APPENDIX L:
SOILS AND AGRICULTURAL POTENTIAL REPORT

REPORT

EIA PHASE SOIL, LAND USE, LAND CAPABILITY AND AGRICULTURAL POTENTIAL SURVEY:

PROPOSED ESKOM UCG PLANT ON THE FARMS TWEEDEPOORT 54-HS, STRYDKRAAL 53-HS, PALMIETSPRUIT 68-HS, KOPPIES KRAAL 56-HS, ROODEKOPJES 67-HS, WEILAND 59-HS, JAPTRAP 115-HS, RIETFONTEIN 66-HS, KLEIN RIETFONTEIN 117-HS AND BERGVLIET 65-HS, MPUMALANGA PROVINCE

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Declaration

I, Johan Hilgard van der Waals, declare that I –

- act as an independent specialist consultant in the fields of Soil Science and Agricultural Potential in this report on the
  EIA Phase Soil, Land Use, Land Capability and Agricultural Potential Survey – Proposed Eskom UCG Plant on the Farms Tweedepoort 54-HS, Strydkraal 53-HS, Palmietspruit 68-HS, Koppies Kraal 56-HS, Roodekopjes 67-HS, Weiland 59-HS, Japtrap 115-HS, Rietfontein 66-HS, Klein Rietfontein 117-HS and Bergvliet 65-HS, Mpumalanga Province
- do not have and will not have any financial interest in the undertaking of the activity, other than remuneration for work performed in terms of the Environmental Impact Assessment Regulations, 2006;
- have and will not have any vested interest in the proposed activity proceeding;
- have no, and will not engage in, conflicting interests in the undertaking of the activity;
- undertake to disclose, to the competent authority, any material information that have or may have the potential to influence the decision of the competent authority or the objectivity of any report, plan or document required in terms of the Environmental Impact Assessment Regulations, 2006; and
- will provide the competent authority with access to all information at my disposal regarding the application, whether such information is favourable to the applicant or not.

J.H. VAN DER WAALS
TERRA SOIL SCIENCE

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EIA Phase Soil, Land Use, Land Capability and Agricultural Potential Survey – Proposed Eskom UCG Plant on the Farms Tweedepoort 54-HS, Strydkraal 53-HS, Palmietspruit 68-HS, Koppies Kraal 56-HS, Roodekopjes 67-HS, Weiland 59-HS, Japtrap 115-HS, Rietfontein 66-HS, Klein Rietfontein 117-HS and Bergvliet 65-HS, Mpumalanga Province

1. TERMS OF REFERENCE

Terra Soil Science (TSS) was commissioned by Bohlweki-SSI Environmental (Pty) Ltd to conduct an EIA level soil, land use, land capability and agricultural potential survey for the proposed Eskom UCG Plant on the Farms Tweedepoort 54-HS, Strydkraal 53-HS, Palmietspruit 68-HS, Koppies Kraal 56-HS, Roodekopjes 67-HS, Weiland 59-HS, Japtrap 115-HS, Rietfontein 66-HS, Klein Rietfontein 117-HS and Bergvliet 65-HS in the Mpumalanga Province.

2. INTRODUCTION

An EIA level soil, land use, land capability and agricultural potential survey was conducted for the proposed Eskom UCG Plant and broader site. The underground coal gasification process involves a range of surface activities that include the drilling of access holes on a grid, the installation of a network of manifolds and pipes as well as all the construction activities (vehicles, construction worker movement, etc.) that is associated with this process. Post “mining” or extraction activities include the removal of all surface infrastructure and the sealing and capping of the boreholes.

3. DESCRIPTION OF THE SURVEY AREA

3.1 Survey Area Boundary

The broad survey area lies between 26° 58’ 02’’ and 27° 07’ 20’’ south and 29° 40’ 28’’ and 29° 56’ 07’’ east immediately south and west of the town of Amersfoort in the Mpumalanga Province (**Figure 1**). A more intensive survey was conducted for a site on the farm Roodekopjes about 7km southwest of the town of Amersfoort between 27° 02’ 57’’ and 27° 04’ 44’’ south and 29° 47’ 16’’ and 29° 49’ 49’’ east (**Figure 2**).

3.2 Survey Area Physical Features

The survey area lies on undulating terrain between 1600 and 1780 m above mean sea level. The geology of the area is dominated by dolerite, sandstone, grit and shale.

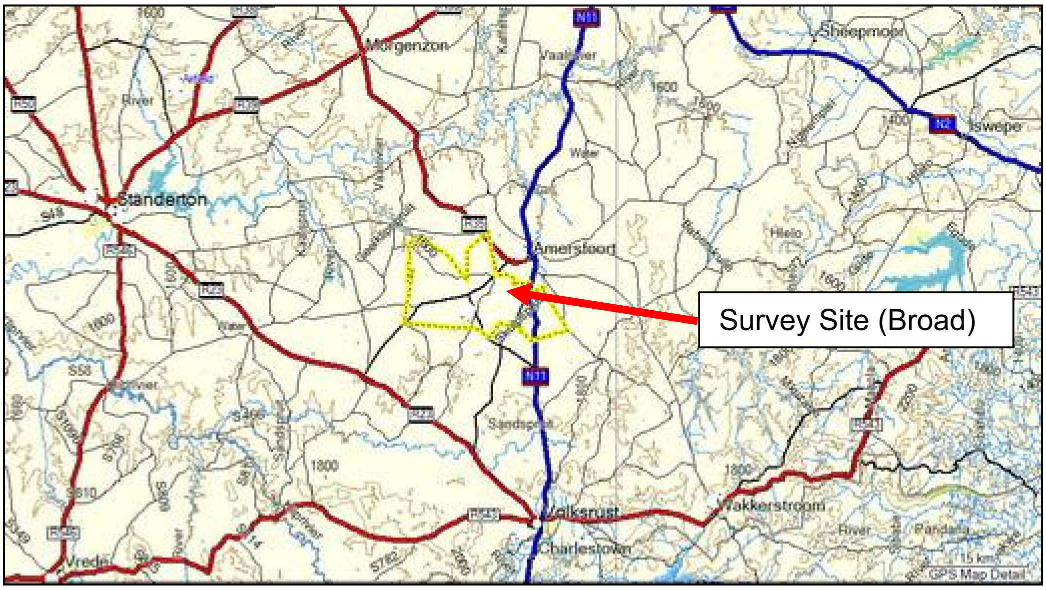


Figure 1 Location of the broad survey site

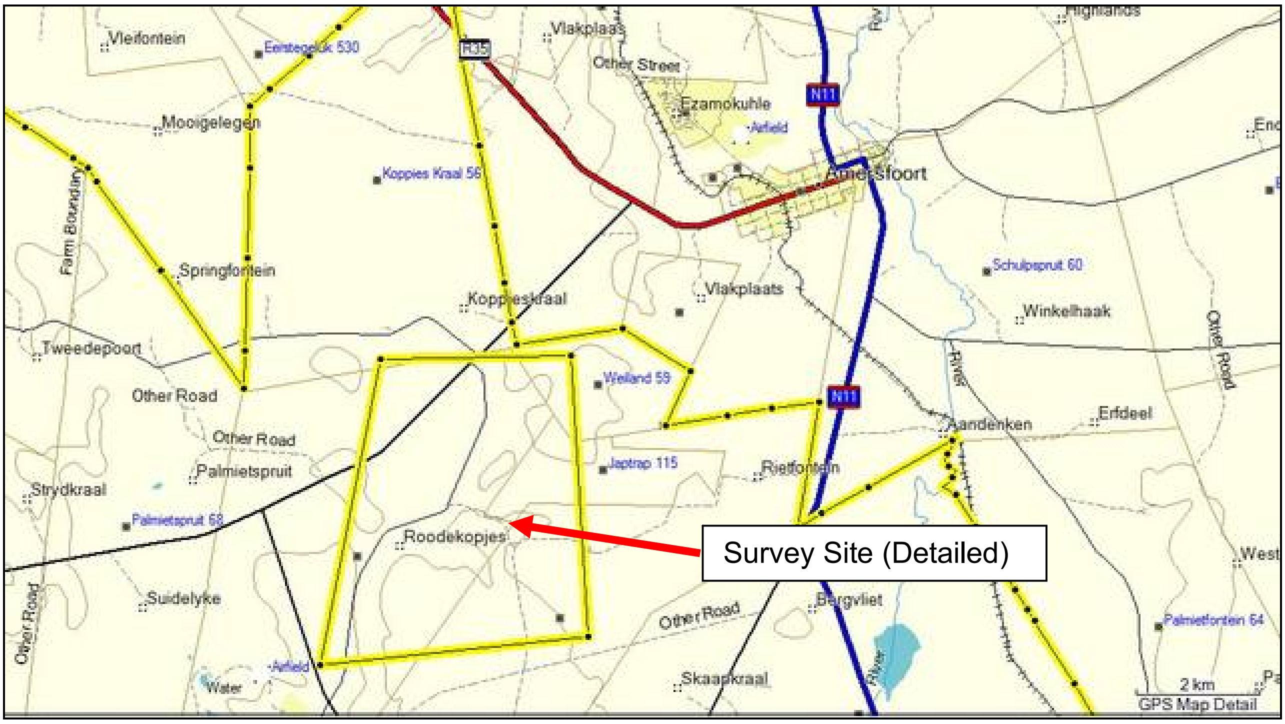


Figure 2 Location of the detailed survey site relative to the broad survey site

4. SOIL, LAND CAPABILITY, LAND USE SURVEY AND AGRICULTURAL POTENTIAL SURVEY

4.1 Method of Soil, Land Capability, Land Use Survey and Agricultural Potential Survey

The EIA soil, land capability, land use and agricultural potential surveys were conducted in five phases.

4.1.1 Phase 1: Land Type Data

Land type data for the site was obtained from the Institute for Soil Climate and Water (ISCW) of the Agricultural Research Council (ARC). The land type data is presented at a scale of 1:250 000 and entails the division of land into land types, typical terrain cross sections for the land type and the presentation of dominant soil types for each of the identified terrain units (in the cross section). The soil data is classified according to the Binomial System (MacVicar et al., 1977). The soil data was interpreted and re-classified according to the Taxonomic System (MacVicar, C.N. et al. 1991).

4.1.2 Phase 2: Aerial Photograph Interpretation and Land Use / Land Capability Mapping

The most up to date aerial photographs of the site were obtained from Google Earth. Additional orthophotos were obtained from the Directorate Surveys and Mapping in Mowbray. These images were used to interpret aspects such as land use and land cover as well as historic land uses such as cultivation. The Google image of the site was used during the field orientation (discussed below) to provide additional interpretable criteria such as vegetation, land cover and surface soil colour and soil characteristics.
The land capability survey was conducted using the results of the soil survey and land use interpretation as well as field observations and discussions with land users in the area.

4.1.3 Phase 3: Reconnaissance Soil Survey

A reconnaissance survey was conducted within the proposed mining area according to standard accepted methodology. The essence of the reconnaissance survey was to ascertain whether the land type data is correct in order to draw up the scoping phase report.

The reconnaissance survey consisted of the traversing of the site in a vehicle and on foot with the occasional auguring of soils on the site.

4.1.4 Phase 4: Semi-Detailed Free Grid Soil Survey

A semi-detailed free grid soil survey was conducted for an area on the farm Roodekopjes to determine the extent and axis of soil variation. Once the variability and axis of variability had been established the semi-detailed survey was expanded to easily accessible areas of the broader survey site. The semi-detailed free grid survey entailed the walking of transects along the axis of variation (perpendicular to the contours) and the auguring of holes at regular intervals to identify and classify the soils. Due to the homogeneity of the soils in the survey area (detailed and broad) the extension of the detailed study area to include the bulk of the broader site was deemed feasible. The results of the semi-detailed survey were used to draw up a soil map of the broader survey area using predictive soil mapping tools as well as physical survey points for verification.

4.1.5 Phase 5: Agriculture Potential Survey

The agriculture potential survey was conducted using the results of the soil survey as well as field observations and discussions with land users in the area. Land users were questioned regarding average and long-term yields of dryland crops as well as the long-term carrying capacity in terms of livestock.

4.1.6 Phase 6: Soil Sample Collection and Analysis

For the EIA phase 12 soil samples were collected at five different points in the detailed study area (**Figure 2**) and these were submitted to the Soil Science laboratory of the University of Pretoria for limited chemical and physical analysis. The following parameters were analyzed according to standard analysis procedures:

- Resistance and pH
- Phosphorus
- Extractable cations (Ca, Mg, K, Na)
- Texture (sand, silt, clay)

The results of the extractable cations analysis were recalculated to reflect values on an equivalent basis (cmol charge per kg of soil – cmol(+) kg^{-1}) and these values were expressed as a percentage of a sum of the values. This calculation is used to provide an indication of the degree of saturation of the soils' exchange complex as well as its relative composition. Values expressed on a mg kg^{-1} basis cannot be compared due to the differing valence of Ca, Mg, K and Na ions.

4.1.7 Phase 7: Interpretation of Soil Survey and Analysis Data

4.1.7.1 Soil Quality and Current Land Use

Soil quality parameters are qualitative and not quantitative in nature and therefore can strictly speaking not be measured. The generation of these parameters rests on a number of aspects of which the most important are the interpretation of quantitative parameters and the inferring of a value of these within a certain geographic/agronomic/economic setting. The soil quality parameters discussed in this report are the result of a number of years of Dr. van der Waals' experience of working in the agricultural and environmental fields on the Eastern Highveld.

4.1.7.2 Derived Soil Quality Parameters

A number of derivations can be made from the soil quality parameters inferred for the survey site. **Table 1** provides sets of criteria for the gauging of these parameters in order to provide a condensed overview of the status and properties of the soils on the survey site.

Table 1 Soil quality parameters and criteria for estimation

Property	Level	Criteria
Natural Fertility	Low	The essential nutrients consisting of macronutrients (N, P, K, Ca, Mg, S, Si, Na and Al) and micronutrients (Zn, Cu, Fe, Mn, B, Mo, Co and Cl) are available at levels much lower than the threshold extraction levels by annual crops. Fertilization should substantially exceed annual crop extraction levels to ensure a build up of the natural fertility
	Medium	The essential nutrients are available at levels similar to the threshold extraction levels of annual crops. Fertilization should exceed annual crop extraction levels to ensure a slow build up of the natural soil fertility
	High	The essential nutrients are available at levels higher than the threshold extraction levels by annual crops. Fertilization should meet annual crop extraction levels to maintain the natural fertility
Erodibility	Low	Soils with stable physical and chemical properties that occur on flat to gentle slopes ensuring low erosion susceptibility in the natural state. Few erosion protection measures are necessary
	Medium	Soils with low to moderately unstable physical or chemical properties or soils occurring on moderate to steep slopes. Sheet and rill erosion often occur in the natural state but may become severe when disturbed or due to any misuse such as overgrazing. Erosion protection measures are necessary
	High	Soils with unstable physical and chemical properties or soils occurring on very steep slopes. Rill and donga erosion often occur in the natural state and will become severe during any disturbance or misuse. Specialized erosion protection measures are necessary
Dry-land crop production potential	Low	Production is seriously limited by negative soil properties such as insufficient soil depth, very sandy textures, abrupt texture and structure transitions between horizons, very high clay contents, strong structured horizons, wet and water logged horizons, steep slopes and low fertility
	Medium	Production is limited by some negative soil property such as insufficient soil depth, very sandy textures, abrupt texture and structure transitions between horizons, very high clay content, strong structured horizons, wet and water logged horizons, steep slopes and low fertility
	High	Production is limited by very few negative soil properties such as insufficient soil depth, very sandy textures, abrupt texture and structure transitions between horizons, very high clay contents, strong structured horizons, wet and water logged horizons, steep slopes and low fertility
Irrigation potential	Low	Irrigation potential is seriously limited by negative soil properties such as insufficient soil depth, very sandy textures, abrupt texture and structure transitions between horizons, very high clay contents, strong structured horizons, wet and water logged horizons, steep slopes and low fertility
	Medium	Irrigation potential is limited by some negative soil properties such as insufficient soil depth, very sandy textures, very high clay contents, strong structured horizons, wet and water logged horizons, steep slopes and low fertility
	High	Irrigation potential is limited by very few negative soil properties such as insufficient soil depth, very sandy textures, very high clay contents, strong structured horizons, wet and water logged horizons, steep slopes and low fertility

4.1.7.3 Agricultural Potential

Agricultural potential is another parameter that is difficult to gauge as it is qualitative in nature rather than quantitative. The results of the soil survey (soil form and depth) and analysis (selected chemical and physical parameters) were interpreted in the context of potential and realistic land uses for the area. The expression of agricultural potential does not imply that this potential will be attained in all instances as management inputs (cannot be measured beforehand but can be planned for) vary considerably due to a range of human factors that cannot be assessed in this report.

4.1.7.4 Influences on Wetland Delineation

The soils on the site have characteristics that lead to difficult wetland delineations. This aspect is explained in detail.

4.2 Soil, Land Capability, Land Use and Agricultural Potential Survey Results

4.2.1 Phase 1: Land Type Data

The Eskom UCG mining area falls into the **Ea20**, **Ea22**, **Ea24** and **Ca2** land types (Land Type Survey Staff, 1972 - 2006). (Refer to **Map 1** for the land type map of the area.) Below follows a brief description of each of the land types that occur on the site.

Land Type Ea20
Soils: Higher lying landscape positions dominated by rock outcrops and shallow swelling soils. Midslope positions dominated by variable depth structured soils, often with swelling properties. Valley bottom positions dominated by poorly drained non-swelling soils and exposed streambeds.
Land capability and land use: Mainly dryland agriculture and extensive grazing.
Agricultural potential: Medium to low except for lower lying areas that constitute wetlands.

Land Type Ea22
Soils: Higher lying landscape positions dominated by rock outcrops and shallow structured soils. Midslope positions dominated by variable depth structured soils, often with swelling properties. Valley bottom positions dominated by poorly drained swelling soils and exposed streambeds.
Land capability and land use: Mainly dryland agriculture and extensive grazing.
Agricultural potential: Medium to low except for lower lying areas that constitute wetlands.

Land Type Ea24
Soils: Higher lying landscape positions dominated by rock outcrops and shallow swelling soils. Midslope positions dominated by variable depth structured soils, often with swelling properties. Valley bottom positions dominated by poorly drained non-swelling soils and exposed streambeds.
Land capability and land use: Mainly dryland agriculture and extensive grazing.
Agricultural potential: Medium to low except for lower lying areas that constitute wetlands.

Land Type Ca2

Soils: Landscape dominated by shallow yellow-brown apedal, distrophic soils in higher lying areas, variable depth bleached apedal soils in midslope positions and poorly drained structured soils of variable depth in low lying areas.
Land capability and land use: Mainly dryland agriculture and extensive grazing.
Agricultural potential: Medium to low except for lower lying areas that constitute wetlands.

4.2.2 Phase 2: Aerial Photograph Interpretation and Land Use / Capability Mapping

The interpretation of aerial photographs yielded eight land use categories. These categories, as well as the areas and percentages they cover, are presented in **Table 1**. **Map 2** provides the spatial results of the aerial photograph interpretation. The land capability mimics the current land use and as such is included in **Table 1**.

Table 1 Land use categories and surface areas for the Eskom UCG site

Land use	Land Capability	Area (ha)	Percentage (%)
Grasslands	Grazing	15451	71.9
Dryland Agriculture	Arable	5561	25.9
Dam	Wetland	161	0.7
Pan	Wetland	24	0.1
Infrastructure	-	304	1.4
Total		21502	100.0

4.2.3 Phase 3: Reconnaissance Soil Survey

The reconnaissance survey confirmed the data provided for the four land types. As a more detailed soil survey was conducted for the site the results of the reconnaissance survey will be incorporated with and reported with the results for the semi-detailed survey.

4.2.4 Phase 4: Semi-Detailed Free Grid Survey

The topography of the broader site is undulating hilly and as such there are numerous low ridges and hills interspersed with drainage depressions and stream/drainage channels. The geology is dominated by dolerite (with inclusions of sandstone, grit and shale) leading to the dominance of shallow to moderately deep structured soils, often with vertic properties in lower lying areas and drainage depressions. These properties have far reaching implications for different land uses and aspects such as wetland delineation exercise as described in the sections that follow below.

The soils on the site can be grouped into three main categories or groups namely: 1) shallow and rocky soils on convex topography; 2) variable depth structured soils in flat terrain outside drainage depressions and 3) structured and swelling soils in drainage depressions (concave topography). A detailed discussion of these groupings is provided below. **Map 3** indicates the spatial distribution of the soils on the site and the hectares and surface coverage are indicated in **Table 2**.

Table 2 Soil associations on the survey site and the areas they cover

Land use	Dominant Soil Forms (Codes)	Area (ha)	Percentage (%)
Shallow and rocky soils on convex topography	Rock / Shallow Soils (R/Sh)	7796	37.8
Variable depth structured soils in flat terrain outside drainage depressions	Sepane / Arcadia (Se/Ar)	8297	40.3
Structured and swelling soils in drainage depressions (concave topography)	Rensburg / Rock (Rg/R)	4508	21.9
No Data		902	
Total		21502	

4.2.4.1 Shallow and Rocky Soils on Convex Topography

The area dominated by shallow and rocky soils is situated mainly on convex topography – that is rock outcrops, hills and ridges as well as vast areas making up the higher lying parts of the landscape. The soils are predominantly of the Mispah (Orthic A-horizon / Hard Rock), Glenrosa (Orthic A-horizon / Lithocutanic B-horizon), shallow Arcadia (Vertic A-horizon / Unspecified – usually hard or weathering rock), Mayo (Melanic A-horizon / Lithocutanic B-horizon) and occasionally Milkwood (Melanic A-horizon / Hard Rock) forms. The texture of the A-horizons varies widely in that some are sandy (and sometimes bleached), some are clayey and some have very distinct structure. During the survey it was found that there is very little predictability in the distribution of the different properties. This is a result of the varying geology as well as topography on the site.

Photograph 1 Shallow and rocky soils on the site


Photograph 2 Shallow and rocky soils on the site (rock outcrop)


Photograph 3 Shallow and rocky soils on the site (rock outcrop)

Photograph 4 Shallow and rocky soils on the site (rocky Mispah)

Photograph 5 Shallow and rocky soils on the site (Mayo)


Photograph 6 Shallow and rocky soils on the site (Glenrosa)


Photograph 7 Shallow and rocky soils on the site (Mayo)

Photograph 8 Shallow and rocky soils on the site (Mispah)

Photograph 9 Shallow and rocky soils on the site (Mayo)

Photograph 10 Shallow and rocky soils on the site (shallow Arcadia)

Photograph 11 Shallow and rocky soils on the site (Mayo)

Photograph 12 Shallow and rocky soils on the site (Mispah)

Photograph 13 Shallow and rocky soils on the site (Glenrosa)

Photograph 14 Shallow and rocky soils on the site (Glenrosa)

4.2.4.2 Variable Depth Structured Soils in Flat Terrain (Outside Drainage Depressions)

The areas of flat terrain consist of a range of soils that vary from structured with swelling properties, to structured without swelling properties to sandy soil material overlying structured subsoils. The soils found in these areas do not occur in clear patterns and only a small degree of predictability is evident (as opposed to areas dominated by Plinthic Catena). Soil forms include Arcadia (Vertic A-horizon / Unspecified – usually hard or weathering rock), Sepane (Orthic A-horizon / Pedocutanic B-horizon / Unconsolidated material with signs of wetness) and Tukulu (Orthic A-horizon / Neocutanic B-horizon / Unspecified material with signs of wetness) soil forms with occasional occurrences of Glenrosa (Orthic A-horizon / Lithocutanic B-horizon), Klapmuts (Orthic A-horizon / E-horizon / Pedocutanic B-horizon), Hutton (Orthic A-horizon / Red Apedal B-horizon), Clovelly (Orthic A-horizon / Yellow-brown Apedal B-horizon), Westleigh (Orthic A-horizon / Soft Plinthic B-horizon), Avalon (Orthic A-horizon / Yellow-brown Apedal B-horizon / Soft Plinthic B-horizon) as well as the shallow soils listed earlier. **Photographs 15** to **24** provide an indication of the soil variation encountered on the site.

Photograph 15 Organic rich Orthic A-horizon of a Tukulu soil form on the site


Photograph 16 Upper Neocutanic B-horizon of a Tukulu soil form on the site


Photograph 17 Lower Neocutanic B-horizon of a Tukulu soil form on the site

Photograph 18 Soil profile of a Sepane soil form on the site

Photograph 19 Soil profile of a Sepane soil form on the site


Photograph 20 Clear eroded terraces of different soils on the site


Photograph 21 Eroded profile of a Sepane soil form on the site

Photograph 22 Excavated profile of a wet Glenrosa soil form on the site

Photograph 23 Excavated profile of a wet Mayo soil form on the site


Photograph 24 Eroded profile of a Sepane soil form on the site

4.2.4.3 Structured and Swelling Soils in Drainage Depressions (Concave Topography)

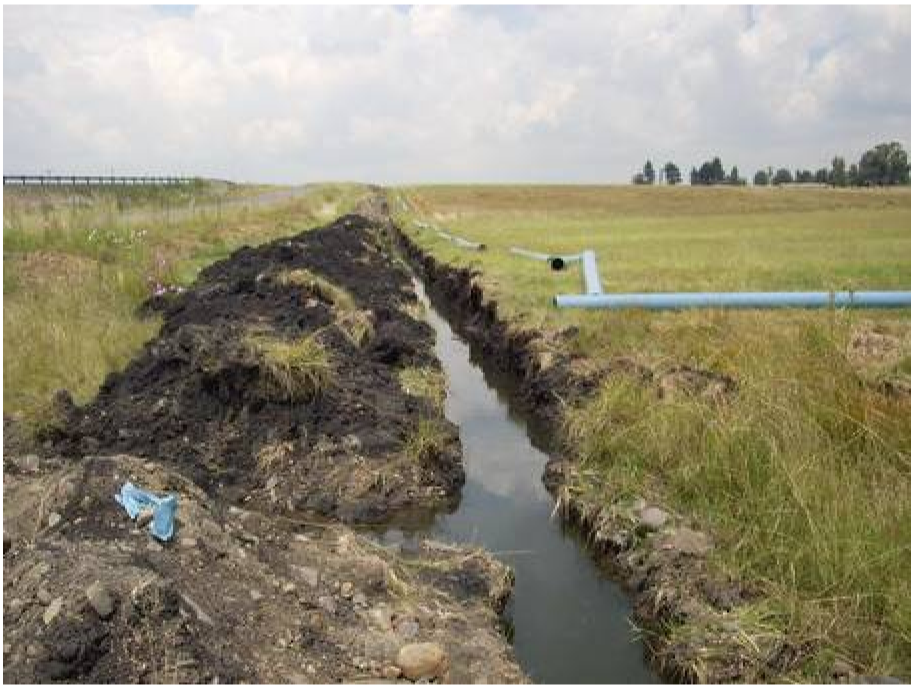
The drainage depressions also exhibited certain degree of soil form variability but one of the constant characteristics is the presence of swelling properties in the soils. The swelling properties imply that most of the soils in lower lying areas are dominated by smectite clay minerals. These clay minerals impart characteristics to the soils that manifest in the form of cracks and slickensides (**Photographs 25** and **26**). These soils are often associated with lime rich subsoil horizons that, when exposed, are characterised by copious amounts of lime nodules (concretions) (**Photograph 27**). Some of the soils had high clay contents without swelling properties indicating the presence of non-swelling 2:1 clay minerals. Even though the soils are dominated by similar clay minerals they vary in terms of soil form due to the variability in depth, rockiness and recently transported or eroded soil horizons / material. The soil forms are, amongst others: Rensburg (Vertic A-horizon / G-horizon), Arcadia (Vertic A-horizon / Unspecified – usually hard or weathering rock), Mayo (Melanic A-horizon / Lithocutanic B-horizon), Milkwood (Melanic A-horizon / Hard Rock), Willowbrook (Melanic A-horizon / G-horizon), Katspruit (Orthic A-horizon / G-horizon), Dundee (Orthic A-horizon / Stratified Alluvium) and Mispah (Orthic A-horizon / Hard Rock). **Photographs 28** to **35** provide additional indications of the soils on the site.

Photograph 25 Distinct slickensides in the G-horizon of a Rensburg soil form

Photograph 26 Soil of the Rensburg form in a drainage line

Photograph 27 Lime nodules associated with eroded and exposed G-horizons in under Vertic (and sometimes Melanic) A-horizons.

Photograph 28 Rocks within the drainage line



Photograph 29 Soil variation (but with similar clay characteristics) along a trench on the site

Photograph 30 Vertic properties in soil material overlying a horizon with distinct signs of waterlogging (gray colours) in a rocky matrix (Arcadia/Rensburg soil form)

Photograph 31 Vertic properties in soil material overlying a horizon with distinct signs of waterlogging (gray colours) in a rocky matrix (Arcadia/Rensburg soil form)

Photograph 32 Vertic properties in soil material overlying a horizon with distinct signs of waterlogging (gray colours) in a rocky matrix (Arcadia/Rensburg soil form)

Photograph 33 Rensburg soil form with transported material (distinctly layered) overlying it. In this case the overlying material is variable and often less than 500 mm thick and the Rensburg soil form was thus classified

Photograph 34 Rensburg soil form with transported material (distinctly layered) overlying it. In this case the overlying material is variable and often less than 500 mm thick and the Rensburg soil form was thus classified

Photograph 35 Eroded drainage channel soils (Rensburg soil form) that are common throughout the site

4.2.5 Phase 5: Agriculture Potential Survey

The agricultural potential of the site varies due to the discussed soils conditions. Large areas are covered by shallow soils that are of low potential. The higher potential soils have to a large extent already been tilled and are currently being used for dryland agriculture. The potential of the areas under crop production varies from low to high due to a range of soil conditions. In many cases these soils are structured and of high clay content but of limited depth. The main land use is grazing and it is also this land use that is considered to be the most viable for the bulk of the area.

4.2.6 Phase 6: Soil Sample Collection and Analysis

The positions where the soil samples were collected are indicated on **Map 3**. **Tables 3** and **4** indicate the analysis results as well as recalculations of data for the samples.

4.2.6.1 Phosphorus (Bray 1) (Table 3)

The Bray 1 extraction and analysis procedure for phosphorus is the preferred one for soils with pH levels below 7 and without free lime in the sample. Although there is considerable debate and research currently being conducted regarding the long-term P supply characteristics of soils to plants it is generally accepted in commercial agriculture that levels around 20 mg kg^{-1} constitute adequate levels for the production of maize on the Eastern Highveld. The P levels encountered in the samples from the site were all very low – consistent with normal background levels. As is expected from the chemistry of P in soil the highest levels were found in topsoil samples with a drastic decrease in depth in the soil profile.

4.2.6.2 Soil pH (Table 3)

One of the most often determined parameters of soils is pH. The pH is determined in the supernatant liquid of an aqueous suspension of soil after having allowed the sand fraction to settle out of suspension. The determination of the pH for the samples collected on the site was conducted in water rather than in a 1N KCl solution, as is sometimes done in SA. Although slightly more difficult to determine soil pH in water, it provides an intuitively better understood value than that determined in 1N KCl.

The pH values determined in the samples varied mostly according to current land use and soil form. Sandy samples often exhibit pH values below 7 on the Eastern Highveld and Vertic and Melanic soils often have pH values above 7 and even 8. The pH values determined in the soil samples are consistent with the soil forms identified at the sample points.

4.2.6.3 Resistance (R, ohm) (Table 3)

The resistance of a saturated soil paste (measured in ohm) is measured to provide an indication of the concentration of readily soluble salts in a soil sample. The resistance is the inverse of electrical conductivity (EC) and high resistance values indicate highly leached and low salt (basic cations, acidic cations, anions) content soils. Low resistance values indicate high salt content soils. The resistance values can often (but not always) be used to confirm observations about pH and the concentration of extractable cations (as discussed later in the report).

The range of the resistance values indicate that the soils are not excessively leached – in all probability due to the regularly occurring high clay content subsoils that have a significant influence of internal and external drainage of the profiles. This observation is confirmed by the relatively high levels of basic cations in the samples (see following section).

4.2.6.4 Exchangeable/Extractable Basic Cations (Ca, Mg, K, Na) (Tables 3 and 4)

The levels of the basic cations Ca, Mg, K and Na are determined in soil samples for agronomic purposes through extraction with a buffered (pH 7) ammonium acetate solution. The levels of the basic cations are determined on a range of flame emission or absorption spectrophotometric apparatus and their levels are expressed initially as milligrams per kilogram (mg kg^{-1}) of soil (**Table 3**). A lot is often read into these values but suffice to say that Ca levels dominate in most normal soils with Mg levels being lower and K levels even lower than Mg. Soils derived from base rich parent materials are often the exception in that Mg levels can exceed Ca levels. Sodium (Na) levels are often very low (absolute as well as compared to Ca, Mg and K) in highly leached soils but can reach relatively high levels in arid and improperly managed irrigation soils. Some workers use the ratios of Ca:Mg:K as indicators of soil health or fertility. High Na levels relative to the other cations, as well as Mg levels under some circumstances, often indicate salt affected soils that are referred to as “sodic” soils. This aspect is often also reflected in the R (or EC) and pH values of a soil sample.

Almost all of the sandier soil samples collected on the site exhibit the profile of Ca>Mg>K>>Na concentrations – as expected. The high clay content Vertic and Melanic soils often exhibit a slightly different profile of Ca=Mg>K>>Na.

Comparison of Ca, Mg, K and Na levels on an mg kg^{-1} basis (**Table 3**) is erroneous however as they are of differing valence. In order to facilitate comparison in the form of ratios the mg kg^{-1} values are recalculated taking into account the cation’s valence and molecular mass and the result is expressed as cmol(+) kg^{-1} (**Table 4**). Here the concentrations are expressed on an equivalent basis and ratios of the cations can be calculated through the expression of their percentage of an S-value (the sum of the concentrations of Ca, Mg, K and Na). Most of the soils on the site exhibit high base saturation levels due to the dominant effect of the base rich soil parent materials.

4.2.6.4 Texture and Texture Class (Table 3)

The sand, silt and clay content of a soil sample is determined through a sieve and hydrometer method and the determined quantities are expressed as a percentage proportional to the sum of the three fractions. The resultant value is termed the texture of a soil and the textural class can be obtained from plotting the three fractions on a textural triangle. The clay content of a soil is for all intents and purposes a constant value (with certain natural and analytical variation) for soils that are not radically disturbed through the addition of soil or other earthy materials.

Table 3 Soil analysis results of samples collected at the detailed survey site

Sample point	Depth (cm)	pH	P Bray-1 (mg kg^{-1})	Resistance (ohm)	Ammonium acetate extractable cations (mg kg^{-1})				Textural Fractions (%)			
					Ca	Mg	K	Na	Sand	Silt	Clay	Texture class
U1	0-20	6.0	1.00	2070	877	371	110	30	42	40	18	Loam
U1	20-40	6.8	0.25	1710	1087	460	96	77	38	36	26	Loam
U1	40-60	7.6	0.12	900	1669	716	120	155	29	35	36	Clay loam
U2	0-20	5.8	1.30	1060	1482	551	272	4	26	40	34	Clay loam
U3	0-20	6.3	1.90	1650	1364	745	112	8	24	50	26	Silt loam
U3	20-40	6.4	0.50	1570	1117	600	58	22	25	45	30	Clay loam
U3	40-60	7.0	0.24	1980	916	543	50	28	24	46	30	Clay loam
U4	0-30	6.9	0.98	680	3163	1274	104	20	38	30	32	Clay loam
U4	30-80	8.4	0.53	460	5480	2033	182	92	20	32	48	Clay
U4	80-100	8.5	0.16	480	4355	1632	123	212	35	25	40	Clay
U5	0-20	6.3	1.80	1360	1240	518	319	3	36	36	28	Clay loam
U5	20-40	6.4	0.23	1490	1058	515	237	2	32	32	36	Clay loam

Table 4 Recalculated Ca, Mg, K and Na values for the samples collected at the detailed survey site

Sample	Depth	Ca	Mg	K	Na	S-value	Ca	Mg	K	Na	Ca:Mg
	(cm)	(cmol$_c$kg^{-1})					(%)				
U1	0-20	4.39	3.05	0.28	0.13	7.85	55.9	38.9	3.6	1.7	1.4
U1	20-40	5.44	3.79	0.25	0.33	9.80	55.5	38.6	2.5	3.4	1.4
U1	40-60	8.35	5.89	0.31	0.67	15.22	54.8	38.7	2.0	4.4	1.4
U2	0-20	7.41	4.53	0.70	0.02	12.66	58.5	35.8	5.5	0.1	1.6
U3	0-20	6.82	6.13	0.29	0.03	13.27	51.4	46.2	2.2	0.3	1.1
U3	20-40	5.59	4.94	0.15	0.10	10.77	51.9	45.9	1.4	0.9	1.1
U3	40-60	4.58	4.47	0.13	0.12	9.30	49.3	48.1	1.4	1.3	1.0
U4	0-30	15.82	10.49	0.27	0.09	26.65	59.3	39.3	1.0	0.3	1.5
U4	30-80	27.40	16.73	0.47	0.40	45.00	60.9	37.2	1.0	0.9	1.6
U4	80-100	21.78	13.43	0.31	0.92	36.44	59.8	36.9	0.9	2.5	1.6
U5	0-20	6.20	4.26	0.82	0.01	11.29	54.9	37.8	7.2	0.1	1.5
U5	20-40	5.29	4.24	0.61	0.01	10.14	52.2	41.8	6.0	0.1	1.2

4.2.7 Phase 7: Interpretation of Soil Survey and Analysis Data

From the soil survey and analysis data as well as other field observations a number of soil quality, land use and land capability aspects can be interpreted. Below follows a dedicated discussion of each of these aspects.

4.2.7.1 Soil Quality and Current Land Use

The interpretation of the land use, land capability and reconnaissance soil survey results yielded a number of aspects that are of importance to the project.

4.2.7.1.1 Crop Production

The soils found on the site are generally of medium to low agricultural potential (dryland and irrigated cropping) due to a number of reasons. These are:

1. The soils are generally shallow with thin soil profiles overlying weathering rock or distinctly higher clay content subsoils.
2. The soils on the site are generally poorly drained with poor internal drainage that hampers aeration. These conditions are problematic during high rainfall years.
3. Due to the high clay content and shallow nature of most of the soils they tend to hold limited quantities of water. This is a restricting factor during low rainfall years.
4. Due to the abundance of rocks as well as the presence of strongly developed structure in most of the soils they are difficult to manage and tilling is very challenging.
5. Due to the poor drainage as well as the presence of swelling clays throughout the landscape the soils are very susceptible to erosion.

4.2.7.1.2 Soil Erosion and Degradation

As mentioned above the soils on the site are very susceptible to erosion. The susceptibility stems from the presence of swelling clays. These clays lead to low water infiltration rates into the soil meaning that surface runoff is a regular occurrence during rainfall events. Once the soil is exposed (through the removal of the vegetation cover or other disturbances) the swelling nature of the clays contributes to dispersive properties of the soil. Under these conditions there is no cohesion between soil particles and they are therefore readily dislodged and transported by water. This aspect is a very real threat to the stability of most of the soils on the site, especially those in drainage depressions and lines. As such eroded stream channels are observed throughout the site.

4.2.7.2 Derived Soil Quality Parameters

Table 5 provides the estimated soil quality parameters for the site as well as their status. It is important to note that the natural fertility of the high potential soils is considered to be low. These soils only attain their true potential after adequate fertilization.

Table 5 Estimated soil quality parameters for the various soil groups

Soil Group	Natural Fertility	Erodibility	Dry-land crop production potential	Irrigation potential
Shallow and rocky soils on convex topography	High	Medium	Low	Low
Variable depth structured soils in flat terrain outside drainage depressions	Medium to High	Medium	Low to Medium	Low
Structured and swelling soils in drainage depressions (concave topography)	High	Medium to High	Low	Very Low

4.2.7.3 Agricultural Potential

The agricultural potential of the soils on the detailed survey site is considered to be low in terms of crop production but medium to high in terms of extensive grazing. This is mainly due to the shallow and rocky nature of the soils as well as their swelling properties.

Post mining agricultural potential depends to a very large extent on the rehabilitation efforts by the mining company and the extent of the impacts of their activities. The baseline agricultural potential is low though meaning that at best the post mining agricultural potential will also be low.

4.2.7.4 Influences on Wetland Delineation

Wetland delineation is a very challenging exercise in areas dominated by vertic soils. This is mainly due to the almost complete absence of Fe-mottles in the soils that grade from the terrestrial to the wetland areas. There are a number of reasons that will be explained in more detail below.

In order to illustrate the stability and distribution of Fe minerals in soils the figure provided below was copied from page 124 of a book entitled “Soil Chemistry” by Bohn, et al., (1990). The essence is that when we consider reduction and oxidation reactions of Fe (in this case) in soils we have to use both the electron activity (driver of reducing conditions) and pH as they are intimately linked and dependent on each other. Suffice to say that for redox and mineral stability purposes they are indicated on the same graph. From Figure 4.6 it is clear that as the Eh decreases (increasing reducing conditions) the dominant Fe specis in solution changes from Fe^{3+} to Fe^{2+}. Once pH is included in the observation it is clear that distinct Fe mineral come into play. Applying the decreasing Eh values to Fe minerals at high pH it is clear that the dominant Fe mineral under oxidizing conditions is FeOOH (Goethite). As the conditions become more reducing the equilibrium shifts to $FeCO_3$ (Siderite) and thereafter to FeS_2 (Pyrite). Whereas goethite has a distinct colour in soil siderite and pyrite are less conspicuous in small quantities. It follows therefore that Fe minerals are much less visible in reduced soils than in oxidised soils. Vertic soils are dark coloured and it is therefore also clear that this dark colour will mask the presence of the above mentioned Fe minerals.

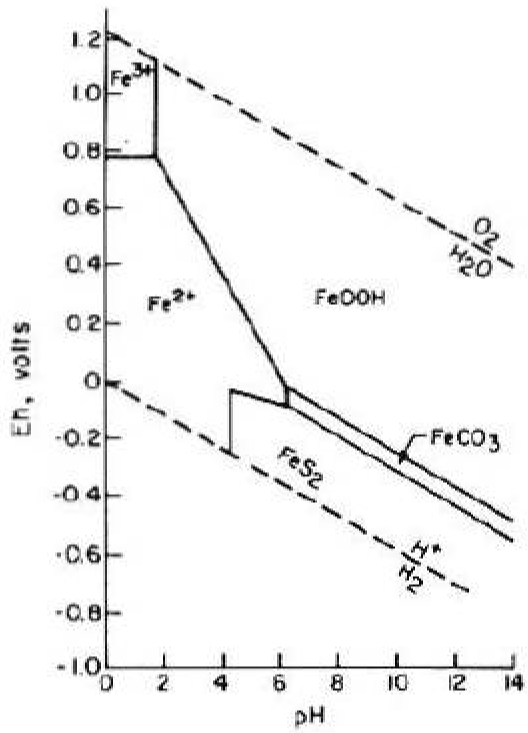


FIGURE 4.6. The *Eh*–pH diagram of various iron ions and compounds.
(From Bohn, et al., (1990) p124)

Another factor related to pH is the degree of reduction that is required to reduce Fe from its oxidised to its reduced state. From the graph it is clear that there is a steep decreasing gradient as the pH of the soil increases. This implies that much more intensive reducing conditions are required for the same degree of Fe reduction when high pH conditions (as those experienced in vertic soils) are compared to low pH conditions.

The situation becomes even more complex as other intermediate Fe minerals (blue green rusts) come into play. For a more detailed explanation of these refer to the attached document entitled "Blue-green Colouration in Soil: Introducing Layered Double Hydroxides" authored by PS Rossouw from Terra Soil Science (dated October 15th, 2010). The essence of the presence of blue-green rusts is that they are tints that occur extensively in poorly drained and poorly aerated soils such as G-horizons under Vertic A-horizons. These minerals are not stable and often disappear within a few minutes of exposure to the atmosphere. They in all probability form some of the most important Fe phases in vertic soils but disappear rapidly. Before they disappear it is also evident that these minerals visible against a grey matrix but poorly visible against a black or dark background.

In essence therefore, a number of factors, including degree of reduction, soil pH and dominant Fe minerals, conspire against the use of Fe indicators in vertic soils for the delineation of wetlands. There is no quick solution to this problem and delineators should use as many other indicators of wetland conditions in vertic soils as they can.

One word of caution: The wetland delineation guidelines (DWAF, 2005) indicate the Rensburg and Willowbrook soil forms as occurring in the permanent wetland zone. This is somewhat erroneous. Although these can occur in permanent wetland zones their formation is dependent on distinct cycling between wet and dry seasons. The development of 2:1 clays (found in these soils) depends on the accumulation of weathering products and clays in lower lying landscape positions. These clays are, depending on a range of factors, either swelling or non-swelling and their formation requires a distinct time (seasonally) where evaporation exceeds precipitation, with consequent drying of the soil, to lead to a concentration of bases (Ca and Mg). These clay minerals (such as smectite) often express themselves in the form of distinct cracks in Vertic soils. From this discussion it follows that the Rensburg and Willowbrook soils could only have formed in conditions that resemble a **seasonal wetland**. Drainage lines on the site can, if dominated by Rensburg soils, therefore not be classified as permanent wetlands unless there are other characteristics indicating conditions of permanent saturation.

5 ENVIRONMENTAL IMPACT ASSESSMENT AND MITIGATION MEASURES

5.1 Theoretical Background

In terms of soils human impacts are described as different forms of soil degradation. Soil degradation can be divided into the following classes and subclasses:

- Physical degradation
    - Compaction
    - Surface crusting
    - Erosion
    - Structural degradation/hardsetting
- Chemical degradation
    - Eutrophication
        - Nitrogen
        - Phosphorus
    - Soil organic carbon losses or alteration
    - Trace element and heavy metal pollution
    - Acidification
    - Salinisation and sodification
    - Nutrient mining
- Biological degradation
    - Soil microbial activity decrease/increase
    - Soil borne human, animal and plant pathogens
- Soil quality deterioration (compound effects)
- Soil health deterioration
- Soil destruction

5.1.1 Physical Degradation

The physical degradation of soils has many forms and causes. Compaction of soil usually occurs when vehicles, or other heavy loads, traverse soils or are placed on soil. The compactability of soil is a function of a range of parameters that include: the grading of the sand fraction, soil water content, weight of load, shape and deformation of tyre, frequency and number of passages, etc.

Compaction is the decrease in porosity of a soil with a subsequent increase in bulk density that leads to impeded water infiltration and root penetration. In most soils compaction can only be alleviated through the physical breaking up or ripping up of compacted layers. Refer to Håkansson, and Voorhees (1998) for a general description of soil compaction.

Surface crusting often has a physical and chemical component. Under dispersive conditions (sodium rich irrigation water, certain dominant soil minerals, removal of organic matter) raindrop impact can dislodge soil surface particles that then re-orientate to form a surface seal. Raindrop impact can also have localised impacts on the bulk density of soils in that it can lead to a degree of compaction. Animals (and vehicles) can under certain conditions cause surface disturbances and compaction through trampling. Refer to Valentin and Bresson (1998) for a general description of soil crusting.

Erosion of soil is caused by a range of factors that include other forms of physical degradation as well as chemical and biological degradation. The essence is that soil material is removed through the action of water or wind and transported further downslope or into water bodies. When most of the other factors of degradation are addressed soil erosion can usually be prevented or contained. Refer to Laflen and Roose (1998) for a general description of soil erosion.

Structural degradation and/or hardsetting occurs when soils with adequate structure are subjected to a range of activities (physical, chemical and biological degradation) with the effect that their structure is destroyed. In this sense “structure” refers to the type and grade of aggregation of soil particles under the influence of organic compounds, dominant clay minerals and its exchangeable cation composition. When the structure is degraded soil particles tend to reorganise as well as become “cemented” to form a denser or harder soil horizon. Compounds such as clays and soluble silicon can also act as binding agents for soil particles to lead to hardsetting. Refer to Mullins (1998) for a general description of hardsetting and to Kay (1998) for a discussion on soil structure and organic carbon.

5.1.2 Chemical Degradation

Chemical degradation of soils has varied and often complex causes and can in turn exacerbate physical and biological degradation. One of the most common human induced forms of degradation is the elevation of P and N levels in soils. Their effects in soils can be mitigated through a range of activities but these elements tend to be more problematic where terrestrial and aquatic ecosystems meet or overlap. The main effect of this form of degradation is the alteration of natural biological conditions in a landscape. Refer to Pierzynski et al. (1994) for further information on N and P in the environment.

One of the largest negative impacts of human farming and mining activities is the reduction of soil organic carbon levels. Soil organic carbon is readily oxidised or mineralised when soils are tilled and fertilizers added. The effect of soil organic carbon loss can be observed in increased soil physical problems (compaction, crust formation, etc.) as well as a decreased soil nutrient buffer capacity and altered biological activity and organism population composition. This currently forms one of the main focus areas regarding global climate change and carbon sequestration. Refer to Lal et al. (1998) for further information on organic carbon in soils.

Trace element and heavy metal pollution is mostly associated with industrial activities and effluents. There is a wide range of pollutants with an even wider range of effects on humans and the environment largely determined by the pollutant's chemical reactivity in soil and water. Remediation is case specific and requires proper assessment as well as understanding of the chemical equilibria of these elements in a range of environments. Refer to Davies (1980), Alloway (1995), Kabata-Pendias (1995) and Bourg (1995) for further information on trace elements and heavy metals in soils.

Soil acidification is often the product of agronomic practices, mine and industrial effluents and acid rain. The degree to which a soil can be acidified depends on the source and concentration of the acid as well as the buffer capacity of the soil. Soil acidification is often associated with coal mining due to the presence of pyrites in coal that form acids upon oxidation and exposure to water and air. Soil acidification is in most cases ameliorated through the addition/application of lime – of which there are a number of sources, some of which can also contribute to metal and trace element pollution. Refer to Pierzynski et al. (1994) for further information on acid rain and the environment as well as Sumner (1998) for information on soil acidification.

Salinisation is the build-up of salts in soils due to the use of high salt content irrigation water, salt containing waste spillages and/or poor drainage conditions in soils. In most cases the most detrimental effects are on plants and crops but concrete and iron structures can also be detrimentally affected through corrosion. Sodification is the increase of Na in a soil due to irrigation or pollution processes. Increased Na leads to the dispersion of clays in the soil with a subsequent degradation in structure as well as increasing the likelihood of surface crusts. Refer to Szabolcs (1998) for further information on salinisation of soils and to Rengasamy (1998) for further information on sodification of soils

Nutrient mining occurs mainly in subsistence farming areas where fertilizers are not readily accessible and soil nutrients are depleted through continuous cropping. This form of degradation also occurs in environments where commercial plant production practices are conducted without fertilisation – such as forestry. Reclamation of such degraded soils is relatively easy as a standard soil analysis should provide enough information for rectification.

5.1.3 Biological Degradation

Biological degradation of soil is difficult to determine when natural systems are considered. Microbial diversity is high in most soils and very little is understood or known about the microbial diversity, functioning or complex interactions that take place in soil. An increase in microbial activity in soils (above the natural background) can be just as detrimental to soil as a decrease in microbial activity. Where humans, animals and plants are concerned specific soil borne pathogens have been identified that could be detrimental. Pathogens have been the subject of more intense study than many other ubiquitous but "harmless" soil organisms and the epidemiology of many is well understood. Although not as spectacular as physical degradation of soils the biological degradation in the form of increased human, animal and plant pathogens can have far reaching implications on human, animal and plant communities. Examples are the parasites of humans and animals, cancer causing mycotoxins (toxins produced by soil borne fungi in food crops) in maize and groundnuts, several well known and emerging soil borne plant pathogens on maize, wheat, potato, banana, etc.

5.1.4 Soil Quality Deterioration

Soil quality is a term that is qualitative and it encompasses the interpretation of a range of quantitative parameters to make a pronouncement on a broader concept. Examples are “the suitability of soil for maize production” or the degree to which soils in a landscape can contribute to the mitigation of water pollution – taking into account chemical, physical and biological parameters. Soil quality parameters are not easily measured but it becomes very evident when soils lose certain natural abilities to mitigate detrimental environmental effects on crops, water quality and the quality of human life.

5.1.5 Soil Health Deterioration

The concept of “Soil Health” is a relatively new one and its interpretation is often as varied as the human population itself. Suffice to say that it links up with the concept of Soil Quality and there is an increasing effort underway to identify and quantify soil health parameters.

5.1.6 Soil Destruction

A drastic form of soil degradation is the total destruction of natural soil bodies and all the parameters that led to the formation of the soil in the first place. The best known example is opencast mining that drastically disturbs the soil profile itself, destroys the topographical and profile sequence of soils, alters the geohydrology of the landscape that in most cases determines the types and position of soil horizons and soil forms and that removes all original vegetation cover and animals from the specific soils. The effect is a combination of drastic physical, chemical and biological degradation of the soils on the mining site with the resultant drastic alteration in soil quality. The most desired approach in such cases is to rehabilitate the soils to the best possible state – taking into account the current technology and knowledge available as well as the financial means to conduct such rehabilitation. In many landscapes it is impossible to rehabilitate soils to near pre-mining conditions. This is especially true for areas where the geohydrology plays a major role in the determination of soil quality – such as the plinthic catena of the Eastern Highveld where water storage and movement within the top 1.5 m of the soil surface determine the types and distribution of diagnostic soil horizons as well as the agricultural potential in terms of available water for crop production.

5.1.7 Geographical Distribution of Soil Degradation Effects

A further factor determining the impacts of soil degradation processes and activities is their geographical distribution. These can be divided into point, one, two and three dimensional effects.

- Point effects are restricted to specific points in the landscape – such as boreholes, single electricity poles, etc.
- One dimensional (linear) effects are essentially power lines, roads (within limits), polluted streams flowing through a landscape – all line sources of pollutants and degrading activities.
- Two dimensional effects are essentially those that affect a specific land surface. Examples are the tilling and fertilization of land, atmospheric influences on land

qualities (pathogen distribution, deposition of air borne pollutants, Infrastructural development that takes up large tracts of land, etc.).

- Three dimensional effects are those where a large land surface is disturbed with a concurrent disturbing of soil and geological layers underlying that land. In this sense open cast mining is the best example.

Combinations of the above effects are common and the extent of the combination determines the degree and extent of soil degradation.

5.1.8 Soil Impacts vs Land Capability / Agriculture Impacts

The impacts of mining activities on soils are often drastic but this does not imply that the impacts on agriculture or land capability are the same (and vice versa). It is important to note that these impacts can and should be assessed separately as is done in the following sections.

5.2 Impact Criteria

The effect of mining activities on the soil, land capability and land use has been assessed using the ratings provided in **Table 6**. The criteria are limited in the sense that it does not account for the loss of agricultural production and related food security per se. Although additional criteria will not be introduced the overall impact on agricultural production and food security will be assessed in sections 5.4.4 and 5.4.5.

Table 6 Impact Assessment Criteria

CATEGORY	DESCRIPTION OF DEFINITION
Cumulative Impact	In relation to an activity, means the impact of an activity that in itself may not be significant but may become significant when added to the existing and potential impacts eventuating from similar or diverse activities or undertakings in the area.
Nature	A brief written statement of the environmental aspect being impacted upon by a particular action or activity.
Extent (Scale) • Site • Local • Regional • National • International	The area over which the impact will be expressed. Typically, the severity and significance of an impact have different scales and as such bracketing ranges are often required. This is often useful during the detailed assessment phase of a project in terms of further defining the determined significance or intensity of an impact. For example, high at a *local* scale, but low at a *regional* scale. • The immediate vicinity of the project (radius ±100 m). • Within a radius of 10-12 km of the project. • Provincial (and parts of neighbouring provinces). • The whole of South Africa. • Beyond the borders of South Africa.
Status	Denotes the perceived effect of the impact on the affected area.

CATEGORY	DESCRIPTION OF DEFINITION
• Positive (+) • Negative (-) • Neutral	• Beneficial impact. • Deleterious or adverse impact. • Impact is neither beneficial nor adverse. It is important to note that the status of an impact is assigned based on the *status quo* – i.e. should the project not proceed. Therefore not all negative impacts are equally significant.
Duration • Short-term • Medium-term • Long-term • Permanent	Indicates what the lifetime of the impact will be. • 0 - 10years • 11 - 20 years • Impact will cease after the operational life of the activity • Permanent
Probability • Improbable • Probable • Highly probable • Definite	Describes the likelihood of an impact actually occurring. • Possibility of the impact materialising is very low • Distinct possibility that the impact will occur • Most likely that the impact will occur • Impact will occur regardless of any preventative measures (i.e. mitigation)
Intensity • Low • Medium • High	Describes whether an impact is destructive or benign. • Impact affects the environment in such a way that natural, cultural and social functions and processes are not affected • Effected environment is altered, but natural, cultural and social functions and processes continue albeit in a modified way • Natural, cultural and social functions and processes are altered to extent that they temporarily or permanently cease
Significance • Low • Medium • High • Very High	The significance of an impact is determined through a synthesis of <u>all</u> of the above aspects. • No influence. • Will have an influence. • Will have an influence on decision-making regardless of mitigation. • Fatal flaw (an impact that is unable to be mitigated to within an acceptable level. A fatal flaw can also be regarded as any problem, issue or conflict (real or perceived) that could result in a proposed project being rejected or stopped).

We would like to compare the significance prior to mitigation and after. Furthermore, in the Conclusions and Recommendations chapter we will combine all of the impact tables, therefore consistency amongst the specialist reports is key.

5.3 List of Activities for the Site

Table 7 lists the proposed activities for the site. The last two columns in the table list the anticipated forms of soil degradation and geographical distribution of the impacts.

Table 7 List of activities and their associated forms of soil degradation

Activity	Form of Degradation	Geographical Extent	Comment (Section described)
Construction Phase			
Drilling of holes and associated vehicle movement	Physical degradation (surface)	Two dimensional	Impact small due to localised nature (Section 5.4.1.1)
Construction of manifold system and pipes	Physical degradation (surface)	Two dimensional	Impact small due to localised nature (Section 5.4.1.2)
Construction of temporary buildings and other infrastructure	Physical degradation (compound)	Two dimensional	(Section 5.4.1.3)
Construction Phase Related Effects			
Vehicle operation on site	Physical and chemical degradation (hydrocarbon spills)	Mainly point and one dimensional	(Section 5.4.1.4)
Dust generation	Physical degradation	Two dimensional	(Section 5.4.1.5)
Dust suppression	Chemical degradation	One and potentially two dimensional	(Section 5.4.1.6)
Operation Phase			
Operation and gas extraction	No additional degradation	No additional degradation	No additional degradation (Section 5.4.2.1)
Operation Phase Related Effects			
Vehicle operation on site	Physical and chemical degradation (hydrocarbon spills)	Mainly point and one dimensional	(Section 5.4.2.2)
Dust generation	Physical degradation	Two dimensional	(Section 5.4.2.3)
Dust suppression	Chemical degradation	One and potentially two dimensional	(Section 5.4.2.4)
Decommissioning Phase			
Capping and sealing of boreholes	No additional degradation	No additional degradation	No additional degradation (Section 5.4.3.1)
Removal of manifold system and pipes	No additional	No additional	No additional

Activity	Form of Degradation	Geographical Extent	Comment (Section described)
	degradation	degradation	degradation (Section 5.4.3.2)
Rehabilitation of access roads and drill areas	No additional degradation	No additional degradation	No additional degradation (Section 5.4.3.2)
Vehicle operation on site	Physical and chemical degradation (hydrocarbon spills)	Mainly point and one dimensional	(Section 5.4.3.3)
Dust generation	Physical degradation	Two dimensional	(Section 5.4.3.4)
Dust suppression	Chemical degradation	One and potentially two dimensional	(Section 5.4.3.5)

5.4 Assessment of the Impacts of Activities

Many of the impacts are generic and their impacts will remain similar for most areas on the site. The generic activity will therefore be assessed. The impacts associated with the different activities have been assessed below for each activity. These impacts have been summarized in **Table 16**.

5.4.1 Construction Phase

5.4.1.1 Drilling of Holes and Associated Vehicle Movement

Table 8 presents the impact criteria and a description with respect to soils, land capability and land use for the drilling of holes and associated vehicle movement.

Table 8 Drilling of holes and associated vehicle movement impacts

Criteria	Description
Cumulative Impact	The cumulative impact of this activity will be significant and will contribute to altered land use patterns and soil quality after mining.
Nature	This activity entails the movement of a drill rig and the drilling of holes on a grid. Soils will impacted directly through wheels and the hole that is drilled with the traffic of the drilling team
Extent	Site: The impact is two dimensional but then limited to the immediate area that is being drilled
Status	Negatiive
Duration	Long-term
Probability	Definite
Intensity	Medium
Significance of impact	Soils: High Land Capability: High – unless mining does not continue

	Land Use: High – unless mining does not continue
Mitigation	None possible. Limit extent as far as possible

5.4.1.2 Construction of Manifold System and Pipes

Table 9 presents the impact criteria and a description with respect to soils, land capability and land use for the construction of a manifold system and pipes.

Table 9 Construction of a manifold system and pipes

Criteria	Description
Cumulative Impact	The cumulative impact of this activity will be significant and will contribute to altered land use patterns and soil quality after mining.
Nature	This activity entails the construction of a system of pipes with manifolds. Soils will impacted directly through wheels of vehicles
Extent	Site: The impact is two dimensional but then limited to the immediate area of construction
Status	Negatiive
Duration	Long-term
Probability	Definite
Intensity	Medium
Significance of impact	Soils: High Land Capability: High – unless mining does not continue Land Use: High – unless mining does not continue
Mitigation	None possible. Limit extent as far as possible

5.4.1.3 Construction of Temporary Buildings and Other Infrastructure

Construction activities, whether for temporary or permanent structures, have very generic impacts. **Table 10** presents the impact criteria and a description with respect to soils, land capability and land use for the construction of temporary buildings and other infrastructure.

Table 10 Assessment of impacts of the construction of temporary buildings and other infrastructure

Criteria	Description
Cumulative Impact	The cumulative impact of this activity will be significant and will contribute to altered land use patterns and soil quality after mining.
Nature	This activity entails the construction buildings and infrastructure that will alter foundation conditions in soil
Extent	Site: The impact is two dimensional but then limited to the immediate area of construction
Status	Negatiive
Duration	Long-term
Probability	Definite
Intensity	Medium
Significance of impact	Soils: High Land Capability: High – unless mining does not continue Land Use: High – unless mining does not continue
Mitigation	None possible. Limit extent as far as possible

5.4.1.4 Vehicle Operation on Site

It is assumed that vehicle movement will be restricted to the construction site, immediate mining site and established roads. Vehicle impacts in this sense are restricted to spillages of lubricants and petroleum products. **Table 11** presents the impact criteria and a description with respect to soils, land capability and land use for the operation of vehicles on the site.

Table 11 Assessment of impact of vehicle operation on site

Criteria	Description
Cumulative Impact	The cumulative impact of this activity will be small if managed.
Nature	This activity entails the operation of vehicles on site and their associated impacts in terms of spillages of lubricants and petroleum products
Extent	Site: The impact is two dimensional but then limited to the immediate area of construction and vehicle operation
Status	Negatiive
Duration	Long-term
Probability	Probable
Intensity	Low
Significance of impact	Soils: Medium Land Capability: Medium – unless mining does not continue Land Use: Medium – unless mining does not continue
Mitigation	Maintain vehicles, prevent and address spillages

5.4.1.5 Dust Generation

Generated dust can impact large areas depending on environmental and climatic conditions. **Table 12** presents the impact criteria and a description with respect to soils, land capability and land use for dust generation on the site.

Table 12 Assessment of impact of dust generation on site

Criteria	Description
Cumulative Impact	The cumulative impact of this activity will be small if managed but can have widespread impacts if ignored.
Nature	This activity entails the operation of vehicles on site and their associated dust generation
Extent	Local: The impact is diffuse (depending on environmental and climatic conditions) and will probably be limited to within 3 – 5 km of the site
Status	Negatiive
Duration	Long-term
Probability	Probable
Intensity	Low
Significance of impact	Soils: Medium Land Capability: Medium – unless mining does not continue Land Use: Medium – unless mining does not continue
Mitigation	Limit vehicle movement to absolute minimum

5.4.1.6 Dust Suppression

Dust suppression activities take place on dirt roads and there are a range of dust suppression techniques. Without prior knowledge of the specific technique it is assumed that various compounds will be sprayed onto the roads and that these compounds could have negative effects on the environment. **Table 13** presents the impact criteria and a description with respect to soils, land capability and land use for the suppression of dust on the site.

Table 13 Assessment of impact of dust suppression on site

Criteria	Description
Cumulative Impact	The cumulative impact of this activity will be small if managed but can have widespread impacts if ignored..
Nature	This activity entails the active dust suppression on the site
Extent	Site: impact limited to the immediate roadside
Status	Negatiive
Duration	Long-term
Probability	Probable
Intensity	Low
Significance of impact	Soils: Medium Land Capability: Medium – unless mining does not continue Land Use: Medium – unless mining does not continue
Mitigation	Limit vehicle movement to absolute minimum

5.4.2 Operational Phase

5.4.2.1 Operation and Gas Extraction

This activity will have no additional impacts as compared to the establishment of infrastructure and drilling.

5.4.2.2 Vehicle Operation on Site

See point 5.4.1.4

5.4.2.3 Dust Generation

See point 5.4.1.5

5.4.1.4 Dust Suppression

See point 5.4.1.6

5.4.3 Decommissioning Phase

5.4.3.1 Capping and Sealing of Boreholes

This activity will have no additional impacts and has been addressed under the duration under point 5.4.1.1.

5.4.3.2 Removal of Manifold System and Pipes

This activity will have no additional impacts and has been addressed under the duration under point 5.4.1.2.

5.4.3.3 Rehabilitation of access roads and drill areas

This activity will have no additional impacts and has been addressed under the duration under points 5.4.1.1 and 5.4.1.2.

5.4.4 Overall Impact of Mining on Agricultural Production and Food Security

Table 14 presents the overall (cumulative) impact on agricultural production and food security.

Table 14 Assessment of impact on agricultural production and food security

Criteria	Description
Cumulative Impact	The cumulative impact of this activity will be low due to a low baseline agricultural production for the area.
Nature	This aspect entails the impact on agricultural production in general
Extent	Site: The impact is two dimensional but then limited to the immediate area of construction and mining

Status	Negatiive
Duration	Long-term
Probability	Definite
Intensity	Low to Medium
Significance of impact	Land Capability: Medium – unless mining does not continue Land Use: Medium – unless mining does not continue
Mitigation	None possible. Limit extent as far as possible

5.4.5 Overall Impact of Mining on Soils

Table 15 presents the overall (cumulative) impact on soils.

Table 15 Assessment of impact on agricultural production and food security

Criteria	Description
Cumulative Impact	The cumulative impact of this activity will be low due to the localised nature of the soil impacts.
Nature	This aspect entails the impact on soils and soil properties such as soil profiles, horizonation and surface disturbance
Extent	Site: The impact is two dimensional but then limited to the immediate area of construction and mining
Status	Negatiive
Duration	Permanent
Probability	Definite
Intensity	High
Significance of impact	High
Mitigation	None possible. Limit extent of impact as far as possible

Table 16 Assessment of Impacts

Activity	Extent	Status	Duration	Probability	Intensity	Significance
Categories	**Site**	**Positive**	**Short-term**	**Improbable**	**Low**	**Low**
	Local	**Negative**	**Medium-term**	**Probable**	**Medium**	**Medium**
	Regional	**Neutral**	**Long-term**	**Highly Probable**	**High**	**High**
	National		**Permanent**	**Definite**		**Very High**
	International					
Impacts						
Construction Phase						
Drilling of holes and associated vehicle movement	Site	Negative	Long-term	Definite	Medium	High
Construction of manifold system and pipes	Site	Negative	Long-term	Definite	Medium	High
Construction of temporary buildings and other infrastructure	Site	Negative	Long-term	Definite	Medium	High
Construction Phase Related Effects						
Vehicle operation on site	Site	Negative	Long-term	Probable	Low	Medium
Dust generation	Local	Negative	Long-term	Probable	Low	Medium
Dust suppression	Site	Negative	Long-term	Probable	Low	Medium
Operation Phase						
Operation and gas extraction	No additional impacts					
Operation Phase Related Effects						
Vehicle operation on site	Site	Negative	Long-term	Probable	Low	Medium
Dust generation	Local	Negative	Long-term	Probable	Low	Medium
Dust suppression	Site	Negative	Long-term	Probable	Low	Medium
Decommissioning Phase						
Capping and sealing of boreholes	No additional impacts					
Removal of manifold system and pipes	No additional impacts					

Activity	Extent	Status	Duration	Probability	Intensity	Significance
Rehabilitation of access roads and drill areas	No additional impacts					
Vehicle operation on site	Site	Negative	Long-term	Probable	Low	Medium
Dust generation	Local	Negative	Long-term	Probable	Low	Medium
Dust suppression	Site	Negative	Long-term	Probable	Medium	Medium
Overall impact of mining on agricultural production and food security	Site	Negative	Long-term	Definite	Medium	Medium
Overall impact of mining on soil	Site	Negative	Long-term	Definite	Low	Medium

6. SOIL IMPACTS AND SENSITIVITY ANALYSIS

The overall impacts on the soils of the site due to the proposed mining activities are significant. The significance of these impacts cannot be mitigated in full due to a number of restrictions associated with the types of soils and their characteristics. Due to the dominantly low agricultural potential of the site the broader significance of these impacts is not considered to be significant and impacts will therefore be localised to the immediate site.

Due to the specific properties of the soils on the site a number of aspects have to be noted and incorporated into the mining procedures and planning for post mining rehabilitation. The main of these aspects is the erodibility of the soils once the vegetation cover has been removed. The following have to be addressed / adhered to in detail to mitigate the impact of the mining activities:

1. Vehicle movement has to be restricted to a distinct grid in order to prevent degradation of any additional land or parts of land.
2. Vehicle movement has to be restricted to an absolute minimum that is required for the mining exercise. Unnecessary movement of vehicles will increase the degradation of paths and dirt roads leading to an increased erosion risk.
3. Drill rigs should remain stationary for as long a time as possible without unnecessary movement.
4. A grass bedding can be considered for the area under the drill rig tyres to prevent sinking into wet soils once the rainy season starts.
5. Boreholes should be rehabilitated once all infrastructure has been removed. Soil erosion mitigation measures should be implemented on each of the borehole sites to ensure minimal land degradation once mining has ceased.

A sensitivity analysis was conducted and the results are indicted on **Map 4**.

7. CONCLUSIONS AND RECOMMENDATIONS

The soils found on the site of the proposed Eskom UCG project are mainly restricted to structured soils of shallow to variable depth. These soils can be divided into three main categories namely 1) shallow and rocky soils on convex topography; 2) variable depth structured soils in flat terrain outside drainage depressions and 3) structured and swelling soils in drainage depressions (concave topography). The soils found on the site pose a challenge in terms of wetland delineation due to their specific chemical and mineralogical composition.

The main land use is grassland used for extensive grazing. A limited area is used for dryland agriculture and the agricultural potential of these areas is relatively low due to the dominance of structured and limited depth soils.

The proposed mining process will impact large areas but soil conditions will not be altered drastically due to the characteristics of the soils. In the case of swelling soils their self-mulching nature will lead to the disappearance of small disturbances over time. It is anticipated that the grazing potential of the impacted areas will be negatively impacted but it is possible that this potential will improve with time as the signs of impacts fade.

The major risk to the soils is erosion due to the removal of the vegetation cover. All mining construction activities should take into account the erodibility of the soils and make provision for its prevention.

The overall impacts on soils and agricultural potential are considered to be low due to a low baseline. However, the impact area is considered to be large and as such the activities can impact negatively on the low intensity land use of extensive grazing.

References

Alloway, B.J. 1995. origin of heavy metals in soils. *In* Alloway, B.J., (Ed.). Heavy Metals in Soils. Blackie Academic & Professional, Suffolk, pp 38-57.

Bohn, H.L., McNeal, B.L., & O'Connor, G.A. 1990. Soil Chemistry. 3rd Ed. John Wiley & Sons, Inc. New York, p 307.

Bourg, A.C.M. 1995. Speciation of Heavy Metals in Soils and Groundwater and Implications for Their Natural and Provoked Mobility. *In* Salomons, W., Förstner, U., & Mader, P., (Eds). *Heavy metals*. Springer-Verlag, Berlin, p 19-31

Cole, G.M. 1994. Assessment and Remediation of Petroleum Contaminated Sites. Lewis Publishers / CRC Press, Boca Raton, FL.

Davies, B.E., (Ed.) 1980. Applied Soil Trace Elements. Wiley, New York.

Department of Water Affairs and Forestry (DWAF). 2005. A practical field procedure for identification and delineation of wetland and riparian areas. DWAF, Pretoria.

Håkansson, I., & Voorhees, W.B. 1998. Soil Compaction. *In* Lal,. R, Blum, W.H., Valentin, C., & Stewart, B.A., (Eds). *Methods for assessment of soil degradation*. CRC Press, pp 167-179.

Kabata-Pendias, A. 1995. Agricultural Problems Related to Excessive Trace Metal Contents of Soils. *In* Salomons, W., Förstner, U., & Mader, P., (Eds). *Heavy metals*. Springer-Verlag, Berlin, pp3-18

Kay, R.D. Soil Structure and Organic Carbon: A Review. 1998. *In* Lal,. R, Blum, W.H., Valentin, C., & Stewart, B.A., (Eds). *Methods for assessment of soil degradation*. CRC Press, pp 169-197.

Laflen, J.M., & Roose, E.J. 1998. Methodologies for Assessment of Soil Degradation Due to Water Erosion. *In* Lal,. R, Blum, W.H., Valentin, C., & Stewart, B.A., (Eds). *Methods for assessment of soil degradation*. CRC Press, pp 31-55.

Lal, R., Kimble, J.M., and Follet, R.F. 1998. Pedospheric Processes and the Carbon Cycle. *In* Lal, R., Kimble, J.M., Follet, R.F., & Stewart, B. A., (Eds) *Advances in Soil Science: Soil processes and the carbon cycle*. CRC Press, pp1-8.

Land Type Survey Staff. 1972 – 2006. Land Types of South Africa: Digital map (1:250 000 scale) and soil inventory databases. ARC-Institute for Soil, Climate and Water, Pretoria.

MacVicar, C.N. et al. 1977. Soil Classification. A binomial system for South Africa. Sci. Bull. 390. Dep. Agric. Tech. Serv., Repub. S. Afr., Pretoria.

MacVicar, C.N. et al. 1991. Soil Classification. A taxonomic system for South Africa. *Mem. Agric. Nat. Resour. S.Afr.* No.15. Pretoria.

Mullins, C.E. Hardsetting. 1998. *In* Lal,. R, Blum, W.H., Valentin, C., & Stewart, B.A., (Eds). *Methods for assessment of soil degradation*. CRC Press, pp 109-127.

Pierzynski, G.M., Sims, J.T., & Vance, G.F., 1994. Soils and Environmental Quality. Lewis, Boca Raton.

Rengasamy, P. 1998. Sodic Soils. . *In* Lal,. R, Blum, W.H., Valentin, C., & Stewart, B.A., (Eds). *Methods for assessment of soil degradation*. CRC Press, pp265-277.

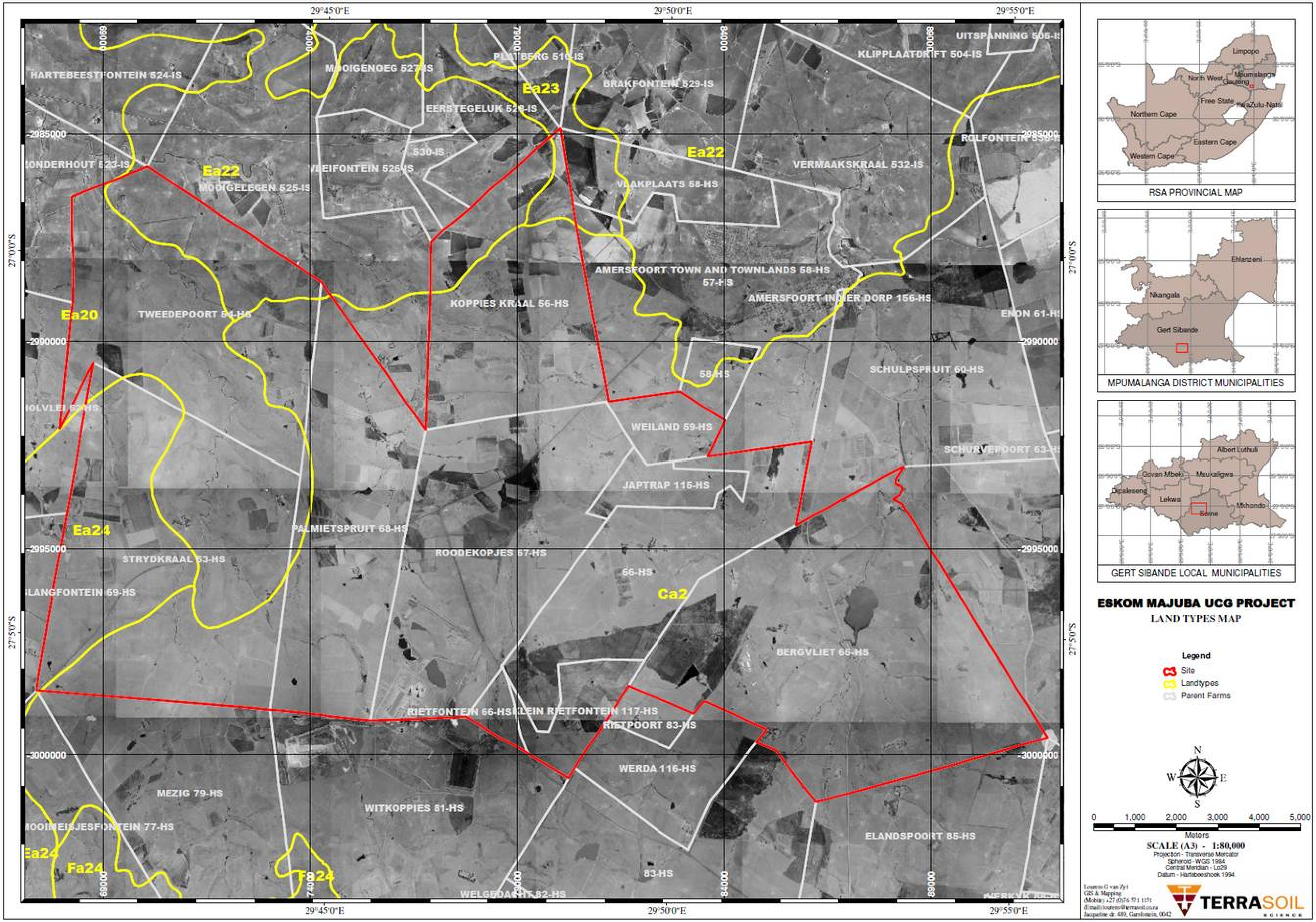
Steenekamp, P.I. 2007. Soil, land capability and land use assessment of Tweefontein and Goedgevonden Divisions: (Waterpan, Boschmans, Witcons and Goedgevonden Collieries). Rehab Green Monitoring Consultants CC. Report No: RG/2005/05/17

Sumner, M.E. 1998. Acidification. *In* Lal,. R, Blum, W.H., Valentin, C., & Stewart, B.A., (Eds). *Methods for assessment of soil degradation*. CRC Press, pp213-228

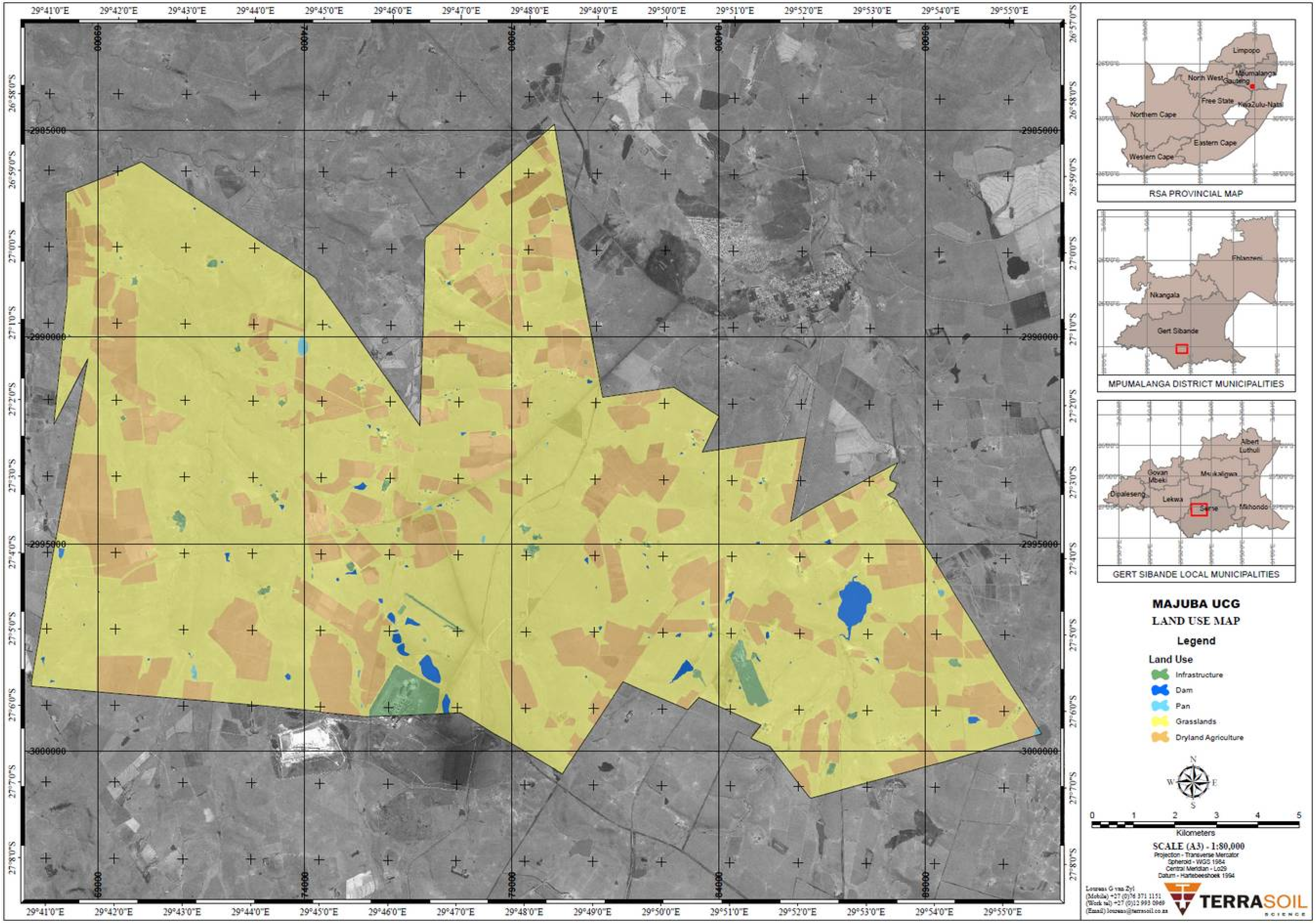
Szabolcs, I. 1998. Salt Buildup as a Factor of Soil Degradation. *In* Lal,. R, Blum, W.H., Valentin, C., & Stewart, B.A., (Eds). *Methods for assessment of soil degradation*. CRC Press, pp253-264.

Valentin, C., & Bresson, L.M. 1998. Soil Crusting. *In* Lal,. R, Blum, W.H., Valentin, C., & Stewart, B.A., (Eds). *Methods for assessment of soil degradation*. CRC Press, pp 89-107.

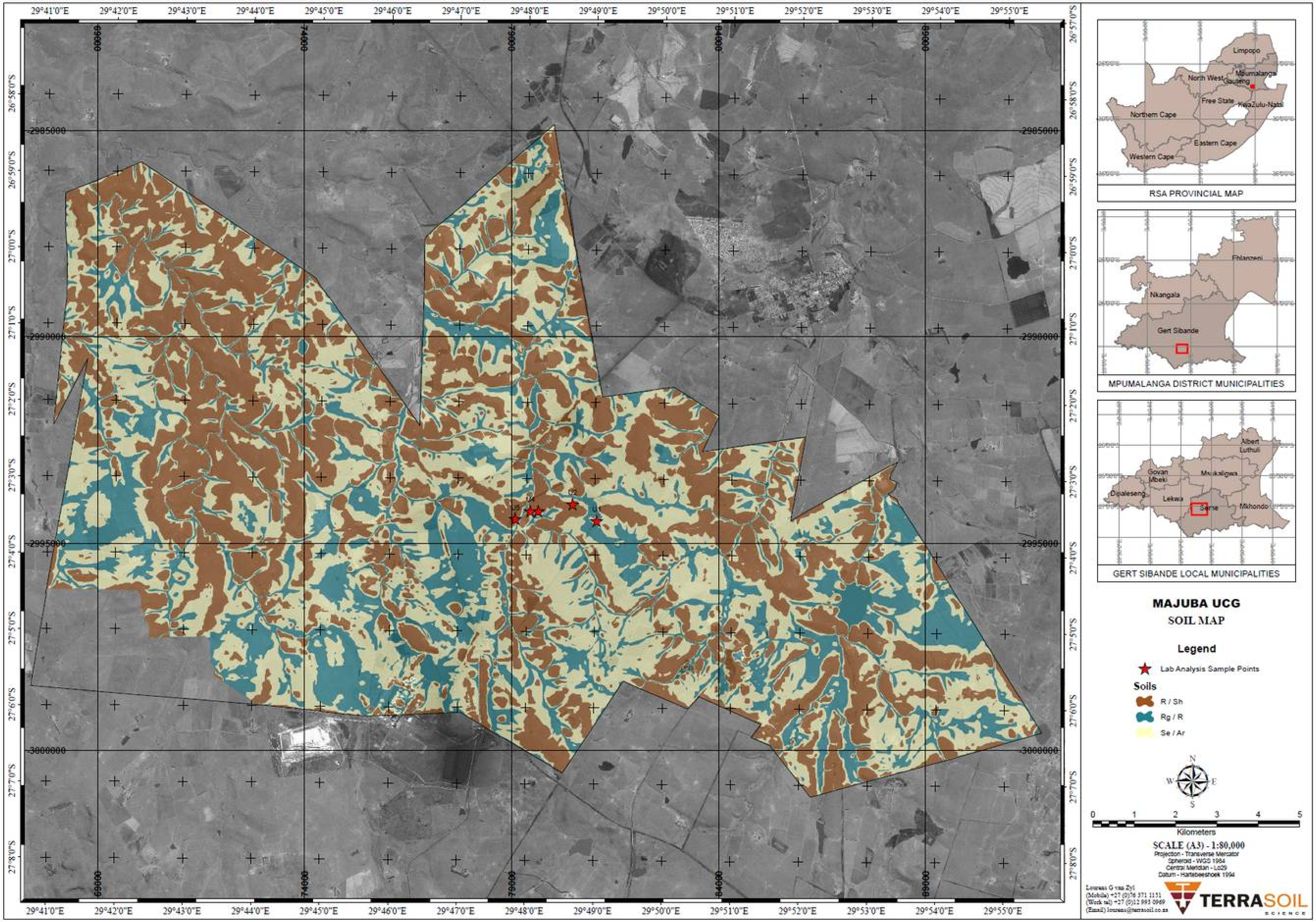
Van der Watt, H.v.H. & van Rooyen, T.H. 1995. A Glossary of Soil Science. Soil Science Society of South Africa, Pretoria.



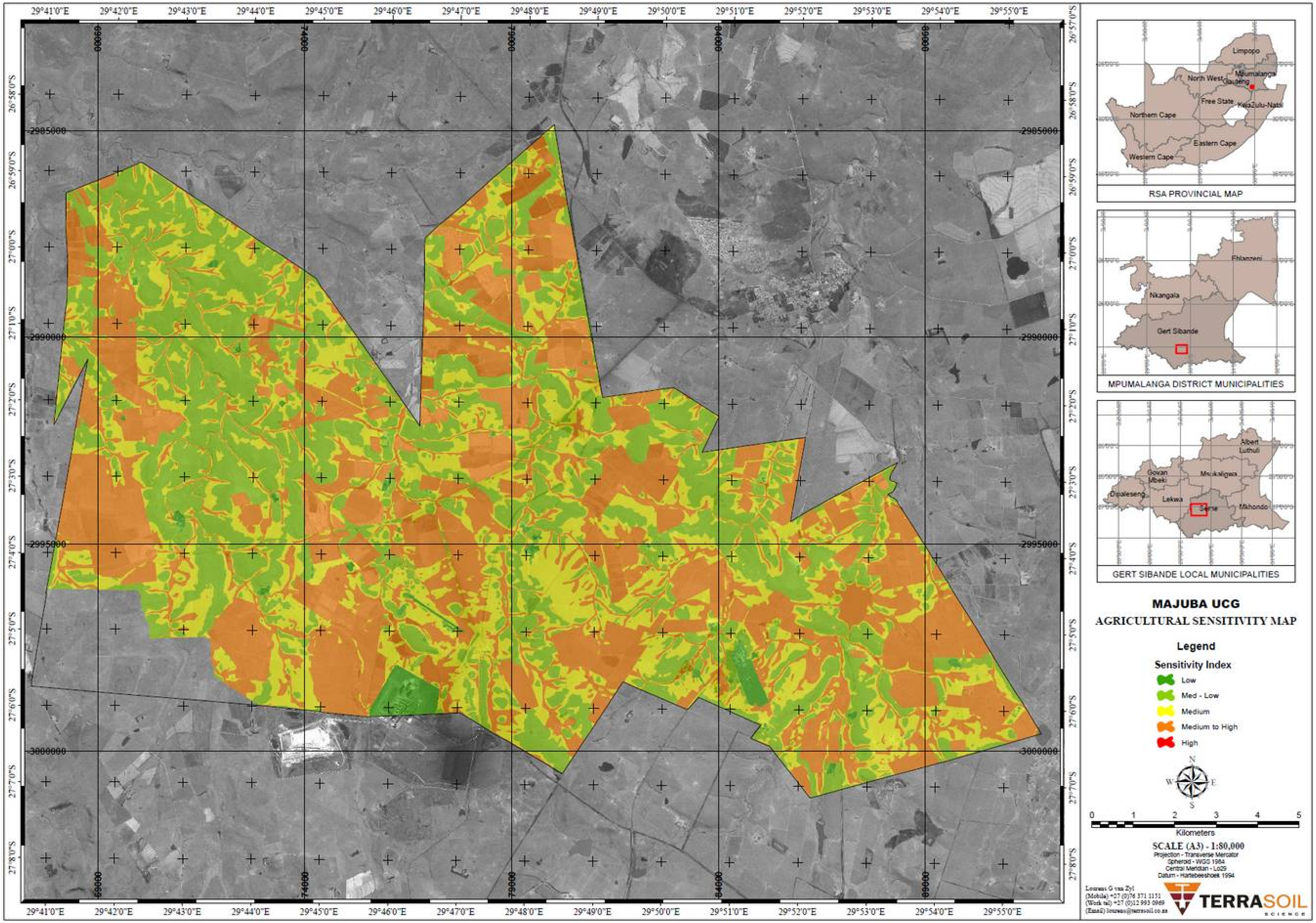
Map 1 Land type map of the survey area



Map 2 Land use map of the survey area



Map 3 Soil map of the survey area



Map 4 Sensitivity map of the survey area