Inherent Constraints of Southern Africa Soils:
Implications for Sustainable Land Use

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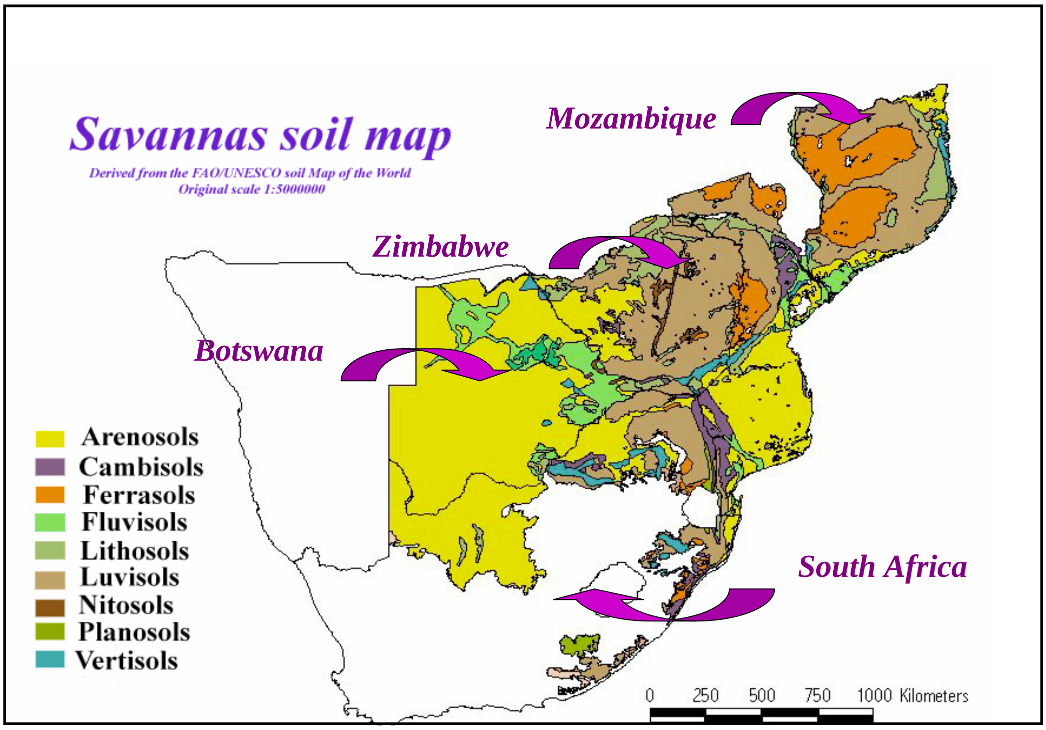
The well being of people, plants and animals in Southern Africa Countries largely depends on sustainable land use and soil management .

The region has a wide variety of soil types often affected by serious inherent constraints.



Under natural conditions soils generally support considerable bio-mass without appreciable degradation, due to the effective functioning of a well established self sustaining ecosystem.

As a consequence of human activities soils can undergo rapid and severe degradation, depending on their characteristics and on the intensity of the impact of the adverse external factors.

Topics of this talk

1) Identification of the main inherent constraints affecting the overall fertility of some soil types, and survey of the balance of soil organic carbon (SOC) in these soils under the pressure of human activities;

2) Identification of the land uses, farming systems and agronomic practices most appropriate to a long-term sustainable management of these vulnerable soils;

3) Comprehensive synthesis of regional distribution in savanna areas of several inherent and environmental constraints to soil productivity.

Soil types considered

Arenosols and Luvisols, dominant in the region (about 83% of total surface);

Vertisols (only 3% of total surface), but potentially very productive if appropriately managed.

***Ferrasols*, concentrated in northern Mozambique, usually are not affected by inherent constraints, have favourable physical properties and exhibit a good resilience to the impact of human activities.**

Appropriately managed and protected from erosion, particularly in steep-lands areas, these soils can respond well even to low input farming, and sustain a fair to good yield.

Soils with very low inherent fertility

Prevailing soil type: Arenosols

Extension: about 100Mha (most of Botswana, western parts of Zimbabwe, south-east Mozambique and north western areas of South Africa);

Parent Material: mostly originated from Kalahari sands. Minor patches from granite, sandstone and sand parent materials;

Fertility: overall poor fertility.

In natural environment, the sustainability of the soil ecosystem is maintained mainly by the re-cycling of litter by living organisms, both flora and fauna.

When human settlement occurs, the soil's inherent poor fertility further decreases.

Clearing and cultivation lead to rapid oxidation of organic matter and depletion of nutrients, and exacerbate the impact of the inherent poor physical properties, such as excessive permeability and low water holding capacity.

Options for sustainable management of Arenosols

Most of these sandy soils are not suitable for sustainable agriculture.

When human settlement is inevitable a regular application of adequate amounts of cattle or other manure, for maintaining the quantity and quality of SOC can reduce the loss of soil fertility.

Only sustainable farming system:

Extensive livestock rearing

Conditions might be improved by:

- ***Introducing drought resistant fodder crops;***
- ***Selection of locally adapted cattle;***
- ***Rearing of game for production of meat.***

Best Options:

Forestry - Natural reserves

Soils prone to physical degradation (Compaction, Crusting and Hardsetting)

Most susceptible soil type: Luvisols

Extension: ***about 50 Mha (mostly in South Africa, Zimbabwe and Mozambique);***

Parent Material: ***various types of igneous and metamorphic rocks;***

Fertility: ***natural fertility generally moderate to rather good. Under cultivation, soils with a specific particle size distribution, are susceptible to severe physical degradation.***

Main specific constraints encountered on cultivating the susceptible soils

Raindrop impact on bare soil degrades soil structure.

Excessive hardness of the dry soil, makes it difficult to get a good seedbed.

Poor infiltration capacity, results in inefficient rainwater storage and difficulties in irrigation.

High runoff rate determines increased susceptibility to water erosion.

Crusting and compaction inhibit germination and seedling emergence.

Options for controlling physical degradation (crusting, hardsetting, compaction) of susceptible soils

Maintain an adequate level of organic matter;

Surface addition of chemicals to promote flocculation of colloidal particles (short term effect only);

Protect the soil from kinetic rain energy with mulch straw or similar materials.

Swelling, heavy textured soils

Dominant soil type: Vertisols

***Extension:** Limited - estimated to cover about 9 Mha (mostly in Botswana, Zimbabwe and South Africa).*

***Parent Material:** Various types of sedimentary and basaltic rocks.*

***Fertility:** Resilient soils with a relative good fertility, in spite of the serious constraints imposed by their physical properties.*

Vertisols

Main specific constraints encountered on cultivating Vertisols

Excessive swell-shrink properties, that make soil very sticky when wet, but hard with deep and wide cracks, when dry.

Tillage difficult with animal-drawn or mechanized cultivation.

Restriction to roots penetration, and difficulties for large animals to walk across .

Very low permeability.

Large amounts of standing water in the wet season.

Severe erosion hazard due to the low permeability and high runoff.

Serious salinisation problems can develop under irrigation.

High bulk density.

If machinery is used, it can get stuck in the wet plastic clay.

Options for sustainable management

Subsistence farming difficult because of:
1) difficult tillage with hand implements.
2) soil propensity to waterlog and general difficulty of water control.

Sustainable use as pastures by avoiding overgrazing and the consequent physical soil degradation and bush encroachment.

Suitable for commercial farming if:
1) correctly managed and properly irrigated.
2) adequate energy and nutrients inputs are provided.

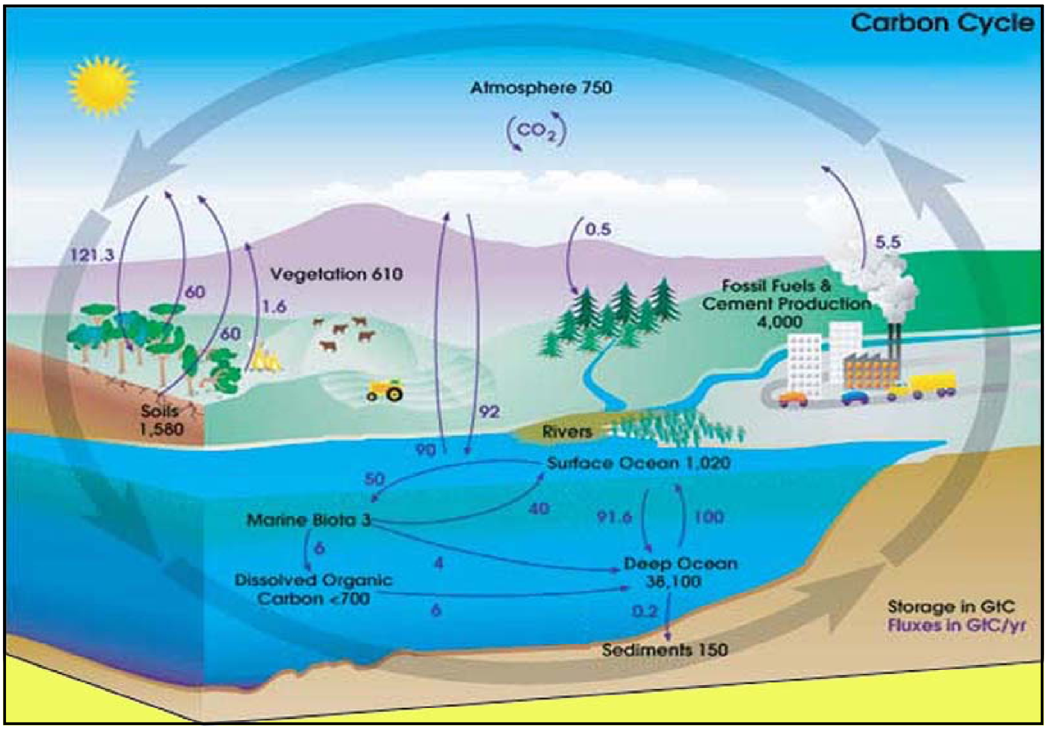
To improve productivity of commercial farming further research is needed focusing on:

land forming/shaping strategies to conserve moisture in the dry season;

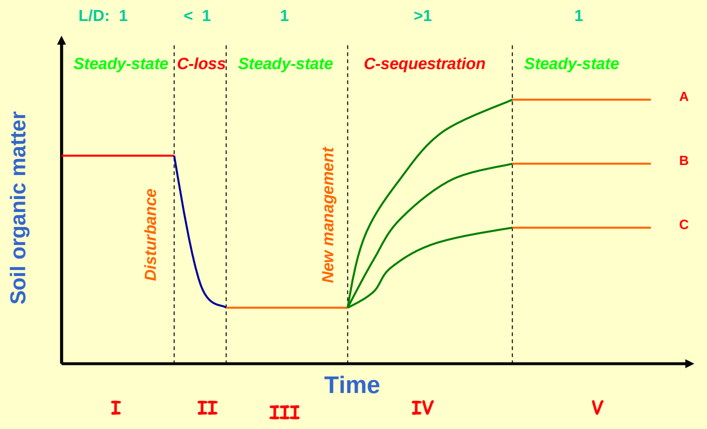
appropriate field machinery;

strategies for soil fertility management, and weed control;

impact and fate of pesticides.



Conceptual model of the most common (SOC) dynamics under the pressure of human activities



L/D = Litter production over decomposition

After Jhonson,1995

Tanzanian soils

	Mkindo (g kg^{-1})			Mafiga (g kg^{-1})	
	Uncultivated	*Fallow*	*Cultivated*	*Uncultivated*	*Fallow*
C	15.0	10.4	28.9	12.3	8.3
N	0.9	0.6	2.1	1.1	0.8
C/N	6.6	17.3	13.8	12.3	10.8

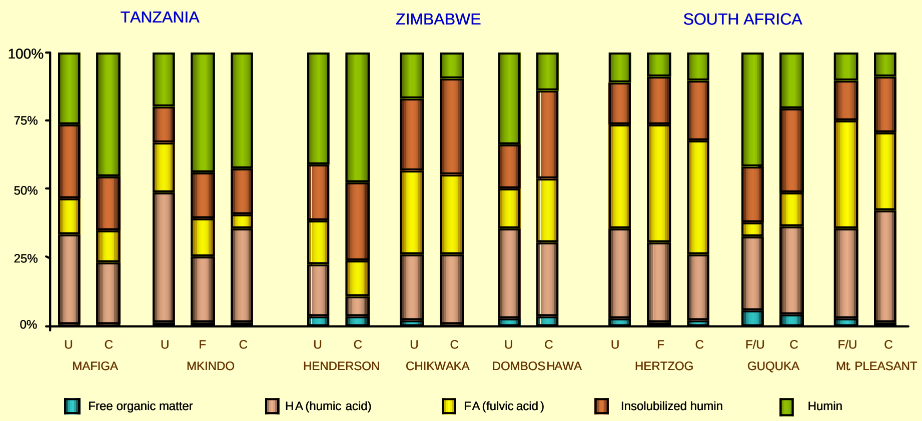
Zimbabwean soils

	Henderson (g kg^{-1})		Domboshawa (g kg^{-1})			Chikwaka (g kg^{-1})		
	Uncultivated	*Cultivated*	*Uncultivated*	*Fallow*	*Cultivated*	*Uncultivated*	*Fallow*	*Cultivated*
C	20.0	7.9	10.2	6.9	6.3	6.7	4.9	3.8
N	1.4	0.6	0.8	0.5	0.5	0.3	0.4	0.3
C/N	14.3	13.2	12.8	13.8	12.6	22.3	12.2	12.7

South African soils

	Mt Pleasant (g kg^{-1})		Guquka (g kg^{-1})		Hertzog (g kg^{-1})			Qunu (g kg^{-1})
	Fallow/Uncult.	*Cultivated*	*Uncultivated*	*Cultivated*	*Uncultivated*	*Fallow*	*Cultivated*	*Fallow*
C	14.9	10.5	10.1	6.1	16.1	9.0	7.7	1.4
N	1.2	0.9	0.4	0.4	1.4	0.8	0.7	0.1
C/N	12.4	11.7	25.3	15.3	11.3	10.3	10.2	12.7

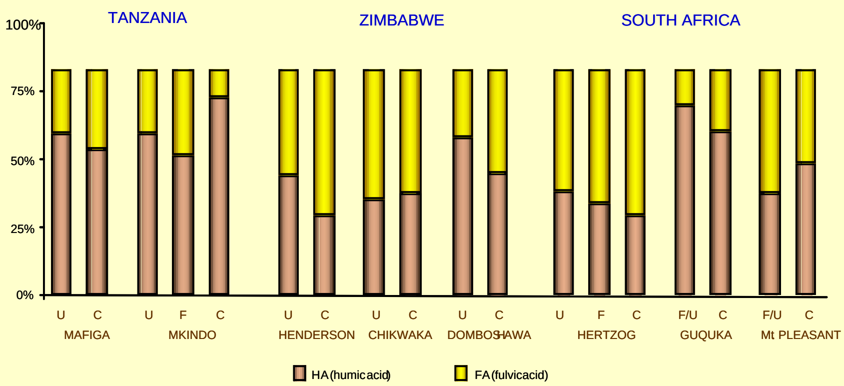
SOM fractions (percentage of total soil C)



U= uncultived, F =fallow, C=cultived

Pardo et al., 2006

Proportion of humic and fulvic acids in soils from uncultived and cultived sites



U= uncultived, C=cultived

Pardo et al., 2006

General overview of quantitative distribution of some major soil inherent and environmental constraints

Figures were based on soil fertility constraints data, reported on Digital Soil Map of the World and Derived Soil Properties (FAO, 1997).

To focus the outcomes on savanna areas, a digital map of savanna eco-zone distribution was superimposed to the general soil map to obtain the Southern Africa savannas soil map previously shown.

The resulting data on limitations to overall soil productivity are expressed in terms of:

A) ***Fertility Capability Soil Classification (FCC) system.***

B) ***Problem Soils identification methodology.***

***FCC** is a technical system for grouping soils according to the kind of problems they present for agronomic management of their chemical and physical properties (Sanchez and Buol 1985; Smith et al., 1990).*

***FCC-classes** indicate the main fertility-related soil constraints identified, for each Country, on the basis of Derived Soil Properties data (FAO, 1997). These constraints can be interpreted in relation to specific farming systems or land utilisation types.*

The system is complex because:

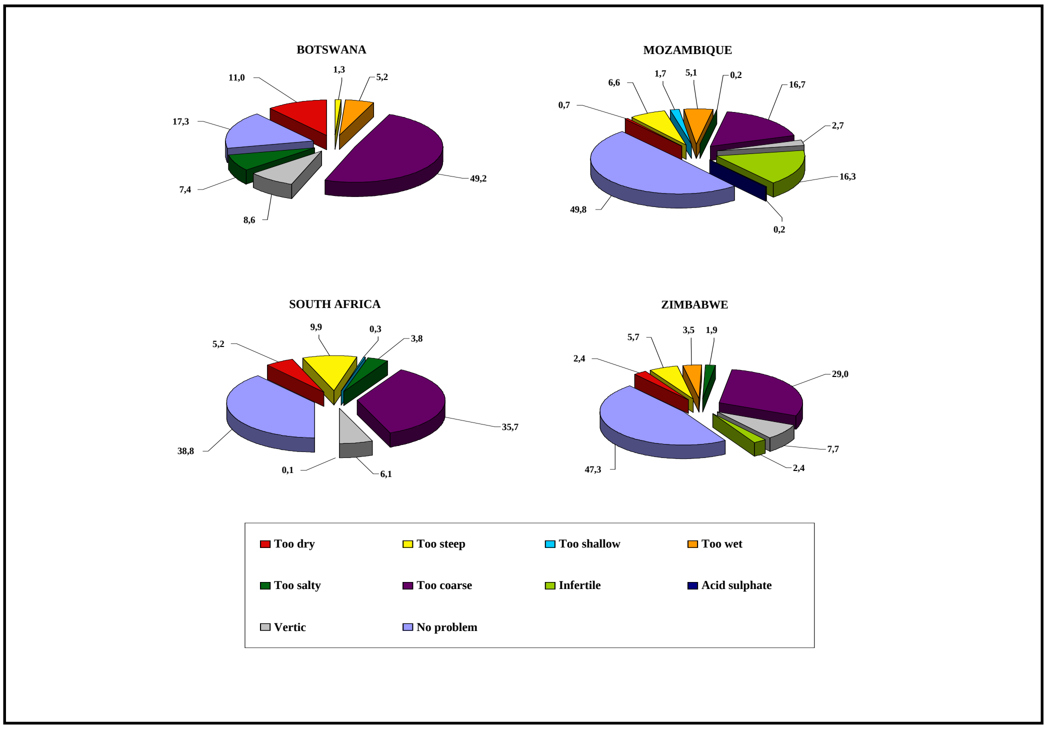
- ***in many cases tracts of land will exhibit a combination of a number of soil and agro-climatic constraints;***

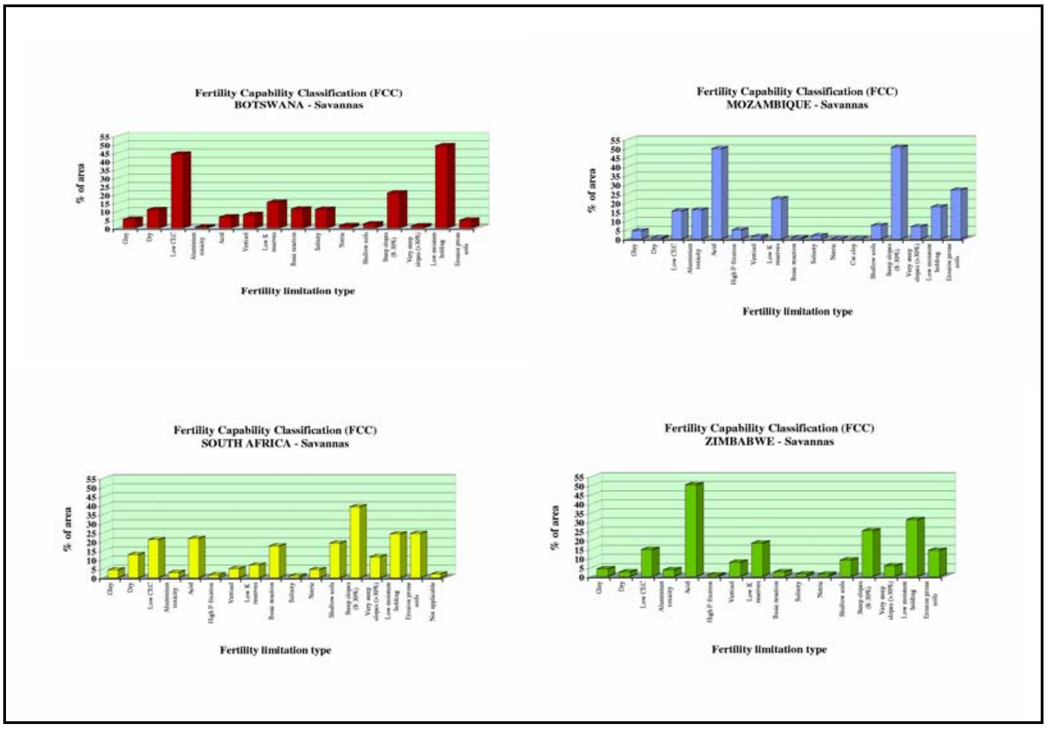
- ***environmental requirements of individual crops vary considerably so that what is a severe constraint for one crop may be less severe or non-existant for another crop.***

Problem soils identification

Problem soils have been defined as soils with intrinsic and/or environmental constraints to agricultural production.

in these soils, degradation hazards are more severe, with respect to no problem soils, and adequate soil management measures are more difficult or costly to apply.


BOTSWANA
1,3
11,0
5,2
17,3
49,2
7,4
8,6
MOZAMBIQUE
6,6
1,7
5,1
0,2
16,7
0,7
2,7
16,3
49,8
0,2
SOUTH AFRICA
9,9
0,3
3,8
5,2
35,7
38,8
0,1
6,1
ZIMBABWE
5,7
3,5
1,9
2,4
29,0
7,7
2,4
47,3
Too dry
Too steep
Too shallow
Too wet
Too salty
Too coarse
Infertile
Acid sulphate
Vertic
No problem


Fertility Capability Classification (FCC)
BOTSWANA - Savannas
% of area
Fertility limitation type
Fertility Capability Classification (FCC)
MOZAMBIQUE - Savannas
% of area
Fertility limitation type
Fertility Capability Classification (FCC)
SOUTH AFRICA - Savannas
% of area
Fertility limitation type
Fertility Capability Classification (FCC)
ZIMBABWE - Savannas
% of area
Fertility limitation type

ISE approach to the assigned tasks in COMPETE

Focusing on soils quality and constraints and in particular on SOC dynamics and changes under pressure of human activities, the ISE team will contribute to identify land potentially suitable for bio-energy production, by :

- ***Collecting information from local partners, existing database and literature on soil ecosystem status and overall fertility in target areas;***
- ***Assessing the impact of energy crops on SOC turnover in soils from Partner Countries with experience of different existing biomass production systems;***
- ***In situ survey of actual soil condition, SOC balance and problems in target areas;***
- ***Identify sustainable soil management to support farm-system strategies for increasing C sequestration in soil and maintaining good bio-energy productivity.***