Baseline Report on

The Soils of the Limpopo River Basin

a contribution to the Challenge Program on Water and Food Project 17

"Integrated Water Resource Management for Improved Rural Livelihoods: Managing risk, mitigating drought and improving water productivity in the water scarce Limpopo Basin"

C. Bangira
Department of Soil Science and Agricultural Engineering, University of Zimbabwe, PO Box MP167, Mt. Pleasant, Harare, Zimbabwe

A. Manyevere
Chemistry and Soil Research Institute, Pedology and Soil Survey Section P.O. Box CY 550 Causeway, Harare, Zimbabwe

WaterNet Working Paper 8
July 2009

WaterNet is a regional network of university departments and research and training institutes specialising in water. The Mission of WaterNet is to enhance regional capacity in Integrated Water Resources Management through training, education, research and outreach by sharing the complementary expertise of its members. WaterNet member institutions have expertise in various aspects of water resources management, including water supply, sanitation, groundwater, wetlands, irrigation, water law, water economics, community based resource management, flood forecasting, drought mitigation, water conservation and information technology. These institutions are based in Angola, Botswana, Kenya, Lesotho, Mozambique, Namibia, Rwanda, South Africa, Tanzania, Uganda, Zambia and Zimbabwe.

The Challenge Program on Water and Food (CPW&F) is a research initiative of the Consultative Group on International Agricultural Research (CGIAR). It is a partnership between national and international research institutes, NGOs and river basin communities. Its goal is to identify and encourage practices and institutional strategies that improve water productivity, and is committed to the overall goals of addressing improvements in levels of food security, poverty, health, and environmental security.

WaterNet is leading Project 17 under the Challenge Program on Water and Food, entitled "*Integrated Water Resource Management for Improved Rural Livelihoods*". The project is financed by the CGIAR through the CPW&F and by the partners in the project.

The partners in the project are:
Project leader: WaterNet
International Research Institutes:
- **International Crop Research Institute for the Semi-Arid Tropics (ICRISAT)**
- **International Water Management Institute (IWMI)**

Universities:
- **UNESCO-IHE**
- **Universidade Eduardo Mondlane: Faculdade de Agronomia e Engenharia Florestal**
- **University of the Witwatersrand: School of Civil and Environmental Engineering**
- **University of Zimbabwe: Centre for Applied Social Sciences; Department of Civil Engineering; Department of Soil Science and Agricultural Engineering; Mineral Resources Centre**

National Water and Agricultural Authorities:
- **Administracao Regional de Aguas do Sul, Mozambique**
- **Instituto de Investigacao Agronomica deMozambique**
- **Mzingwane Catchment Council, Zimbabwe**
- **Water Research Commission, South Africa**

Non-governmental Organisations:
- **World Vision Zimbabwe**

Suggested citation:
Bangira, C. and Manyevere, A. 2009. Baseline Report on the Soils of the Limpopo River Basin, a contribution to the Challenge Program on Water and Food Project 17 "Integrated Water Resource Management for Improved Rural Livelihoods: Managing risk, mitigating drought and improving water productivity in the water scarce Limpopo Basin". *WaterNet Working Paper* **8**. WaterNet, Harare.

SOILS OF THE LIMPOPO RIVER BASIN: PROJECT PN17

BY
[1]C. BANGIRA AND [2]A. MANYEVERE

1. University of Zimbabwe, Department of Soil Science and Agricultural Engineering Box MP 167 Mount Pleasant Harare Zimbabwe.

2. Chemistry and Soil Research Institute, Pedology and Soil Survey Section P.O. Box CY 550 Causeway, Harare

Executive Summary

The Limpopo River Basin is a semi-arid to arid region that is shared by Botswana, Mozambique, South Africa and Zimbabwe. Its 14 million inhabitants are dependent on land cultivation, pasture and irrigation for livelihood. Although the region has high potential for agricultural production current levels are very low leaving households vulnerable to food shortages and hunger. As part of the Limpopo River Basin Project PN17 overall goal of improving food security, incomes and livelihoods of smallholder farmers in the Limpopo River Basin, an inventory of soil resources was conducted in the study area. The objectives of this study were to compile, map and describe the soils and their potential land use in the Limpopo River Basin. Such information is critical in decision-making, planning and implementation processes of the proposed developmental projects within the study area.

Soils information was compiled from the existing maps, bulletins, documents and other published reports obtained from the participating countries' national institutions and international organizations. A total of 16 dominant soil groups, classified according to the FAO system, were identified and described (see Table 1). About 40% of the soils are moderately suitable to suitable for the production of a wide range of crops under rain-fed or irrigated agriculture and about 60% is unsuitable to marginally suitable but for wildlife, forestry and grazing. Soil depth, salinity, texture and poor chemical fertility are the most soil limiting factors for crop production.

Notwithstanding challenges of data availability, mapping scale and soil analytical methods and classification systems with other countries, a soil map of the Limpopo River Basin was produced at a scale of 1: 1000 000. This report starts by describing the general information of the area. The second part describes the identified soils and their potential land use and limitations.

The GIS files are available here.

Table 1. Dominant soil groups in the Limpopo River Basin and their recommended use

Soil classification	**Estimated Area (km^2)**	**Limitations**	**Recommended use**	**Suitability for crop production**
Luvisols	46 000	Shallow depth	Grazing, wildlife, citrus, small grains	Moderately suitable
Lixisols	23 000	Low fertility status, low pH	Most crops (tobacco, maize etc) after liming and fertilization.	Moderately suitable
Nitisols	15 300	Low fertility, high leaching	Most crops	Moderately suitable
Leptosols	70 000	Extremely shallow depth. Steep lands.	Wildlife, grazing, woodland and recreation	Not suitable
Arenosols	45 100	Low chemical fertility & available water, excessive drainage	Horticulture, tobacco, livestock production	Marginally suitable
Ferrasols	1000	Low chemical fertility	Perennial crops, forestry, fodder production	Moderately suitable
Cambisols	60 250	Low available water	Most crops, pasture	Moderately suitable
Acrisols	23 000	Highly leached	Most crops, pasture	Moderately suitable
Phaeozems	4 800		Most crops, intensive grazing,	Suitable
Plinthisols	4 800	Low chemical fertility, permeability restrictions	Grazing	Marginally suitable
Solonetz	71 600	High sodium content	Grazing, forestry and wildlife	Not suitable
Calcisols	2 400	Nutritional deficiencies (Zn, P & Fe), water percolation	Variable but under irrigation	Marginally suitable
Solonchaks	2 400	High salt content, poor permeability	Salt tolerant crops (eg sorghum, millet)	Marginally suitable
Vertisols	29 000	Restricted permeability, root pruning, workability & trafficability	Cotton, winter cereals, rice, citrus and pasture	Moderately suitable
Regosols	30 000	Low nutrient reserves, excessive permeability	Forestry, grazing and wildlife	Marginally suitable
Fluvisols	7 800	Variable; crusting and sealing	Most crops, citrus and pasture	Moderately suitable

Table of Contents

1. Introduction

The Limpopo River Basin is a semi-arid to arid region that is shared by Botswana, Mozambique, South Africa and Zimbabwe. It has a population of about 14 million whose livelihood is dependent on land cultivation, pasture and irrigation (***http://www.ifpri.cgiar.org/Themes/globalchange/pubs/SA_sampling_design.pdf***). Although the region has high potential for agricultural production current levels are very low leaving households vulnerable to food shortages and hunger. As part of the Limpopo River Basin Project PN17 overall goal of improving food security, incomes and livelihoods of smallholder farmers in the Limpopo River Basin, an inventory of soil resources was conducted in the study area. Such information plays a critical role in decision-making, planning and implementation processes of the proposed developmental projects in this region. In an effort to increase agricultural productivity and food security through irrigation development and use of inorganic/organic fertilisers, appropriate mitigatory measures should be considered against potential soil degradation (chemical and physical) and pollution of water bodies. Inadequate project planning can thus be costly and could lead to the creation of serious environmental problems that would far outweigh the beneficial effects of the project itself. The objectives of this study were to compile, map and describe the soils and their potential land use in the Limpopo River basin. This report starts by describing the general information of the area. The second part describes the identified soils and their potential land use and limitations.

2. General Description of Area

Limpopo River Basin is located in Southern Africa between latitudes 20^o S and 26^o S and longitudes 25^o E and 35^o E. It comprises catchments of Limpopo River from four different countries namely Botswana, Mozambique, South Africa and Zimbabwe. The basin covers an area of approximately 430 $000km^2$.
The altitude of the area ranges between 150m and 1200m. Major rivers draining into Limpopo are Nuanetsi and Tuli in Zimbabwe, Shashe in Botswana, Oliphats, Luvuvhu and Crocodile in South Africa and Mokolo in Mozambique.

3. Soils

The soil map of the Limpopo Basin was produced at an approximate scale of 1: 1000 000 by compiling soils information from various sources and then delineating soil boundaries by digitizing using AutoCad and ArcView software. Soil classification was based on the FAO system (1998). The four countries covering the basin have different soil classification systems and to harmonize the classification systems Food and Agriculture Organization (FAO) soil classification system was used. Diagnostic horizons and diagnostic properties were mainly considered during classification. Diagnostic horizons are soil horizons that combine a set of properties that are used for identifying soil units (World Soil Resource Report 60, 1998). Diagnostic properties are features of horizons or soil materials which, when used for classification purposes, need to be quantitatively defined.

Soils in this area are very variable due to differences in parent material, climate and other soil forming factors. Soils are less developed; generally below 40cm in low rainfall areas and mountainous/hilly areas. Conversely, areas of the basin that receive high rainfall and high temperature are characterized by deep (>100cm), leached clay and sand soils. The parent material from where the soils are derived influences the texture and mineralogical soil properties. Where granites, gneisses and sandstones form the major parent material, soils are generally coarse textured and gravelly. Furthermore, solonetz (sodium-affected soils) cover a greater part of the drier southern Mozambique or the south-eastern part of the Limpopo basin.

A total of 16 dominant soil units were identified in the basin. These units are acrisols luvisols, lixisols, arenosols, regosols, solonetz, leptosols, cambisols, fluvisols, solonetz, solonchaks, vertisols, calcisol, ferrasols, nitisol, plinthosols and phaeozems. A detailed description of the identified soil units and some of their morphological characteristics are given in the following sections.

3.1. Luvisols

These soils are characterized by a sandy loam or finer texture and more total clay than an overlying coarse textured horizon. The cation exchange capacity of these soils is equal to or more than 24cmol+ kg^{-1} clay throughout.

They occupy the position of the Limpopo basin where rainfall is high enough to cause clay migration down the profile. Their reaction is slightly acid to alkaline. A greater proportion of these soils are found in the northwest area bordering Zimbabwe and South Africa. The average depths of these soils are about 40cm and are mostly derived from gneisses and granites.

Land Use

Luvisols are suitable for intensive crop production especially under irrigation. The main limitation of these soils is shallow depth that can limit root penetration and may cause water logging.

Typical profile: ZW 02/II/04

Location: **S** 21°25.8′ **E** 030°12.6′

Approximate area: 46 000 km^2

Morphological features

Colour:	Dark brown (7.5YR 3/2m) over	brown (7.5YR 4/4m)
Texture:	Coarse grained sand clay	loam over coarse grained sandy loam
	Top (20cm)	**Bottom**

Sand (%):	59	50
Silt (%):	8	7
Clay (%):	32	43
Depth:	40-60cm	
Structure:	Moderately developed sub-angular blocky	
Permeability and drainage:	Good permeability and well drained	

Subsoil chemical properties

CEC (cmol+ kg^{-1}):	31.6
Base saturation (%):	100
pH ($CaCl_2$):	4.7

3. 2. Acrisols

These soils are similar to Luvisols. However, they are characterized by the accumulation of low activity clay in a subsurface horizon and by a low base status.

They are strongly weathered and tend to be acidic in nature. The cation exchange capacity and base saturation of these soils are less than 24cmol+ kg^{-1} clay and less than 50% respectively.

Acrisols are found mainly on the South African side between latitudes 28°1.2′ and 24°44.4′ and longitudes 27°42′ and 28°36′.

Land Use

Intensive crop and livestock production is possible in these soils provided they are well fertilized and limed. The main soil limitations are their low fertility, high P fixation capacity, low pH and high contents of Al which can be phytotoxic. Good management of these soils includes the use of organic manures that has multiple beneficial effects to the soil.

Typical profile:	ZA 280
Location:	**S** 24°06′ **E** 028°17.4′
Approximate area:	23 200km^2

Morphological Properties

Colour:	Brown (10 YR5/3m) over yellowish brown (10YR5/6m)	
	Top (20cm)	**Bottom**
Sand (%):	91	80
Silt (%):	5	6
Clay (%):	4	14
Texture:	Coarse grained sandy loam	
Depth:	> 110cm	
Structure:	Weakly developed medium sub-angular blocky	
Permeability and drainage:	Good permeability and well drained	

Subsoil chemical properties

CEC ($cmol_+ kg^{-1}$):	1.8
Base saturation (%):	<40
pH ($CaCl_2$):	4.9

3.3. Arenosols

These soils are characterized by a loamy sand texture or coarser (> 70% sand) to a depth of at least 100cm from the soil surface or to a depth-limiting layer within 50-100cm. These soils generally lack evidence of profile development and thus no diagnostic horizons can be recognized except the cemented plinthite or salic layer which may be below 50cm from the surface or a clay accumulation layer below 200cm depth.

They are of low cation exchange capacity and acidic in reaction. They cover a greater proportion of north-eastern Botswana and the eastern parts of the Limpopo Basin bordering Mozambique, South Africa and Zimbabwe. Most arenosols are thought to have developed on Kalahari Sands of aeolian origin (Stagman, 1978).

Land Use

Crops that require deep, good drainage and sandy texture can be grown successfully on arenosols. Melons, fodder crops, groundnuts and potatoes are grown successfully on these soils. However, the sandy texture, poor nutrient status, low pH, excessive drainage limit these soils for crop production. Application of organic and inorganic fertilizers and lime, and a good crop water use management are therefore recommended in these soils. These soils can best be put under extensive grazing, wildlife and forestry. In South Africa arenosols tend to develop water-repellency behaviour which leads to uneven water infiltration (http://www.fao/org/ag/Agl/agll/wrb/doc/wrb2006final.pdf). Various surfactants are therefore sometimes used to reduce this effect.

Typical profile: BW-D10901

Location: **S** 23°30′ **E** 026°6′

Approximate area: 45 100km^2

Morphological properties

Colour:	Dark yellowish brown (10 YR4/4m) over yellowish brown (10YR5/4m)	
Texture:	Coarse grained sands	
	Top (20cm)	**Bottom**
Sand (%):	95	94
Silt (%):	2	3
Clay (%):	3	3
Depth:	> 120cm	
Structure:	Apedal, single grain	
Permeability and drainage:	Rapid permeability and excessively well drained	

Subsoil chemical properties

CEC (cmol+ kg^{-1}):	1.6
Base saturation (%):	<40
pH(CaCl2):	4.2

3.4. Cambisols

These soils are in a transitional stage of development, from a young soil to a mature soil. Such soils have a subsurface horizon that shows evidence of alteration relative to the underlying horizons. The alteration can be in the form of stronger chroma, redder hue, or higher clay content than the underlying horizon or show evidence of removal of carbonates. Cation exchange capacity is greater than 16 cmol$_c$kg^{-1} clay.

They are mainly found in young deposition but also in erosion areas where they form after genetically mature soils such as Luvisols have eroded away. About 15% of the Limpopo basin is under these soils with a greater proportion being found around Mussina and at latitudes 22^{o} and 23^{o} South and longitudes 28^{o} and 30^{o} East.

Land Use

Good chemical and physical fertility of these soils make them suitable for intensive crop production. A wide variety of crops can be grown in these soils depending on climate and other factors. In the Limpopo basin crop production in Cambisols is limited by the availability of adequate water. Crop productivity can be significantly improved under irrigation.

Typical profile:	ZA10132	
Location:	**S** 22^{o}45$^{/}$	**E** 029^{o} 11.4$^{/}$
Approximate area:	60 250km^{2}	

Morphological properties

Colour:	Dark reddish brown (2.5YR3/3m) over red (2.5YR4/8m)	
Texture:	Coarse grained sandy loam	
	Top (20cm)	**Bottom**
Sand (%):	79	71
Silt (%):	8	10
Clay (%):	13	19
Depth:	> 120cm	
Structure:	Moderately developed medium subangular blocky	
Permeability and drainage:	Good permeability and well drained	

Subsoil chemical properties

CEC (cmol$_{+}$ kg^{-1}):	5
Base saturation (%):	40 - 50
pH ($CaCl_2$)	4.6

3.5. Leptosols

These are soils with limited depth (<25cm). The depth limiting material can be continuous hard rock or calcium carbonate equivalent of more than 40%. Due to limited time for soil development beyond the 25cm depth, diagnostic horizons are often lacking.

Because of the importance of depth as the distinguishing property, the texture, pH and cation exchange capacity of these soils is very variable and largely depends on climate and the parent material from which they were derived. These soils tend to be located in the mountainous/hilly and very low rainfall areas of the Limpopo basin. They are scattered throughout the basin and are of very little agricultural significance and as such they are rarely sampled for analyses. Leptosols cover about 70 000km2 of the basin.

Land Use

The main limitations of Leptosols to crop production in the Limpopo Basin are depth and terrain. Moderate to severe erosion can occur when these soils are exposed to raindrop impact. A greater proportion of these soils is thus under extensive grazing, wildlife and forestry.

3.6. Plinthosols

The important feature about these soils is that they have plinthite (an iron-rich, humus poor mixture of kaolinite clay with quartz and other constituents, which changes irreversibly to a hardpan or to irregular aggregates on exposure to repeated wetting and drying cycles with free access to oxygen).

Plinthosols have very low cation exchange capacity and base status.

Land Use

Plinthosols can form a cemented layer of iron and aluminium in subsurface soil that restricts water and root permeability. Furthermore, restricted soil depth significantly reduces water storage capacity of these soils. As a result they are prone to water logging. Due to high leaching of bases, chemical soil fertility is also very low and large amounts of P can be fixed. These soils are not suitable/ marginally suitable to crop production. Grazing is the recommended agricultural land use.

Typical profile:	ZA 298
Location:	**S** 24°15.6′ **E** 27°46.2′
Approximate area:	4 800km^2

Morphological properties

Colour:	Dark brown (10YR 3/3m)
Texture:	Coarse grained sandy loam
	Top (20cm)
Sand (%):	74
Silt (%):	16
Clay (%):	10
Depth:	<30cm
Structure:	Structureless
Permeability and drainage:	Good permeability and well drained

Subsoil chemical properties

CEC ($cmol_+ kg^{-1}$):	2.9
Base saturation (%):	80
pH($CaCl_2$):	5.7

3.7. Solonetz

The distinguishing feature of soils in this group is that they have appreciable amounts of exchangeable sodium in the subsoil. Exchangeable sodium percentage (ESP) is more than 15 within the upper 40cm, or more magnesium plus sodium than calcium plus exchangeable acidity within the same depth. The mobility of sodium down the soil profile results in the formation of a columnar or prismatic structure and an increase in clay content in the underlying horizons than the overlying ones. Soil pH in the underlying horizons is frequently more than 9.0.

Solonetz soils are mainly associated with low rainfall areas and parent materials rich in sodium-releasing feldspars. About 20% of solonetz soils are found in the extreme eastern part of the Basin (in Mozambique) at latitudes $21^o42^/$ and $24^o18^/$ South and longitudes 32^o and 34^o East.

Land Use

Solonetz present chemical and physical challenges for crop production. High pH of these soils causes trace element (Zn and Fe) deficiencies. Excessive amounts of Na induce nutritional imbalances and osmotic potential problems. Boron toxicity may also be a problem in these soils. Poor soil structure in the subsoil impedes water, air and root penetration. These soils are susceptible to severe gully erosion. Solonetz are thus not suitable for normal crop production. Gazing, forestry and wildlife are some of the best land uses in these soils. Management of these soils include the application of gypsum followed by leaching of exchangeable Na. Improvement of drainage is important. Quite a number of irrigation schemes in the Limpopo Basin have been affected by salinization.

Typical profile:	MZ 050	
Location:	**S** 21°42′ and 24°18′	**E** 32° and 34°

Morphological features

Colour:	Dark brown (10 YR3/3m) over dark grayish brown (2.5Y4/2m)	
Texture:	Coarse grained sandy loam over sandy clay loam and sandy clay to clay	
	Top (20cm)	**Bottom**
Sand (%):	70	59
Silt (%):	21	6
Clay (%):	9	35
Depth:	> 125cm	
Structure:	Strong coarse prismatic	
Permeability and drainage:	Restricted permeability and moderately well drained	

Subsoil chemical properties

CEC ($cmol_+kg^{-1}$):	31.6
Base saturation (%):	>80
pH ($CaCl_2$):	8.7
ESP:	20 - 50

3.8. Solonchak

Solonchak soils are characterized by a surface or shallow subsurface horizon (within 50cm from the surface), which contains a secondary enrichment of readily soluble, salts, i.e salts more soluble than qypsum. The soluble salts may include alkaline carbonates or acid sulphates. The electrical conductivity of the saturation extract of these soils is usually more than 15 dS m^{-1} at some part of the year. Depending on the composition of the salts, EC values of 3.5 dS m^{-1} for acid sulphate soils and 8 dS m^{-1} for saturation extracts with pH higher than 8.5 respectively qualify in this group. Sometimes salts may precipitate at the surface or at depth.

Like Solonetz, solonchaks tend to occur in areas with low rainfall and warm/hot areas where leaching is minimal. The eastern part of the Limpopo basin (mainly in Mozambique) is dominated by these soils.

Land Use

Solonchak are not suitable for normal crop production owing to high salinity, acidity and alkalinity, nutritional imbalances, toxicity of Al and trace elements under acidic conditions. The solubility of salts in these soils can cause some tunneling in the soils leading to severe erosion. Land use in these soils is thus mainly grazing, wildlife and forestry.

3.9. Calcisol

These soils show a secondary accumulation of lime (calcium carbonate) and as such the colour of these soils is usually pinkish, grayish or whitish. Their pH is between 8.0-8.7 due to the dominance of lime.

Their occurrence tends to be limited to low rainfall areas but of varied geological material. A greater part of these soils are found in the Botswana and South African sides of the Limpopo Basin. In Zimbabwe they are found in very small proportions that can only be mapped at very detailed scales.

Land Use

Because calcisols are associated with arid/semi arid conditions accumulation of calcium and sometimes magnesium carbonate in the soil may result in the formation of hard layer in the soil which can be difficult for water percolation and plant roots penetration. Crusts can also form on the surface and prevent seedlings emergence. High pH of these soils also induces some plant nutritional deficiencies particularly P, Zn and Fe. In some cases the predominance of Ca or Mg in soil results in nutritional imbalances that negatively affect crop growth. Land use under Calcisols is very variable but crop production is mostly done under irrigation. The problem with irrigation, however, is that salinity may also build up in the soil due to high evaporation under these soil conditions.

Profile:	BW 10018
Location:	**S** 22^{o} $325.8^{/}$ **E** $026^{o}27.8^{/}$
Approximate area:	2 400km^2

Morphological features

Colour:	Very dark greyish brown (10 YR3/2m) over dark brown (7.5YR 4/4m)	
Texture: loam	Coarse grained sandy loam over sandy clay	
	Top (20cm)	**Bottom**
Sand (%):	69	68
Silt (%):	3	11
Clay (%):	28	21
Depth:	80 – 100 cm	
Structure:	Moderately developed sub-angular blocky	
Permeability and drainage:	Good permeability and well drained	

Subsoil chemical properties

CEC ($cmol_+ kg^{-1}$):	16.5
Base saturation (%):	100
pH ($CaCl_2$):	8.1

3.10. Vertisols

These are swelling and shrinking soils with at least 30% clay throughout the horizon. Vertisols show cracks of one centimetre or more wide when dry.

Vertisols are of variable depth and are normally associated with a variety of geologies. About 15% of the soils in the Limpopo are vertisols. Vast areas of vertisols are found in the Middle Sabi (Zimbabwe) and near Johannesburg (South Africa).

Land Use

These are some of the most fertile soils in the Limpopo Basin. A wide variety of crops can be grown under irrigation or rain-fed agriculture. Common crops grown include cotton, sugar cane and maize. The main limitations of these soils are high soil pH, workability and trafficability. They are difficult to work when wet or dry. In some cases wide cracks can cause uneven water infiltration due to preferential flow of water. Minimum tillage and water conservation methods are recommended in vertisols. When these soils are irrigated then adequate soil drainage should be put in place in order to avoid salt build-up.

Typical Profile: ZA 10792

Location:	**S** 24° 53.4′ **E** 027°2.4′	
Approximate area:	29 000km^2	

Morphological properties

Colour:	Black (2.5Y 2/0m)	
Texture:	Clay	
	Top (20cm)	**Bottom**
Sand (%):	26	17
Silt (%):	23	21
Clay (%):	50	59
Depth:	> 130cm	
Structure:	Strong coarse sub-angular blocky	
Permeability and drainage:	Restricted permeability and moderately poorly drained	

Subsoil chemical properties

CEC (cmol+ kg^{-1}):	>29
Base saturation (%):	100
pH ($CaCl_2$):	8.0

3.11. Lixisols

These are strongly weathered soils in which clay is washed down from the surface and accumulates at some lower depth. They have low activity clays (CEC <24 cmol+kg^{-1}) and a moderate to high base saturation level (>50%). They normally occur on slopes and other surfaces subject to erosion. They are formed under tropical/subtropical conditions with a pronounced dry season or were formed under past humid climatic conditions. They are found mainly in South Africa, Zimbabwe and Botswana.

Land Use

Successful intensive crop production can be done with the application of fertilizers and lime in order to increase the fertility and increase the pH of the soil. A wide variety of the crops can be grown in these soils. Extensive grazing can also be the alternative land use. The main limitations of these soils are their susceptibility to heavy machinery compaction, degradation of soil structure and soil erosion.

Typical profile:	ZW 43/ PP/ 82	
Location:	**S** 20° 51.6′ **E** 028° 48.6 ′	
Approximate area:	23 000km^2	

Morphological properties.

Colour:	Dark yellowish brown (10YR 4/4m) over dark reddish brown (2.5YR 3/3m)	
Texture:	Coarse grained sandy clay loam over clay	
	Top (20cm)	**Bottom**
Sand (%):	39	30
Silt (%):	11	14
Clay (%):	50	56
Depth:	> 110cm	
Structure:	Weakly developed medium sub-angular blocky	
Permeability and drainage:	Good permeability and well drained	

Subsoil chemical properties:

CEC (cmol+kg^{-1}):	9.7
Base saturation (%):	80
pH($CaCl_2$):	4.8

3.12. Fluvisols

These are soils that show stratification as a result of deposited sediments by river or marine activities. As such they have variable pH, base status and cation exchange capacity. However, they are generally deeper than 100cm.

They occur mainly in the alluvial and flood plains of major rivers such as the Limpopo and Shashe Rivers.

Land Use

These are some of the most fertile soils in the Limpopo Basin. Intensive crop and livestock production are the main land uses. Irrigated citrus and winter cereals are widely grown in these soils. The main limitations of these soils is their high silt and fine sand that can cause surface sealing and capping thus reducing seedling emergence and water infiltration. Severe erosion can also be a problem. Maintenance of organic matter is therefore important in these soils.

Typical profile: ZW 01/II/04

Location: **S** 21° 53.271' **E** 29° 45.028'

Approximate area: 7 800km^2

Morphological properties

Colour: Dark brown (10YR 3/3m) over dark yellowish brown (10YR 3/4m)

Texture: Fine to medium grained sandy loam over similar texture.

	Top (20cm)	**Bottom**
Sand (%):	82	83
Silt (%):	8	8
Clay (%):	10	9
Depth:	>150cm	

Structure: Moderately developed medium subangular blocky

Permeability and drainage: Good permeability and well drained

Subsoil chemical properties

CEC (cmol+ kg^{-1}): 10.8 – 15.9

Base saturation (%): 50 - 80

pH ($CaCl_2$): 6.7 – 7.5

3.13. Phaeozems

These are dark coloured soils rich in humus on the surface and high base status. They are normally formed on fine textured basic parent material.

Phaeozems occupy about 4 800 km^2 of the basin

Land Use

These soils are suitable for intensive crop and livestock production because of their fertility status. A wide variety of crops can be grown depending on climate and other production factors.

3.14. Nitisols

These soils are deep, well drained red low activity clay soils with a moderate to strongly developed angular blocky structural elements that easily fall into shiny, polyhedric (“nutty’’) elements. They are strongly weathered and of variable base status. Soil pH is slightly acid .

The soils are mainly found on the South African side of the basin. Minor soils of this group are found on the Zimbabwe side where parent material is gabbro or ultramafic.

Land Use

The main limitation of these soils to crop production is their low fertility status. Intensive crop production is therefore possible under irrigation with the application of fertilizers.

Typical profile: ZA 961

Location: **S** 22°48′ **E** 030°32.4′

Approximate area: 15 300km^2

Morphological properties

Colour: Dark red (2.5 YR3/6m)

Texture: Clay

	Top (20cm)	**Bottom**
Sand (%):	38	35
Silt (%):	12	10
Clay (%):	46	54

Depth: > 120 cm

Structure: Moderately developed sub-angular blocky structure

Permeability and drainage: Good permeability and well drained

Subsoil chemical properties

CEC (cmol+ kg^{-1})	15.6
Base saturation (%)	100
pH($CaCl_2$)	5.7

3.15. Ferrasols

This group of soils has a texture of at least sandy loam with clay content more than 8% in all horizons. Clay active is also low with CEC clay less than 16 cmol+ kg^{-1} clay

They are minor soils and are mappable on the South African side basin.

Land Use

Intensive crop and livestock production can be practiced with the application of organic and inorganic fertilizers. However, these soils have a high capacity to fix P.

Typical profile:	ZA2011
Location:	**S** 22°37.2′ **E** 031°18.4′
Approximate area:	1 000km^2

Morphological properties

Colour:	Dark brown (10YR 3/3m) over light brown (7.5YR 6/4m)	
Texture:	Coarse grained sandy loam over coarse grained sandy clay loam	
	Top (20cm)	**Bottom**
Sand (%):	80	60
Silt (%):	3	6
Clay (%):	17	34
Depth:	> 120cm	
Structure:	Moderately developed sub-angular blocky structure	

Permeability and drainage:	Good permeability and well drained

Subsoil chemical properties

CEC (cmol+ kg^{-1}):	6.3
Base saturation (%):	>50
pH($CaCl_2$):	4.4

3.16. Regosols

These soils are formed from unconsolidated material. The formation process is similar to arenosols but the two soils differ in texture. Arenosols are mainly sands and loamy sands while regosols are finer.

The soils are found mainly in South Africa between longitudes 30^o and 31^o East and latitudes 23^o and 24^o South.

Land Use

Extensive grazing, wildlife and forestry are the most common land uses under regosols. The main limitations to crop production are excessive drainage, low water holding capacity, poor nutrient status and low pH. These soils are prone to soil erosion and thus exposure to raindrop/wind impact should be minimized.

Typical profile:	ZA 943	
Location:	**S** 23^{o}07.2$^/$	**E** 030^{o}07.8$^/$
Approximate area:	30 000km^2	

Morphological properties

Colour:	Dark brown7.5YR 4/4	
Texture:	Fine grained sandy clay loam	
	Top (20cm)	**Bottom**
Sand (%):	56	49
Silt (%):	17	25
Clay (%):	25	28
Depth:	> 120cm	

Structure:	Massive
Permeability and drainage:	Good permeability and well drained

Subsoil chemical properties

CEC ($cmol_+ kg^{-1}$):	8.6
Base saturation (%):	>50
$pH(CaCl_2)$:	4.7

4. Acknowledgements

Compilation of this report was made possible using information gathered from various sources such as the Global and National Soils and Terrain Database (SOTER)

and Communal Land Physical Resource Inventory (CLPRI) and soil survey reports conducted in the participating countries. We appreciate their contribution.

5. Bibliography

Anderson, I.P., Brinn, P.J., Moyo, M. and Nyamwanza, B. 1993. Physical Resource Inventory of the Communal Lands of Zimbabwe-An Overview. NRI Bulletin 60. Chatham, UK: Natural Resources Institute.

Buol, S.W, Hole F.D and MacCracken M (1980). Soil Genesis and classification. Second Edition. The Iowa State University Press. Ames.

Brinn, P. and Moyo, M. 1988. Communal land Resource Inventory of Maranda. Chemistry and Soil Research Institute.

FAO. 1983. Guidelines: Land evaluation for rainfed Agriculture. FAO Soils Billetin 52.

FAO/ ISRIC. 2004. Land and water Digital Media Series 25. Soil and Terrain Database for Southern Africa (1: 2 million scale).

FAO/ ISRIC/ ISSS. 1998. World Reference Base for Soil Resources. World Soil Resources Report 60. Rome

Landon, J.R.1984. Booker Tropical Soil Manual. A handbook for Soil Survey and Agricultural Land evaluation in the tropics and subtropics. Booker Agricultural International limited

Manyevere, A., Mubvumba, P. and Gotosa, J. 2004. Soils of the proposed Zhove Dam irrigation Scheme. Chemistry and Soil Research Institute. Report No A 671.

Moyo, M and Brinn, P. 1988. Communal land Resource Inventory of Mberengwa. Chemistry and Soil Research Institute. Report No A 600.

Moyo, M and Nyamwanza, B. 1997. Soils of the proposed Zhove irrigation scheme, Mtetengwe communal lands, Beitbridge District. Chemistry and soil Research Institute Report No A646.

Munsell Soil Colour Charts.1990. Revised Edition.

Nyamapfene, K. 1991. Soils of Zimbabwe. Nehanda Publishers.

Nyamwanza, B., Bangira, C., Phiri, G. and Chikwari, E. Soils of the proposed Ziminya irrigation scheme. Chemistry and Soil Research Institute. Report No A 665.

Stagman, J.G. 1978. An outline of the geology of Rhodesia. *Bulletin of the Geological Survey of Rhodesia. No.71*

Appendix 1. Profile nomenclature

Country codes for profiles used

BW- Botswana
MZ- Mozambique
ZA-South Africa
ZW-Zimbabwe

The format used for naming the soil profile depended upon the country of origin.

Appendix 2. Glossary of technical terms

Soil Texture class

C	clay
CL	clay loam
L	loam
SiC	silty clay
SiCL	silty clay loam
Si	silt
SaC	sandy clay
SaCL	sandy clay loam
SaL	sandy loam
LS	loamy sand
S	sand

Texture classification-coarse(c), medium (m), and fine (f).

Express each sand fraction as a % of the total sand fraction in the sample.
If the coarse sand is > or = 25% the texture will be prefixed with a "c".
If the fine sand is > or = 60% the texture will be prefixed with "f".
If the coarse sand < 25% and the fine sand is < 60% the texture will be prefixed with "m".
If the total sand fraction is < 45% there is no prefix.

Particle size grades

Coarse sand:	2,0mm (2000µm) - 0,5mm (500µm).
Medium sand:	0.5mm (500µm) - 0,2mm (200µm).
Fine sand:	0,2mm (200µm) - 0,02mm (20µm).
Silt:	0,02mm (20µm) - 0,002mm (2µm).
Clay:	<0,002mm (2µm).

Other abbreviations

d-dry; m-moist; K-Potassium; Na-Sodium; Ca-Calcium; Mg-Magnesium; Fe-Iron; CEC-Cation exchange capacity; TEB-Total exchangeable bases; me%-milli-equivalents percent or per 100 grams of soil; Base saturation%-100 x TEB (cmolc kg-1)/CEC (cmolc kg-1); ESP-Exchangeable sodium percentage

Appendix 3. Summary of soil analytical procedures used in Zimbabwe

Parameter	Procedure
Cationic exchange capacity:	Saturation with pH 7.0, 1M NH4Ac if pH > 6.4 and with 0.2M NH_4Cl if soil pH < 6.5. NH_4Cl is adjusted to 0.4 pH units of the soil.
Exchangeable bases:	Extract as above and read using atomic spectroscopy

Soil pH:	1 part soil to 2.5 parts of 0.01M $CaCl_2$ and shake for one hour
Particle Size Distribution:	Hydrometer Method (Bouyoucos) and sieve
Free Fe oxide:	Sodium di-thionite procedure
Organic carbon:	$K_2Cr_2O_7$ digestion (Walkely and Black)
Water-soluble salts:	Saturation paste analysis

Points of Contact and Additional Information

This and other Challenge Program on Water and Food Project No 17 reports can be accessed online from www.waternetonline.org - follow the menu: Research > Challenge Program or click here.

Electronic supplementary material:
http://www.waternetonline.ihe.nl/challengeprogram/Soil.zip

This Report:

Department of Soil Science and Agricultural Engineering, University of Zimbabwe, PO Box MP167, Mt. Pleasant, Harare, Zimbabwe
Tel.: +263-4-333407
Fax.: +263-4-333407
Email.: inyagumbo@agric.uz.ac.zw
Contact: Dr. Isaiah Nyagumbo

Project and WaterNet Secretariat:

WaterNet, PO Box MP 600, Mt. Pleasant, Harare, Zimbabwe
Tel.: +263 (0)4 333248/336725
Fax.: +263 (0)4 336740
Email.: waternet@waternetonline.org
Contact: Dr. Innocent Nhapi

WaterNet Working Paper Series:
1. An overview of the Mzingwane Catchment, Zimbabwe, a contribution to the Challenge Program on Water and Food Project 17 “Integrated Water Resource Management for Improved Rural Livelihoods: managing risk, mitigating drought and improving water productivity in the water scarce Limpopo Basin”. February, 2005.
2. Short report on five masters projects from the Mzingwane Catchment, Zimbabwe, a contribution to the Challenge Program on Water and Food Project 17 “Integrated Water Resource Management for Improved Rural Livelihoods: managing risk, mitigating drought and improving water productivity in the water scarce Limpopo Basin”. February, 2005.
3. Short Report on Masters research in the Mzingwane Catchment, Zimbabwe, 2004/5 – 2005/6, a contribution to the Challenge Program on Water and Food Project 17 “Integrated Water Resource Management for Improved Rural Livelihoods: Managing risk, mitigating drought and improving water productivity in the water scarce Limpopo Basin”. September, 2006.
4. Short Report on Masters research cofunded by RELMA-in-ICRAF in the Mzingwane Catchment, Zimbabwe, 2004/5, a contribution to the Challenge Program on Water and Food Project 17 “Integrated Water Resource Management for Improved Rural Livelihoods: Managing risk, mitigating drought and improving water productivity in the water scarce Limpopo Basin”. November, 2006.
5. Short Report on Doctoral research within Challenge Program on Water and Food Project PN17, a contribution to the Challenge Program on Water and Food Project 17 “Integrated Water Resource Management for Improved Rural Livelihoods: Managing risk, mitigating drought and improving water productivity in the water scarce Limpopo Basin”. November, 2006.
6. Short Report on Masters research in progress in the Mzingwane Catchment, Zimbabwe, 2006/7, a contribution to the Challenge Program on Water and Food Project 17 “Integrated Water Resource Management for Improved Rural Livelihoods: Managing risk, mitigating drought and improving water productivity in the water scarce Limpopo Basin”. May, 2007.
7. Baseline Report on the Geology of the Limpopo Basin Area, a contribution to the Challenge Program on Water and Food Project 17 “Integrated Water Resource Management for Improved Rural Livelihoods: Managing risk, mitigating drought and improving water productivity in the water scarce Limpopo Basin”. July, 2009.
8. Baseline Report on the Soils of the Limpopo River Basin, a contribution to the Challenge Program on Water and Food Project 17 “Integrated Water Resource Management for Improved Rural Livelihoods: Managing risk, mitigating drought and improving water productivity in the water scarce Limpopo Basin”. July, 2009.