From Space to Plot: Assessment of Land Degradation Patterns in Kenya and its Implication for Sustainable Land Management

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The situation

‘*The recurrent famines in Horn of Africa have been exacerbated by decades of deforestation* and other forms of human-caused land degradation *that has made land unproductive*’ (CIFOR, 2011)

Significance of land degradation

- LD is a threat to:
  - future global food and energy security (World Bank, 2008)
  - water availability (MA, 2005),
  - capacities to adapt to and mitigate climate change (Neely et al., 2009)
  - biodiversity conservation (UNCBD, 1992)

Land degradation assessment methods

- LD assessment methods: *Expert opinion, Direct field measurements, use of models, RS and GIS*
- Various projects
  - *Desertification Mitigation and Remediation of Land (DESIRE) project,*
  - *the Dryland Development Paradigm (DDP)*
  - *the UN Food and Agriculture Organisation's UNEP/GEF-funded land degradation Assessment in Drylands (LADA)*
  - *World Overview of Conservation Approaches and Technologies (WOCAT)*

The challenge

- The methods/approaches have different strengths and limitations
- The methods/approaches differ in spatial and temporal scales
- Do not explicitly outline how scales could be bridged

- *Cross-scale/Integrated methodological framework for land degradation and SLM M&A* (Reed et al 2011)

Goal

- This study sort to illustrate how scale of assessment impacts on LD pattern mapping?

Study area

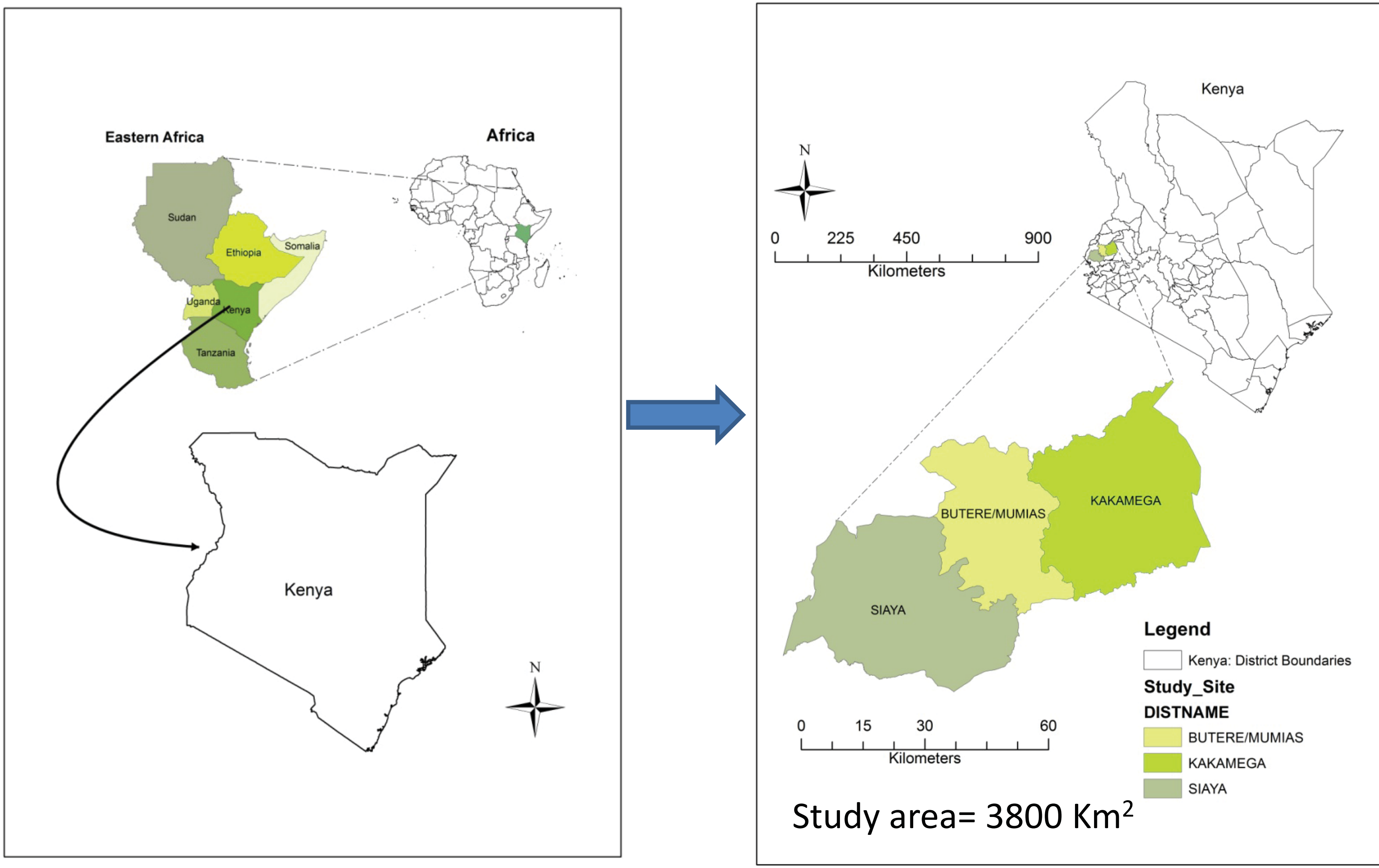


Fig 1: Study area

Highly fragmented & diverse farming systems

Mixed cropping - maize & beans

Livestock rearing

Fragmented natural forests

Fig 2: Characteristics of study area

Study area

- Bimodal rainfall: 800 - 1800 mm
- AEZ: Humid, sub humid, semi-humid, semi-humid to semi-arid
- Soil types: Ferralsols, Acrisol, Nitisols, Cambisols, Planosols

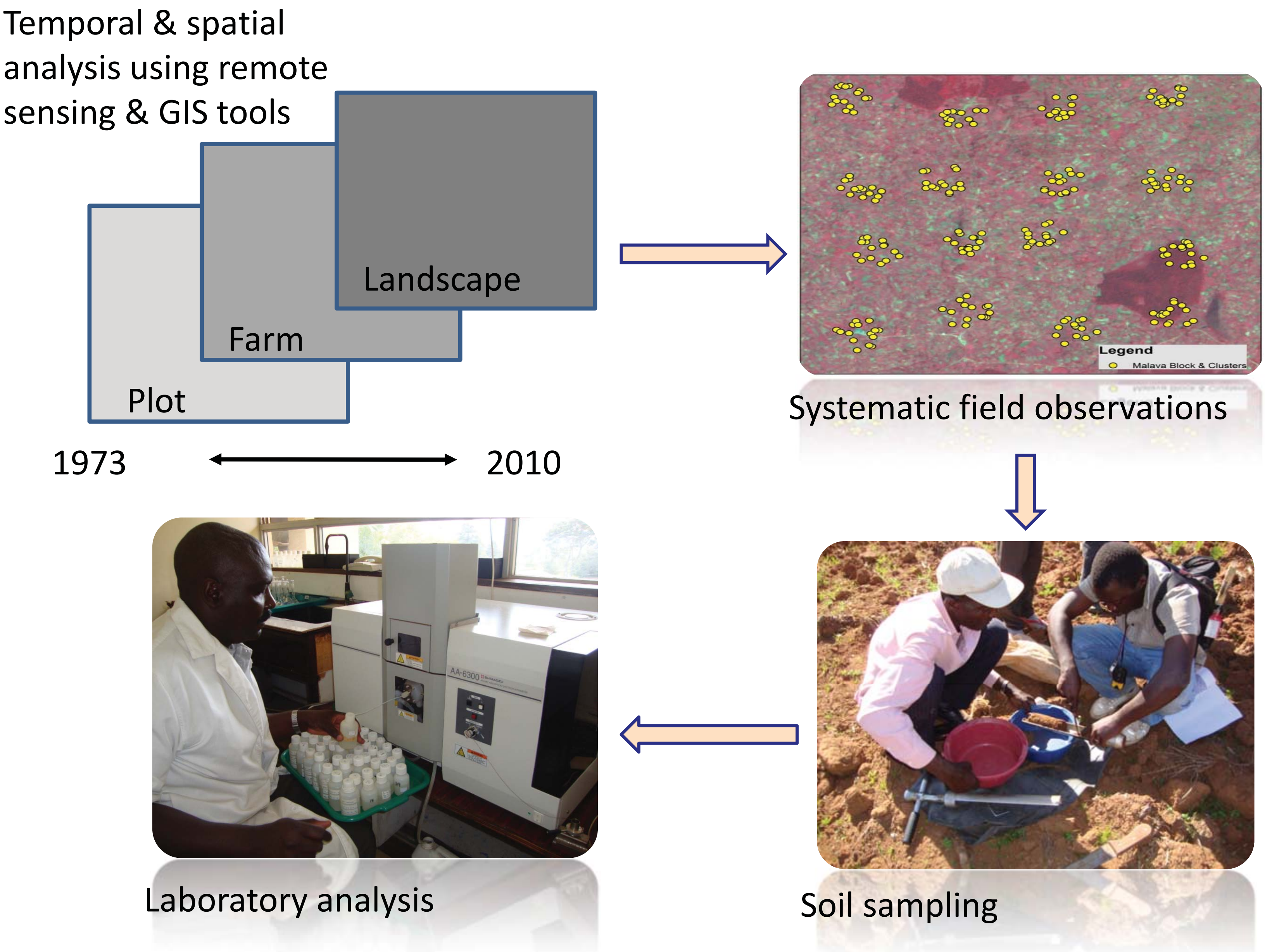


Fig 4: Summary of methodology

LD mapping using NDVI as a proxy

- Target: National level with projection at regional level
- Data sources:
  - 500 m, Moderate Resolution Imaging Spectroradiometer Normalized Difference Vegetation Index (MODIS/NDVI)- period (2000-2009)
    - Downloaded from the USGS, GLOVIS website
  - Gridded climate CRU TS 3.1 ($0.5° \times 0.5°$) data
    - Downloaded from the CGIAR-CSI website
    - Region of interest clipped, scaled and averaged to get the Mean Annual Precipitation (MAP)

Inter-annual NDVI change analysis

- Linear regression used to determine the magnitude of change of the NDVI over time (inter-annual NDVI change) (Vlek et al., 2008)

$$NDVI = A \times Year + B$$

Where:

NDVI:	*Normalized Difference Vegetation Index*
A:	*Slope coefficient*
Year:	*Period of assessment (2000-2009)*
B:	*Error term*

Correlation between NDVI and MAP

- Pearson's correlation coefficient for the period 2000-2009

$$R_{xy} = \frac{\sum\left(X_i - \bar{\bar{X}}\right)(Y_i - \bar{Y})}{\sqrt{\sum(X_i - \bar{X})^2 \sum(Y_i - \bar{Y})^2}}$$

Where:

R_{xy}:	Pearson's coefficient
X_i:	Mean annual precipitation (MAP)
i =	2000 to 2009
Y_i :	Mean annual NDVI

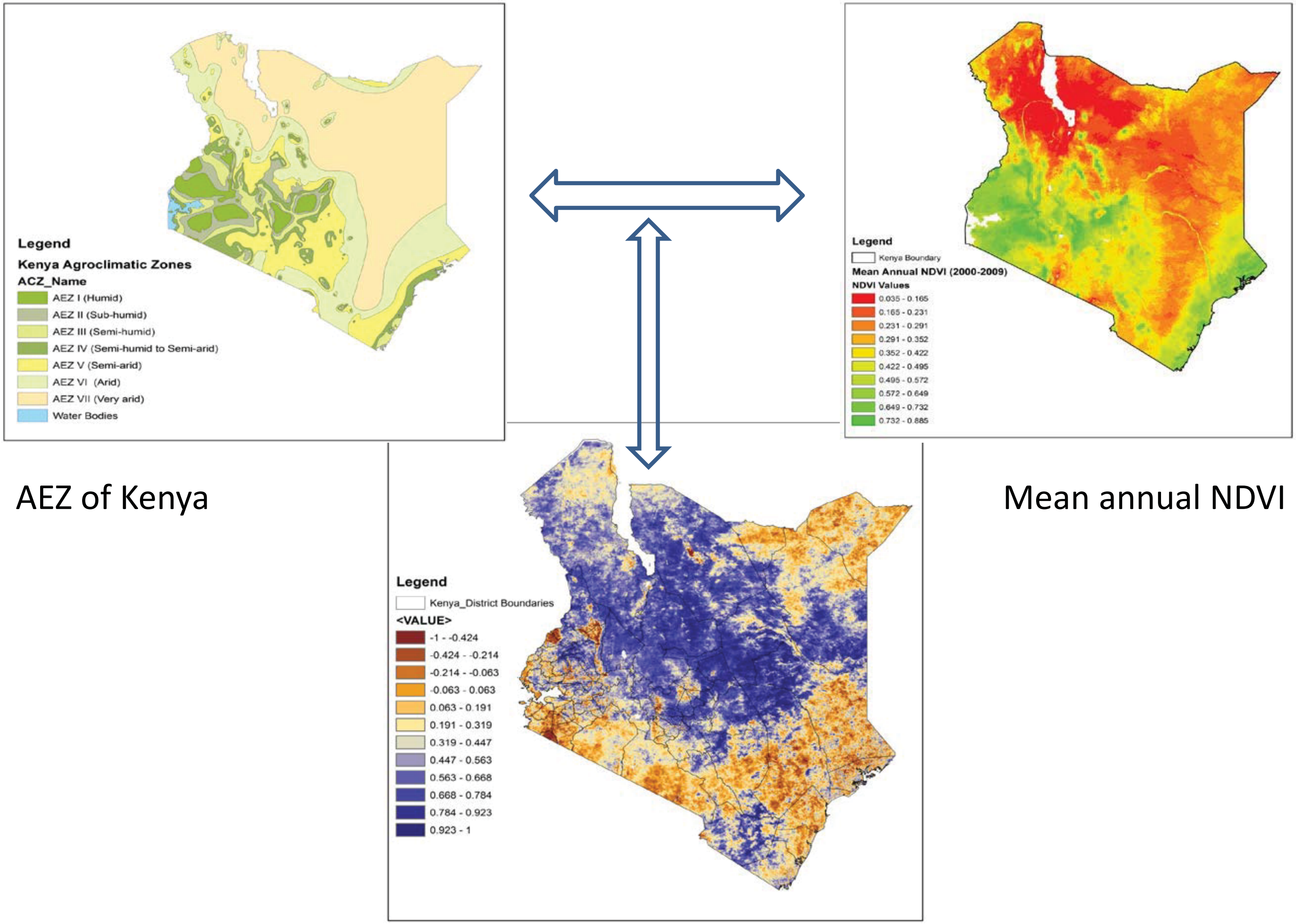


Fig 5: Pearson's coefficient of correlation between annual NDVI and precipitation (2000-2009)

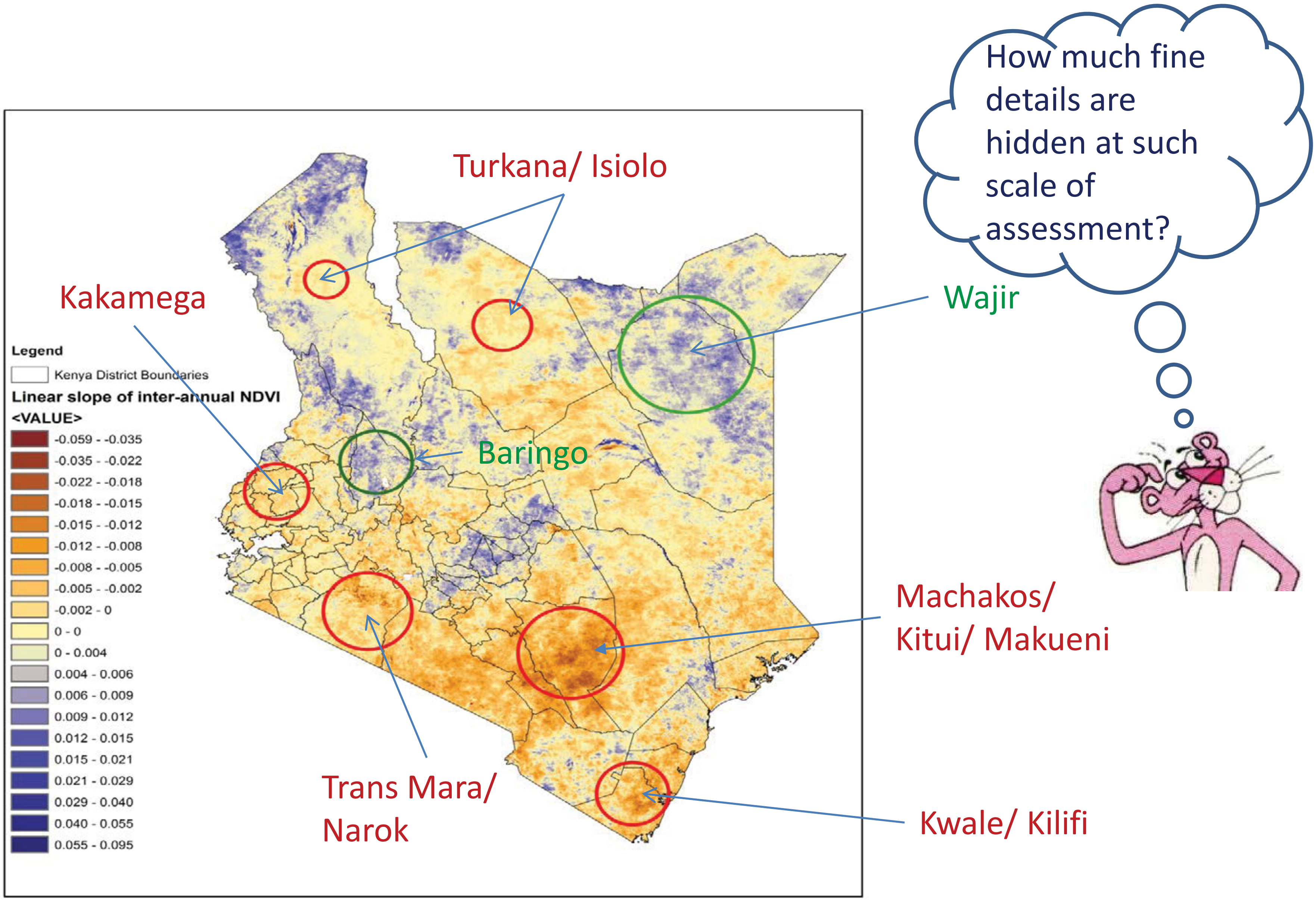


Figure 6. Linear slope of annual NDVI for the period 2000-2009

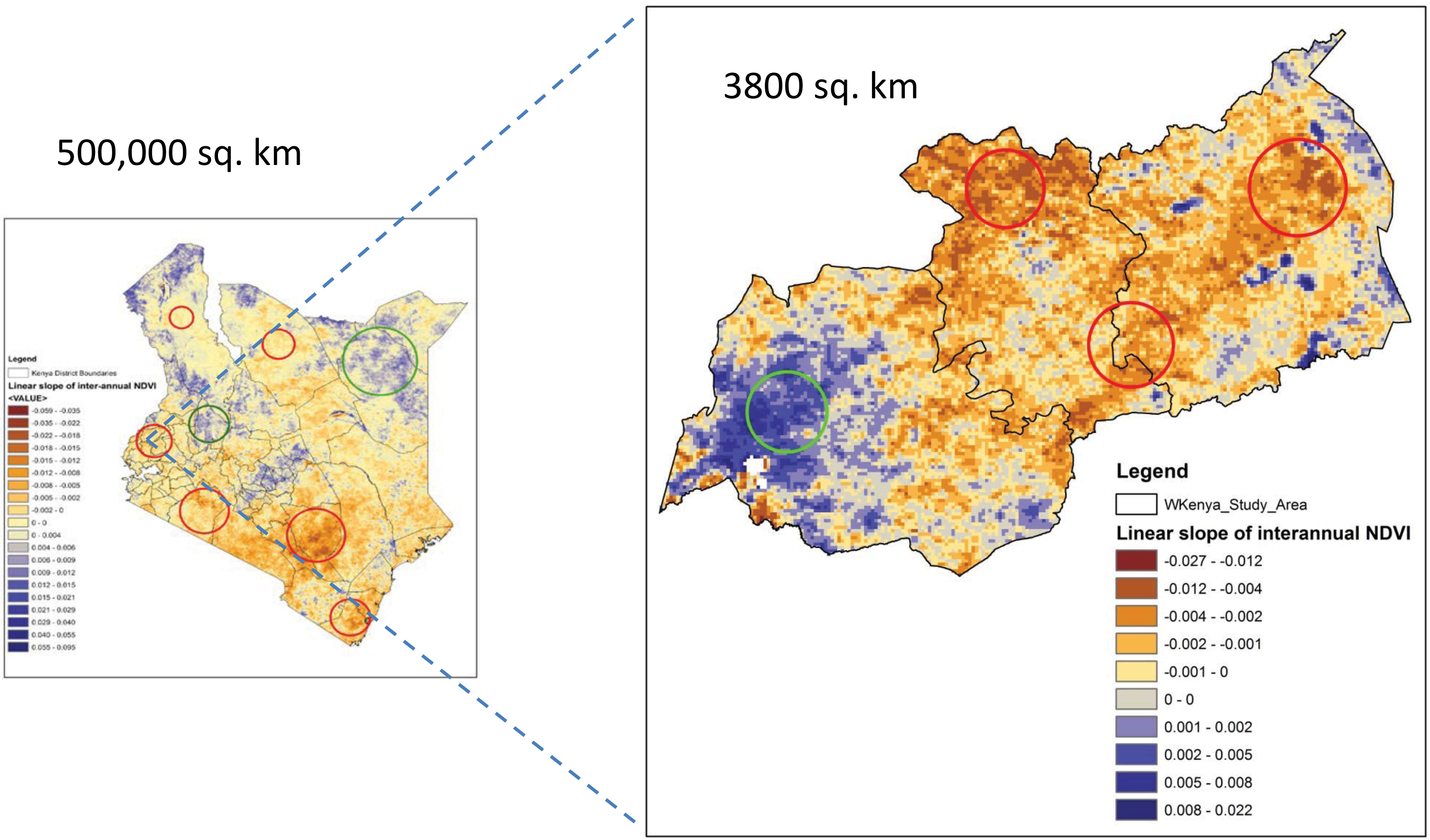


Fig 7: Linear slope of inter-annual NDVI for the period 2000-2009 for Western Kenya

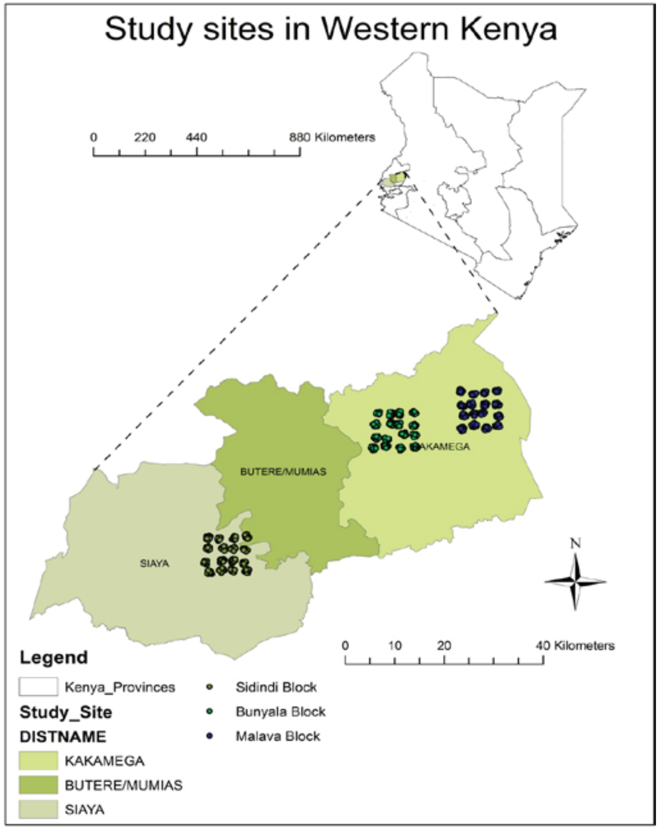
Table 1: Land use/cover evolution (%) between 1973 and 2003

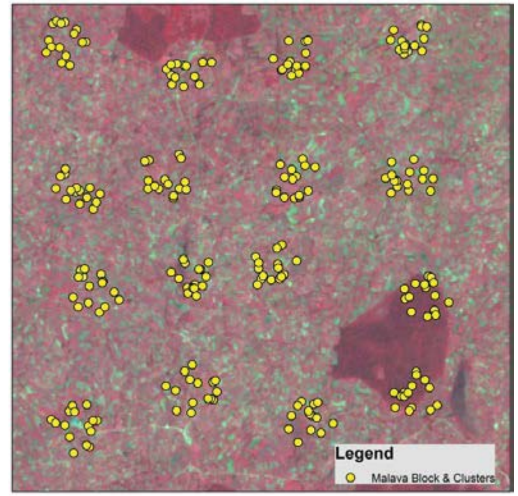
Class	1973	1988	2003
	Percentage (%)		
Natural Forest	3.9	3.8	3.4
Plantation Forest	0.2	0.1	0.3
Secondary Forest	0.3	1.2	0.5
Bushland	1.7	3.1	5.7
Wooded Grassland	51.3	30.2	11.8
Agricultural Land	27.9	50.5	70.4
Bareland	12.3	8.9	7.4
Water Bodies	2.3	1.1	0.5
Unclassified	2.6	2.1	2.0
Total	100.0	100.0	100.0

But is all LULC = Land degradation? Not necessarily

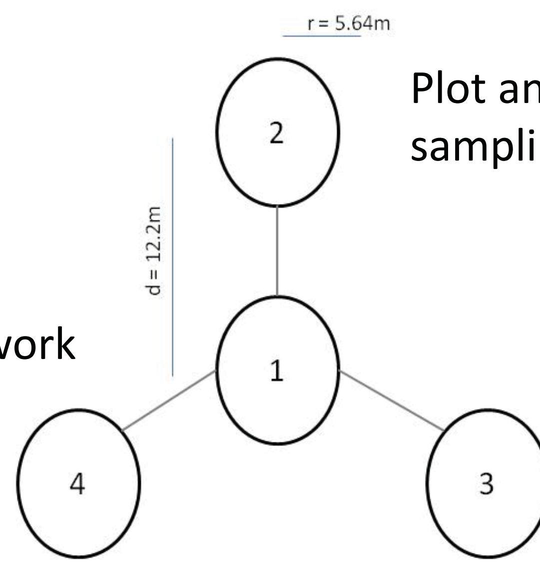
Detailed characterization of sites

- Indicator attributes:
  - ***Soil stability*** – capacity of site to limit redistribution and loss of soil/nutrients by wind or water;
  - ***Hydrologic Function*** – capacity to capture, store and safely release water from rainfall
  - ***Integrity of the Biotic Community*** – capacity of site to support characteristic functional and structural communities and to resist loss caused by disturbance





The 10×10 km sampling block with the sampling clusters in Malava Block



Plot and sub-plot sampling layout

Fig 8: Land Degradation Sampling Framework (LDSF) (Vågen et al., 2010)

Sheet erosion

Exposed rock pedestals

Sheet erosion

Gully erosion

Plant parasitic weeds

Unpalatable pasture species

Fig 9: Indicators of land degradation

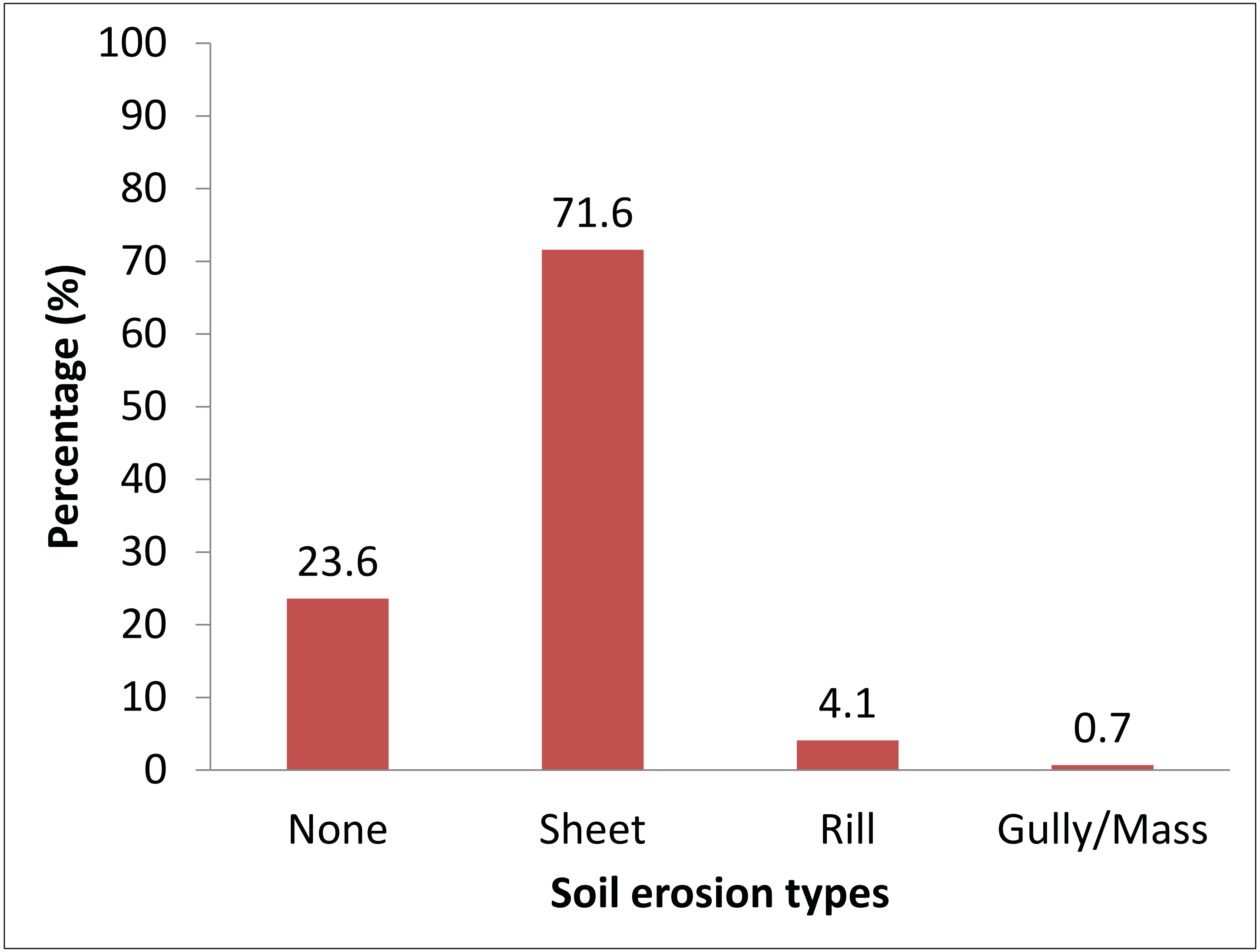


Fig 10: Types of soil erosion in the study area

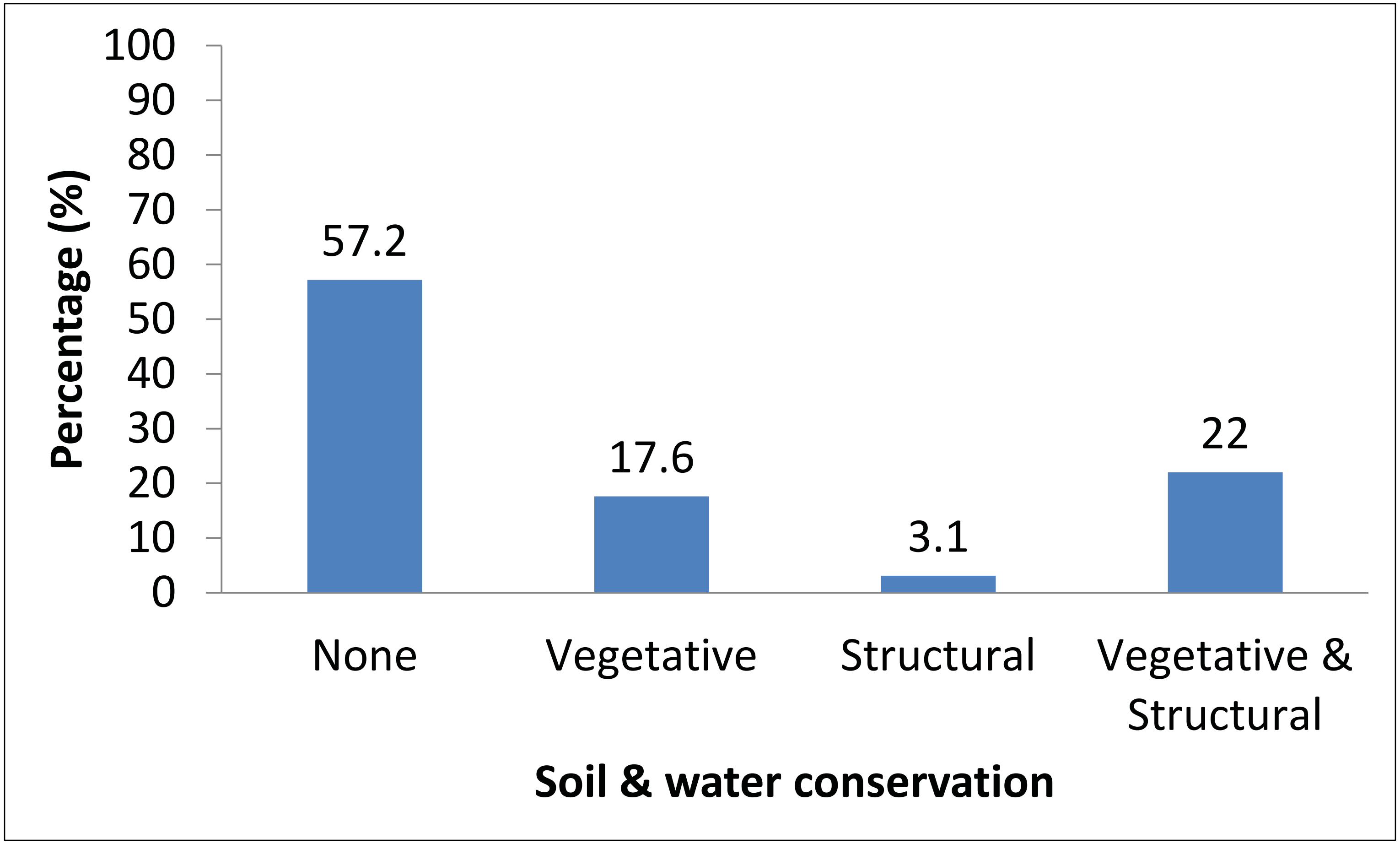
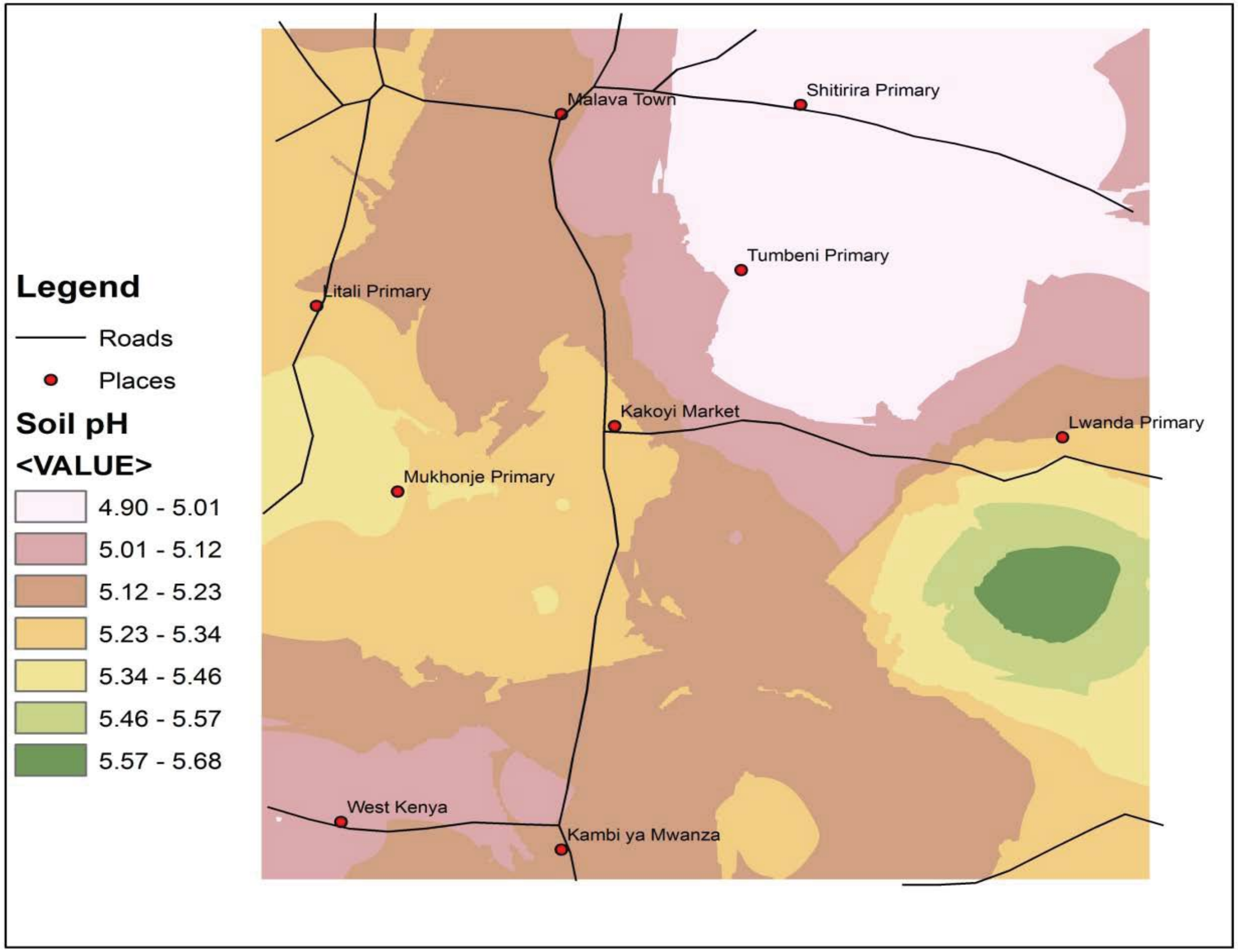
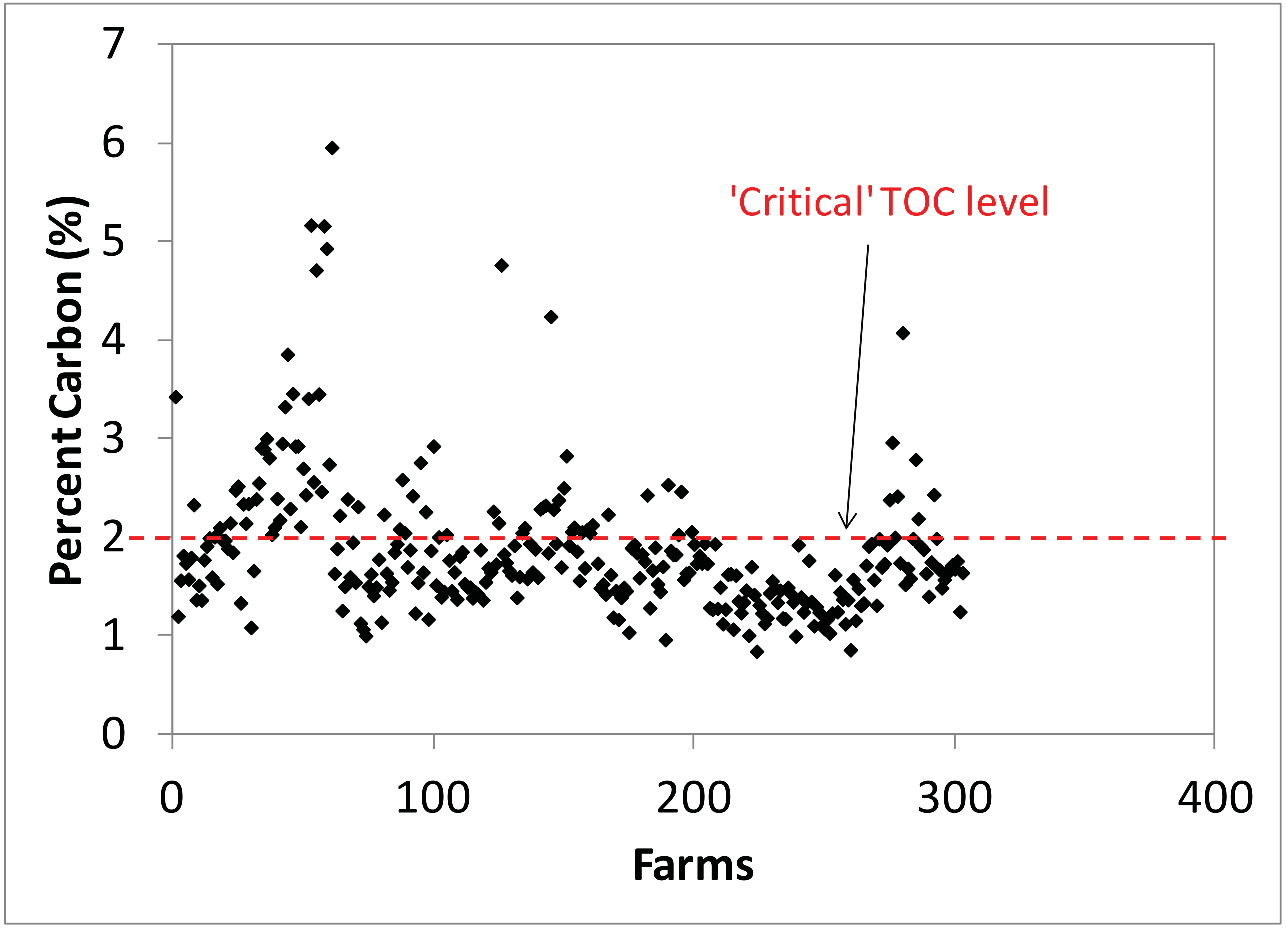


Figure 11: Soil and water conservation practices on the farms



Majoty of farms with slightly acidic (pH 6.1-6.5) to stronlgly acidic (pH 4.5-5.5)

Figure 12: Soil pH pattern in Malava Block



55% and 88% of farms in Malava and Sidindi respectively had SOM below the critical level!!

Figure 13: Soil organic Carbon (TOC) variation across the farms sampled in Malava and Sidindi Blocks

Fig 14: Types of land degradation in the study area

Overall Conclusions…

- Different indicators, patterns and types of land degradation are evident at different scales of assessment
  - National level patterns can aid in national policy making and modeling environmental change
  - Landscape level patterns can aid in project targeting
  - Plot and sub-plot level patterns can aid land user select specific integrated technologies

- Using GIS tools, it is possible to scale out measurements at different scales of assessment
- Visual and quantitative basis of land degradation assessment is essential for different users
- Irrespective of scale LD assessment should provide basis for future M&A (georeferencing needed)

Research partnerships

AfricaSoils.net

Africa Soil Information Services (AfSIS)

KARI

Kenya Agricultural Research Institute

TSBF

Tropical Soil Biology & Fertility Institute of CIAT (TSBF-CIAT)

Stiftung fiat panis

IPNI

International Plant Nutrition Institute

DAAD

Deutscher Akademischer Austausch Dienst
German Academic Exchange Service