Using Systematic Field Surveys to Assess the Effects of Land Use on Soil Health Across Diverse Landscapes

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Land Degradation, Ecosystem Services, Land Health, Soil Health, and Agricultural Production are inextricably linked.
Systematic assessments for cross-site analysis

To feed the world system experts the myriad impacts of different farming practices need to be captured. Monitoring the world's agriculture on the basis of a narrow range of criteria, such as traditional pastoralist systems, are often under-represented in monitoring efforts. Effective monitoring of agriculture: a response

Effective monitoring of agriculture: a response


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DOI: 10.1039/c2em10584e
Objectives

• To illustrate the use of a systematic sampling framework to multi-level modeling for cross-site/cross-country analysis
• To assess the linkages between inherent soil properties, land cover typologies and soil health
• To explore the LDSF data from five SL
Importance of Soil

- Soil provides multiple ecosystem services:
  - medium for plant and ag production;
  - filter for toxins;
  - regulating hydrologic cycle (Millennium EcoSystem Assessment, 2005)
- Plant-soil relationships that determine the distribution of aboveground vegetation
Factors of Soil Formation
Climate, organisms, relief, parent material, time....
Influence of Soil Forming Factors on Inherent Soil Properties

- **Parent material** - > soil texture (% clay), total elemental composition
- **Climate** - > degree of weathering and available nutrients

Forming inherent constraint envelopes for the soil (e.g., capacity to store and exchange cations (nutrients))
Influence of Organisms (Land Cover/Land Use) on Dynamic Soil Properties

Land use can influence soil health but inherent soil properties determine the magnitude of these effects.

Hence it is important to understand the complexity of the soil system.

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<th>Bukwaya</th>
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</table>

![SOC graph](image-url)
Land Degradation Surveillance Framework (LDSF)
Plot observations

- Land cover and land-use history
- Topographic position
- Primary use
- Woody leaf types
- Landform
- Slope
- Vegetation structure
- Impact on habitat

**Plot observations**

- Vegetation structure
- Slope
- Landform
- Primary use
- Woody leaf types
- Landform designation:
  - Level
  - Sloping
  - Steep
  - Composite

Position on topographic sequence:
- Upland
- Ridge/Crest
- Mid slope
- Foot slope
- Bottomland

**Notes:**
- *forest, woodland, bushland, thicket, shrubland, grassland, wooded grassland, cropland, mangrove, freshwater aquatic, halophytic, other*

**Plot:**
- Bare? Yes

**Major landform:**
- Medium gradient mountain
- Medium gradient hill
- Medium gradient escarpment
- Ridges
- Mountainous highland

**Subplot:** (100 m²)

- Rock/stone, Gravel cover (%)
- Woody Cover rating (%)
- Herbaceous Cover rating (%)

**Auger depth restriction (cm):**

- Topsoil (ribbon length [mm]):
- Subsoil (ribbon length [mm]):

**Observations:**
- Herbaceous annual
- Herbaceous perennial
- Forbs
- Other

**Land ownership:**
- Private
- Communal
- Government
- Don't Know

**Soil and water conservation:**
- Number:
  - None
  - Vegetative
  - Structural

**Impact on habitat:**
- Impact of tree cutting
- Impact of agriculture
- Impact of grazing/browsing
- Impact of fire
- Impact of alien vegetation
- Impact of firewood collection

**Other:**
- Impact of erosion
- Impact of urban activities
- Impact of deforestation

**Descriptive notes:**
- Describe land cover/use history:
## Subplot observations

- Tree and shrub densities
- Woody cover rating
- Herbaceous cover rating
- Erosion prevalence
- Root depth restrictions
- Composite soil samples (320 per site) (0-20 cm and 20-50 cm)

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### Electronic field data entry

CyberTracker is a data capture tool, but also has some basic GIS functionality. It was originally developed to record wildlife movement in the Central African rainforest. We developed a CyberTracker application for LSDF field data.

The CyberTracker (http://www.cybertracker.co.za) software is a free and efficient method for direct data entry in the field. The data entered is uploaded to the central database in Nairobi, Kenya, after the completion of a survey. These systems increase efficiency and reduce potential errors in the data capture process.

### LDSF START NEW PLOT

- **Name:**
- **Country:**
- **Date:**
- **Latitude:**
- **Longitude:**
- **Cluster:**
- **Elevation:**
- **Plot:**
- **Photo ID:**
- **Pos error:**

### LDSF Field Form v4 2013

- **Visible erosion:**
- **Woody Cover rating (%):**
- **Herbaceous Cover rating (%):**
- **Auger depth restriction (cm):**
- **Topsoil thickness (mm):**
- **Subsoil thickness (mm):**
- **Notes:**

### Vegetation structure:

- **Vegetation types:**
- **Forbs:**
- **Other:**
- **Trees:**
- **Broadleaves:**
- **Evergreen:**
- **Deciduous:**

### Impact:

- **Impact on habitat:**
- **Impact of alien vegetation:**
- **Impact of erosion:**
- **Impact of urban activities:**
- **Impact of industry:**
- **Impact of alien vegetation:**
- **Impact of firewood collection:**

CyberTracker is primarily a data capture tool, but also has some basic GIS functionality. It was originally developed to record wildlife movement in the Central African rainforest. We developed a CyberTracker application for LSDF field data.
LDSF Database-FileMaker mirrored in MSQL

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<th>Broadleaf</th>
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Sampling a Landscape-WGSL
Sampling a Landscape - WGSL

Nilgris LDSF Site Land Cover Classes

Legend
- Nilgris
- Vegetation:
  - Agricultural
  - Agricultural/other land use
  - Coffee
  - Coffee + Orchards
  - Dry deciduous forests
  - Dry evergreen and semi-evergreen climax forests
  - Dry evergreen or semi-evergreen forests
  - Eucalyptus
  - Grassland
  - Miscellaneous
  - Moist deciduous forests
  - Montane Formations (>1800m)
  - Other degraded stages
  - Secondary or degraded stages; (semi-)evergreen
  - Secondary or degraded stages; secondary moist decid. forests
  - Tea
  - Water Tanks
  - Wet evergreen or semi-evergreen climax forests

Nilgris

100 0 100 km

RESEARCH PROGRAM ON
Forests, Trees and Agroforestry

CGIAR
Assessing Soil Carbon Storage as Potential Climate Change Mitigation Strategy

- Soil organic carbon is an indicator of soil health
- Contrasting sites in Tanzania, Ethiopia and Kenya to demonstrate utility of method: SOC stocks to 30 cm
- To understand landscape patterns of SOC stocks
- To target areas for SOC strategies

Vågen and Winowiecki, 2013. Mapping of SOC stocks for spatially explicit assessments of climate change mitigation potential. Environmental Research Letters. 8
Assessing Soil Carbon Storage as Potential Climate Change Mitigation Strategy

- Climate and texture explained only 47% of the variation
- Cross-site comparison to include land cover and land degradation
- 0.9 kg m\(^{-2}\) less C in eroded plots
- Most pronounced in Mbinga woodland/grasslands

Vågen and Winowiecki, 2013. Mapping of SOC stocks for spatially explicit assessments of climate change mitigation potential. Environmental Research Letters. 8
Cross site comparisons: SL - Nicaragua & Honduras

- Two LDSF sampled in Nicaragua - 2013: Columbus Mine and El Tuma La Dahlia
- Two LDSF sampled in Honduras - 2013: Rio Platano and Rio Blanco
- Nicaragua soil samples at ICRAF lab

The Nicaragua team, led by Dr. Norvin Sepulveda and Dra. Jenny Ordonez of CATIE, will sample both LDSF sites in Nicaragua. The Honduran teams are led by Dr. Juan Carlos Flores of CATIE working together with Dr. Kenny Najera of UNA and Jaime Enrique Peralta of FMV. The UNA team will sample the Rio Blanco site near Catacamas and the FMV team will sample the remote Rio Platano site in the north. Field training was extended to students, local farmers, NGOs, CGIAR centres and others. Participants were trained in navigation with the GPS units to locate the randomly generated LDSF plots (160 per site); all aspects of the LDSF, including soil sample collection, tree and shrub measurements, erosion observations, among other variables; and electronic data entry. Preliminary data analysis was conducted on the newly collected data, including infiltration capacity curves and tree density estimates. Students from UNA will use the LDSF data for undergraduate theses.
Tree Densities and Erosion Prevalence - Cultivation in El Tuma and Columbus Mine, Nicaragua

![Box plot showing tree density and erosion prevalence at El Tuma and Columbus Mine.](image)
Cross site comparisons: SL - South Africa

- Two LDSF - 2013: Agincourt and Bushbuckridge, South Africa
- Soil samples are in the ICRAF Laboratory
- Link to Agincourt social-economic surveys
Cross site comparisons: SL - Burkina Faso/WGSL

- One LDSF - 2013: Cassou, Burkina Faso
- Soil samples are being processed by WASL
- WGSL - March 2014
Cross site comparisons: Cultivated area within the five LDSF sites in the SL
Cross site comparisons: Trees and Erosion
Nicaragua Infiltration Capacity - Effect of Trees

Average Infiltration Capacity

Site
- colombusmine
- eltuma

Average Infiltration Capacity - Nicaragua

Trees
What’s next.....

- Linking interdisciplinary datasets
- Understanding and linking land health with socio-economic assessments/analysis
- ..
- ....
- ..Let’s open R
Let's Download R & RStudio

The R Project for Statistical Computing

Getting Started:
- R is a free software environment for statistical computing and graphics. It compiles and runs on a wide variety of UNIX platforms, Windows and MacOS. To download R, please choose your preferred CRAN mirror.
- If you have questions about R like how to download and install the software, or what the license terms are, please read our answers to frequently asked questions before you send an email.

News:
- R 3.0.3 (Warm Puppy) prerelease versions will appear starting February 24. Final release is scheduled for March 6, 2014.
- The R Journal Vol.5/2 is available.
- R version 3.0.2 (Frisbee Sailing) has been released on 2013-09-25.
- useR! 2013, took place at the University of Castilla-La Mancha, Albacete, Spain, July 10-12 2013.
- R version 2.15.3 (Security Blanket) has been released on 2013-03-01.
Let's Download R & RStudio
Let's Open R - RStudio - Install Packages

```r
R version 3.0.2 (2013-09-25) -- "Frisbee Sailing"
Copyright (C) 2013 The R Foundation for Statistical Computing
Platform: x86_64-apple-darwin10.8.0 (64-bit)

R is free software and comes with ABSOLUTELY NO WARRANTY.
Type 'license()' or 'licence()' for distribution details.
Natural language support but running in an English locale
R is a collaborative project with many contributors.
Type 'contributors()' for more information and 'citation()' on how to cite R or R packages in publications.
Type 'demo()' for some demos, 'help()' for on-line help, or 'help.start()' for an HTML browser interface to help.
Type 'q()' to quit R.

[Workspace loaded from ~R/Projects/LDSF tutorial/.RData]
```
Install Packages

- lme4
- lattice
- ggplot2
Save the Dataset

- Save the .csv file somewhere on your computer- where you will remember!!!
- IdfNicaSAWA
Open a New Project in R Studio!!

Project - New -
Set Working Directory
Let's explore the data
Asante!