AWF Project in MLW Watershed, DRC
Yamboyo LDSF Site: Soil Health Results

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Introduction

The Maringa-Lopori-Wamba Landscape (MLW) in DRC (Figure One) encompasses a wide range of land cover types, including dense moist semi-deciduous alongside smallholder agricultural systems (Figure Two). Regional interventions aimed to increase productivity was conserving natural resources have lacked baseline information on soil and land health for making informed decisions. This initiative aimed to fill gaps related to biophysical constraints in order to inform decisions.

An assessment of land and soil health was carried out at the Yamboyo site, in the central eastern region of The Maringa-Lopori-Wamba Landscape (MLW) (Figures One and Two) in June 2012 using the Land Degradation Surveillance Frameworks (LDSF). The LDSF is a spatially stratified, randomized sampling design, developed to provide a biophysical baseline at landscape level and a monitoring and evaluation framework for assessing processes of land degradation and effectiveness of rehabilitation measures, over time. The LDSF was developed by ICRAF scientists and is implemented in projects, globally.

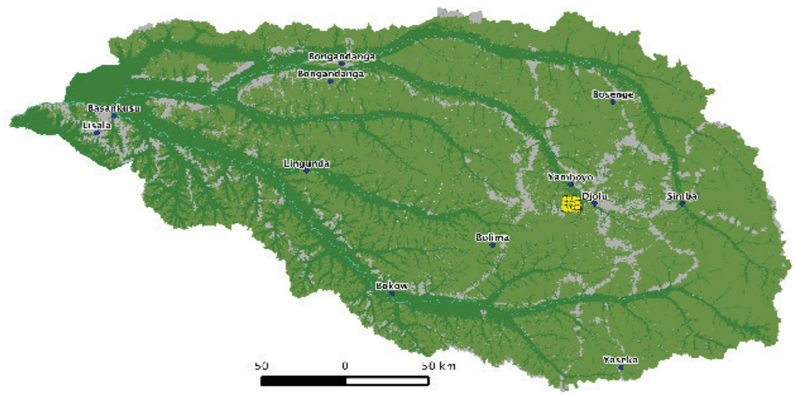

Figure One: This land cover map highlights the dense moist semi-deciduous and evergreen forest and the fingers of swamp forest throughout the MLW landscape. The LDSF is located west of Djolu. **Source:** Janet Nackoney.

This report highlights the sampling methodology and key results of the soil health indicators. Predictions results using MIR are also reported. Preliminary analysis on the effect of land cover on dynamic soil properties are also included. The measured and predicted soil analytical data (among other data files are available in the Yamboyo DropBox Folder.

Materials and Methods: The Land Degradation Surveillance Framework (LDSF)

The LDSF employs a hierarchical sampling design. Each site is 100 km^2 and contains 16-1 km^2 clusters. Each cluster contains 10-1000 m^2 sampling plots and each plot contains 4-100 m^2 subplots. Figure Two shows the layout of the Yamboyo LDSF site, yellow circles are the 158 sampled plots. This replication of measurements at various spatial scales (subplot, plot, cluster and site) allows for a systematic assessment of variability and spatial dynamics for each metric.

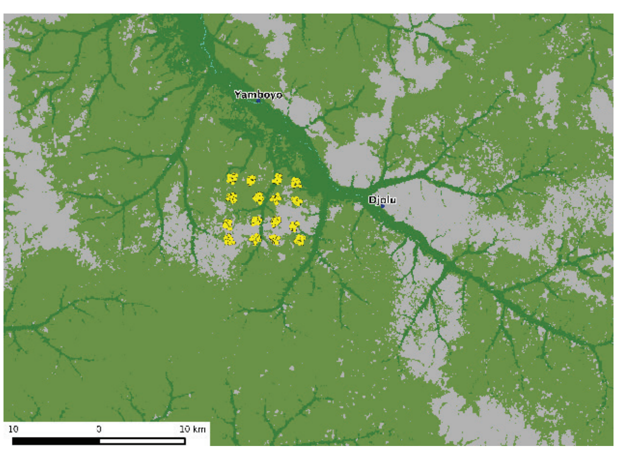

Figure Two: Layout of the 158 sampled LDSF plots at the Yamboyo site.

Measurements and observations were made at the plot and subplot level. Variables measured at the Plot level variables include: land cover, landform designation, position on topographic sequence, vegetation structure, primary current use, along with an assessment of impact to habitat and occurrence of soil conservation structures. Subplot measurements include: tree and shrub densities, erosion prevalence, root depth restrictions, as well as herbaceous and woody cover ratings. Infiltration capacity is measured using a single ring infiltrometer at 30% of the plots.

Field training of technicians was completed in October 2012 in Nairobi, Kenya by Leigh Winowiecki. Field surveys were conducted by partners from Catholic University in Bukavu, DRC and the International Centre for Tropical Agriculture (CIAT).

Materials and Methods: Soil Sample Collection, Processing and Analysis

Composite soil samples were collected at each plot at 0-20 cm and 20-50 cm (n=158 topsoil and 158 subsoil samples). Cumulative soil mass samples were also collected to 100 cm at half of the plots (n=305). Soil samples were air-dried and sieved to 2 mm at the laboratory in Bukavu. All processed samples were shipped to Nairobi in March 2013.

Sub samples were further ground to <50 µm for spectral analysis. MIR diffuse reflectance was measured on each sample using a mid-infrared spectrometer (Bruker HTS-TX (FTIR)) at the ICRAF Plant and Soil Spectroscopy Laboratory in Nairobi in September 2013 (n=621) according to procedures described in Terhoeven-Urselmans et al. (2010). The measured wavebands ranged from 4000 to 601 cm-1 with a resolution of 4 cm-1. Thirty-two reference samples were subjected to wet chemistry analysis at Crop Nutrition Laboratory in Nairobi in July 2013. Nitrogen and Carbon analyses were conducted using dry combustion at ICRAF. Sand content was measured on a Laser Diffraction Particle Size Analyzer (LDPSA) at the ICRAF Soil and Plant Spectroscopy Laboratory. The samples were dispersed in calgon and subjected to ultrasonification for four minutes.

Results: Site Characteristics

Cultivated Area and Slope

The Yamboyo site, while dominated by forest vegetation, does contain cultivated plots. Figure Three highlights the LDSF plots that are cultivated and LDSF plots that have semi-natural vegetation. Modeled average of cultivation across the site, estimates that ~25% of the region is under cultivation.

Upslope and downslope measurements were taken at every plot. Figure Four illustrates that the Yamboyo sites is generally level, and has a mean slope of 1.6 degrees.

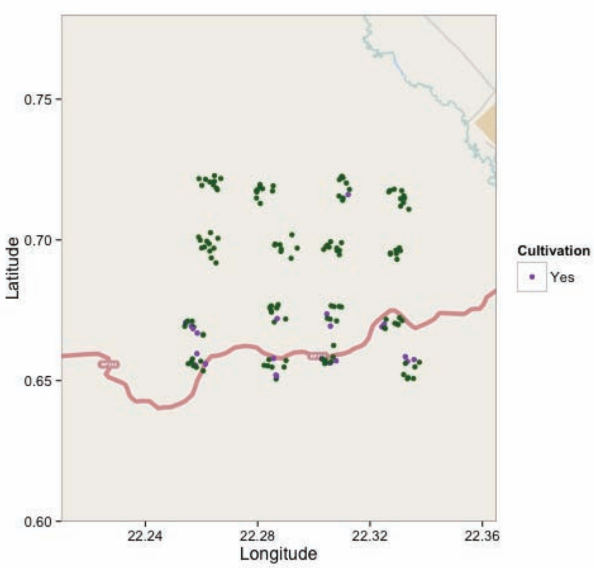

Figure Three: Purple circles indicate LDSF plots dominated by cultivation. Green circles indicate LDSF plots that are uncultivated.

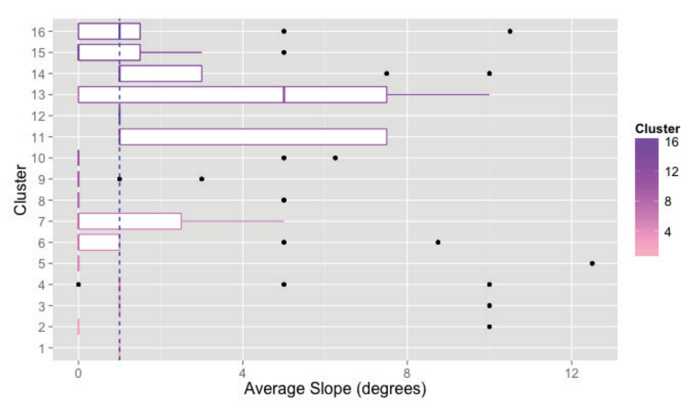

Figure Four: Boxplots of slope measurements from each of the ten plots per cluster. Abline is the average.

Results: Predictions of Soil Properties using Mid-infrared (MIR) Spectroscopy

This report highlights predictions made using MIR and summarizes the results for important indicators of soil health. The measured and predicted soil analytical data, among other data files are available in the Yamboyo DropBox Folder. Figure Five shows the spectral signatures of the top and sub soil at the Yamboyo site. Top and sub soil spectral signatures had similar variation (Figure Five). These spectra were used to make predictions of soil properties.

Prediction results generated for the Yamboyo LDSF site were based on models developed using the global ICRAF soil MIR spectral library by the GeoScience Lab (http://gsl.worldagroforestry.org). The figures below show the validation results for these models using independent datasets. SOC was predicted using randomforest ensemble models, with a calibration set of 3791 samples and a validation set of 1625. The R^2 for the independent validation predictions of SOC was 0.93 (Figure Six). Sand content was predicted using randomforest ensemble models, with a calibration set of 3791 samples and a validation set of 1625. The R^2 for the independent validation predictions of sand content was 0.82 (Figure Seven).

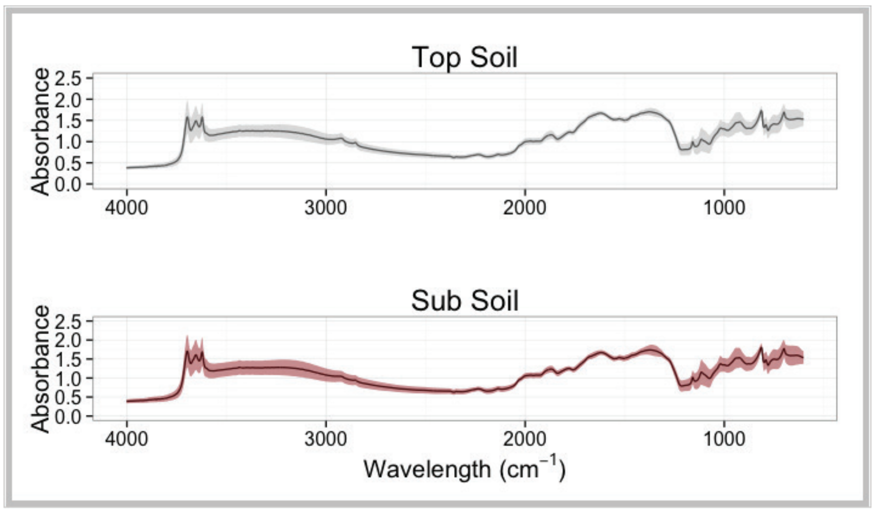

Figure Five: Spectral signatures of the top and sub soil at the Yamboyo site (n=621). The center line is averaged spectra and the shaded area represents the standard deviation.

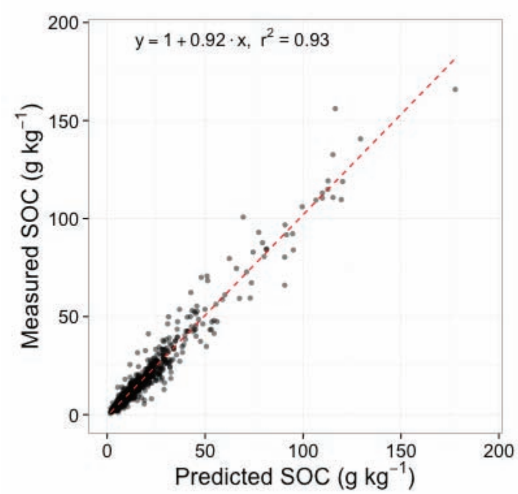

Figure Six: Measured vs. predicted SOC using the validation set.

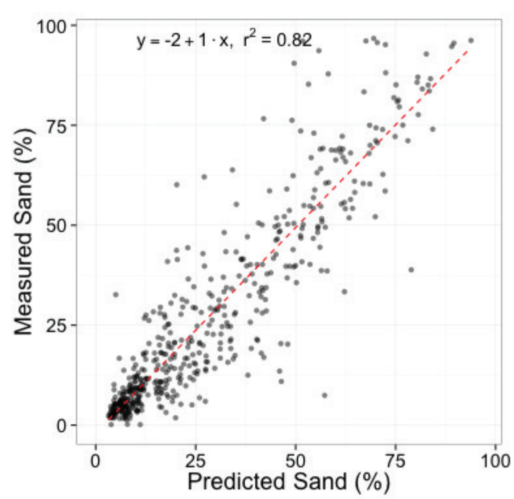

Figure Seven: Measured vs. predicted sand using the validation set.

Results: Soil Characteristics

Soil organic carbon is an important indicator of soil health. Figure Eight shows the distribution of soil organic carbon in the top (0-20 cm) (n=207) and sub (20-50, 50-80, 80-110 cm) (n=278) soil samples for the Yamboyo LDSF site. Mean top and sub soil OC was 30 g kg^{-1} and 20 g kg^{-1}, respectively. Note the more narrow distribution of subsoil SOC content. Figure Nine shows the distribution of pH values in the top and sub soil samples. Median topsoil pH was 4.6 and median subsoil pH was 4.7.

SOC and exchangeable bases ($ExMg^{+2}$+$ExCa^{+2}$+ExK^{+}+$ExNa^{+}$) have a strong relationship (Figure Ten). As exchangeable bases increase, so does SOC content. Mean exchangeable bases for topsoil was 5.4 $cmol_c$ kg^{-1} and 4 $cmol_c$ kg^{-1} for subsoil. These exchangeable base contents are considered quite low.

Mean sand content for topsoil was 48 % and mean sand content for subsoil was 49 %. No difference in sand content was observed between topographic positions (Figure Eleven).

Each subplot was scored according to herbaceous rating categories. These data were used to calculate overall herbaceous cover ratings for the entire plot. Plots with an herbaceous cover rating greater than 40 % are given a score of 1 and plots with less than 40 % herbaceous cover are given a score of 0. Figure Twelve illustrates how total nitrogen values in top and sub soil vary in plots with greater or less than 40 % herbaceous cover rating. Median top and sub soil total nitrogen content was 0.19 g kg^{-1} and was 0.09 g kg^{-1}, respective-

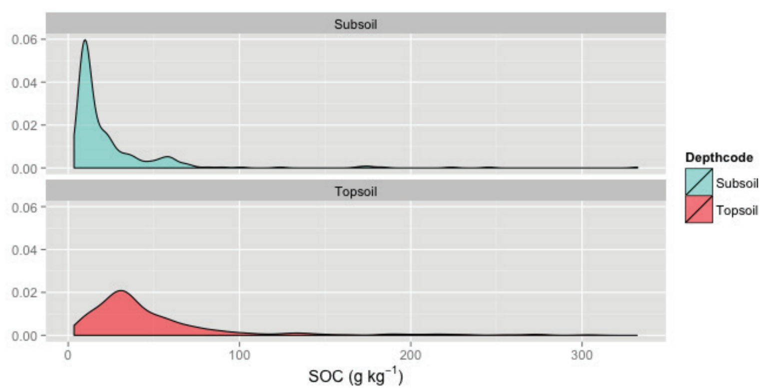

Figure Eight: Soil organic carbon content in top and sub soil at the Yamboyo LDSF site.

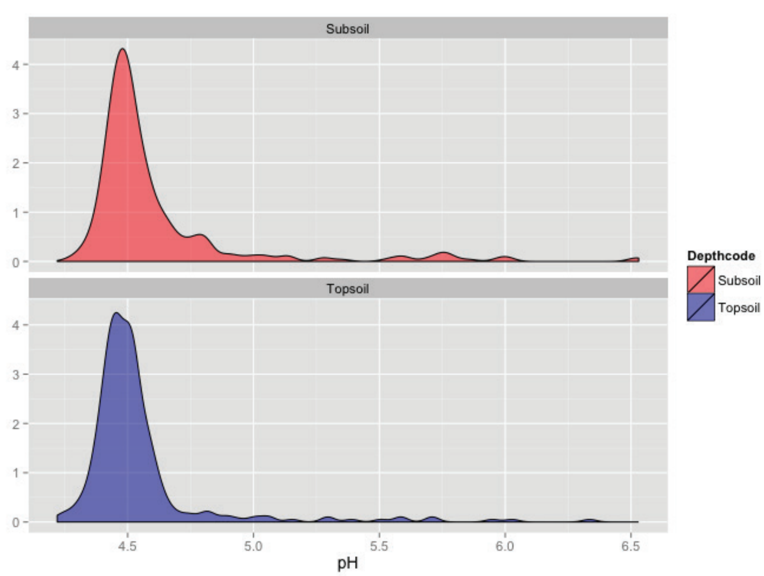

Figure Nine: Soil pH values in top and sub soil at the Yamboyo LDSF site.

Results: Soil Characteristics and Landscape Attributes

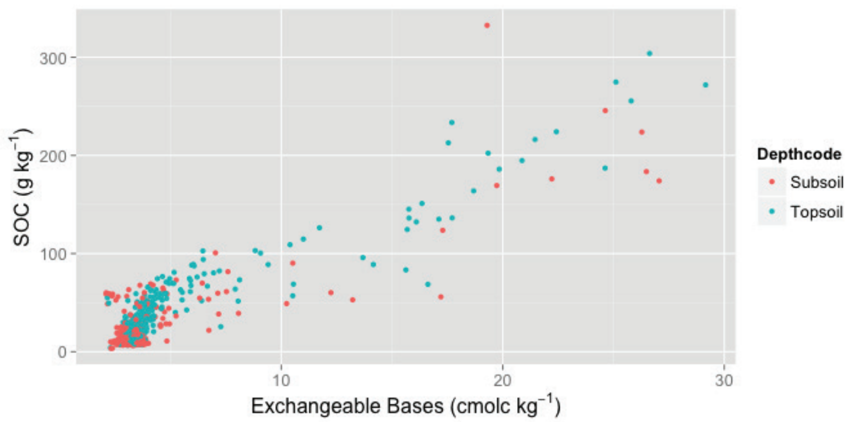

Figure Ten: SOC vs. Exchangeable bases for topsoil and subsoil samples at the Yamboyo LDSF site.

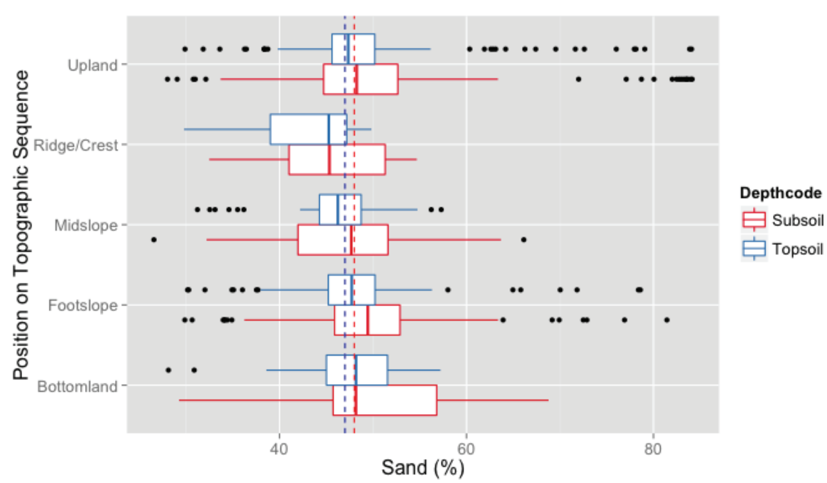

Figure Eleven: Boxplots of sand content for top and sub soil samples at the different topographic positions. Dotted lines are the median values.

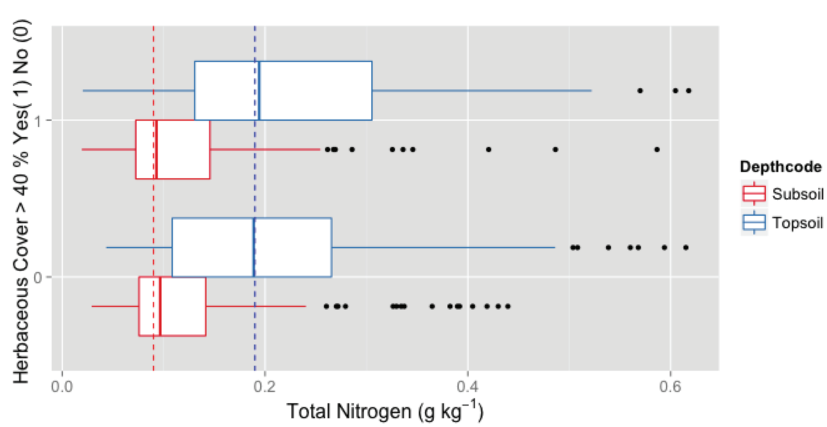

Figure Twelve: Boxplots of total nitrogen in topsoil and subsoil under different herbaceous cover categories. Ablines indicate median values.

Results: Tree and Shrub Densities

Average tree and shrub densities were modeled using generalized linear mixed effects model, using the tree count data from each of the four subplots per plot, for a total of 632 subplots at the Yamboyo site. Trees are woody vegetation over 3 meters tall. Shrubs are woody vegetation between 1.5 and 3 m tall. Average tree density for the Yamboyo site was 344 ± 193 tree ha^{-1}. Figure Thirteen illustrates the variation in tree densities in each cluster. Average shrub density for the Yamboyo site was 686 ± 490 tree ha^{-1}. Figure Fourteen illustrates the variation in shrub densities within and between each cluster.

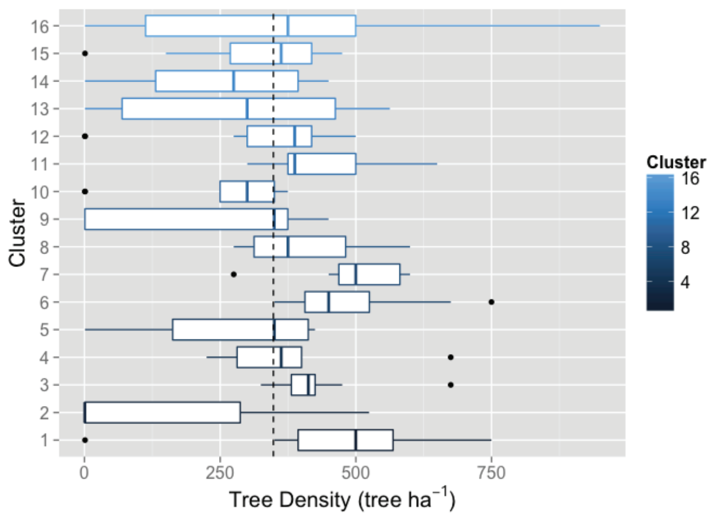

Figure Thirteen: Boxplots of tree densities per cluster.

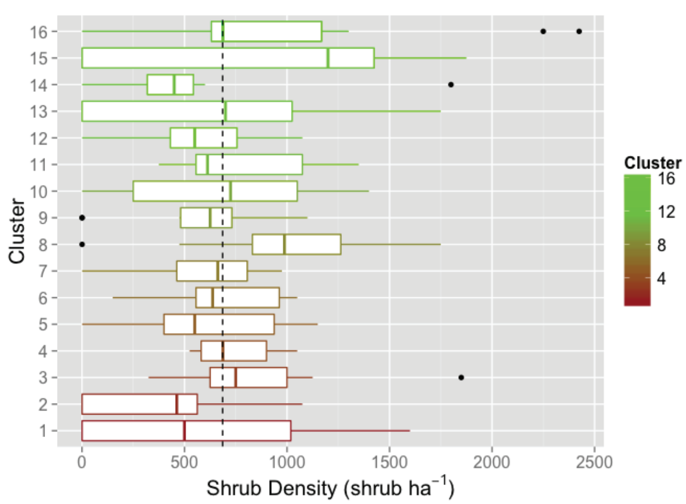

Figure Fourteen: Boxplots of shrub densities per cluster.

Results: Mapping Soil Condition

Mapping dynamic soil properties can help guide and target land management strategies across the landscape. An important product of the LDSF is the creation of maps of key indicators of soil condition, such as topsoil organic carbon (SOC). Maps were generated based on ensemble models at a spatial resolution of 30m using Landsat ETM+. Figure Fifteen illustrates the variation in SOC values across the landscape. Figure Seventeen illustrates the spatial patterns of topsoil pH.

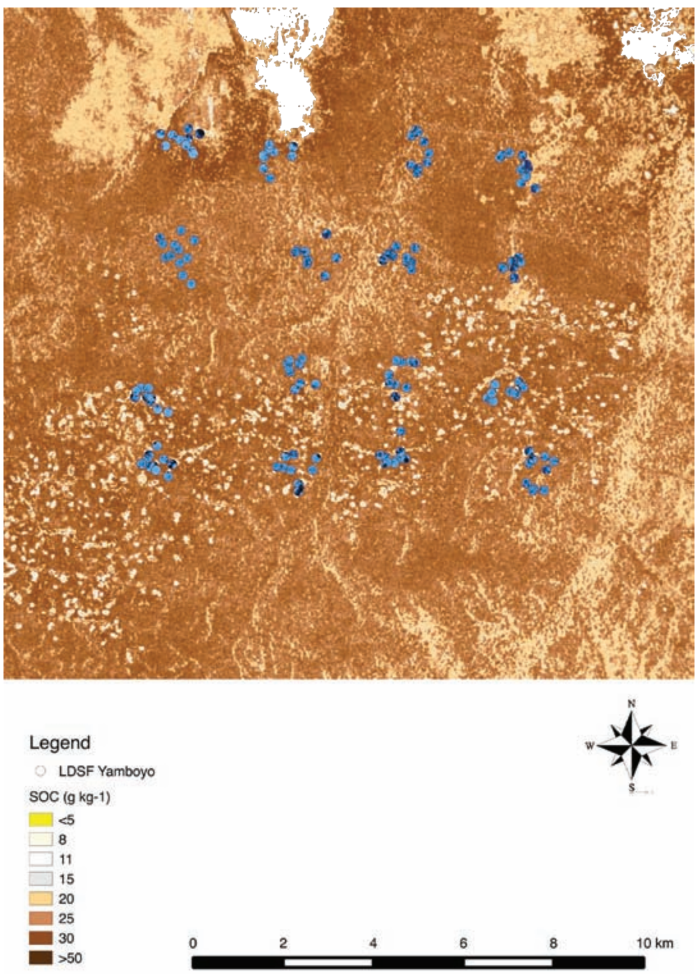

Figure Fifteen: Map of topsoil organic carbon (SOC). The blue circles are the LDSF Yamboyo site sampling plots. White areas are clouds.

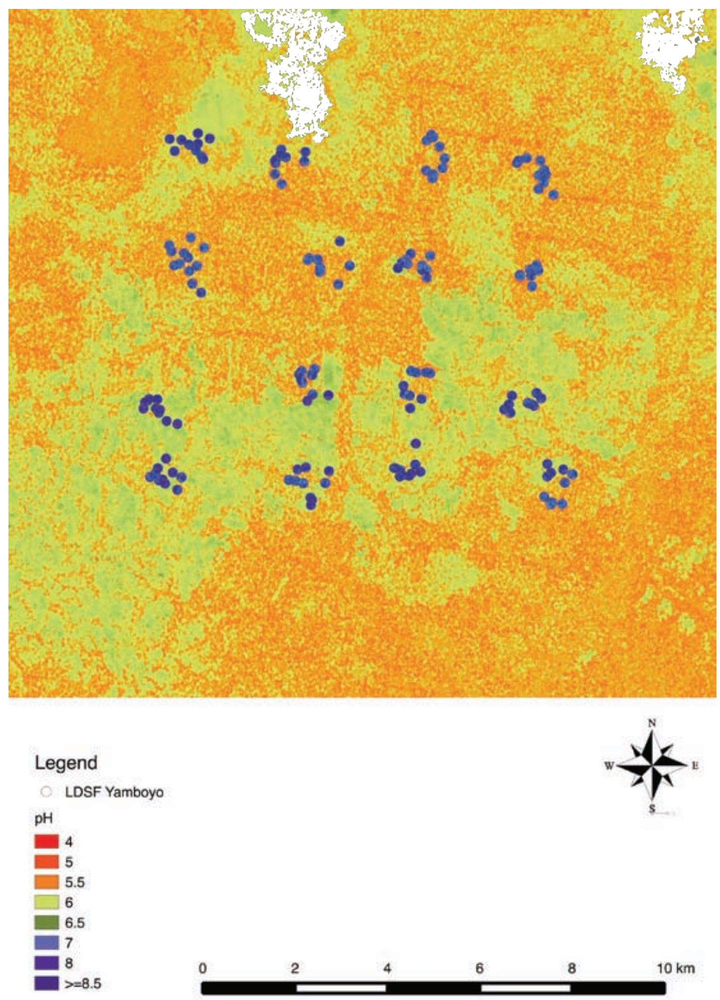

Figure Sixteen: Map of topsoil pH values. The blue circles are the LDSF Yamboyo site sampling plots. White areas are clouds.