Introduction

The Land Degradation Surveillance Framework

The LDSF was developed by the authors and colleagues over several years of land degradation research in Kenya’s Lake Victoria basin, Madagascar, Mali and southern Africa.

The LDSF is designed to provide a biophysical baseline at landscape level, and a monitoring and evaluation framework for assessing processes of land degradation and the effectiveness of rehabilitation measures (recovery) over time.

The framework is built around a hierarchical field survey and sampling protocol using sites that are 100 km² (10 x 10 km).

LDSF sites may be selected at random across a region or watershed, or they may represent areas of planned activities (interventions) or special interest. Within each site, 16 tiles (2.5 x 2.5 km in size) are created and random centroid locations for clusters within each tile are generated. Each cluster consists of 10 plots, with randomized centre-point locations falling within a 564 m radius from each cluster centroid. Thus, the LDSF has two (or in some cases three) levels of randomization, which minimize local biases that may arise from convenience sampling. Each plot is 0.1 ha (1000 m²) and consists of 4 subplots, 0.01 ha in size.

The various observations recorded and measurements made at plot- and subplot levels are described in this field guide.

Why use a hierarchical sampling design?

Due to the complex nature of ecosystems, multiple perspectives are needed to understand ecosystem processes, and variability of ecological variables at different spatial scales. A nested hierarchical sampling design is useful for developing predictive models with global coverage, while maintaining local relevance.

The Land Degradation Surveillance Framework was developed as a response to a lack of methods for systematic landscape-level assessment of soil and ecosystem health. The framework provides field protocols for measuring indicators of the “health” of an ecosystem, including vegetation cover, structure and floristic composition, historic land use, visible signs of soil degradation, and soil physical characteristics. A sampling framework for collection of soil samples is also provided, as described in more detail later.

Few soil surveys have been conducted in Africa during the last 25 years, and much of the data lacks georeferencing information. Moreover, chemical and physical data from different countries or different survey campaigns are based on a wide variety of laboratory tests and analytical procedures, which are often difficult to harmonize from a diagnostic perspective.

The Africa Soil Information Service (AfSIS) project is based on the LDSF sampling framework. The AfSIS project proposes a statistically designed baseline effort that uses standardized sampling and analytical procedures to facilitate a comprehensive assessment of soil health and degradation prevalence for an area that is statistically representative of about 18.1 million km² of sub-Saharan Africa. Specific estimates include: tree and shrub densities, erosion risk, and carbon stocks at both regional and continental scales.

This field guide describes the LDSF field survey methods and is designed to be used in both training and as a reference in field, during survey campaigns.

Why systematic baselines?

Very little is known about the state of ecosystems across Africa, including land cover and vegetation trends. This is particularly important in understanding land degradation processes, predicting changes in climate and improving land management.

Systematic baselines of soil and ecosystem properties allows for a proper assessment of landscape performance and/or prediction of change over time.

Few soil surveys have been conducted in Africa during the last 25 years, and much of the data lacks georeferencing information. Moreover, chemical and physical data from different countries or different survey campaigns are based on a wide variety of laboratory tests and analytical procedures, which are often difficult to harmonize from a diagnostic perspective.
Proper preparation before going to the field is critical to ensure a successful field sampling campaign, and for the safety and well-being of the field team. Prior to any field campaign, it is important to have a good understanding of the area to be surveyed, including its topography, climate and vegetation characteristics, accessibility, and its security situation.

When conducting field campaigns in new countries it is generally recommended that a reconnaissance survey is conducted where local contacts are established and agreements are made.

Obtain permission from the land owner(s) to sample a given area, and make sure that he/she understands what you are doing. Informing local government officers and community leaders about your activities is also a good idea.

Example of pre-existing information about the area to be surveyed include: maps (topographical, geological, soils and/or vegetation), satellite images and/or historical aerial photographs, long-term weather station data, government statistics, census data etc.

Load coordinates of sampling locations into the GPS units before going to the field. If possible, load local maps into the unit to aid in navigation in the field.

Do a thorough equipment check (see Appendix) before leaving for the field. This includes making sure you have enough water to complete the infiltration tests.

Ideally, a 4- to 5-person field team can complete 10 sampling plots per day, this includes completing 3 infiltration tests per cluster.

Safety Tips:

Avoid any areas where you might be placing the field team at any risk of harm or injury.

Always carry an emergency first aid kit.

When in remote areas, be sure someone knows where the team will be operating.

Carry a satellite phone, where necessary.

At least one field crew member should be properly trained in first aid.

Identify emergency evacuation routes and nearest hospitals in case of emergency.

the LDSF sampling design

LDSF “Sites” or “Blocks” are 10 x 10 km in size. The basic sampling unit is called a “Cluster”, and consists of 10 “Plots” (described later).

The centre-point of each cluster in LDSF is randomly placed within a “tile” in each Sentinel Site. The sampling plots are then randomized around each cluster centre-point, resulting in a spatially stratified, randomized sampling design (see example on the left).

Randomizing the plots in the cluster is extremely important as you will want to minimize any local biases that may arise from convenience sampling. The randomization procedures are normally done using customized programs or scripts.
the LDSF sampling design

At the plot level, basic site characteristics are described and recorded, including site ID, georeferencing (coordinates) of the center-point (1), altitude, date, and a photograph is taken. Slope, landform, presence/absence of soil and water conservation structures are also recorded. The figure on the right shows a LDSF radial-arm plot. Each plot is designed to sample a 1,000 m² area.

Plot-level vegetation cover types and strata, land use, land ownership and primary current use are based on a modification of the FAO Land Cover Classification System (LCCS).

Initially, georeference the center of the plot by letting the GPS average the position for at least 5 minutes. Store this as a waypoint in your GPS, and record the easting (longitude), northing (latitude), elevation and position error on the field recording sheet.

**Setting up the Plot**

Using a measuring tape or a pre-marked chain, measure out the distance (12.2 m) from the plot center-point to the center of the up-slope sub-plot (2). Mark this sub-plot center point. Subplots 3 and 4 should be offset 120 and 240 degrees from the up-slope point, respectively.

**Slope Measurements**

Stand in the centre of the plot and take an up-slope sighting along the steepest part to a point on the up-slope plot boundary. Use a clinometer to measure the slope in degrees. Repeat the process in the down-slope direction. Ensure that you sight to a location that is at the same height as the observer’s eye-level.

In steep terrain (slope > 10°), use the following formula to calculate the distance from the center-point to the other sub-plots; slope distance = horizontal distance/cos(Slope)

**Soil Sampling**

Top- and subsoil samples are collected from the center of each subplot at 0-20 cm and 20-50 cm depth increments, respectively. Top soil subplot samples are pooled (composted) into one sample for each plot, the same is done with subsoil samples.

Before samples are pooled, soil field texture is determined on top- and subsoil samples. Auger depth restrictions are recorded at each sub-plot (in cm), if present.

**Soil erosion by water**

**Sheet erosion** is the removal of soils in thin layers by raindrop impact. Overgrazed and cultivated soils are most vulnerable to sheet erosion, and signs of sheet erosion include bare areas, water puddling on the surface as soon as rain falls, visible grass roots, exposed tree roots, and exposed subsoil or stony soils.

**Rill erosion** is the intermediate stage between sheet and gully erosion. Rills are shallow drainage lines less than 30 cm deep. The channels are shallow enough that they can usually be removed by tillage; thus, after an eroded field has been cultivated, determining whether the soil losses resulted from sheet or rill erosion is generally impossible.

**Gully erosion** is the consequence of water that cuts into the soil along the line of flow. Gully channels are deeper than 30 cm. In contrast to rills, they cannot be obliterated by ordinary tillage.
Field Measurements

Measuring soil infiltration capacity

Soil infiltration measurements are the most time consuming aspect of the field measurements, so these should be set as soon as possible. It is desirable to obtain as many infiltration measurements as possible, with a minimum of 3 in each cluster. Allocate these randomly to the different plots in the cluster.

1. To complete the infiltration measurement you will need; a 17 cm outer diameter, 20 cm in height infiltration ring, a sledge hammer, approximately 25 liters of water, and an infiltration field recording sheet.

2. The infiltration ring should be placed at the center of subplot one. To ensure that the ring does not leak, drive it at least 2 cm into the soil taking care not to disturb the soil surface too much.

3. Remove any vegetation, litter and large stones from inside the ring, but make sure not to disturb the soil surface (e.g. by digging out large stones or uprooting vegetation). If the soil surface is accidentally disturbed, reset the ring at another location.

4. Pre-wet the soil with 2-3 liters of water. Let this soak in for at least 15-20 minutes. Then slowly pour water into the ring to a level of 20 cm, again making sure not to disturb the soil surface.

5. The infiltration rates at the beginning of the test will be quite variable. So for the first half-hour of the test record at 1-5 minute intervals. Note that it will be easier to process the data if you record time in minutes since initiation of the test rather than as clock time.

6. After each recording top up the water level to 20 cm. After the first half hour record at 10-20 minute intervals for an additional 2 hours, or until the infiltration rates have stabilized. Top-up the water level to 20 cm after each reading (see infiltration field data entry sheet in the Appendix).

Why are we using single-ring infiltration testing?

The LDSF emphasizes landscape level measurements, or in other words measurements are repeated many times across large areas (landscapes).

The single-ring infiltration test is a robust method for calculating infiltration rates. While double-ring may also be used, they are often too time consuming and require very large quantities of water, not allowing for repeated measurements across a landscape.
Landform and land cover classification

Land cover is recorded in all plots using a simplified version of the FAO Land Cover Classification System (LCCS), which was developed in the context of the FAO-AFRICOVER project (http://www.africover.org). In addition, vegetation is classified according to White, 1983. Also, scores are made of “impact on habitat”, adapted from Royal Botanic Gardens, Kew (http://www.kew.org).

The “binary phase” of LCCS recognizes 8 primary land cover types, 5 of which are sampled in the LDSF. These are (i) cultivated and managed terrestrial areas, (ii) natural and semi-natural vegetation, (iii) cultivated aquatic or regularly flooded areas, (iv) natural or semi-natural aquatic or regularly flooded vegetation, and (v) bare areas.

Artificial surfaces, natural and artificial water bodies, and surfaces covered by snow, or ice are not formally surveyed in the LDSF, but if a plot falls within such features this is noted and the plot is georeferenced.

The LCCS further differentiates primary land cover systems on the basis of dominant vegetation life form (tree, shrub, herbaceous), vegetation cover, leaf phenology and morphology, and spatial and floristic aspects. All the associated features are assessed visually and are generally coded on either categorical or ordinal rating scales. The questions in the field recording sheet are designed to guide you through the classification process.

Topographic Position

To complete the section describing landform and topographic position, visually inspect the area surrounding the plot and select the appropriate categories provided on the field recording sheet and the major landform designation table. Skip the section on topographic position if the Major Landform is “Level Land”.

Continue through the form completing the “plot-level” information before moving to sub-plots.
You will need a soil auger marked at 20 and 50 cm, sturdy plastic bags, a mixing trowel, a permanent marker, labels and buckets. You will need a different bucket for topsoil and subsoil samples from each subplot (8 buckets in total).

Topsoil (0-20 cm) and subsoil (20-50 cm) samples are collected from the center of each subplot using an auger.

Auger depth restrictions are recorded (in cm), if restrictions occur.

Field texture using the texture by feel method (see Appendix) is recorded for each topsoil and subsoil sample.

Pooling (composite) topsoil samples from each subplot into one bucket, and do the same for subsoil (in a different bucket). Mix the soil thoroughly in the buckets. Then, take a representative ~700 g sub-sample and place it in a plastic bag. Note that there should be one bag of topsoil and one bag of subsoil for each plot.

After getting back from the field the samples should be air-dried for at least 3 days as described in the laboratory SOP.

**Cumulative mass soil sampling**

Cumulative mass sampling is done to calculate nutrient and/or carbon stocks on a soil mass basis rather than using bulk density. The idea is to auger in 20 cm increments to at least 100 cm collecting ALL of the soil from each increment.

The cumulative mass sample is collected in the center of the same plot where infiltration tests are made (three plots per cluster).

A sampling plate is used to easily capture any soil that falls out of the auger before transferring it to the bucket and to prevent collapse of the auger hole (see inset photo below).

Press the sampling plate firmly onto the soil, so the plate is flush with the soil surface.

Place the auger in the centre of the hole in the plate and begin to auger straight down.

Auger down to 20 cm, collecting ALL of the soil from the auger into the bucket.

The next samples to be collected are from 20-50, 50-80 and 80-100 cm.

Depending on soil texture, a clay, combination or sand auger can be used, but use the same auger for the entire depth (do not switch augers as this may change the volume of auger hole). Always record diameter of auger.

Caution: You must auger straight down. If your augering becomes slanted so that you are augering at an angle, stop and start again in a new location because this will not be an accurate measurement of the depth.

If the soil is very dry, it may be difficult to auger. Pre-wetting the soil before augering each increment may be helpful.

**Caution: Do not overfill the auger when taking a cumulative mass sample as this will distort the volume of sample hole and mass of soil collected. To avoid this, empty the auger regularly (after approximately every 4 turns).**

**Labeling is critical!**

Site, cluster, plot and sample material ID’s should be legibly recorded with a permanent marker on the outside of the plastic bag. A paper label containing the same information (written with a pencil) should be placed inside.

Example from Kisongo site, cluster one, plot one (topsoil and cumulative mass sample):

Kiso.1.1.TOP and Kiso.1.1.CM.0-20
measuring Woody Cover

**The T-square method**

The “T-square” method is one of the most robust distance methods for sampling woody plant communities, particularly in forests, but also in rangelands. It can be used to estimate stand parameters such as density, basal area, bio-volume, and depending on the availability of suitable allometric equations, also biomass. The advantage of this method, over other commonly used distance methods such as the point-centered quarter (PCQ) method, is that it is less prone to bias where plants are not randomly distributed.

Shrubs and trees are sampled separately. To complete the T-square measurements for trees and shrubs you will need, the field recording sheet, a 15+ meter measuring tape, a diameter tape, a height pole and/or a clinometer.

Standing at the center of each subplot record the distance \( x \) from the subplot center point \( (x_i) \) to the nearest tree and shrub \( (x_j) \) (see figure). Measure this either to the center of the tree trunk, or to the central portion of the shrub.

Next, measure the distance \( t \) to its nearest neighboring plant \( (x_j) \). Note, however that the angle of the measurement must be constrained to lie in the hemisphere of a line that lies perpendicular to \( x \). This is the T-square distance.

For both trees and shrubs, the height of the 2nd plant identified (i.e. the tree or shrub identified by the plant-to-nearest-plant measurement) is measured using either the height pole or clinometer. For trees, the diameter at breast height (DBH) (1.3 m above ground level) of the 2nd tree is measured. In instances where a tree branches below this level, measure the diameters of all of the branches that have a DBH > 2.5 cm at 1.3 meters above ground level and sum these. For trees that are tilted determine the 1.3 meter level from the down-slope direction and measure the diameter there. For shrubs, also measure the width and length of the 2nd shrub.

Note: the 2nd tree or shrub does not have to be within the plot.
In the LDSF, databases and data entry screens have been developed for various mobile devices and smartphones 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.

**CyberTracker**

The CyberTracker (http://www.cybertracker.co.za) software is a free and efficient method for GPS field data collection, and can be used on smartphones or handheld computers.

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 rain forest. We developed a CyberTracker application for LSDF field data entry.

**FMTouch (FileMaker)**

A mobile data entry system for the iPhone and iPad has also been developed, which includes automatic syncing with field computers and with 3G-enabled iPads with remote syncing to the central server.

The interface on the iPad is very similar to the paper data entry form used as part of every survey.

The software used in the current version of this system can be purchased through the iTunes store (http://www.fmtouch.com).
LDSF Data Entry

### PLOT
- **Slope Up:**
- **Slope Down:**
- **Major landform:**
  - [ ] Level
  - [ ] Sloping
  - [ ] Steep
  - [ ] Composite
- **Landform designation:**
  - [ ] Medium gradient mountain
  - [ ] High gradient mountain
  - [ ] High gradient valley
  - [ ] Major depression
  - [ ] Medium gradient hill
  - [ ] Mountainous highland
  - [ ] High gradient hill
  - [ ] Valley
  - [ ] Medium gradient escarpment
  - [ ] Dissected plain
  - [ ] High gradient escarpment
  - [ ] Narrow plateau
- **Position on topographic sequence:**
  - [ ] Upland
  - [ ] Ridge/Crest
  - [ ] Microlode
  - [ ] Fooslope
  - [ ] Bottomland
- **Artificial surface?**
  - [ ] Yes
  - [ ] No
- **Vegetation cover <4% for 10 mo yr?**
  - [ ] Yes
  - [ ] No
- **Plot regularly flooded?**
  - [ ] Yes
  - [ ] No
- **Plot cultivated or managed?**
  - [ ] Yes
  - [ ] No

### Vegetation types
- **Tree**
  - [ ] Yes
  - [ ] No
- **Graminoid**
  - [ ] Yes
  - [ ] No
- **Other**
  - [ ] Yes
  - [ ] No

### Woody leaf types
- **Broadleaf**
  - [ ] Yes
  - [ ] No
- **Deciduous**
  - [ ] Yes
  - [ ] No
- **Needleleaf**
  - [ ] Yes
  - [ ] No

### Herb Height
- [ ] 0.80 - 3.00
- [ ] 0.30 - 3.00
- [ ] 0.30 - 0.60
- [ ] 0.03 - 0.30
- [ ] Herbaceous annual?
  - [ ] Yes
  - [ ] No
  - [ ] Mixed

### Vegetation strata description

### Same landuse since 1950
- [ ] Yes
- [ ] No
- [ ] Don't know

### Land ownership
- [ ] Private
- [ ] Communal
- [ ] Government
- [ ] Don't know

### Primary current use
- **Food/Beverage**
  - [ ] Yes
  - [ ] No
- **Forage**
  - [ ] Yes
  - [ ] No
- **Timber/Fuelwood**
  - [ ] Yes
  - [ ] No
- **Other**
  - [ ] Yes
  - [ ] No

### Describe land cover / use history

### Soil and water conservation structures
- [ ] None
- [ ] Vegetative
- [ ] Structural

### SUB-PLOT
#### Rock / stone / gravel cover
- [ ] None
- [ ] 15-40
- [ ] >40

#### Visible erosion
- [ ] None
- [ ] Sheet
- [ ] Rill
- [ ] Gully/Mass

#### Woody cover rating
- [ ] Absent
- [ ] 15 - 40
- [ ] >40

#### Herbaceous cover rating
- [ ] Absent
- [ ] 15 - 40
- [ ] >40

#### Auger depth (cm)

#### Topsoil ribbon (mm) / Texture soil

#### Subsoil ribbon (mm) / Texture soil

### Subplot plant density (count)

### Point - plant distance (m)

### Plant - plant distance (m)

### Height (m)

### Length (m) / Circ (cm)

### Width (m)

### Tree species

### Impact on habitat

<table>
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<th>Impact of tree cutting</th>
<th>Impact of agriculture</th>
<th>Impact of grazing</th>
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<th>Urban activities</th>
<th>Industrial activities</th>
<th>Impact of erosion</th>
<th>Impact of alien vegetation</th>
<th>Impact of firewood collection</th>
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Notes:
Soil Texture By Feel Flow Chart

Place approximately two teaspoons of soil in your palm. Add a few drops of water and kneed soil to break down all the aggregates. Soil is at proper consistency when it feels plastic and moldable, like moist putty.

Does the soil remain in a ball when squeezed?

Yes
No

Is the soil too dry?

Yes
No

Is the soil too wet?

Yes
No

Sand

Loamy Sand

Place ball of soil between thumb and forefinger, gently pushing the soil with your thumb, squeezing it upward into a ribbon. Form a ribbon of uniform thickness and width. Allow the ribbon to emerge and extend over forefinger, breaking from its own weight. Does the soil form a ribbon?

Yes
No

Does soil make a weak ribbon < 1" long before it breaks?

Yes
No

Does soil make a medium ribbon 1-2" long before it breaks?

Yes
No

Does soil make a strong ribbon > 2" long before it breaks?

Yes
No

Excessively wet a small pinch of soil in your palm and rub it with your forefinger.

% CLAY

% SAND

HI

LO

Does soil feel very gritty?

Yes
No

Does soil feel very smooth?

Yes
No

Neither gritty nor smooth?

Yes
No

Sandy Loam

Silt Loam

Sandy Clay Loam

Silty Clay Loam

Sandy Clay

Silty Clay

Clay

Loam

Clay Loam

Clay Loam

Neither gritty nor smooth?
## List of equipment

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<tr>
<td><strong>Other</strong></td>
<td>First aid kits</td>
</tr>
<tr>
<td></td>
<td>Satellite phones</td>
</tr>
</tbody>
</table>