was informed by an understanding of soil morphological properties gained through long-term trial and error. The two soils identified for non-agricultural uses either had low agricultural potential (*ukhethe*) or were soils (e.g. *ibomvu*) with identified alternative functional roles such as healing, cosmetic or sunscreen when topically applied.

6.4.1 Geophagy

By local description, *ukhethe* has a large constituent of weathering rock if not entirely bedrock found to be shale. The soil was least preferred for agriculture due to lack of "enough" soil i.e., shallow effective rooting depth. However, the same soil was commonly preferred by individuals who practiced geophagy and who only focus on the diagnostic layer (i.e., weathering rock or bedrock) not the entire profile. The agricultural constraints farmers associated with this soil thus did not matter when the soil was used as a raw material. Identified local suitability of these soils seemed to reflect more than just an understanding of macro-morphology but also of their inherent chemical and mineralogical composition. For example, *ukhethe* is preferred mostly based on its sour taste, soft and smooth feel in the mouth and earthy smell. Sour taste is imparted by acidic soil pH while the dominant silt-sized particles led to a soft and smooth feel to ingested soil. The earthy smell of weathered *ukhethe* is probably due to the presence of kaolinite in some soils. The geophagic individuals interviewed were women of childbearing age that are susceptible to blood loss, either through menstruation or pregnancy and may thus be subconsciously reacting to iron deficiency by ingesting the weathered rock material as it had a high iron content. Geophagists ingesting rock (i.e., shale) are not likely to obtain similar benefits as those ingesting soil. It is difficult to speculate how people became aware of these properties as they could not give definite answers. While *ukhethe* soils are shallow and have low agricultural potential, it has high value as raw material for geophagic purposes and thus attempts should be made to protect it while allowing for effective utilization.

Although the studied samples were generally comparable in terms of chemical composition and mineralogy, these were contrary to most reported geophagic soils with respect to the latter. Similar to Ekosse et al. (2017) and Sumbele et al. (2014) the *ukhethe* soils were dominated by quartz and mica instead of the more commonly reported quartz and kaolinite mineralogy. This suggests differences in the provenance as well as extent of weathering in geophagic soils. *Ukhethe* seems to have not undergone extensive weathering as indicated by incomplete weathering of the mica. Moreover, consistent with the common geology of the study sites (shale and sandstone), the geophagic materials had a high Ba concentration that was indicative of a felsic source (Ure and Berrow, 1982).

Ingested soil inevitably has an influence on the health of the geophagists. The extent to which the ingested soil affects the geophagic individual is largely dependent on the chemical and mineralogical composition of the soil. Mica and some feldspar with potential to provide essential nutrients (e.g. K and Mg) to geophagic individuals dominated the *ukhethe* soils. Moreover, the soils also had high Cu, Zn and Co that all play significant structural and protective physiological roles. This suggests that geophagic individuals may benefit from ingesting the soil as these elements are mostly likely to be released at low pH similar to that of the stomach. Moreover, *ukhethe* contained a significant concentration of Pb that could present risks if ingested continually, potentially causing renal, gastro-intestinal and haematological problems. Caution therefore needs to be taken to avoid risks associated with long-term ingestion and consequent accumulation of such heavy metals that are harmful to human health.

6.4.2 Healing, cosmetic and sunscreen

Ibomvu was classified based on colour with the name directly translating to "red". It served a number of functions including healing, cosmetic and sunscreen purposes. It is important to note that colour was not the exclusive determinant of either the soil's suitability or classification. As a result, this soil was different from red agricultural soils such as *isibomvu*/*obomvu*. This shows a shift in significance and thus implications for soil use as indicated by the considered soil morphological properties. Although the original use of *ibomvu* was attributed to its deep symbolic meaning with the red colours reminiscent of natural substances that share the same colour such as blood (Zagorska, 2008), continued use revealed other characteristic functions of this soil in cosmetics and healing. *Ibomvu* (samples H1 –H4; Chapter 5) had very distinctive chemical composition from those of *isibomvu/obomvu* (samples C1 and C2; Chapter 5) that may explain these roles. Contrary to *isibomvu/obomvu*, *ibomvu* had high iron and titanium oxide contents. The effectiveness of Fe (particularly in the form of hematite) in healing severe skin infections has been documented by Haydel et al. (2008). Healing soils also had high Al that has been shown to play a significant role in the antibacterial action of kaolin-rich clays (Londono et al., 2017). Despite being problematic in agricultural soils (P fixation, Al toxicity and Mo deficiency), Al could be valuable as an antibacterial agent in healing and cosmetic materials.

Titanium oxide is one of the active ingredients used in commercial physical sunblock (Elmarzugi et al., 2013) due to its high refractive index (Judin, 1993). The occurrence of this oxide in the clays may explain their efficacy in UV-protection despite their measured low SPF values. Moreover, high Fe content (particularly in the form of hematite) significantly increases the UV-protection value of clays by reducing UV-transmission levels (Haydel et al., 2008). However, high Fe content has also been associated with adsorption of large amounts of elements such Co and Ni which were evident in the samples. Individuals subjected to continued application of these materials (particularly samples H1, H3 and H4; Chapter 5) may be at risk of developing dermatitis which has been associated with exposure to these elements.

Despite commonly reported low SPF values (<5) for South African *ibomvu*, the soils do provide some degree of both UVA and UVB protection as indicated by a critical wavelength of >370 nm. Furthermore, the presence of kaolinite in the *ibomvu* samples (H1 –H4) further supports their use for healing and cosmetic purposes. This clay mineral is commonly used in pharmacy and cosmetics due to its ability to adsorb proteins and viruses thus acting as a dermatological protector.

6.5 Ethnopedological knowledge

Local soil classification largely dictates local land-use and management decisions as shown by the sole dependence on the classification criteria (i.e., observed morphological properties) determining soil behaviour and potential for any specified use. Local soil fertility perceptions are largely informed by physical and/or hydrological soil conditions at the expense of absolute fertility status. Nonetheless, application of ethnopedological knowledge in agriculture (mainly soil fertility management) has potential to complement technical fertility reports and vice versa. However, local needs and conditions (particularly management constraints) have to be taken into consideration to ensure sustainable integration of the two systems. Soils are locally valued for the different properties they possess which are perceived to make them suitable for a particular role. The fact that scientific land capability classification is biased towards arable crop production means that the least arable soils will be classified for pasture or wildlife use. Scientific soil suitability classifications can be expanded to include non-agricultural uses to help avoid possible land-use conflicts. However, these are still largely based on the concept of a soil profile which does not leave room for evaluation of individual diagnostic horizons. The local soil suitability classification on the other hand is flexible allowing for classification and evaluation of soils as diagnostic layers (e.g. *ukhethe* -weathering rock or bedrock and *ibomvu* – red, highly weathered, unspecified material) not the entire profile. This allow options for alternative uses of soil as a raw material. Beyond agricultural applications, ethnopedological knowledge has helped local people adapt to changing environments. For example, local people have adopted *ibomvu* to provide effective UV-protection that is affordable and readily available. The same soil has also provided a cheap 'band-aid' option for people. Moreover, they have used their understanding of soil to become geophagists despite a lack of explanation of how the required soil properties are perceived or were discovered by local people. The value of these materials to local and possibly urban communities could increase, especially considering the possible increase in UV and other radiation associated with climate change and depletion of the ozone layer.

Rural people are vested with ethnopedological wisdom which has informed their classification, soil fertility assessments and general uses of soils as raw materials. They have detailed understanding of soil morphological properties which is fundamental in making decisions on soil use and which has proven significant in the studied villages.

6.6 Recommendations and possible future work

Findings of this study relating to indigenous soil classification revealed a possibility for integration with the national soil classification. It is thus recommended further studies be conducted to explore the feasibility of adding a higher level to the national classification based on local soil classes. Using the important ethnopedological knowledge contained in the local classification possible options are that either (a) it be a permanent fixture of the classification, or (b) that it be included as an add-on when needed i.e., when surveys are conducted in rural areas and where the results will be specifically used by local people.

Small-scale farmers used comprehensive soil fertility indicators. However, the disregard and/or unavailability of the absolute fertility status of the soil has resulted in poor management of soil nutrients and pH. Laboratory analysis of the soils showed poor chemical fertility and could inform accurate fertiliser and lime requirements that could help increase crop yields. It is thus recommended that in addition to their local soil fertility assessment, farmers consider laboratory data to complete their evaluation. Despite considerable possibilities for sustainable soil fertility, this may not be feasible in subsistence farming unless certain interventions in terms of developing policies aimed at extending agricultural extension services beyond technical assistance to include local farmers' budget are implemented. Educating and empowering farmers regarding the importance of soil analysis data as well as proper soil management will ensure that returns on such funds are realised not only in increased crop yields and improved livelihoods but also in achieving sustainability of subsistence agriculture based on indigenous knowledge. This could be an optimistic proposal and one that will take time to be implemented. It is thus recommended that farmers explore working together in small groups to become financially viable and able to afford the costs of soil analysis. Subsistence agriculture based on indigenous knowledge is threatened should issues of soil fertility management not be attended to. This becomes a serious matter given the land reform policies currently under discussion that may result in more arable land being made available for small-scale farmers. It is thus important to explore the feasibility of integrating local and scientific soil fertility assessment by finding possible alternatives to deal with the problems of using laboratory data and reducing production constraints experienced by subsistence farmers. For example, the possibility of soil analysis every three to five years could give a cheaper guide than annual analysis.

Soils used for non-agricultural uses are valued for a wide range of properties that can possibly explain their effectiveness. The study has provided baseline information on these properties and inferred linkages to their functions. There is, however, need for further research into the possible mechanisms through which the identified characteristic properties of the soils perform the indicated functions. For example, the healing properties of soils could be explained by either chemical or physical mechanisms. Both of these could be based on the constituents of *ibomvu*. The presence of high Al suggested a possibility of antibacterial properties, especially in the presence of kaolin-rich clays found in these soils. Further investigation is necessary to identify specific mechanisms that will shed more light onto the healing properties of these soils and the effects of their long-term use.

There is also a need for research to focus on non-agricultural soils important to rural people. Such research will provide further information on the need for comprehensive soil suitability assessments that will inform proper and sustainable land-use plans that will value all local uses of soils. More research is required to investigate local soil uses and associated indigenous knowledge in order to understand how rural people deal with possible land-use conflicts when, for example, the same soil is valued for different functions. Understanding these land-use dynamics will inform better land-use plans that will take into account soils with low agricultural potential but which may be highly regarded for other uses.

References

Abdulrashid, L. and Yaro, A. 2014. Local Theories on Soil Formation and Classifications by Farming Communities of Semi-Arid Areas of Katsina State, Nigeria. Journal of Environment and Earth Science, 4: 65-67.

Abrahams, P.W. 1997. Geophagy (soil consumption) and iron supplementation in Uganda. Tropical Medicine & International Health, 2: 617-623.

Abrahams, P.W. 2002. Soils: their implications to human health. Science of the Total Environment, 29: 1 - 32.

Abrahams, P.W. and Parsons, J.A. 1997. Geophagy in the tropics: An appraisal of three geophagical materials. Environmental Geochemistry and Health, 19: 325 - 334.

Abrahams, P.W., Follansbee, M.H., Hunt, A., Smith, B. and Wragg, J. 2006. Iron nutrition and possible lead toxicity: an appraisal of geophagy undertaken by pregnant women of UK Asian communities. Applied Geochemistry, 21: 98 - 108.

Agency for Toxic Substances and Disease Registry. 2004. Toxilogical Profile for Cobalt. US Department of Health and Human Services, Atlanta.

Ahaneku, I. 2010. Conservation of soil and water resources for combating food crisis in Nigeria. Scientific Research and Essays, 5: 507-513.

Ajibade, L. 2008. Indigenous Approach to the Control of Soil Erosion among Small Scale Farmers in Asa LGA, Kwara State, Nigeria. Ethiopian Journal of Environmental Studies and Management, 1: 1-6.

Al-Rmalli, S.W., Jenkins, R.O., Watts, M.J. and Haris, P.I. 2010. Risk of human exposure to arsenic and other toxic elements from geophagy: trace element analysis of baked clay using inductively coupled plasma mass spectrometry. Environmental Health, 9: 79. [http://dx.doi.org/10.1186/1476-069X-9-79]

Amsalu, A. and de Graaff, J. 2006. Farmers' views of soil erosion problems and their conservation knowledge at Beressa watershed, central highlands of Ethiopia. Agriculture and Human Values, 23: 99–108.

Barrera-Bassols, N. 2016. Linking Ethnopedology and Geopedology: A Synergistic Approach to Soil Mapping. Case Study in an Indigenous Community of Central Mexico. Geopedology. Springer, Cham. pp 167-181.

Barrera-Bassols, N. and Zinck, J.A. 1998. The other pedology: empirical wisdom of local people. Proceedings of 16th World Congress of Soil Science. ISSS/AFES, Montpellier, France: CD-ROM.

Barrera-Bassols, N. and Zinck, J.A. 2000. Ethnopedology in a worldwide perspective: an annotated bibliography. ITC Publication 77. Enschede, The Netherlands:ITC.

Barrera-Bassols, N. and Zinck, J.A. 2003. Ethnopedology: a worldwide view on the soil knowledge of local people. Geoderma, 111: 171-195.

Barrera-Bassols, N. and Toledo, V.M. 2005. Ethnoecology of the Yucatec Maya: symbolism, knowledge and management of natural resources. Journal of Latin American Geograpgy, 4: 9 - 41.

Barrera-Bassols, N., J.A. Zinck and Van Ranst, E. 2006. Symbolism, knowledge and management of soil and land resources in indigenous communities: Ethnopedology at global, regional and local scales. Catena, 65: 118-137.

Barrera-Bassols, N., J. Zinck and Van Ranst, E. 2009. Participatory soil survey: experience in working with a Mesoamerican indigenous community. Soil Use and Management, 25: 43-56.

Berazneva, J., McBride, L., Sheahan, M. and Guerena, D. 2016. Perceived, measured and estimated soil fertility in east Africa: Implications for farmers and researchers. Agricultural and Applied Economics Association, No. 235466.

Bewket, W. 2007. Soil and water conservation intervention with conventional technologies in northwestern highlands of Ethiopia: Acceptance and adoption by farmers. Land Use Policy, 24: 404-416.

Bezabih, B., M. Iemenih and Regassa, A. 2016. Farmers perception on soil fertility status of small-scale farming system in southwestern Ethiopia. Journal of Soil Science and Environmental Management, 7: 143-153.

Birmingham, D.M. 2003. Local knowledge of soils: the case of contrast in Côte d'Ivoire. Geoderma, 111: 481-502.

Blome, M.W., Cohen, A.S., Tryon, C.A., Brooks, A.S. and Russell, J. 2012. The environmental context for the origins of modern human diversity: a synthesis of regional variability in African climate 150,000–30,000 years ago. Journal of Human Evolution, 62: 63–592.

Bonsu, M. 2004. Indigenous knowledge: the basis for survival of the peasant farmer in Africa. Journal of Philosophy and Culture, 1: 49-61.

Brady, N.C. and Weil, R.R. 2014. Nature and properties of soils. Dorling Kindersley, New Dehli.

Braimoh, A.K. 2002. Integrating indigenous knowledge and soil science to develop a national soil classification system for Nigeria. Agriculture and Human Values, 19: 75-80.

Breuning-Madsen, H., Bruun, T.B. and Elberling, B. 2010. An indigenous soil classification system for Belloan Island - a raised atoll in Solomon Islands. Singapre Journal of Tropical Geography, 31: 85 - 99.

Brevik, E.C. 2009. Soil, food security, and human health. In Verheye, W. (Ed.), Soils, Plant Growth and Crop production. Encyclopedia of Life Spupport Systems (EOLSS) Publishers, Oxford, England.

Brevik, E.C. and Hartemink, A. 2010. Early soil knowledge and the birth and development of soil science. Catena, 83: 23-33.

Brevik, E. and Sauer, T. 2015. The past, present, and future of soils and human health studies. Soil, 1: 35 - 46.

Buol, S., F. Hole, R. McCracken andSouthard, R. 2003. Soil genesis and classification. Iowa State Univ. Press, Ames USA.

Burt, E.C. 1982. Eroticism in Baluyia Body Arts. African Arts, 15: 68-88.

Buthelezi, N., Hughes, J.C. and Modi, A. 2013. The use of scientific and indigenous knowledge in agricultural land evaluation and soil fertility studies of two villages in KwaZulu-Natal, South Africa. African Journal of Agricultural Research, 8: 507-518.

Bwambale, N. 2015. Farmers' knowledge, perceptions, and socioeconomic factors influencing decision making for integrated soil fertility management practices in Masaka and Rakai districts, Central Uganda. Graduate Theses and Thesis. Paper 15231. Iowa State University, Ames, Iowa.

Cabral, R.L., Alves, Â.G.C., Ribeiro Filho, M.R., Souza Júnior,V.S.D., Ribeiro M.R. and Santos, C.G.R.2015. Peasant and scientific knowledge on planosols as a source of materials in the making of non-industrial pottery. Revista Brasileira de Ciência do Solo 39: 303-313.

Calmeyer, T. and Muruven, L. 2014. Environmental Assessment for the Mzimvubu WATER Project. Iliso Consulting (PTY) LTD, PWMA 12/T30/00/5314/2. http://www.dwaf.gov.za/mzimvubu/documents/scoping/Final%20Scoping%20Report%20Part%201%20(Cover%20page%20to%20Chapter%202).pdf

Camp, K. and Hardy, M. 1999. Veld condition assessment. Veld in KwaZulu-Natal. KwaZulu-Natal Department of Agriculture, Pietermaritzburg: 18-31.

Campbell, J. and Morrison, A. 1963. Some factors affecting the absorption of vitamins. The American Journal of Clinical Nutrition, 12: 162-169.

Capra, G.F., Ganga,A., Buondonno, A., Grilli, E., Gaviano C. and Vacc,a S. 2015. Ethnopedology in the study of toponyms connected to the indigenous knowledge on soil resource. PloS one, 10: e0120240.
Cardoso, E.J.B.N., Vasconcellos, R.L.F., Bini, D., Miyauchi, M.Y.H., Santos, C.A.D. and Alves, P.R.L. 2013. Soil health: looking for suitable indicators. What should be considered to assess the effects of use and management on soil health? Scientia Agricola, 70: 274-289.
Carretero, M., Gomes, C. and Tateo, F. 2006.Clays and Human Health. Developments in Clay Science, 1: 717-741.
Carretero, M.I. 2002. Clay minerals and their beneficial effects upon human health. A review. Applied Clay Science, 21: 155-163.
Carretero, M.I. and Pozo, M. 2009. Clay and non-clay minerals in the pharmaceutical industry: Part I. Excipients and medical applications. Applied Clay Science, 46: 73-80.
Carretero, M.I. and Pozo, M. 2010. Clay and non-clay minerals in the pharmaceutical and cosmetic industries Part II. Active ingredients. Applied Clay Science, 47: 171-181.
Chapagain, T. and Raizada, M.N. 2017. Agronomic challenges and opportunities for smallholder terrace agriculture in developing countries. Frontiers in Plant Science, 8: 331.
Chaudhri, S. and Jain, N. 2009. History of cosmetics. Asian Journal of Pharmaceutics, 3: 164.
Chen, Z.Z., Feng, F., Yang, W.J., Liang, W.J. and Wang, C. 2008. Investigation of interaction between levofloxacin and bovine serum albumin by fluorescence analysis based on liquid drop. Spectroscopy and Spectral Analysis , 28: 1612 - 1616.
Choy, J.-H., Choi, S.J., Oh, J.M. and Park, T. 2007. Clay minerals and layered double hydroxides for novel biological applications. Applied Clay Science. 36: 122-132.
Cosmetic, Toiletry and Fragrance Association. 2004. International Cosmetic Ingredient Dictionary and Handbook, 11th Edition. Color Additive Information. Washington, DC.
Cools, N., De Pauw, E. and Deckers, J. 2003. Towards an integration of conventional land evaluation methods and farmers' soil suitability assessment: a case study in northwestern Syria. Agriculture, Ecosystems & Environment, 95: 327-342.
Cooper, M., Teramoto, E.R., Vidal-Torrado, P. and Sparovek, G. 2005. Learning soil classification with the Kayapó Indians. Scientia Agricola, 62: 604 - 606.
Corbeels, M., Shiferaw, A. and Haile, M. 2000. Farmers' knowledge of soil fertility and local management strategies in Tigray, IIED-Drylands Programme, Ethiopia.
Crane, T. 2001. Ethnopedology in central Mali. A paper presented at the SANREM/ CRSP Scientific Research Meeting, Nov. 28-30, University of Georgia, Athens, GA.

Dalal, R., Henderson, P. and Glasby, J. 1991. Organic matter and microbial biomass in a vertisol after 20 yr of zero-tillage. Soil Biology and Biochemistry, 23: 435-441.

Dawoe, E.K., Quashie-Sam, J., Isaac M.E. and Oppong, S.K. 2012. Exploring farmers' local knowledge and perceptions of soil fertility and management in the Ashanti Region of Ghana. Geoderma, 179: 96-103.

Denison, J. and Wotshela, L. 2009. Indigenous water harvesting and conservation practices: historical context, cases and implications. Water Research Commission Report No. TT 392. Pretoria, South Africa.

Dent, D. and Young, A. 1981. Soil survey and land evaluation. George Allen & Unwin, London.

Desbiez, A., Matthews, Tripathi, R. B. and Ellis-Jones, J. 2004. Perceptions and assessment of soil fertility by farmers in the mid-hills of Nepal. Agriculture, Ecosystems & Environment, 103: 191-206.

Dialla, B.E. 1993. The Mossi indigenous soil classification in Burkina Faso. Indigenous Knowledge and Development Monitor, 1: 17 - 18.

Diffey, B. and Robson, J. 1989. A new substrate to measure sunscreen protection factors throughout the ultraviolet spectrum. Journal of the Society of Cosmetic Chemists, 40: 127-133.

Diko, C.S. and Diko, M. 2013. Geophagia among female adolescents as a culturally driven practice. Indilinga African Journal of Indigenous Knowledge Systems, 12: 242-251.

Diko, M. and Ekosse, G. 2013. Characterisation of two kaolin facies from Ediki, Southwest Cameroon. Scientific Research and Essays, 8: 698-704.

Diko, M. and Ekosse, G. 2014. Soil ingestion and associated health implications: a physicochemical and mineralogical appraisal of geophagic soils from Moko, Cameroon. Studies on Ethno-Medicine, 8: 83-88.

Dlamini, P. and Chaplot, V. 2012. On the interpolation of volumetric water content in research catchments. Physics and Chemistry of the Earth, 50: 165-174.

Dlova, N.C., Nevondo, F.T., Mwangi, E.M., Summers, B., Tsoka-Gwegweni, J. and Martincigh, B.S. 2013. Chemical analysis and in vitro UV-protection characteristics of clays traditionally used for sun protection in South Africa. Photodermatology, Photoimmunology & Photomedicine, 29: 164-169.

Dokuchaev, V. 1883. The Russian Chernozem Report to the Free Economic Society. Imperial Univ. of St. Petersburg, St. Petersburg, Russia.

Douangsavanh, l., Manivong, V., Plthanee, A., Katawatin, R. and Inoue, Y. 2006. Indigenous knowledge on soil classification of ethnic groups n Laung Prabang province of the Lao PDR. Journal of Mountain Science, 3: 247 - 258.

Droy-Lefaix, M. and Tateo, F. 2006. Clays and Clay Minerals as Drugs. Developments in Clay Science, 1: 743-752.

Duarte-Silva, R., Villa-García, M.A., Rendueles, M. and Díaz, M. 2014. Structural, textural and protein adsorption properties of kaolinite and surface modified kaolinite adsorbents. Applied Clay Science, 90: 73–80.

Dušenkova, I., Kusina, I., Mālers, J. and Bērzina-Cimdina, L. 2015. Application of Latvian illite clays in cosmetic products with sun protection ability. Proceedings of the 10th International Scientific and Practical Conference, 1: 28–32. Rezekne, Latvia

Eigbike, C., Nfor, B. and Imasuen, I. 2013. Physico Chemical Investigations and Health Implications of Geophagial Clays of Edo State, Mid-Western Nigeria. Journal of Geology Geosciences, 3: 140. doi: 10.4172/2329-6755.1000140. 2013.

Ekosse, G. and Ngole, V. 2012. Mineralogy, geochemistry and provenance of geophagic soils from Swaziland. Applied Clay Science, 57: 25-31.

Ekosse, G.-I.E., Ngole-Jeme, V.M. and Diko, M.L. 2017. Environmental Geochemistry of Geophagic Materials from Free State Province in South Africa. Geosciences, 9: 114-125.

Ekosse, G.-I.E. and Obi, L.C. 2015. Minerals in Human Geophagic Soils from Selected Rural Communities in Gauteng and Limpopo Provinces in South Africa. Journal of Human Ecology, 50: 253-261.

Elmarzugi, N.A., Keleb, E.I., Mohamed, A.T., Issa, Y.S., Hamza, A.M. and Layla, A.A. 2013. The Relation between Sunscreen and Skin Pathochanges Mini Review. International Journal of Pharmaceutical Science Invention, 2: 43-52.

Engberg, D.E. 1995. Geophagy: adaptive or aberrant behavior. Nebraska Anthropologist, Paper 84. http://digitalcommons.unl.edu/nebanthro/84.

Engdawork, A. and Bork, H.R. 2014. Long-term indigenous soil conservation technology in the Chencha Area, Southern Ethiopia: origin, characteristics, and sustainability. Ambio, 43: 932-942.

Ericksen, P. and Ardón, M. 2003. Similarities and differences between farmer and scientist views on soil quality issues in central Honduras. Geoderma, 111: 233-248.

ESRI. 2012. ArcGIS 10.1. ESRI; Redlands, CA.

Estrada-Medina, H., Bautista-Zuniga, F., Jiménez-Osornio, J.J.M., González-Iturbe, J.A. and Aguilar-Cordero, W.J. 2013. Maya and WRB soil classification in Yucatnn, México:

differences and similarities. Soil Science., ISSN: 2090-875X (http://www. hindawi.com/isrn/soil.science/aip/634260).

Ettema, C. 1994. Indigenous soil classifications. What are their structure and function and how do they compare with scientific soil classifications? http://www.nrel.colostat.8080/~bobn/rkn.3b.soil.tek.o4.che.html.

Ferrell, R.E. 2008. Medicinal clay and spiritual healing. Clays and Clay Minerals, 56: 751-760.

Fey, M. 2010. Soils of South Africa. Cambridge University Press, Cape Town.

Fitzpatrick, R. 2013. Demands on soil classification and soil survey strategies: special-purpose soil classification systems for local practical use. Developments in soil classification, land use planning and policy implications. Springer. Netherlands. pp 51-83.

Flowerdew, B. 2012. Sowing, Planting, Watering, and Feeding: Bob's Basics. Skyhorse Publishing, Inc. London.

Gee, G.W. and Bauder, J.W. 1986. Particle-size analysis. In Klute, A. (Ed.) Methods of soil analysis: Part 1. Physical and mineralogical methods. ASA, CSSA and SSSA, pp. 312-383. Madison, USA.

Geissler, P.W., Prince, R.J., Levene, M., Poda, C., Beckerleg, S. and Mutemi, W. 1999. Perceptions of soil-eating and anaemia among pregnant women on the Kenyan coast. Social science & medicine, 48: 1069-1079.

George, G. and Ndip, E. 1997. Prevalence of Geophagia and it's possibleimplication to health- A study in rural South Africa. 2011 International conference on environmental health and development. ICPBEE (2011) Lacsit Press, 4, Singapore.

Gichumbi, J.M., Ombaka, O. and Gichuki, J.G. 2012. Geochemical and mineralogical characteristics of geophagic materials from Kiambu, Kenya. International Journal of Modern Chemistry, 2: 108 - 116.

Gobin, A., Campling, P., Deckers, J., and Feyen, J. 1998. Integrated toposequence analysis at the confluence zone of the river Ebonti headwater catchment (south-eastern Nigeria). Catena, 32: 173 - 192.

Gobin, A., Campling, P., Deckers, J., and Feyen, J. 2000. Integrated toposequence analyses to combine local and scientific knowledge systems. Geoderma, 97, 103 - 123.

Gobin, A., Campling, P., Deckers, J., and Feyen, J. 2001. Integrated land resources analysis with an application of Ikem (south-eastern Nigeria). Landscape and Urban Planning, 53: 95 - 109.

Gowing, J., Payton, R. and Tenywa, M. 2004. Integrating indigenous and scientific knowledge on soils: recent experiences in Uganda and Tanzania and their relevance to participatory land use planning. Uganda Journal of Agricultural Sciences, 9: 184-191.

Graham, P.H. and Vance, C.P. 2003. Legumes: importance and constraints to greater use. Plant Physiology, 131: 872-877.

Grealish, G., Fitzpatrick, R. and Hutson, J. 2015. Soil survey data rescued by means of user friendly soil identification keys and toposequence models to deliver soil information for improved land management. Geo Research Journal, 6: 81-91.

Gruver, J. and Weil, R. 2007. Farmer perceptions of soil quality and their relationship to management-sensitive soil parameters. Renewable Agriculture & Food Systems, 22: 271-281.

Habarurema, E. and Steiner, K.G. 1997. Soil suitability classification by farmers in southern Rwanda. Geoderma, 75: 75-87.

Harvey, P.W., Dexter, P.B. and Darnton-Hill, I. 2000. The impact of consuming iron from non-food sources on iron status in developing countries. Public Health Nutrition, 3: 375-383.

Haydel, S.E., Remenih, C.M. and Williams, L.B. 2008. Broad-spectrum in vitro antibacterial activities of clay minerals against antibiotic-susceptible and antibiotic-resistant bacterial pathogens. Journal of Antimicrobial Chemotherapy, 61: 353-361.

He, Z., Griffin, T.S. and Honeycutt, C.W. 2004. Phosphorus distribution in dairy manures. Journal of Environmental Quality, 33: 1528-1534.

Henry, J., Cring, F. Brevik, E. and Burgess, L. 2013. Geophagy: An anthropological perspective. CRC Press, Boca Raton, USA. pp 179-199.

Henry, J. and Kwong, A.M. 2003. Why is geophagy treated like dirt?. Deviant Behavior, 24: 353 - 371.

Hiddink, G.A., Termorshuizen, A.J. and van Bruggen, A.H. 2010. Mixed cropping and suppression of soilborne diseases. Genetic, Engineering, Biofertilisation, Soil Quality and Organic Farming. Springer, Dordrecht. pp 119 - 146.

Hillyer, A., McDonagh, J. and Verlinden, A. 2006. Land-use and legumes in northern Namibia—The value of a local classification system. Agriculture, Ecosystems & Environment, 117: 251-265.

Hoang-Minh, T. 2006. Characterization of clays and clay minerals in industrial application: Substitution non-natural additives by clays in UV protection. PhD thesis, Ernst-Moritz-Arndt-University Greifswald., Germany.

Hoang-Minh, T., Le,T., Kasbohm, J. and Gieré, R. 2010. UV-protection characteristics of some clays. Applied Clay Science, 48: 349-357.

Hunter, J.M. 1973. Geophagy in Africa and in the United States: a culture-nutrition hypothesis. Geographical Review, 170-195.

IBM Corp. Released 2016. IBM SPSS Statistics for Windows, Version 24.0. Armonk, NY: IBM Corp.

Irungu, J.W., Warren, G.P. and Sutherland, A. 1996. Soil fertility on smallholder farms in the semi-arid areas of Tharaka Nithi District:farmers' assessment compared to laboratory analysis. In Kenya Agricultural Research Institute 5th Scientific Conference, vol. 30. Nairobi.

IUSS Working Group WRB. 2014. World Reference Base for Soil Resources 2014. International soil classification system for naming soils and creating legends for soil maps. World Soil Resources Reports No. 106. FAO, Rome.

Jenny, H. 1941. Factors of soil formation: A system of quantitative pedology. McGraw-Hill Book Co, New York.

Judin, V. P.S. 1993: The lighter side of TiO_2. Chemistry in Britain, 29: 503-505.

Jugdaohsingh, R., Watson, A.I., Pedro, L.D. and Powell, J.J. 2015. The decrease in silicon concentration of the connective tissues with age in rats is a marker of connective tissue turnover. Bone, 75: 40-48.

Kawai, K., Saathoff, E., Antelman, G., Msamanga, G. and Fawzi, W.W. 2009. Geophagy (soil eating) in relation to enemia and helmith infection among HIV-infected pregnant woman in Tanzania. The American Journal of Tropical Medicine and Hygiene, 80: 36 - 43.

Khiari, I., Mefteh, S., Sánchez-Espejo, R., Cerezo, P., Aguzzi, C. and López-Galindo, A. 2014. Study of traditional Tunisian medina clays used in therapeutic and cosmetic mud-packs. Applied Clay Science, 101: 141-148.

Khurana, I.S., KauR, S., Kaur, H. and Khurana, R.K. 2015. Multifaceted role of clay minerals in pharmaceuticals. Future Science, 3. https://www.future-science.com/doi/10.4155/fso.15.6.

Kiguli, L., Palmer, A. and Avis, A. 1999. A description of rangeland on commercial and communal land, Peddie district, South Africa. African Journal of Range and Forage Science,16: 89-95.

Kim, J.H., Gibb, H.J. and Howe, P.D. 2006. Cobalt and inorganic cobalt compounds. Concise International Chemical Assessment Document, vol. 69. World Health Organisation, Geneva, Switzerland.

Kongo, V., Kosgei, J. Jewitt, G. and Lorentz, S. 2010. Establishment of a catchment monitoring network through a participatory approach in a rural community in South Africa. Hydrology and Earth System Sciences, 14: 2507 - 2525.

Krasilnikov, P., Ibanez, J.J., Arnold, R.W. and Shoba, S. (Eds.). 2009. A handbook of soil terminology, correlation and classification. Earthscan, London.

Krasilnikov, P. and Tabor, J. 2010. Ethnopedology and folk soil taxonomies. In Verheye, W.H. (Ed.) Soils, plant growth and crop production Volume III, EOLSS Publishers, United Kingdom. pp 135 - 161.

Krasilnikov, P.V. and Tabor, J.A. 2003. Perspectives on utilitarian ethnopedology. Geoderma, 111: 197-215.

Kuldip, G., Arunachalam, A., Dutta, B.K. and Kumar, G.V.P. 2011. Indigenous knowledge of soil fertility management in the humid tropics of Arunachal Pradesh. Indian Journal of Traditional Knowledge, 10: 508 – 511.

Lal, R. (Ed.). 2006. Encyclopedia of Soil Science, 2nd Edition, Vol. 2. Taylor and Francis Group, London.

Lar, U., Agene, J. and Umar, A. 2015. Geophagic clay materials from Nigeria: a potential source of heavy metals and human health implications in mostly women and children who practice it. Environmental Geochemistry and Health, 37: 363-375.

Laufer, B. 1930. Geophagy. Publications of the Field Museum of Natural History. Anthropological Series 18: 99-198.

Lavelle, P. and Spain, A. 2001. Soil ecology. Kluwer Academics Pulishers, Dordrecht, Netherlands. pp 654.

Limpitlaw, U.G. 2010. Ingestion of earth materials for health by humans and animals. International Geology Review, 52: 726-744.

Londono, S.C., Hartnett, H.E. and Williams, L.B. 2017. Antibacterial activity of aluminum in clay from the Colombian Amazon. Environmental Science andTechnology, 51: 2401-2408.

Lopes, G., Àvila, F. W., and Guilherme, L. R. G. 2017. Review: Selenium behavior in the soil environment and its implication for human health. Ciência e Agrotecnologia, 41, 605–615.

López-Galindo, A.L. and Viseras, C. 2004. Pharmaceutical and cosmetic applications of clays. Interface Science and Technology, 1: 267 - 289.

López-Galindo, A., Viseras, C. and Cerezo, P. 2007. Compositional, technical and safety specifications of clays to be used as pharmaceutical and cosmetic products. Applied Clay Science, 36: 51-63.

Mäder, P., Fliessbach,A., Dubois, D., Gunst, L., Fried, P. and Niggli, U. 2002. Soil fertility and biodiversity in organic farming. Science, 296: 1694 - 1697.

Madikizela, L.M., Nkwentsha, N., Mlunguza, N.Y. and Mdluli, P.S. 2017. Physicochemical characterization and In vitro evaluation of the sun protection factor of cosmetic products made from natural clay material. South African Journal of Chemistry, 70: 113-119.

Mahaney, W.C., Milner, M., Hancock, R., Aufreiter, S. and Reich, M. 2000. Mineral and chemical analyses of soils eaten by humans in Indonesia. International Journal of Environmental Health Research, 10: 93-109.

Mahurpawar, M. 2015. Effects of heavy metals on human health. International Journal of Research Granthaalayah, 1-7.

Mairura FS, Mugendi DN, Mwanje JI, Ramisch JJ, Mbugua PK, Chianu JN. 2007. Integrating scientific and farmers' evaluation of soil quality indicators in Central Kenya. Geoderma, 139: 134-143.

Manson, A. and Roberts, V. 2000. Analytical methods used by the soil fertility and analytical services section. KwaZulu-Natal Department of Agriculture and Environmental Affairs, p 5. N/A/2001/4.

Manyevere, A., Muchaonyerwa, P., Laker, M. and Mnkeni, P.N.S. 2014. Farmers' perspectives with regard to arable crop production and deagrarianisation: an analysis of Nkonkobe Municipality, South Africa. Journal of Agriculture and Rural Development in the Tropics and Subtropics, 115: 41 - 53.

Mati, B.M. 2006. Overview of water and soil nutrient management under smallholder rain-fed agriculture in East Africa. IWMI.

Matike, D., Ekosse, G. and Ngole, V. 2010. Indigenous knowledge applied to the use of clays for cosmetic purposes in Africa: An overview. Indilinga African Journal of Indigenous Knowledge Systems, 9: 138-150.

Matike, D., Ekosse, G. and Ngole, V. 2011. Physico-chemical properties of clayey soils used traditionally for cosmetics in Eastern Cape, South Africa. International Journal of Physical Sciences, 6: 7557-7566.

Matthews, L. 1982. Pasture weeds of New Zealand. Biology and ecology of weeds. Springer, Dordrecht. pp 387-394.

McNeill, J.R. and Winiwarter, V. 2006. Soils and societies: perspectives from environmental history. The White Horse Press, Isle of Harris, UK. pp 384.

Mhangara, P., Kakembo, V. and Lim, K.J. 2012. Soil erosion risk assessment of the Keiskamma catchment, South Africa using GIS and remote sensing. Environmental Earth Sciences, 65: 2087-2102.

Misra, S., Maikhuri, R. and Dhyani, D. 2008. Indigenous soil management to revive below ground biodiversity-case of Garhwal. Leisa India, 10: 13-14.

Moges, A. and Holden, N. 2007. Farmers' perceptions of soil erosion and soil fertility loss in Southern Ethiopia. Land Degradation & Development 18: 543-554.

Molefe, O. 2015. Physico-chemical characterization of African traditional cosmetics produced by the Ovahimba tribes of Northern Namibia. MSc. Thesis, University of Witwatersrand, South Africa.

Morekhure-Mphahlele, R., Focke, W.W. and Grote, W. 2017. Characterisation of vumba and ubumba clays used for cosmetic purposes. South African Journal of Science, 113: 1-5.

Morrison, K.D., Underwood, J.C., Metge, D.W., Eberl, D.D. and Williams, L.B. 2014. Mineralogical variables that control the antibacterial effectiveness of natural clay deposit. Environmental Geochemistry and Health, 36: 613 - 631.

Mountjoy, D.C. and Gliessmann, S.R. 1988. Traditional manegement of a hillside agroecosystem in Tlaxcala, Mexico: an ecologically based maintainace system. American Journal of Alternative Agriculture, 3: 3 - 10.

Moyal, D.D. and Fourtanier, A.M. 2008. Broad-spectrum sunscreens provide better protection from solar ultraviolet–simulated radiation and natural sunlight–induced immunosuppression in human beings. Journal of the American Academy of Dermatology, 58: S149-S154.

Mpako, M.P., Matike, E.M., Ekosse, G.I and Ngole, V.E. 2011. Ceremonial usage of clays for boDy painting according to traditional Xhosa culture. Indilinga African Journal of Indigenous Knowledge Systems, 10: 235 - 244.

Msibi, A.T. 2014. The prevalence and practice of geophagia in Mkhanyakude District of KwaZulu-Natal, South Africa. MSc. Thesis, University of KwaZulu-Natal, South Africa.

Mucina, L. and Rutherford, M.C. 2006. The vegetation of South Africa, Lesotho and Swaziland. Strelitzia 19. South African National Biodiversity Institute, Pretoria.

Mucina, L., Schaminée, J.H. and Rodwell, J.S. 2000. Common data standards for recording relevés in field survey for vegetation classification. Journal of Vegetation Science, 11: 769-772.

Murage, E.W., Karanja, N.K., Smithson, P.C. and Woomer, P.L. 2000. Diagnostic indicators of soil quality in productive and non-productive smallholders' fields of Kenya's Central Highlands. Agriculture, Ecosystems & Environment, 79: 1-8.

Musafir, A. and Chazot, P. 2006. Clay Cures. Mapin Publishing Pvt Ltd. India.

Nagoba, B.S. and Pichare, A. 2016. Medicinal microbiology and parasitology. Prep manual for undergraduates, 3rd Edition. Elsevier, RELX India Private Limited, Haryana, India.

Nath, J.A., Lal, R. and Das, A.K. 2015. Ethnopedology and soil quality of bamboo (Bambusa sp.) based agroforestry system. Science of the Total Environment, 521: 372-379.

Nchito, M., Geissler, P.W., Mubila, L., Friis, H. and Olsen, A. 2004. Eefects of iron and multimicronutrient supplementation on geophagy: a two-by-two factorial study among Zambian schoolchildren in Lusaka. Transactions of the Royal Society of Tropical Medicine and Hygiene, 98: 218 - 227.

Nethononda, L.O. and Odhiambo, J.J.O. 2011. Indigenous soil knowledge of smallholder farmers at Rambuda irrigation scheme, Vhembe District, South Africa. African Journal of Agricultural Research, 6: 2576 - 2581.

Newman, A.C.D. 1987. Chemistry of clays and clay minerals; Mineralogucal Scociety Monograph, No.6. Wiley, New York.

Ngailo, J.A. and Nortcliff, S. 2007. Learning from Wasukuma ethnopedology: An indigenous well-established system for transfer of agro-tehnology in Tanzania. Indilinga African Journal of Indigenous Knowledge Systems, 6: 64 - 75.

Ng'etich, W.K., Mwangi, E.M., Kiptoo, J., Digo, C.A. and Ombito, J.O. 2014. In vitro determination of sun protection factors on clay used for cosmetic purposes in Kenya. Chemistry of Materials, 6: 25 - 30.

Ngomo, O., Sieliechi, J.M., Tchatchueng, J.B., Kamga, R., Tabacaru, A., Dinica, R. and Praisler, M. 2014. Differences between structural, textural and rheological properties of two Cameroonian mineral clays used as cosmectic mask. Advances in Environmental Sciences, Development and Chemistry, Santorini Island, Greece, 17 - 21 July, pp 425 - 431.

Ngole, V., Ekosse, G., De Jager, L. and Songca. S. 2010. Physicochemical characteristics of geophagic clayey soils from South Africa and Swaziland. African Journal of Biotechnology, 9: 5929-5937.

Ngozi, P. 2008. Pica practices of pregnant women in Nairobi, Kenya. East African Medical Journal, 85: 72-79.

Niemeijer, D. and Mazzucato, V. 2003. Moving beyond indigenous soil taxonomies: local theories of soils for sustainable development. Geoderma, 111: 403-424.

Norman, G. 2010. Likert scales, levels of measurement and the “laws” of statistics. Advances in Health Sciences Education 15: 625-632.

Nortcliff, S. 2006. Classification. Need for systems. Encyclopedia of Soil Science, R. Lal (Ed.), 1: 227-229.

Novák, V. and Kňava, K. 2012. The influence of stoniness and canopy properties on soil water content distribution: simulation of water movement in forest stony soil. European Journal of Forest Research, 131: 1727-1735.

Nwankwo, C., Nuga, B.O. and Chukwumati, J. 2011. Indigenous description of soils in some communities in Emuoha local government area of Rivers State, Nigeria. Journal of Agriculture and Social Science, 11: 58 - 62.

Odendo, M., Obare, G. and Salasya, B. 2010. Farmers' perceptions and knowledge of soil fertility degradation in two contrasting sites in western Kenya. Land Degradation & Development, 21: 557-564.

Okunlola, O. and Owoyemi, K. 2015. Compositional characteristics of geophagic clays in parts of Southern Nigeria. Earth Science Research, 4: 1.

Oliver, Y.M., Robertson, M.J., Wong, M.T.T. 2010. Integrating farmer knowledge, precision agriculture tools, and crop simulation modelling to evaluate management options for poor-performing patches in cropping fields. European Journal of Agronomy, 32: 40 – 50.

Oliver, M.A. 1997. Soil and human health: Areview. European Journal of Soil Science, 48: 573 - 592.

Olowoyo, J.O. and Macheka, L. 2013. An assessment of different soil types generally consumed by pregnant women in South Africa. Medical Technology, SA 27: 5-8.

Onduru, D.D., Diop, J.M., Van Der Werf, E. and De Jager, A. 2002. Participatory on-farm comparative assesment of organic and conventional farmers' practices in Kenya. Biological Agriculture and Horticultre, 19: 295 - 314.

Oudwater, N. and Martin, A. 2003. Methods and issues in exploring local knowledge of soils. Geoderma, 111: 387-401.

Payton, R., Barr, J., Martin, A., Sillitoe, P., Deckers, J. and Gowing, J. 2003. Contrasting approaches to integrating indigenous knowledge about soils and scientific soil survey in East Africa and Bangladesh. Geoderma, 111: 355-386.

Pepper, I., Gerba, C. Newby, D. and Rice, C. 2009. Soil: a public health threat or savior? Critical Reviews in Environmental Science and Technology, 39: 416-432.

Pereira, P., Brevik, E.C. Oliva, M., Estebaranz, F. Depellegrin, D. and Novara, A. 2017. Goal Oriented Soil Mapping: Applying Modern Methods Supported by Local Knowledge. In Pereira, P., Brevik, E., Munoz-Rojas, M. and Miller, B. (Eds.), Soil mapping and process modeling for sustainable land use management. Elsevier. 61-83.

Prashanth, L., Kattapagari, K.K., Chitturi,R.T., Baddam V.R.R. and Prasad, L.K. 2015. A review on role of essential trace elements in health and disease. Journal of Dr. NTR University of Health Sciences, 4: 75.

Pusch, R. 2015. Bentonite clay: environmental properties and applications. Taylor & Francis, New York.

Ramisch, J.J. 2005. Inequality, agro-pastoral exchanges, and oil fertility gradients in southern Mali. Agriculture, Ecosystems and Environment, 105: 353 - 372.

Raymond, L.A. and Johnson, N.E. 2017. Crustal Earth Materials. Waveland Press, New York.

Reed, S. 2007. Cosmetics and your health. US Department of Health and Human Services, Washington DC, USA.

Reij, C. 1991. Indigenous soil and water conservation in Africa. Gatekeeper Series 27. International Institute for Environment and Development. London.

Rifkin, R.F. 2012. Processing ochre in the Middle Stone Age: Testing the inference of prehistoric behaviours from actualistically derived experimental data. Journal of Anthropological Archaeology, 31: 174-1

Rifkin, R.F., d'Errico, F., Dayet-Boulliot, L. and Summers, B. 2015. Assessing the photoprotective effects of red ochre on human skin by in vitro laboratory experiments. South African Journal of Science, 111: 1-8.

Ryan, G.W. and Bernard, H.R. 2003. Techniques to identify themes. Field Methods, 15: 85 - 109.

Saathoff, E., Olsen, A., Kvalsvig, J.D. and Giessler, P.W. 2002. Geophagy and its association with geohelminth infection in rural schoolchildren from northern KwaZulu-Natal, South Africa.Transaction of the Royal Society of Tropical Medicine and Hygiene, 96: 485 - 490.

Sanchez, P.A., Shepherd, K.D., Soule, M.J., Place, F.M. andBuresh, R.J. A. 1997. Soil fertility replenishment in Africa: An investment in natural resource capital. In Buresh, R., Sanchez, P and Calhoun, F. (Eds.), Replenishing soil fertility in Africa, Soil Science Society of America, Madison, WI. pp 1-46.

Sanchez, P.A. and Uehara, G. 1980. Management considerations for acid soils with high phosphorus fixation capacity. The Role of Phosphorus in Agriculture, 17: 471-514.

Sandor, J.A. and Furbee, L. 1996. Indigenous knowledge and classification of soils in the Andes of Southern Peru. Soil Science Society of America Journal, 60: 1502-1512.

Schuler, U., Choocharoen, C., Elstner, P., Neef, A., Stahr, K. and Zarei, M. 2006. Soil mapping for land-use planning in a karst area of N Thailand with due consideration of local knowledge. Journal of Plant Nutrition and Soil Science, 169: 444-452.

Scoones, I. 1996. Hazards and opportunities: farming livelihoods in dryland Africa. Lessons from Zimbabwe. Zed Books, London.

Senesil, G.S., Baldassarre, G., Senesi, N and Radina, B. 1999. Trace element inputs into soils by anthropogenic activities and implications for human health. Chemosphere, 39: 343 - 377.

Shah, P.B. 1995. Indigenous agricultural land and soil classifications. In: Schreier, H., Shah, P.B., Brown, S. (Eds.), Challenges in Mountain Resource Management in Nepal. Processes, Trends, and Dynamics in Middle Mountain Watershed. IDRC/ICIMOD, Kathmandu, Nepal.

Shaw, J., West, L. and Hajek, B. 2001. Ca-Mg ratios for evaluating pedogenesis in the piedmont province of the southeastern United States of America. Canadian Journal of Soil Science, 81: 415-421.

Shaxson, T. 1999. New concepts and approaches to land management in the tropics with emphasis on steeplands. FAO Soils Bulletin 75. Rome: FAO.

Showers, K.B. 2006. A history of African soil: Perceptions, use and abuse. Soils and Societies: Perspectives from Environmental History. The White Horse Press, Isle of Harris, UK. pp 118-176.

Shrestha, P.K.,. Sinclair, F.L and McDonald, M.A. 2004. Bridging the gap between farmers' and scientists' soil classification: Revisiting the methodology used in documentation and analysis of farmers' knowledge. International Conference on "Bridging Scales and Epistemologies: Linking Local Knowledge with Global Science in Multi-Scale Assessments" organised by the Millenium Ecosystem Assessment Secretariat from 17 - 20 March 2004 in Alexandria, Egypt.

Sikana, P. 1993. Mismatched models: How farmers and scientists see soils. ILEIA Newsletter, 9: 15-16.

Sillitoe, P. 1998. Knowing the land: soil and land resource evaluation and indigenous knowledge. Soil Use and Management, 14: 188-193.

Sillitoe, P., Barr, J. and Alam, M. 2004. Sandy-clay or clayey-sand? Mapping indigenous and scientific soil knowledge on the Bangladesh floodplains. In Bicker, A., Sillitoe, P. and Pottier, J. (Eds.), Development and local knowledge: New approaches to issues in natural resources management, conservation and agriculture. Routledge, London. pp 174-201.

Smijs, T.G. and Pavel., S. 2011. Titanium dioxide and zinc oxide nanoparticles in sunscreens: focus on their safety and effectiveness. Nanotechnology, Science and Applications, 4: 95 - 112.

Soil Classification Working Group, 1991. Soil Classification, A Taxonomic System for South Africa, Department of Agricultural Development, Pretoria.

Soil Survey Staff, 2014. Keys to Soil Taxonomy Twelth Edition. United States Department of Agriculture, Natural Resources Concervation Service.Washington DC, USA.

Songca, S.P., Ngole, V. Ekosse, G. and De Jager, L. 2010. Demographic characteristics associated with consumption of geophagic clays among ethnic groups in the Free State and Limpopo provinces. Indilinga African Journal of Indigenous Knowlegde, 9: 110- 123.

Southwell, M.R. and Thoms, M.C. 2006. A gradient or masaic of patches? The textural character of infert-flood plain surfaces along a dryland river system. International Association of Hydrological Science, 306: 487 - 495.

Stocking, M. and Murnaghan, N. 2001. Handbook for the field assessment of land degradation. Earthscan, London.

Sumbele, I.U., Ngole, V.M. and Ekosse, G.E. 2014. Influence of physico-chemistry and mineralogy on the occurrence of geohelminths in geophagic soils from selected communities in the Eastern Cape, South Africa, and their possible implication on human health. International Journal of Environmental Health Research, 24: 18-30.

Talawar, S. and Rhoades, R.E. 1998. Scientific and local classification and management of soils. Agriculture and Human Values, 15: 3-14.

Taylor, M.P., Mackay, A.K., Hudson-Edwardsm K.A. and Holz, E. 2010. Soil Cd, Cu, Pb and Zn contaminants around Mount Isa city, Queensland, Australia: Potential sources and risks to human health. Applied Geochemistry, 25: 841 - 855.

Tekwa, I., Belel, M. and Alhassan, A. 2010. The effectives of indigenous soil conservation techniques on sustainable crop production. Australian Journal of Agricultural Engineering, 1: 74- 79.

Tesfahunegn, G.B., Tamene, L. and Vlek, P.L.G. 2011. Catchment-scale spatial variability of soil properties and implications on site-specific soil management in northern Ethopia. Soil and Tillage Research, 117: 124 - 139.

Troeng, J. 1995. Worldwide chronology of fifty-three prehistoric innovations. Acta Archaeologica Lundensia, Series 8, No.21. Almqvist and Wiksell, Stockholm.

Tully, K. Sullivan, C., Weil, R. and Sanchez, P. 2015. The state of degradation in sub-Saharan Africa: Baselines, trajectories and solutions. Sustainability, 7: 6523 - 6552.

Ukaonu, C., Hill., D.A. and Christensen. 2003. Hypokalemic myopathy in pregnancy caused by clay ingestion. Obstetrics and Gynecology, 5: 1169 -1171.

Ure, A.M. and Berrow, M.L. 1982. The elemental constituents of soils. In Bowen, H.J.M (Ed), Environmental Chemistry. Royal Scociety of Chemistry, London. pp 94- 204.

Varisco, D.M. 1991. The future of terrace farming in Yemen: a development dilemma. Agriculture and Human Values, 8: 166-172.

Velo, J. 1984. Ochre as medicine: a suggestion for the interpretation of the archaeological record. Current Anthropology, 25: 674-674.

Veniale, F., Bettero, A., Jobstraibizer, P.G. and Setti. M. 2007. Thermal muds: perspectives of innovations. Applied Clay Science, 36: 141-147.

Vermeer, D.E. and Frate, D.A. 1979. Geophagia in rural Mississippi: environmental and cultural contexts and nutritional implications. The American Journal of Clinical Nutrition, 32: 2129-2135.

VSN International. 2011. Genstat for Windows 14th Edition. VSN International, Hemel Hempstead, UK.

Wakindiki, I.I., Mochoge, B.O. and Ben-Hur, M. 2007. Assessment of indigenous soil and water conservation technology for smallholder farms in semi-srid areas in Africa and close spaced trash lines effect on erosion and crop yield. In Bationo, A., Kihara, J., Waswa, B. and Kimetu, J. (Eds.), Adances in integrated soil fertility management in sub-Saharan Africa: Challenges and Opportunities, Springer, Dordrecht. pp. 805 - 814.

Williams, L.B. and Haydel, S.E. 2010. Evaluation of the medicinal use of clay minerals as antibacterial agents. International Geology Review, 52: 745-770.

Williams, L.B., Haydel, S.E. and Gerrel, R.E. 2009. Bentonites, bandaids and borborygmi. Elements, 5: 99 - 102.

Williams, L.B., Metge, D.W., Eberl, D.D., Harvey, R.W., Turner, A.G. and Prapaipong, P. 2011. What makes a natural clay antibacterial? Environmental Science & Technology, 45: 3768-3773.

Wilson, M. 2003. Clay mineralogical and related characteristics of geophagic materials. Journal of Chemical Ecology, 29: 1525-1547.

WinklerPrins, A.M. 1999. Insights and applications of local soil knowledge: a tool for sustainable land management. Society & Natural Resources, 12: 151-161.

WinklerPrins, A.M. and Sandor, J.A. 2003. Local soil knowledge: insights, applications, and challenges. Geoderma, 111: 162 -170.

Winowiecki, L.A., Whelan, M.P., McDaniel, P.A., Villalobos, M. and Somarriba, E. 2014. Local soil knowledge and its use in crop allocation: Implications for landscape-scale agricultural production and conservation efforts in Talamanca, Costa Rica. Agriculture, Forestry and Fisheries, 32: 93-101.

Woywodt, A. and Kiss, A. 2002. Geophagia: the history of earth-eating. Journal of the Royal Society of Medicine, 95: 143-146.

Yamamoto, O. 2001. Influence of particle size on the antibacterial activity of zinc oxide. International Journal of Inorganic Materials, 3: 643-646.

Yeshaneh, G.T. 2015. Assessment of soil fertility variation in different land uses and management practices in Maybar watershed, South Wollo Zone, North Ethiopia. International Journal of Environmental Bioremediation and Biodegradation, 13: 15 - 22.

Young, S.L. 2010. Pica in pregnancy: new ideas about an old condition. Annual Review of Nutrition 30: 403-422.

Zagorska, I. 2008. The use of ochre in Stone Age burials of the East Baltic. In Fahlander, F. and Oestigaard, T. (Eds.), The Materiality of Death: Bodies, Burials, Beliefs (BAR International Series 1768). Archaeopress, Oxford. pp 115 -124.

Appendices

Appendix 1 Structured questionnaire: household survey.

QUESTIONNAIRE FOR HOUSEHOLD SURVEY (AT A VILLAGE LEVEL)

GPS coordinates of village……………………….E ; ………………………S

Village…………………………………………….. Ethnic group…………………….

Name of the recorder……………………………. Date…………………………….

Name of the respondent……………………………………………..

SOCIOECONOMIC DATA

Household data

1. Province: ☐ Eastern Cape KwaZulu-Natal ☐
2. Gender: Female ☐ Male ☐
3. Marital status: Single ☐ Married ☐ Divorced ☐ Widowed ☐
4. Age: < 30 ☐ 30 - 40 40 – 60 ☐ >60 ☐
5. Number of family members: 1 – 4 ☐ 5 – 10 ☐ >10 ☐
6. Residence duration in the village: < 5 years ☐ 5- 10 years ☐ ☐ 10 – 20 years > 20 years ☐
7. Economic activities: Farming ☐ Employment ☐ Both ☐
8. Annual income: 0 – R 60 000 ☐ 60 – 120 000 ☐ > 120 000 ☐
9. Education level: ☐ No formal education Primary education ☐ ☐ Secondary education Tertiary education ☐

10. Farming scope: Arable crop cultivation only ☐ Livestock ☐

Both ☐

11. Farm size: 1 – 4 ha ☐ 4 – 8 ha ☐ > 8ha ☐

12. Farming duration: < 5 years ☐ 5 – 10 years ☐ 10 – 20 years > 20 years ☐

13. Labour: Family ☐ Hired ☐ ☐

14. Is land ownership: Private ☐ Communal ☐ Clan Other ☐

15. How is land acquired in this village? Chief ☐ ınicipality ☐

AGRICULTURAL USES

SOIL AND LAND USE DATA

Soil Classification

16. Do you identify different types of soils? Yes No ☐ ☐

17. If yes, please list them by

name…………………………………………………………………………………

…………………………………………………………………………………………

…………………………………………………………………………………………

18. Please indicate the criteria used for local soil to distinguish between soils

Colour ☐ exture ☐ sistence Drai ☐ e Stonines ☐ Other ☐

☐

19. From the list in Q 19, please indicate most common soils used for agriculture

B. SOIL MANAGEMENT

Soil fertility

20. Do you recognise different levels of fertility? Yes N☐ ☐

21. If yes , how would you describe them description of each

Fertility level	Description
Low	
Moderate	
High	

22. Which of the following local soil fertility indicators do you use?

Yield ☐ Crop appearance V☐etation S☐auna Trial ☐error

☐ther, please specify…………………………………………….

23. Please indicate agricultural practises common in this area.

Fallowing ☐Crop rotation ☐lication of crop residue Inter☐pping other, ☐

please specify………………………….

Soil knowledge in relation to cropping systems

24. List major crops grown in this village

1. 2. 3. 4.

25. Is any of the below factors a reason for the choice of crops mentioned in Q31

Climate ☐ oils ☐ fit Te ☐ n ☐

☐ Other, specify ………………..

26. From the list provided in Q30, please rank crops that are best grown on the most common soils used for agriculture (those provided in Q20).

27. How many soils can you identify from your field? 1 ☐ > 2 ☐ ☐

28. Is your choice of land use affected by soil type? Yes ☐ ☐

NON-AGRICULTURAL USES

Soil symbolic value

29. Are there any symbolic meanings associated with soils in your culture?

Yes ☐ No ☐

If yes, please elaborate ……………………..

30. ………………………………………………………………………………………

……………………………………………………………………………..

31. Are soils used for ritual purposes in your culture? Yes ☐ ☐

32. If yes, please list them

……………………………………………………………………………………………

…………………………………………………………………………………………..

33. Are there any rituals or beliefs associated with your agricultural activities?

Yes ☐ No ☐

34. If yes, please list

…………………..……………………………………………………………………….

Soil material value

35. Do you use soils for the following uses?

Brick building ☐ Geophagy ☐ Pottery Cosmetics and hair care ☐ ☐

Healing ☐ other, ☐

specify……………………………………………………………………………………

36. If you do not, do you know anyone who does? Yes ☐ ☐

37. If yes, please give contact details or location of the person

Appendix 2 Semi-structured interviews: Local farmer experts

SEMI-STRUCTURED INTERVIEWS

PARTICIPANTS SELECTION CRITERIA

AGRICULTURAL USES

Household coordinates Latitude…………………. Longitude…………………………

Village…………………. Ethnic group ……………......……………….

Name of the recorder……………………. Date: ……………………………….

Name of the respondent………………………………………..

A. Soil indigenous knowledge in relation to farming systems

Soil management

1. Please name and distinguish soils in your field.

Soil type	Properties	Location within field

2. Please indicate the fertility status of the soils listed above.

Soil type	Fertility status* (low, moderate and poor)

3. How do you assess the fertility of the soils mentioned above?

   Laboratory soil testing ☐

   Local soil fertility indicators ☐

4. Can you elaborate on the most commonly used local indicators for fertility assessment

5. Please indicate cropping history of your field for the past three seasons

Year	Use	Yield

6. Which management practices do you use on which soils and how often?

Soil type	Crop rotation			Intercropping			Fallowing		
	Frequent	Sometimes	Never	Frequent	Sometimes	Never	Frequent	Sometimes	Never

*Practices in the table will represent most commonly used practises from general questionnaire

B. Soil knowledge in relation to cropping systems

7. Please indicate cropping seasons in this area

……………………………………………………………………………………….………

…………………………………………………………………………….………………

…………………………………………………………………….

8. Please indicate the terrain of your field

Flat slope ☐]entle slope ☐ ›derate slope steep☐ pe ☐

9. How can you describe the rainfall pattern of this area

………………………………………………………………………………………

………………………………………………………………………………………

………………………………………………………………………………………

10. Please indicate which soils are suitable for each of the crops currently planted in your fields and why?

Field	Soil type (in order of preference and quality)	Crop	Reason for suitability

11. Is the weeding frequency dependent on soil type? Yes N☐ ☐

12. If yes, please indicate weeding frequency for different crops in your field.

Soil type	Weeding frequency

NON-AGRICULTURAL USES

C. Soil symbolic value

13. Please explain how are soils used in rituals.

…………………………………………………………………………………………..…

…………………………………………………………………………………………..…

…………………………………………………………………………………………..…

D. Soil material value

14. How is the soil sampled and prepared for the desired use?

Uses	Soil	Sampling	Preparation

15. How do you know/assess if the soil has the desired properties?

Uses	Soil	Desired properties	Indicators of desired properties

16. Which part of the landscape do these soils occur?

Uses	Soil	Location on the landscape

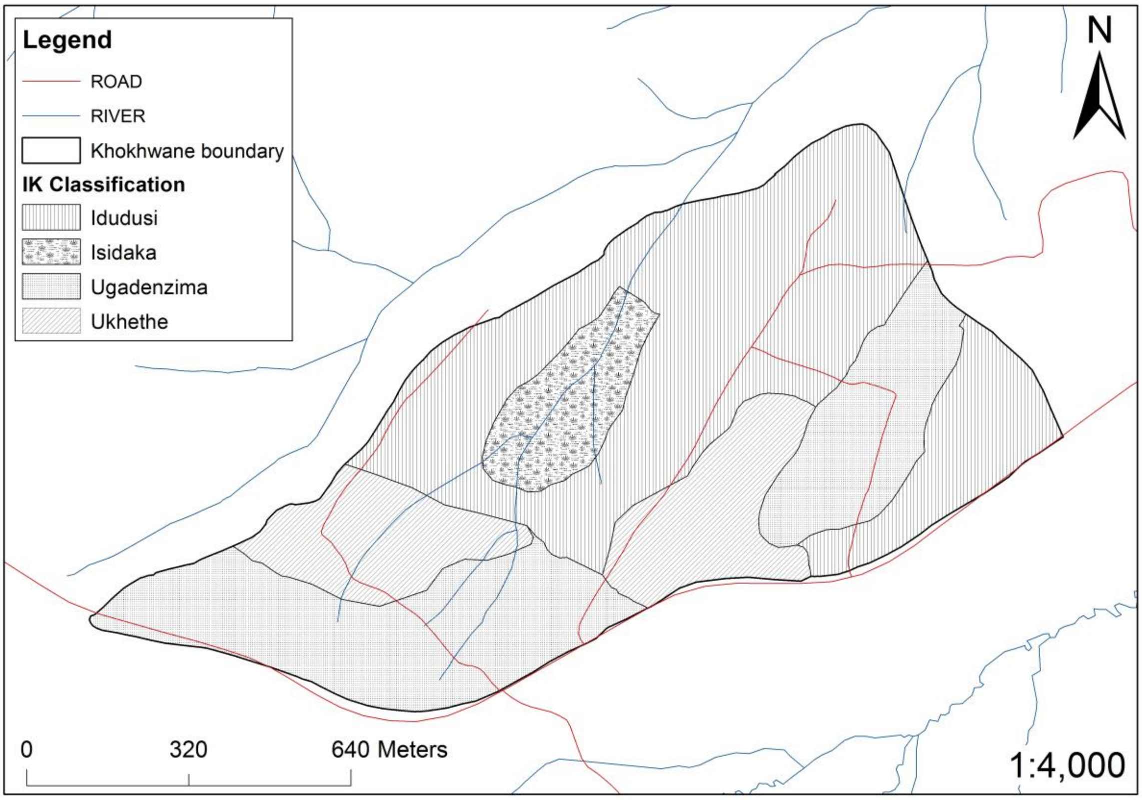
17. Is there any other information you can give on the following aspects relating non-agricultural use of soils,

    History of the use of soils
    Possible conflict between agricultural uses versus non-agricultural use of the same soil and if so how is such resolved? Yes No ☐ ☐

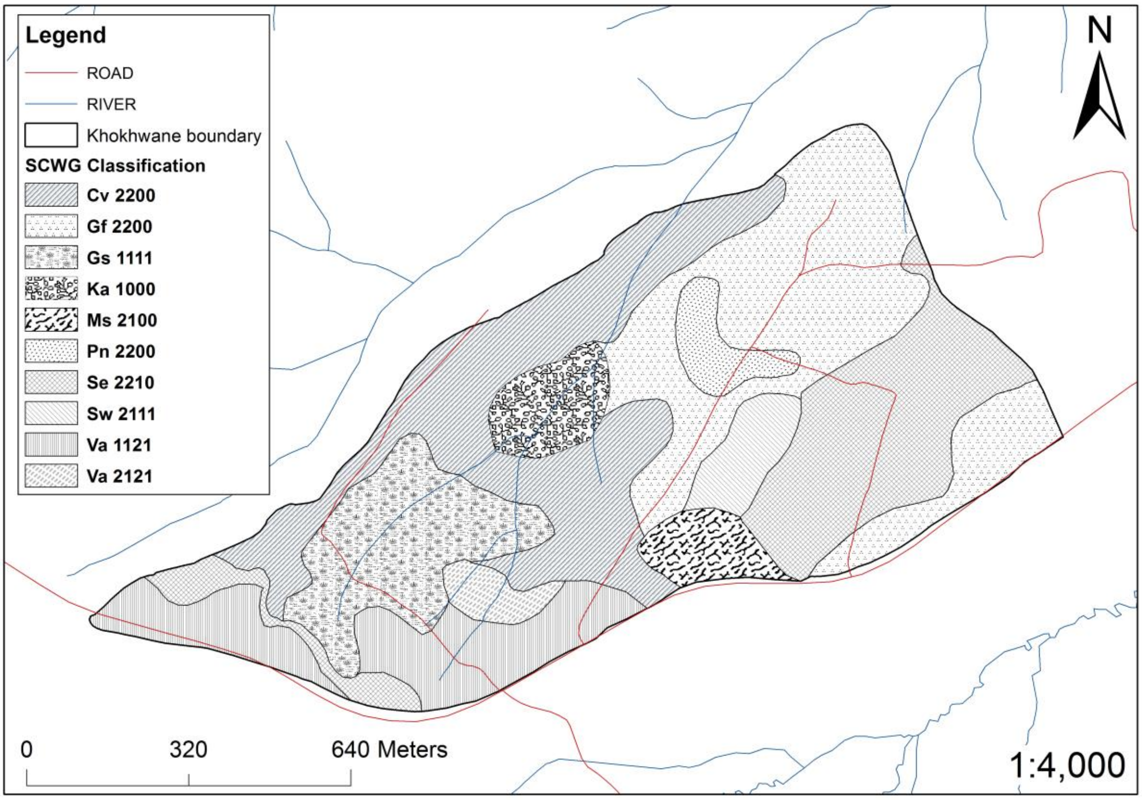
18. If yes, please elaborate

    ……………………………………………………………………………………

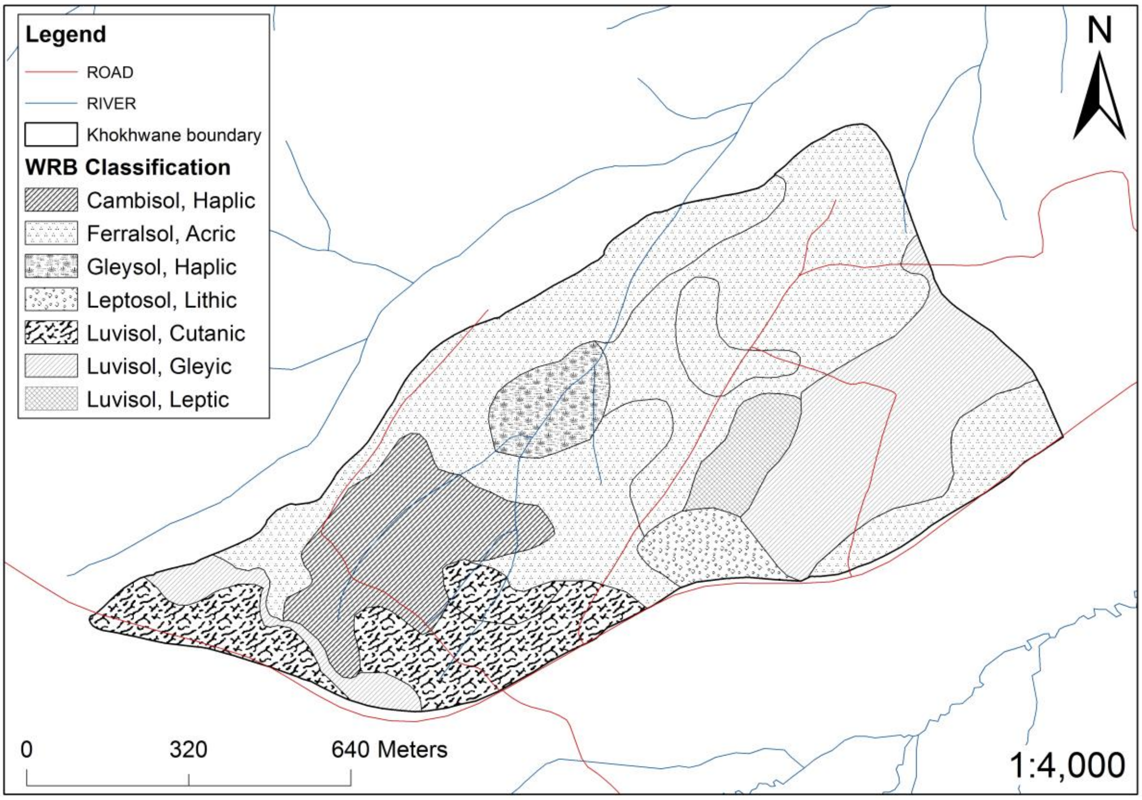
Appendix 3 Khokhwane village soil map based on indigenous knowledge (IK).



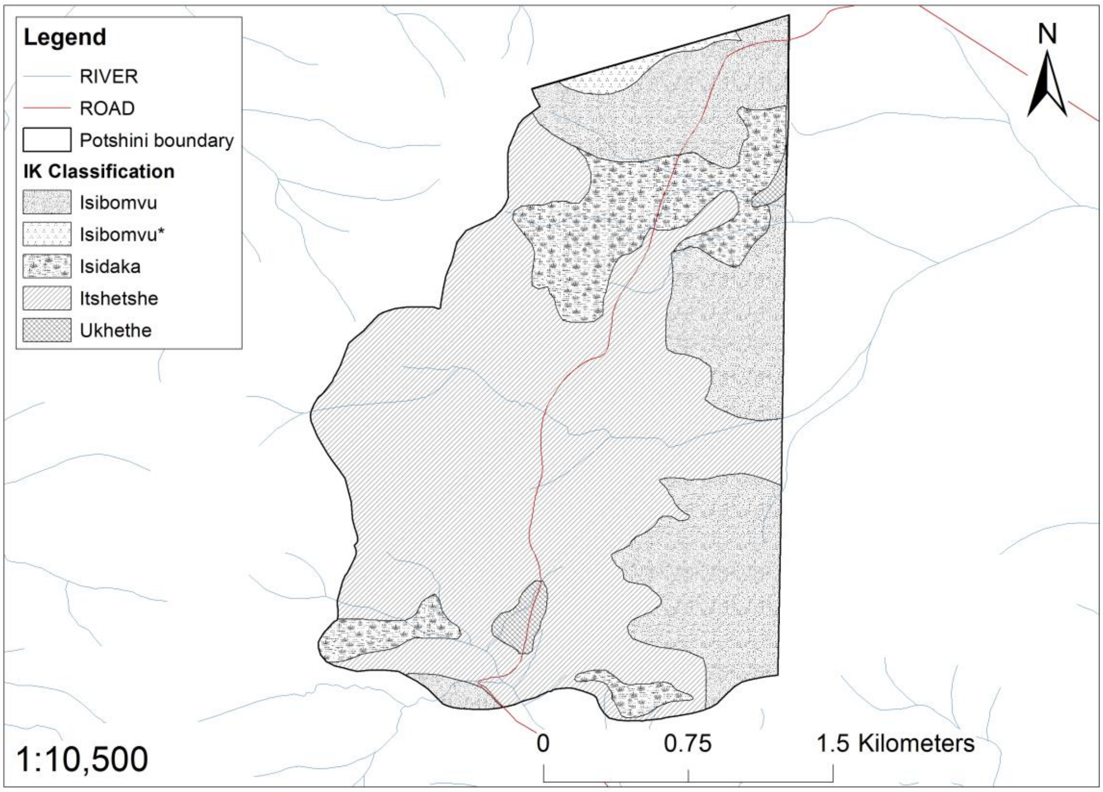
Appendix 4 Khokhwane village soil map based on the South African soil classification (SCWG, 1991).



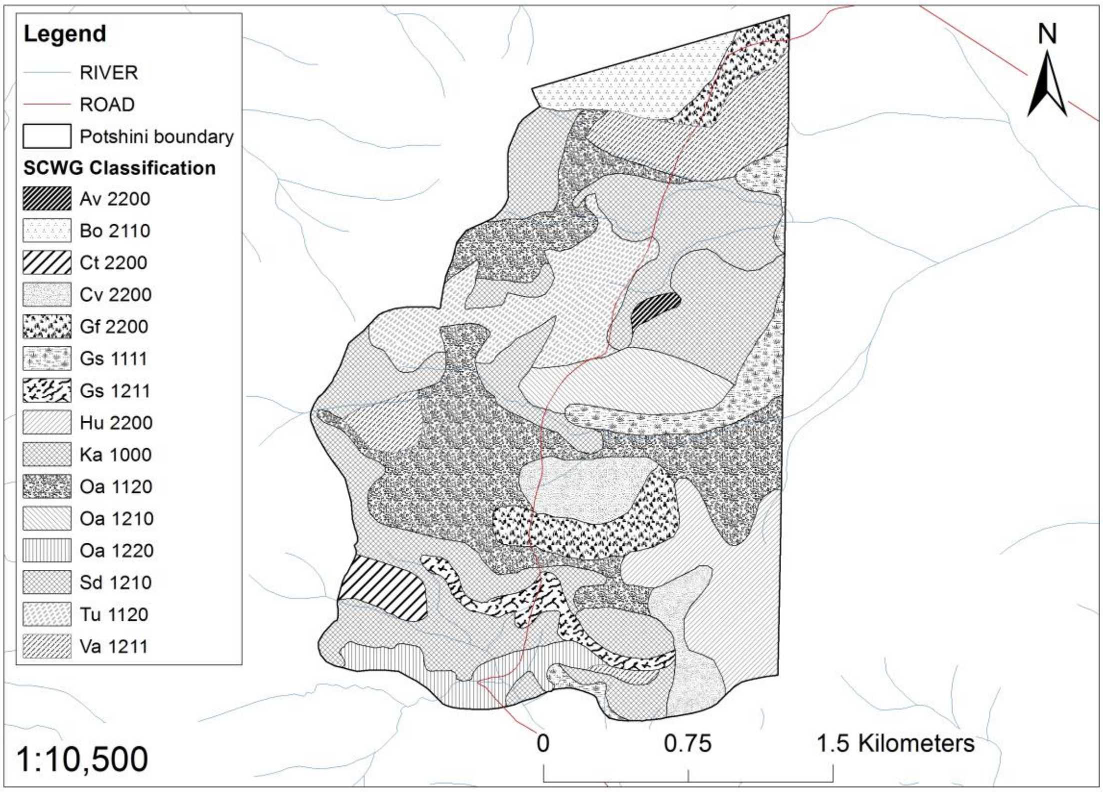
Appendix 5 Khokhwane village soil map based on the World Reference Base classification (IUSS Working Group, WRB, 2014).



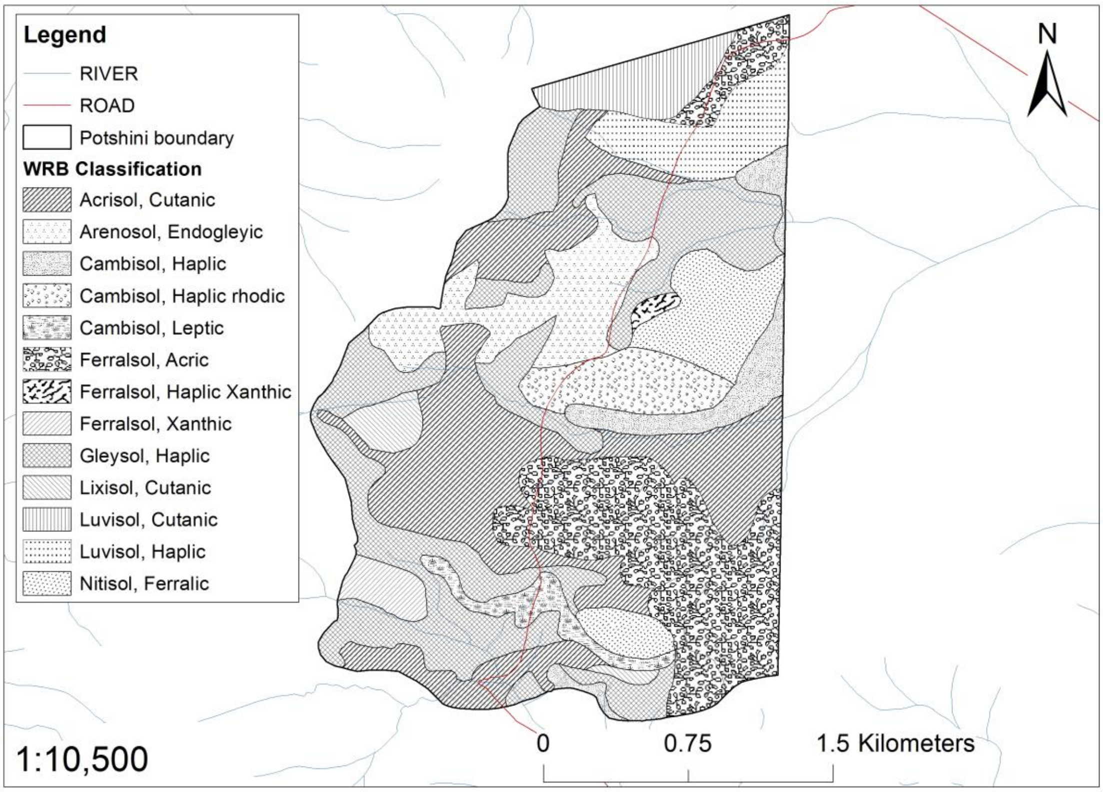
Appendix 6 Potshini village soil map based on indigenous knowledge (IK).



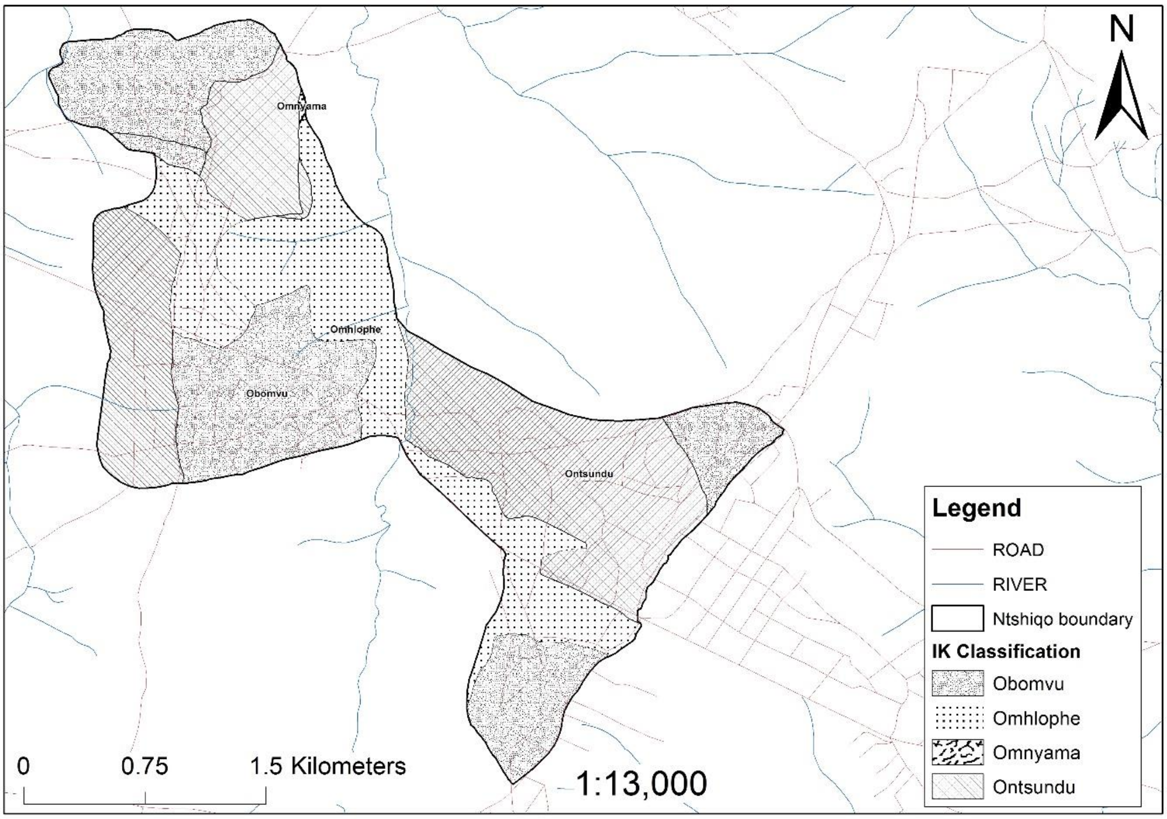
Appendix 7 Potshini village soil map based on the South African soil classification (SCWG, 1991).



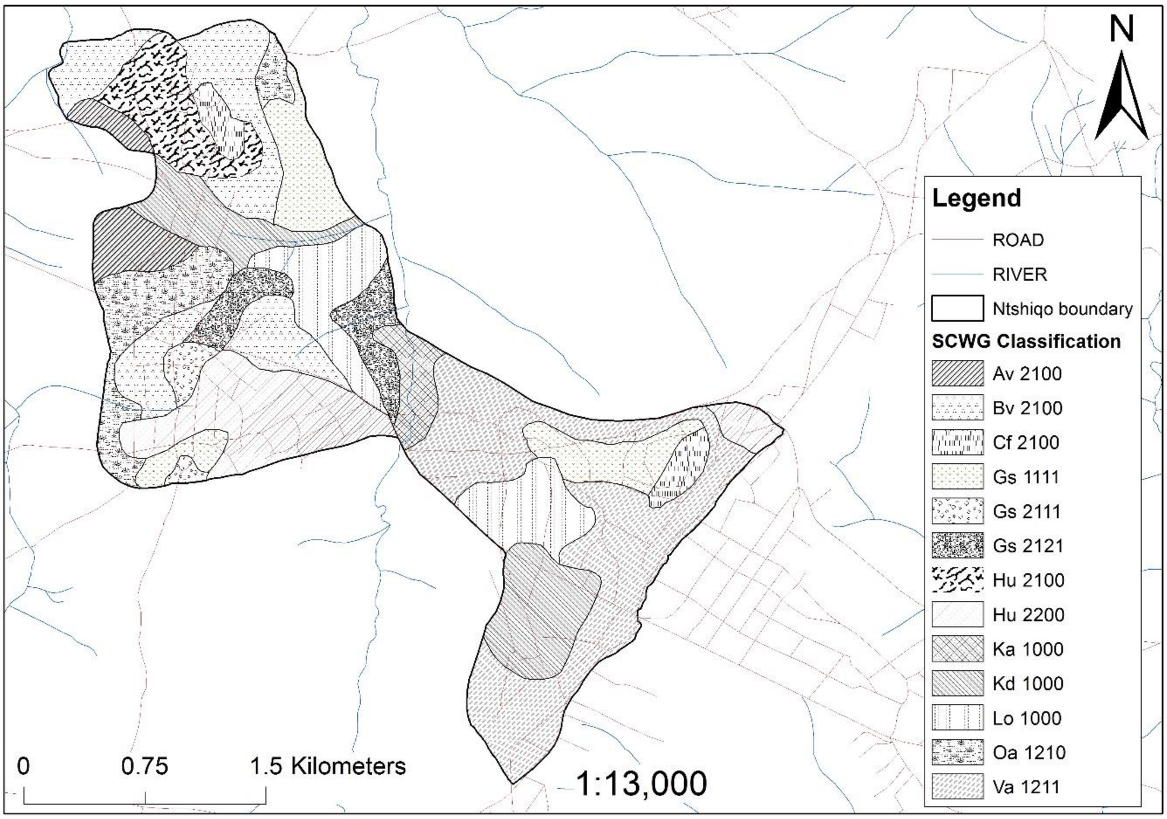
Appendix 8 Potshini village soil map based on the World Reference Base classification (IUSS Working Group, WRB, 2014).



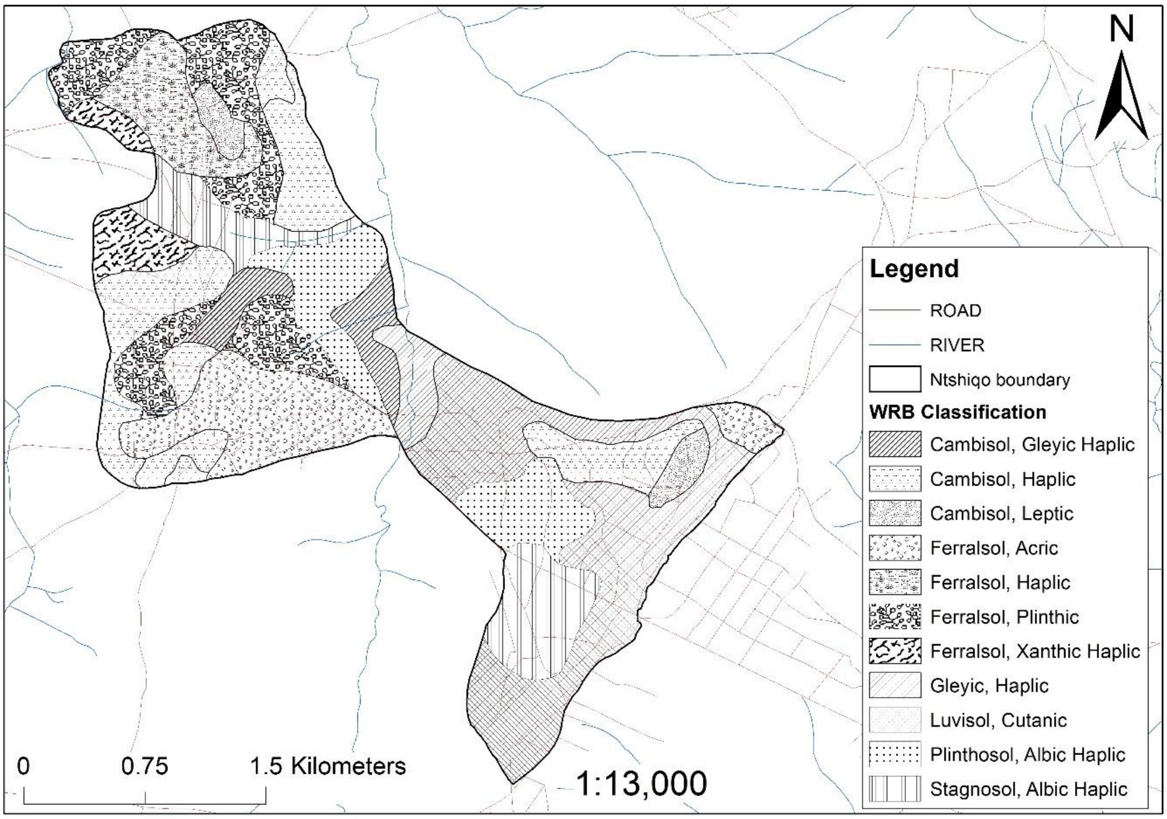
Appendix 9 Ntshiqo village soil map based on indigenous knowledge (IK).



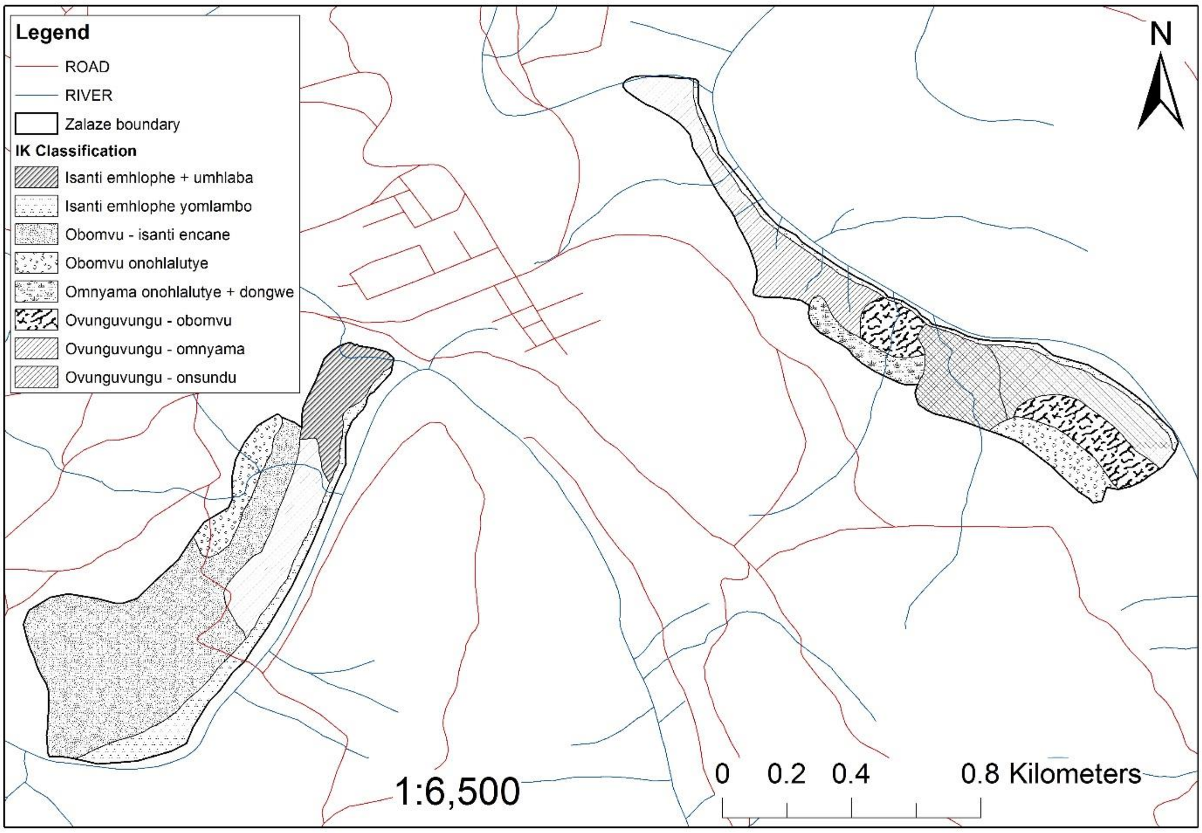
Appendix 10 Ntshiqo village soil map based on the South African soil classification (SCWG, 1991).



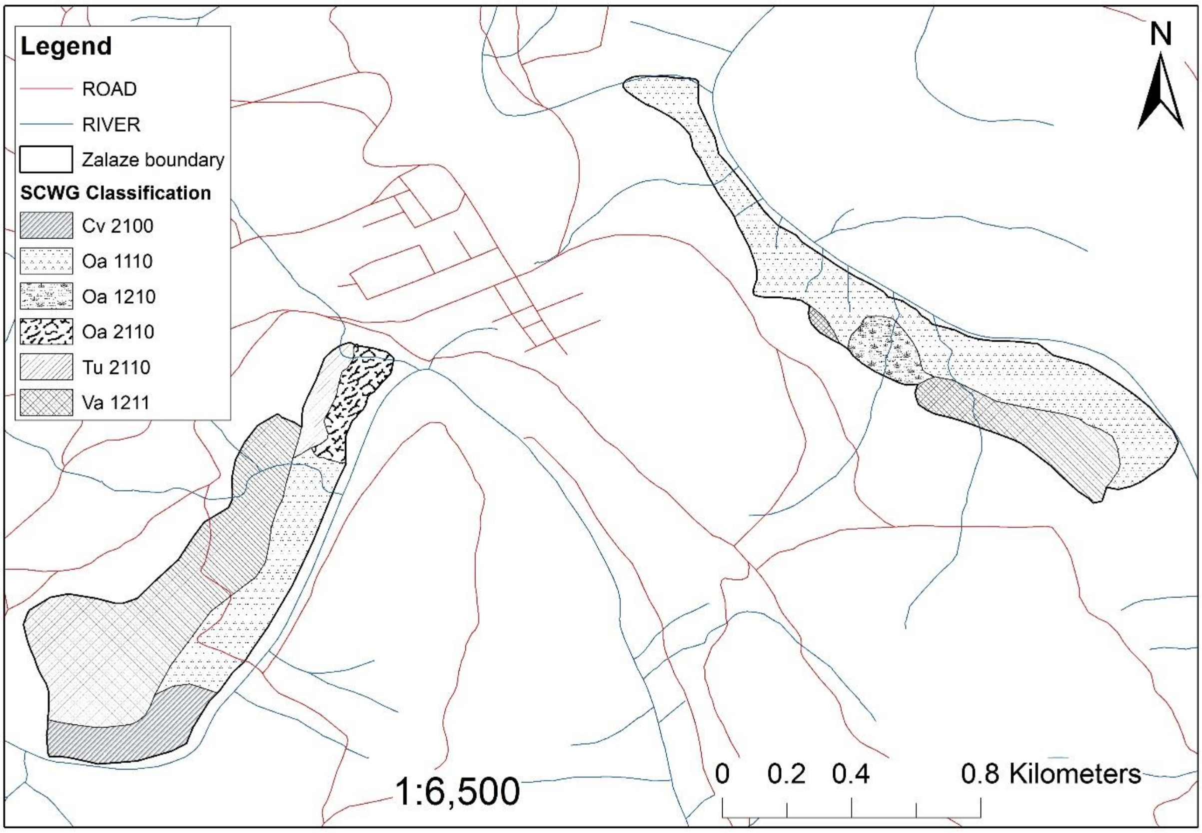
Appendix 11 Ntshiqo village soil map based on the World Reference Base classification (IUSS Working Group, WRB, 2014).



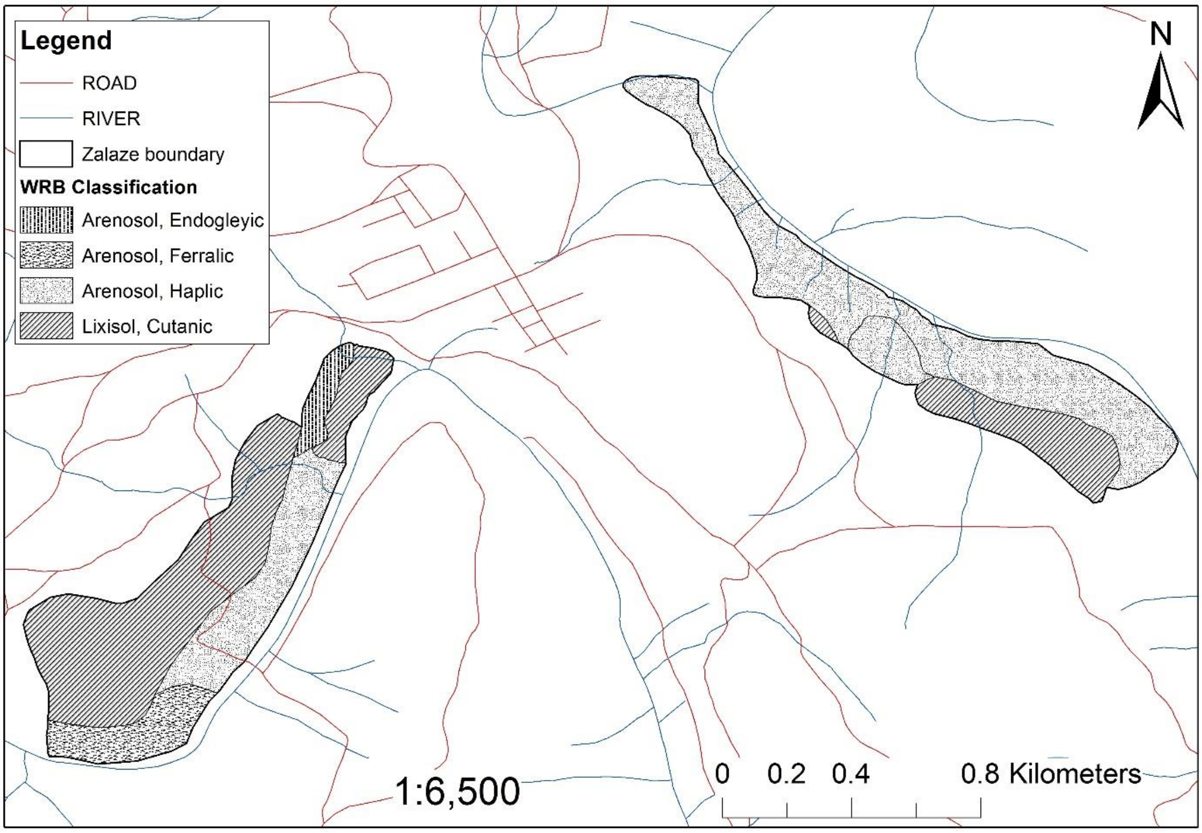
Appendix 12 Zalaze village soil map based on indigenous knowledge (IK).



Appendix 13 Zalaze village soil map based on the South African soil classification (SCWG, 1991).

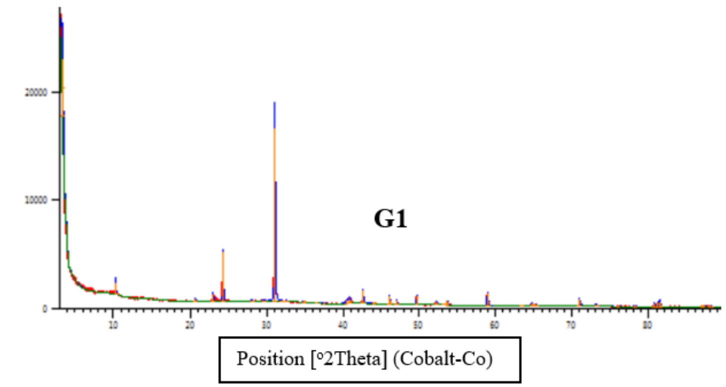


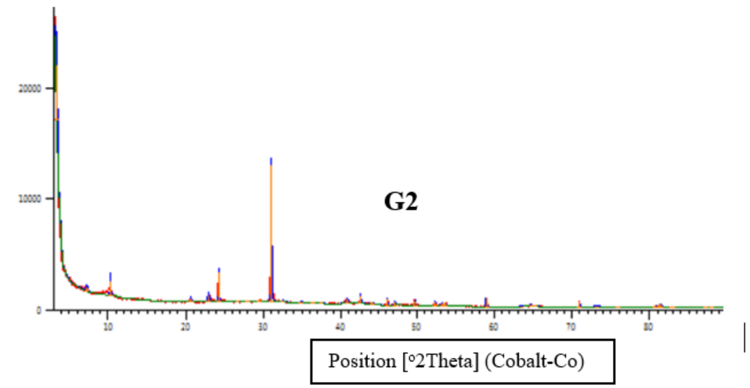
Appendix 14 Zalaze village soil map based on the World Reference Base classification (IUSS Working Group, WRB, 2014).

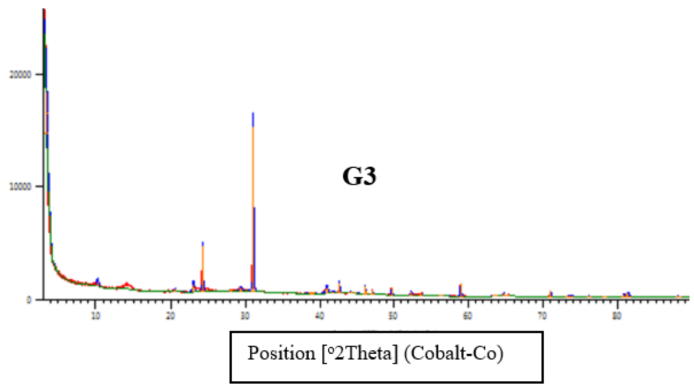


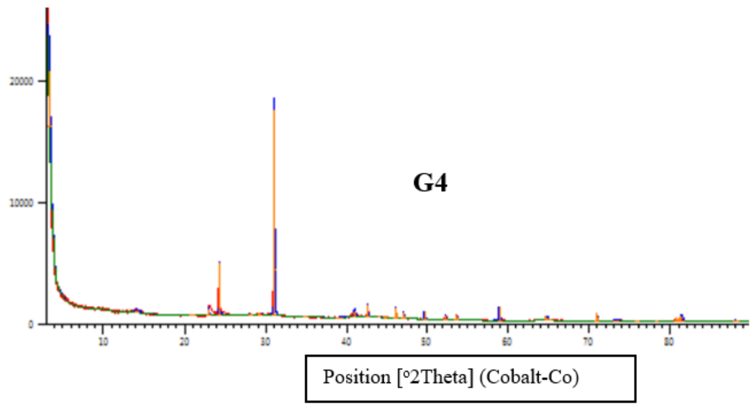
.

Appendix 15 The powder X-ray diffraction traces of the geophagic samples from Potshini (G1 – G5) and Khokhwane (G6 and G7).

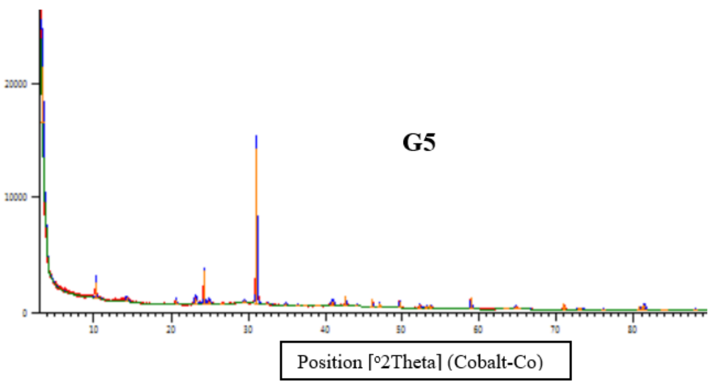


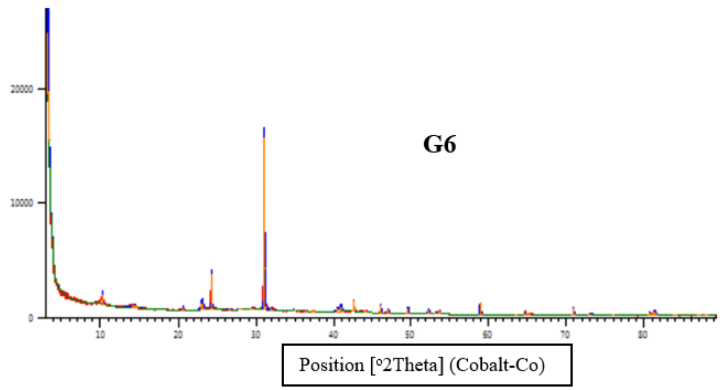


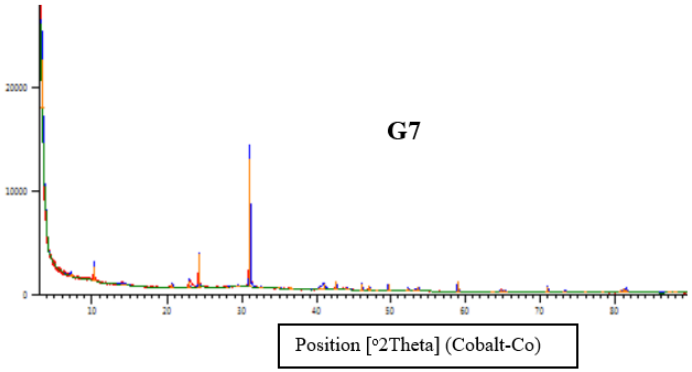




Appendix 15 Continued…….



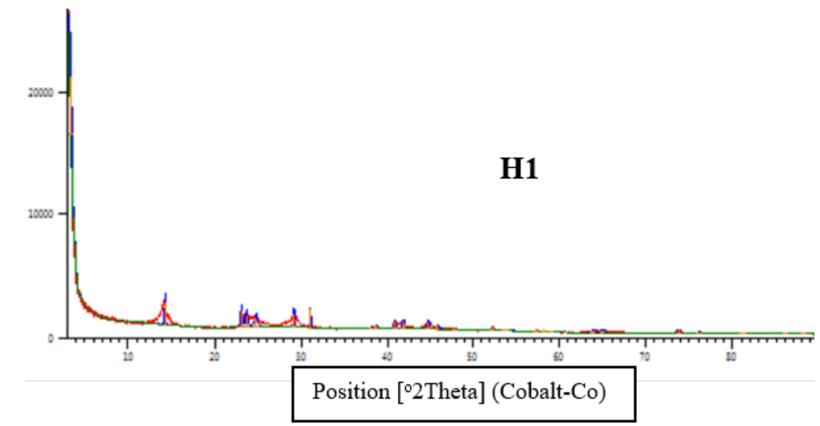


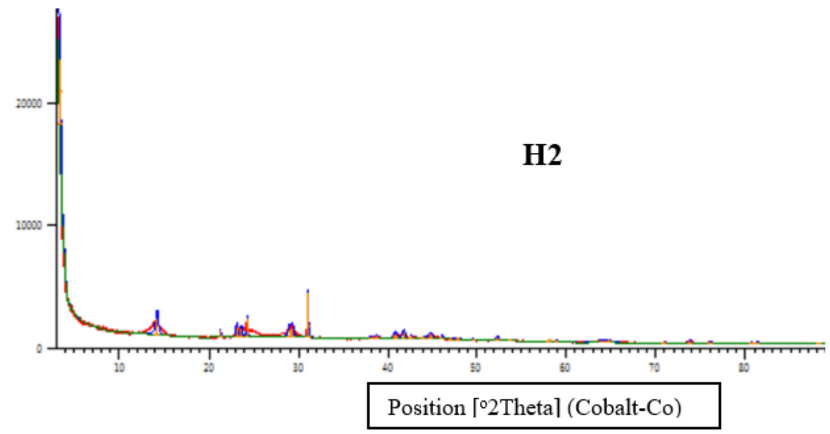


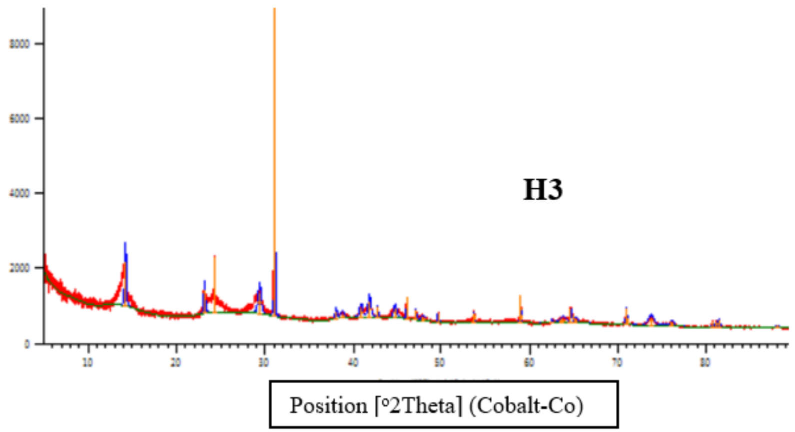
Appendix 16 Total trace element composition (mg kg^{-1}) of the geophagic samples from Potshini (G1 – G5) and Khokhwane (G6 and G7).

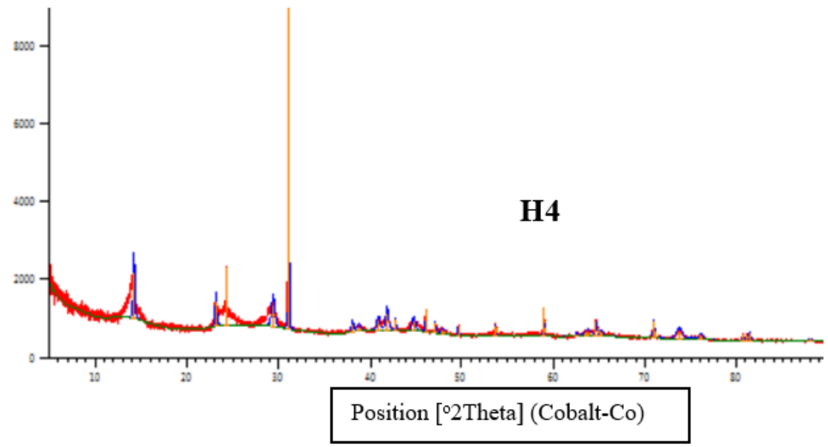
Trace element	Geophagic samples						
	G1	G2	G3	G4	G5	G6	G7
Ba	322.16	510.05	404.76	643.71	603.67	546.28	616.90
Ce	56.78	60.90	105.47	51.78	56.77	30.25	95.61
Co	12.19	16.99	33.43	16.94	13.99	7.82	14.53
Cr	87.08	115.54	84.22	68.95	51.12	63.56	90.55
Cs	5.64	9.27	5.00	10.05	7.53	19.79	21.12
Cu	48.84	38.46	34.12	27.82	14.90	36.01	36.56
Dy	8.13	5.93	5.86	5.53	3.39	2.88	5.29
Er	5.28	3.94	3.97	3.75	2.32	2.06	3.42
Eu	1.43	1.09	1.37	0.91	0.81	0.44	1.17
Gd	7.61	4.65	6.23	4.50	3.86	2.15	5.50
Hf	7.22	9.50	7.59	5.15	11.81	6.47	5.14
Ho	1.81	1.29	1.33	1.17	0.75	0.65	1.16
La	42.31	36.27	42.21	28.83	31.53	10.13	49.74
Lu	0.77	0.63	0.67	0.58	0.40	0.34	0.52
Mo	0.83	1.05	0.63	0.98	0.57	1.14	0.73
Nb	18.17	18.27	18.28	15.73	16.39	18.85	18.42
Nd	38.69	27.53	37.86	23.10	27.10	9.31	35.56
Ni	35.55	224.06	19.45	23.53	15.92	21.88	35.28
Pb	21.40	40.38	32.45	37.79	18.57	21.08	51.10
Pr	9.85	7.35	9.79	6.21	7.16	2.31	9.55
Rb	153.18	153.58	101.02	172.42	140.42	230.71	202.75
Sc	21.35	19.95	20.65	20.22	14.31	18.47	22.06
Sm	7.52	5.23	7.18	4.50	4.95	1.92	6.99
Sr	18.32	15.20	33.54	21.76	18.83	25.27	53.08
Ta	1.36	1.33	1.38	1.22	1.23	1.37	1.35
Tb	1.29	0.87	0.95	0.84	0.56	0.40	0.87
Th	20.61	18.91	20.98	19.92	17.45	20.05	20.43
Tm	0.74	0.62	0.59	0.56	0.35	0.35	0.50
U	4.84	7.11	6.92	4.08	4.70	17.79	5.98
V	116.66	206.09	126.60	106.20	74.34	108.61	120.46
Y	48.29	36.55	38.70	33.91	19.93	18.45	30.73
Yb	5.30	4.33	4.15	3.72	2.63	2.44	3.78
Zn	81.34	73.87	40.68	80.51	56.88	103.72	124.41
Zr	244.39	343.34	264.42	176.05	427.23	218.47	178.03

Appendix 17 The powder X-ray diffraction traces for the healing/cosmetic soils from Potshini (H1), Khokhwane (H2), Louwsburg (H3) and Nkandla (H4). C1 and C2 are the non-healing samples from Potshini and Khokhwane, respectively.

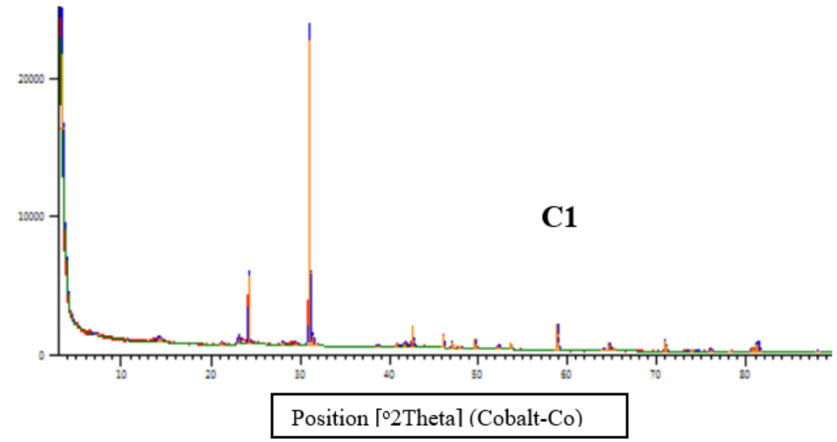


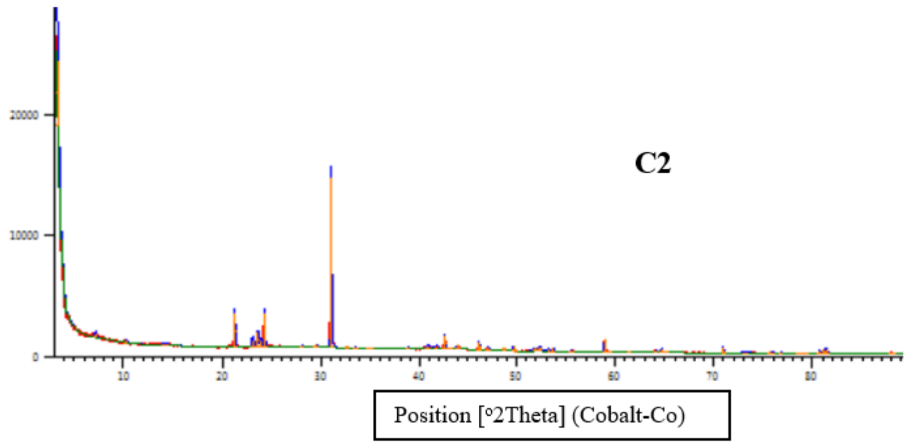






Appendix 17 Continued……………





Appendix 18 Total trace element composition (mg kg^{-1}) of the healing/cosmetic soil samples from Potshini (H1), Khokhwane (H2), Louwsburg (H3) and Nkandla (H4). C1 and C2 are the non-healing samples from Potshini and Khokhwane, respectively.

	Healing soils				Non-healing soils	
Trace element	H1	H2	H3	H4	C1	C2
Ba	72.23	277.88	104.90	500.55	78.15	72.08
Ce	53.17	110.47	47.63	76.05	74.03	68.56
Co	65.80	15.50	22.59	141.17	27.40	27.46
Cr	173.59	194.19	304.75	249.81	203.04	201.85
Cs	0.49	11.63	2.31	2.62	4.41	4.15
Cu	144.15	44.08	98.55	108.37	56.40	52.16
Dy	5.87	4.46	3.64	6.00	5.37	4.88
Er	3.37	2.94	2.25	3.83	3.54	3.27
Eu	1.62	1.01	0.86	1.45	1.09	1.11
Gd	5.30	4.18	3.82	5.41	5.17	4.28
Hf	4.17	11.05	4.47	12.70	19.98	20.50
Ho	1.20	0.93	0.77	1.27	1.12	1.04
La	18.24	27.39	22.52	21.25	19.64	17.89
Lu	0.46	0.50	0.33	0.62	0.60	0.60
Mo	0.91	1.33	1.31	1.45	2.01	2.00
Nb	24.58	22.96	14.11	11.82	17.99	16.71
Nd	22.09	24.01	20.65	24.00	24.76	22.01
Ni	102.93	43.75	128.85	86.06	66.64	65.01
Pb	2.98	35.89	10.14	13.50	17.90	17.93
Pr	5.12	6.31	5.34	5.74	6.16	5.30
Rb	2.60	89.05	20.23	20.62	34.56	33.73
Sm	5.03	5.04	4.13	5.42	5.49	4.84
Sr	17.57	15.58	8.47	6.65	7.81	7.43
Ta	1.38	1.63	0.59	0.82	1.23	1.24
Tb	0.88	0.62	0.53	0.89	0.83	0.73
Th	2.47	23.69	6.27	9.42	14.98	14.34
Tm	0.50	0.41	0.31	0.58	0.50	0.51
U	0.66	9.18	1.61	2.34	4.01	3.95
V	236.79	210.38	254.80	204.65	176.07	170.64
Y	30.86	24.87	18.85	32.87	26.79	25.11
Yb	3.44	3.16	2.38	4.15	3.97	3.86
Zn	63.11	47.64	60.05	73.19	72.40	75.69
Zr	163.73	411.04	173.70	470.92	736.73	751.51