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Updated Report on Field Training and Field Survey: Biophysical Soil and Land Health Assessment using the Land Degradation Surveillance Framework (LDSF) within the Regreening Africa Project

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World Agroforestry (ICRAF)

October 2019

Suggested citation: Winowiecki, LA., Mukuralinda, A., Mujawamariya A., Tobella, A., Mugayi, A. and Vågen, T-G. **Updated Report on Field Training and Field Survey: Biophysical Soil and Land Health Assessment using the Land Degradation Surveillance Framework (LDSF) within the Regreening Africa Project**
30 pgs. World Agroforestry (ICRAF), Kenya.

Acknowledgement: The LDSF field training was organized by World Vision Rwanda. The authors would like to acknowledge Alex Mugayi and his team for their efforts to realize this work.

This report covers both the field training and the preliminary data analysis of the Biophysical Field Assessment carried out in Rwanda for the Regreening Africa project.

Original report preparation date: 19 December 2018
Second revision date: 15 January 2019
Third revision date: 2 May 2019
Fourth revision date: 18 June 2019
Updated report: October 2019

Figure One on cover page: Participants of the LDSF Field Training in September 2018, in Nyagatare district.

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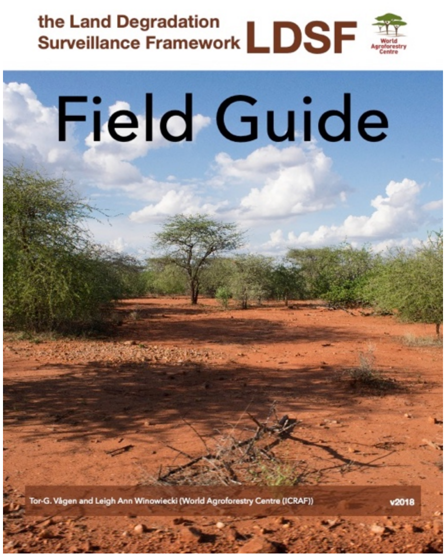
Background of Land and Soil Health Surveillance

Component Two of the Regreening Africa project is "*To equip 8 of these countries with surveillance and analytic tools on land degradation dynamics, including social and economic dimensions, that support strategic decision-making and monitoring in the scaling-up of evergreen agriculture*."

Key to this component is to identify and assess land degradation dynamics, dimensions and indicators across the project action areas. The project will identify and measure key indicators of land and soil health in order to understand drivers of degradation, prioritise areas of intervention and monitor changes over time using the Land Degradation Surveillance Framework (LDSF) methodology. The LDSF provides a field protocol for measuring indicators of the "health" of an ecosystem, including **vegetation cover, structure and floristic composition, historic land use, land degradation, soil characteristics, including soil organic carbon stocks for assessing climate change mitigation potential, and infiltration capacity, as well as providing a monitoring framework to detect changes over time**.

The LDSF was developed by the World Agroforestry Centre (ICRAF) in response to the need for consistent field methods and indicator frameworks to assess land health in landscapes. The framework has been applied in projects across the global tropics[1],[2] and is currently one of the largest land health databases globally with more than 30,000 observations, shared at http://landscapeportal.org. This project will benefit from existing data in the LDSF database, while at the same time contributing to these critically important global datasets through data collection in Rwanda. Earth Observation (EO) data will be combined with the LDSF framework to develop the outputs for the project, including assess land cover changes, land use, land degradation, and soil health. The outputs generated will form part of stakeholder engagement processes through interactive tools and maps that allow stakeholders to explore the complex interactions between land management, regreening efforts and land health through decision dashboards shared at http://landscapeportal.org/tools/.



[1] Vågen, Tor-G., Winowiecki, L., Tondoh, J.E., Desta, L.T. and Gumbricht, T. 2016. Mapping of soil properties and land degradation risk in Africa using MODIS reflectance. Geoderma. http://dx.doi.org/10.1016/j.geoderma.2015.06.023 http://www.sciencedirect.com/science/article/pii/S0016706115300082

[2] Vågen, T-G and Winowiecki, L., Abegaz, A., Hadgu, K. 2013. Landsat-based approaches for mapping of land degradation prevalence and soil functional properties in Ethiopia. Remote Sensing of Environment. 134:266-275. http://dx.doi.org/10.1016/j.rse.2013.03.006

We proposed the establishment of a **two LDSF sites** in Rwanda, co-located with Regreening Africa project activities in Nyagatare and Kayonza districts (Figure 2).

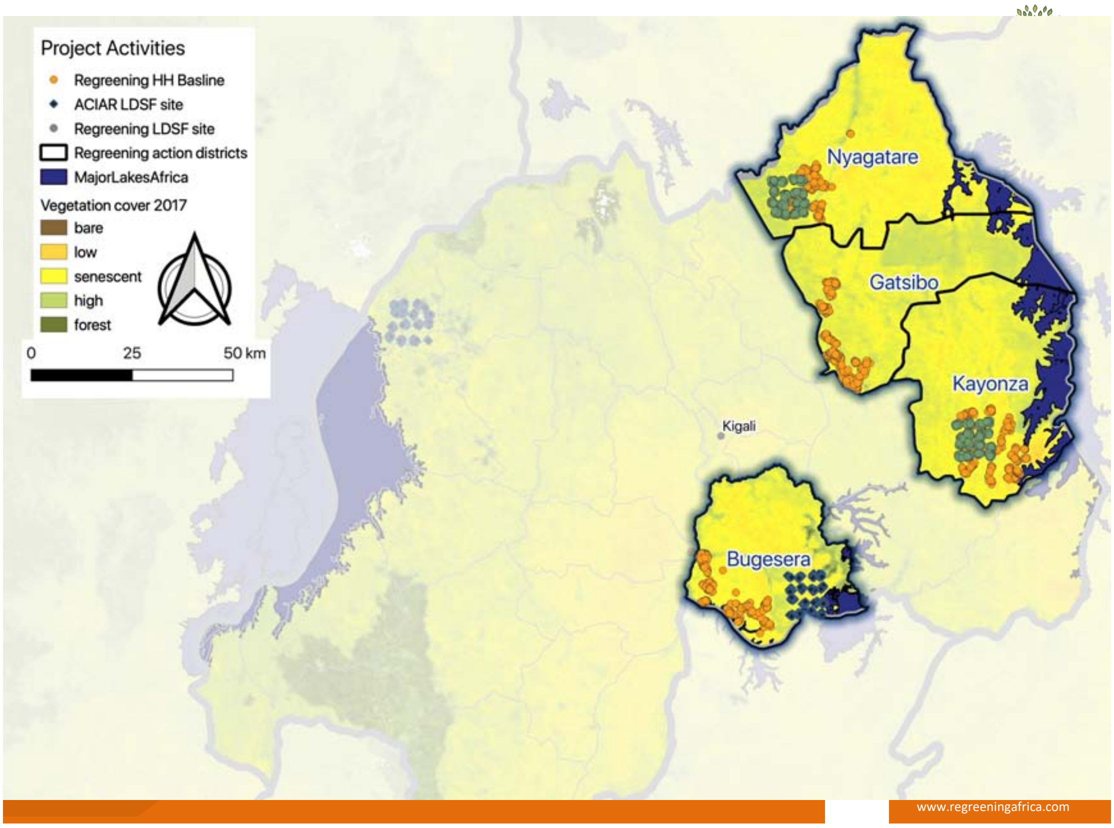


Figure 1: Locations of the two LDSF sites (green) and the previously sampled LDSF site within the ACIAR project (blue), overlaid on a vegetation cover map of Rwanda. The four project districts are highlighted. The orange circles are the locations of the baseline survey.

LDSF field training - 24th – 28th September 2018

This training took place at the Nyagatare LDSF site to equip partners to conduct the Land Degradation Surveillance Framework (LDSF), including establishing monitoring sites (LDSF sites) for assessing change over time. Participants included staff from World Vision Rwanda (WVR), World Agroforestry Centre (ICRAF), local extension agents, botanists, and local farmers.

Table 1: List of participants for the LDSF training in Nyagatare.

#`	Name	Institute
1	MUKURALINDA Athanase	**ICRAF -RWANDA STAFF**
2	MUJAWAMARIYA Providence	**ICRAF -RWANDA STAFF**
3	MUGAYI Billy Alex	**WORLD VISION STAFF**
4	TUYITURIKI Augustin	**WORLD VISION STAFF**
5	HARERIMANA Jeremie	**WORLD VISION STAFF**
6	NIYIBIGIRA Donatien	**WORLD VISION STAFF**
7	RUGEMA Patrick	**WORLD VISION STAFF**
8	HABANABAKIZE Thomas	**WORLD VISION STAFF**
9	NIYIGABA Lambert	**WORLD VISION STAFF**
10	BUCYANA John	**WORLD VISION STAFF**

11	ABAKUNDANYE Gilbert	**WORLD VISION STAFF**
12	MUSENGIMANA Lambert	**RAB-STAFF**
13	GAKWAVU Thomas	**RAB-STAFF**
14	BIJOU Mukobwa	**RAB-STAFF**
15	MAINA John Thiongo	**ICRAF Consultant**
16	VEDASTE Minani	**Forestry Centre**

Objectives of the training:

- Provide in-the-field training for participants on the Land Degradation Surveillance Framework (LDSF) methodology, including:
    - Navigation to randomized plots using global positional systems (GPS)
    - Data entry using Open Data Kit (ODK) as well as back-up paper forms
    - Data upload using ODK
    - All aspects of the LDSF field survey including soil sampling, tree and shrub biodiversity measurements, erosion assessments, infiltration measurements among others
- Interpretation of LDSF data and preliminary analysis
- Equip the team to carry out the LDSF immediately following the training

Annex I contains the agenda of the training.

Photos from the training:

Figure 2: John Maina and Providence Mujawamariya uploading the data into the GPS unit.

Figure 3: RAB Staff, Lambert Musengimana, measuring the diameter at breast height (DBH) of the Eucalyptus tree as part of the LDSF Tree Biodiversity module.

Figure 4: Alex Mugayi of World Vision-Rwanda collecting soil samples from Subplot 2 (left) and Patrick

Rugema of World Vision-Rwanda collecting a cumulative soil mass sample from subplot 1.

Preliminary Results from the LDSF Surveys

The field survey in Nyagatare took place in October 2018 and the field survey in Kayonza took place in November 2018. These surveys were led by Providence Mujawamariya of ICRAF, in collaboration with RAB. In total, 155 plots were sampled in Nyagatare and 157 plots were sampled in Kayonza. These data have been uploaded to the ICRAF LDSF database. Further analysis and data tidying is planned.

Ninety-six percent of the sampled plots in Nyagatare and 79% in Kayonza were classified as cultivated. In Kayonza, land ownership was predominately private (90%), followed by government (6%) and then communal (2%). In Nyagatare 97% of the plots were privately owned, followed by 3% owned by government.

Figure 5: Nyagatare landscape.

Land Cover Classification

The LDSF uses the FAO Land Cover Classification System (LCCS), which was developed in the context of the FAO-AFRICOVER project. Each sampled plot was classified by the vegetation structure. Figure7 shows the number of each plot per site under each classification.

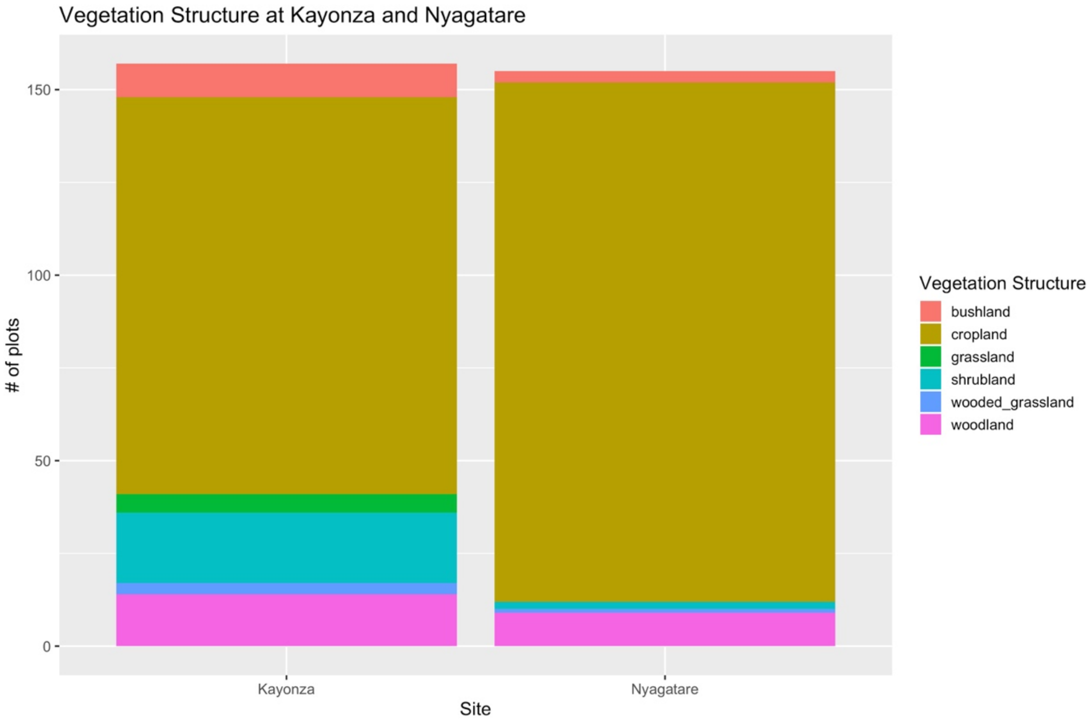


Figure 6: Number of plots classified as bushland, cropland, grassland, shrubland, wooded grassland or woodland for both sampled LDSF sites. Both sites were dominated by annual cropland.

Average Tree and Shrub Densities

In the LDSF, shrubs are classified as woody vegetation between 1.5m and 3.0m tall, trees are classified as woody vegetation above 3.0m tall.

Averages shrub density was higher in non-cultivated plots in Kayonza (317 shrubs per ha) compared to 79 shrubs per ha in cultivated plots. Average shrub density was lower in Nyagatare with an average of 44 shrubs per ha in cultivated plots and 225 shrubs per ha in non-cultivated plots (Figure 8).

Average tree density was higher in cultivated plots in Kayonza (75 trees per ha) compared to 46 trees per ha in non-cultivated plots. In contrast, the average tree density was 120 trees per ha in cultivated plots in Nyagatare and 186 trees per ha in non-cultivated plots (Figure 9).

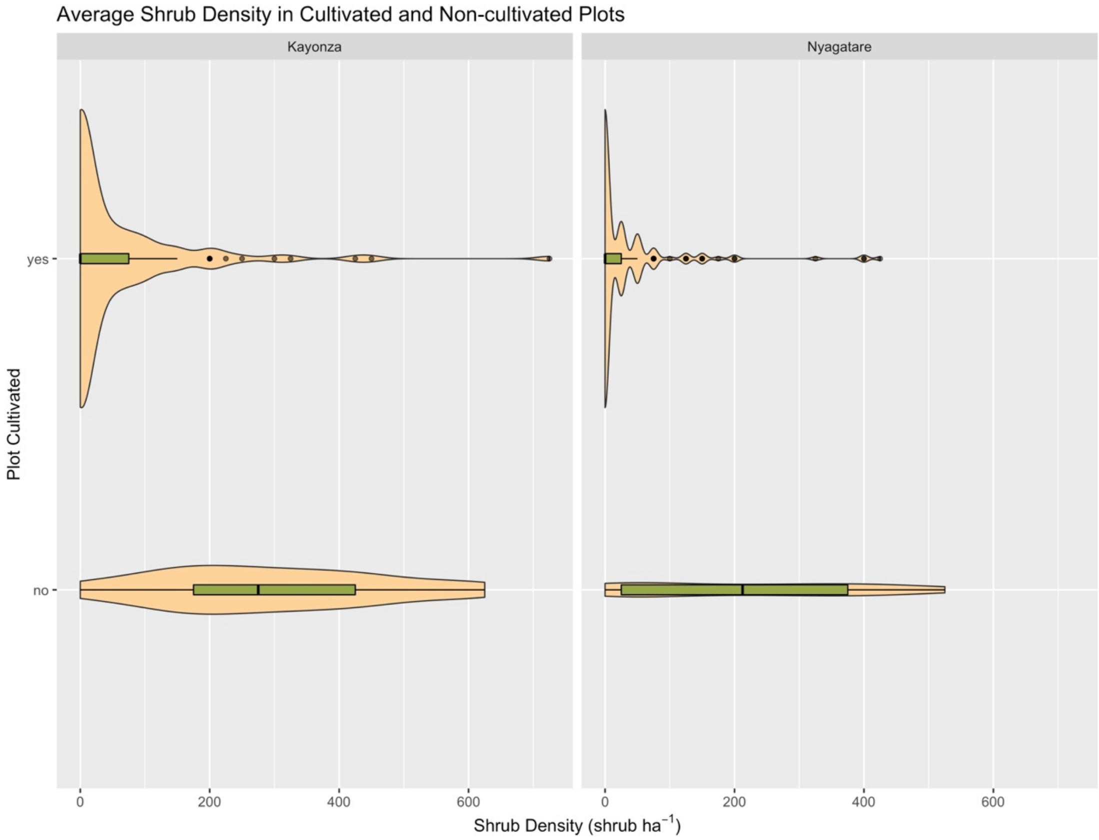


Figure 7: Average shrub densities in cultivated and non-cultivated plots.

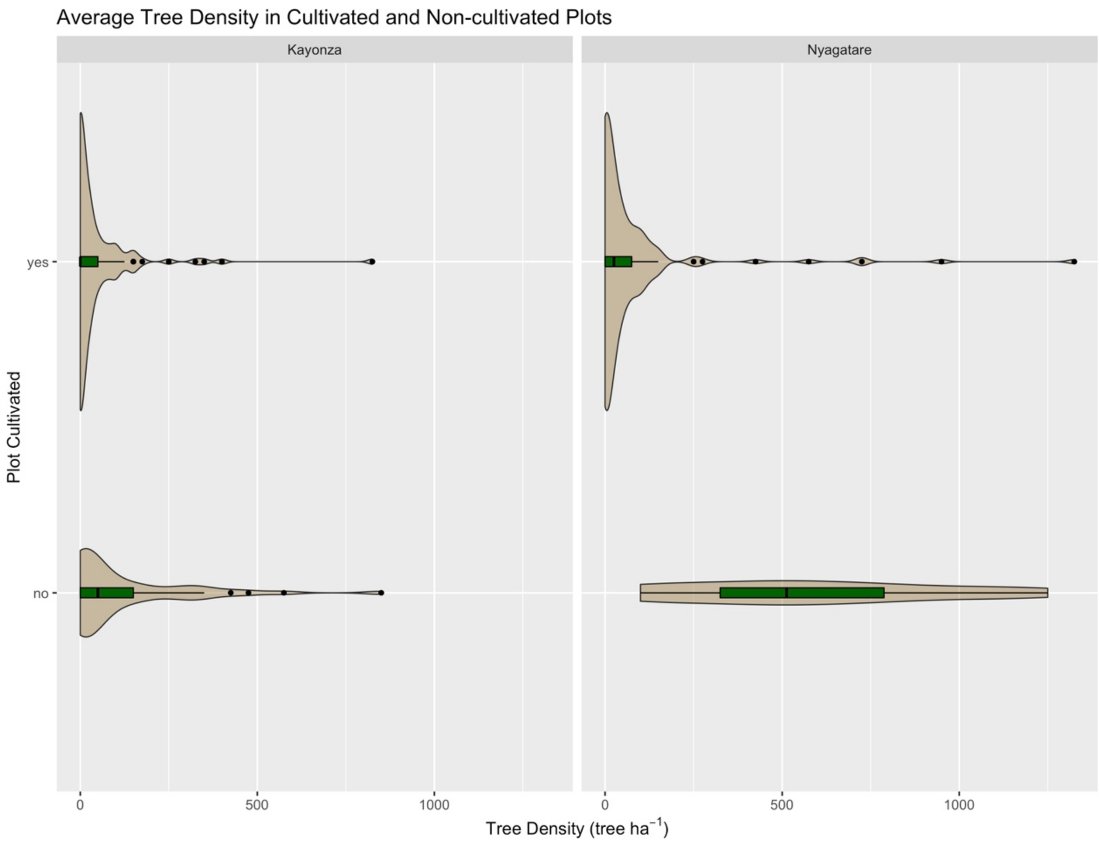


Figure 8: Average tree densities in cultivated and non-cultivated plots.

Tree Diversity

Trees were identified in each 100-m2 subplot (n=4 per plot). In total 62 unique tree species were identified in the two LDSF sites. The most common species were: Eucalyptus spp., Grevillea robusta, Euphorbia tirucalli, Ricinus communis, Mangifera indica, Carica papaya and Senna spectabillis (Figure 10). Differences were observed between the two LDSF sites, most notably that Jatropha curcas was only found in Kayonza and Senna singueana was only found in Nyagatare. In summary, 48 unique species were observed in Kayonza and 39 species in Nyagatare (Figure 11).

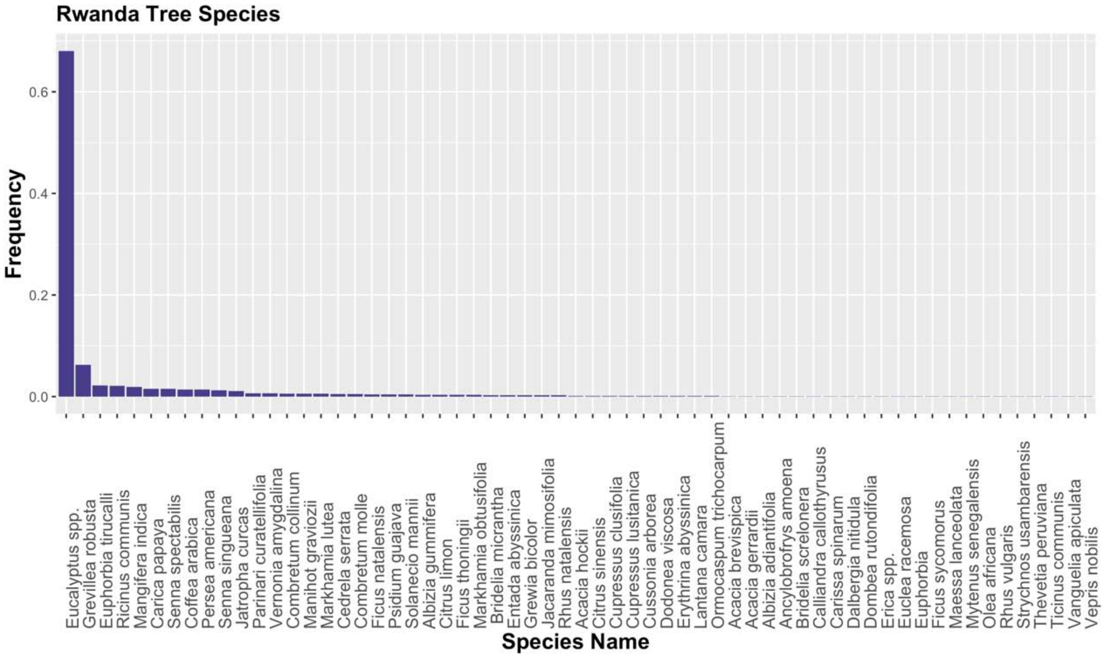


Figure 9: Overall tree species occurrence across the two LDSF sites.

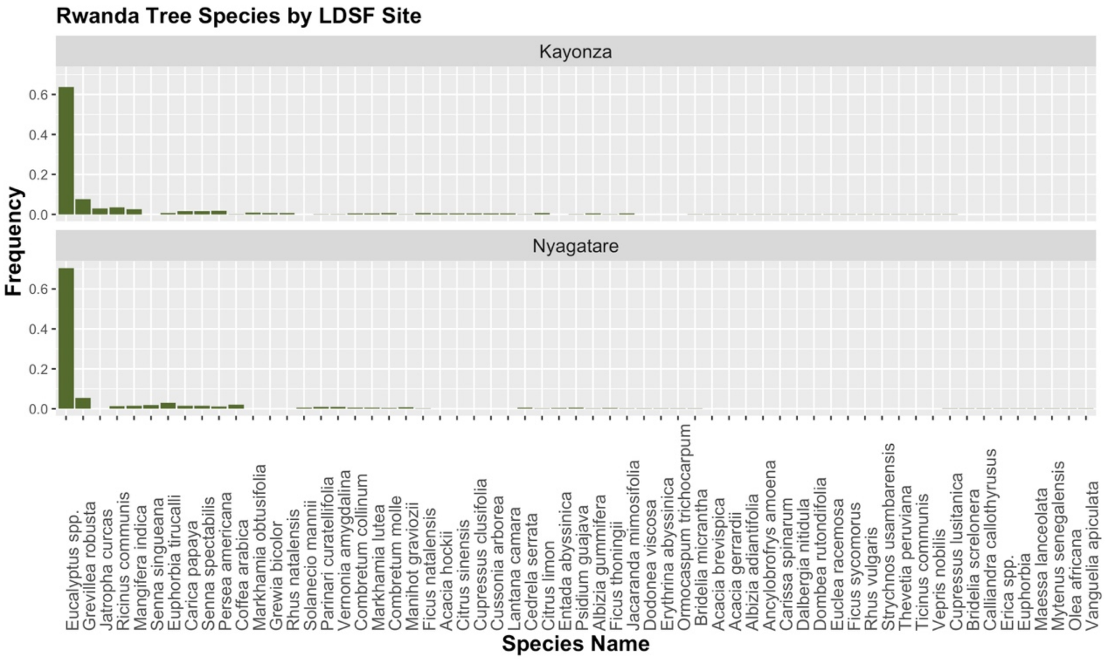


Figure 10: Tree species occurrence at Kayonza (top panel) and Nyagatare (bottom panel).

Tree Diversity in Cultivated and Non-cultivated Plots

In Kayonza, 24 unique species were observed in non-cultivated plots, while 32 species were observed in cultivated plots. Figure 12 illustrates the species occurrence in cultivated and non-cultivated plots.
In Nyagatare, 17 unique species in non-cultivated plots and 32 unique species were identified in cultivated plots and only (Figure 13). Note that most of the sampled plots in each site were cultivated.

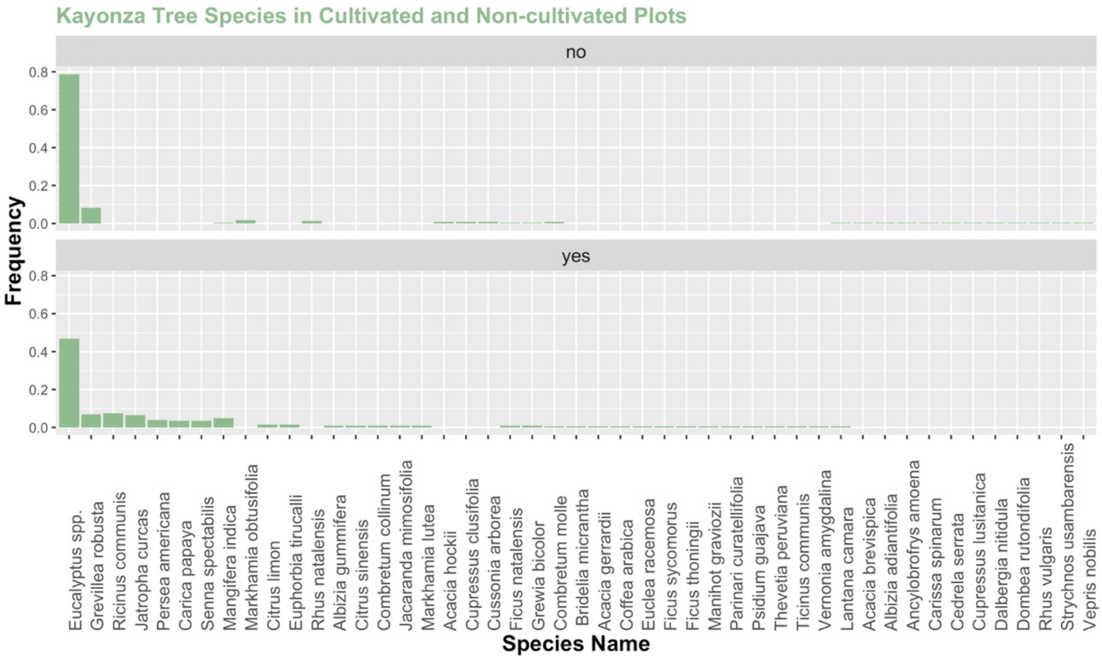


Figure 11: Kayonza tree species in cultivated (yes) and non-cultivated (no) plots.

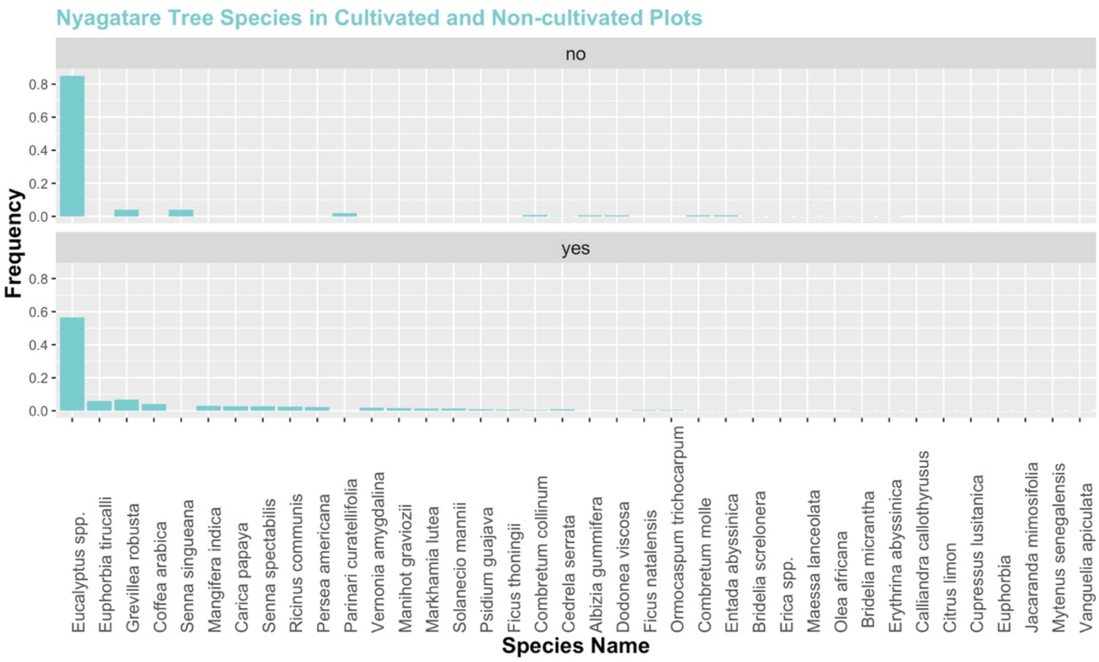


Figure 12: Nyagatare tree species in cultivated (yes) and non-cultivated (no) plots.

Shrub Species Diversity in the two LDSF sites

Shrubs are classified as woody vegetation between 1.5 m and 3 m tall.
In total, 84 unique shrub species were identified. The most common shrub in the Kayonza site was Lantana camara, an invasive and the most common shrub in the Nyagatare site was Eucalyptus spp (Figure 14).

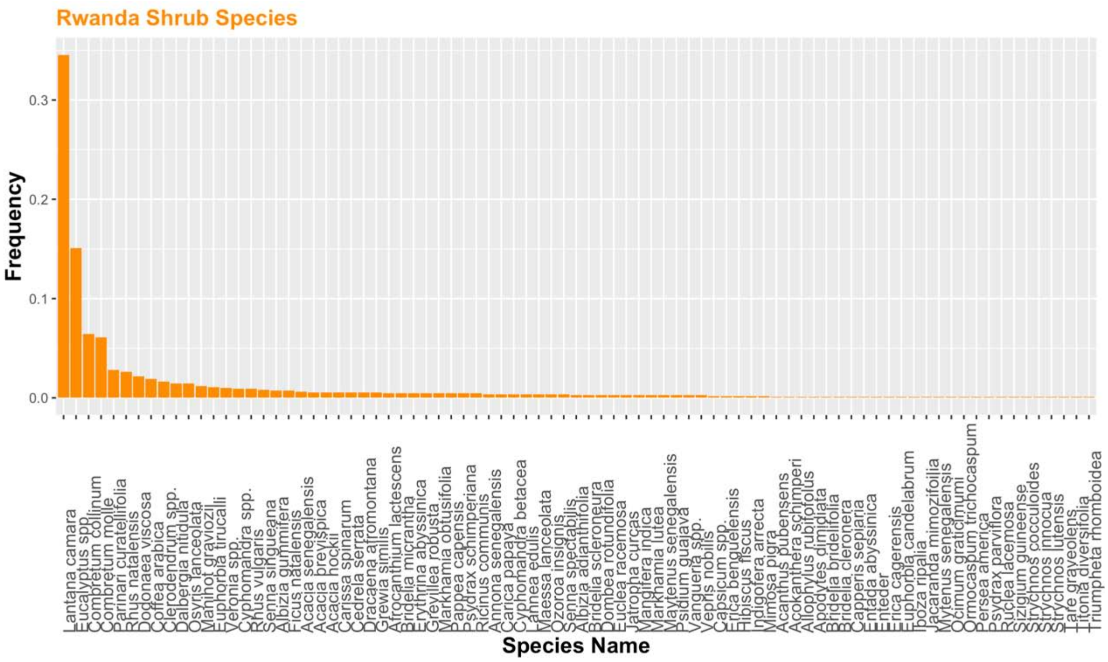


Figure 13: Overall shrub species at the two LDSF sites.

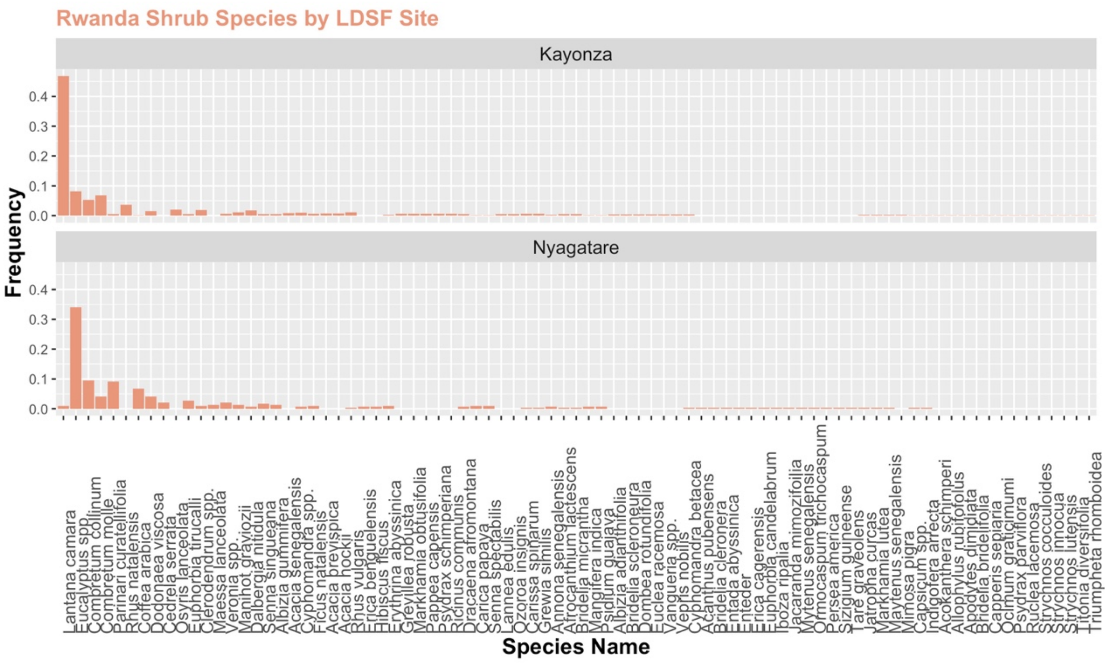


Figure 14: Shrub species occurrence at the two LDSF sites.

Erosion Prevalence

Erosion was scored and classified in each subplot (n=4) per plot. The below graphic shows the percent of plots classified as having severe erosion. Erosion prevalence was on average higher in Kayonza (45%) compared to Nyagatare (27%).

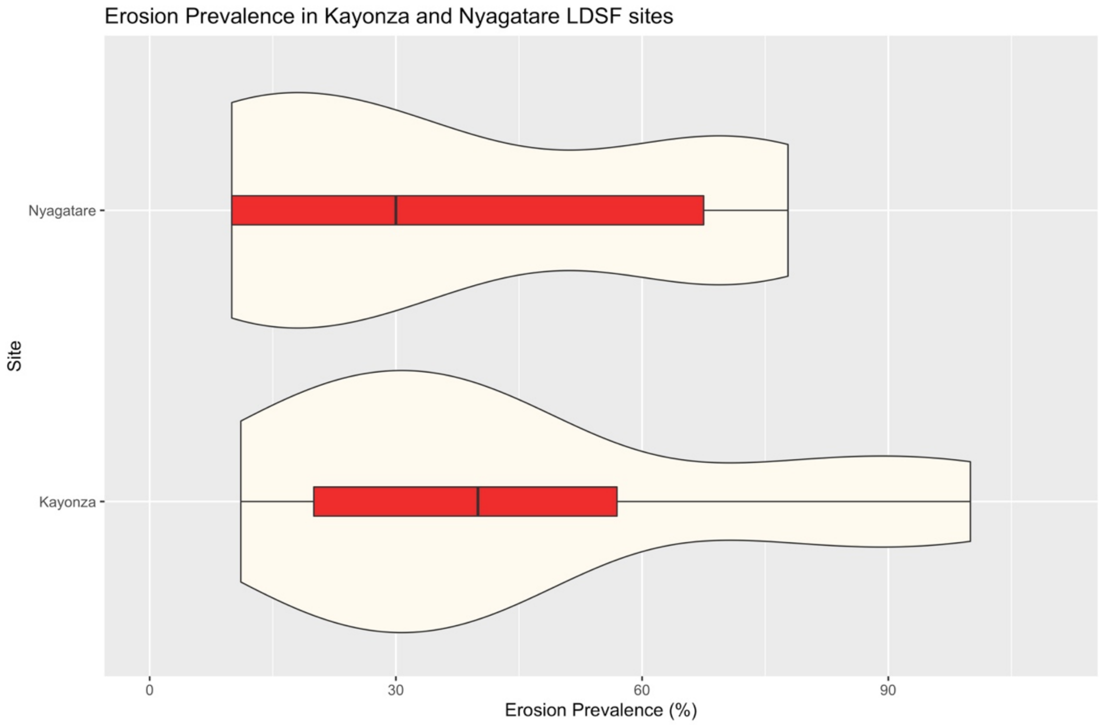


Figure 15: Erosion prevalence in the two LDSF sites, represented by boxplots. The black vertical line within the boxplot indicates the median value. Note, boxplots show the variation that exists within the sites.

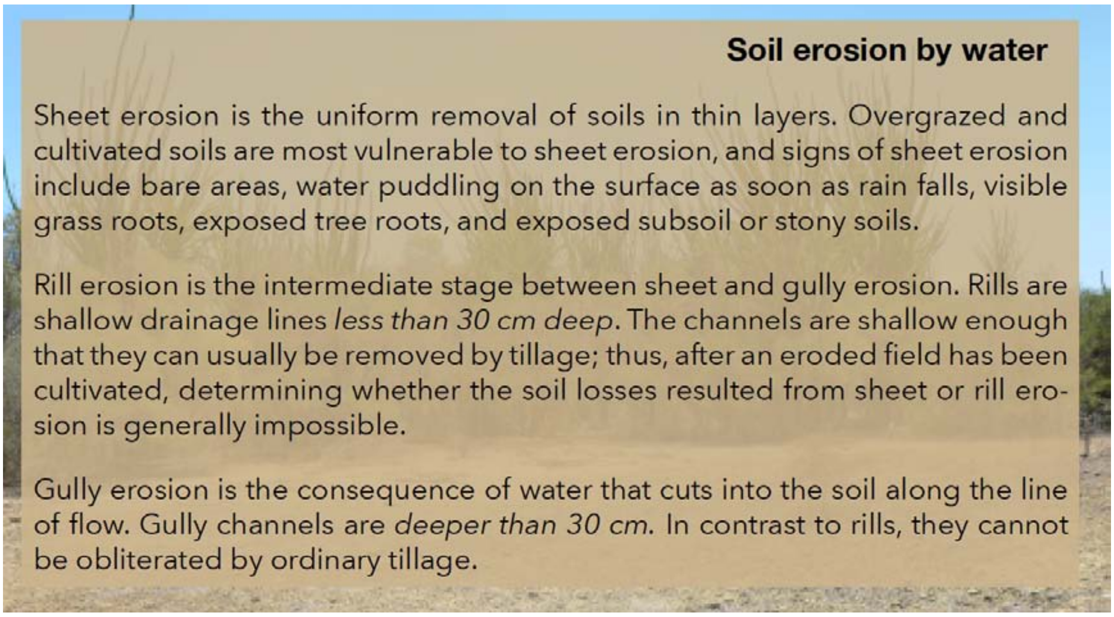


Figure 16: Description of soil erosion types as described in the LDSF field guide.

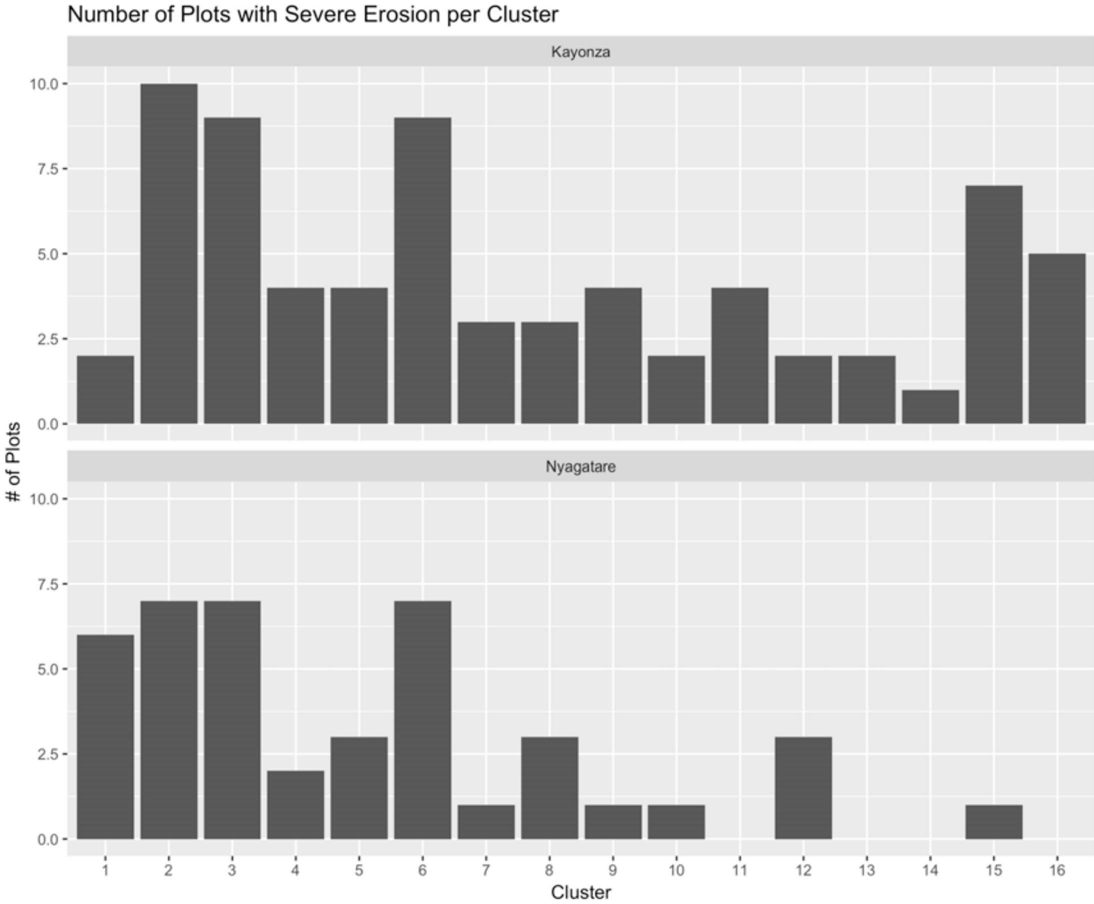


Figure 17: Bar charts of the number of plots per cluster that had severe erosion. Note that in Kayonza site, cluster 2,3,6, and 15 had more than five plots with severe erosion. In Nyagatare, clusters 11,13,14, and 16 had no plots with severe erosion. In general, 10 plots were sampled per cluster.

Soil Water Conservation Measures

Soil water conservation measures were classified and counted at each plot. The below graphic shows the number of plots with structural, vegetative, or both structural and vegetative measures. Note that Nyagatare had higher presence of SWC measures compared to Kayonza.

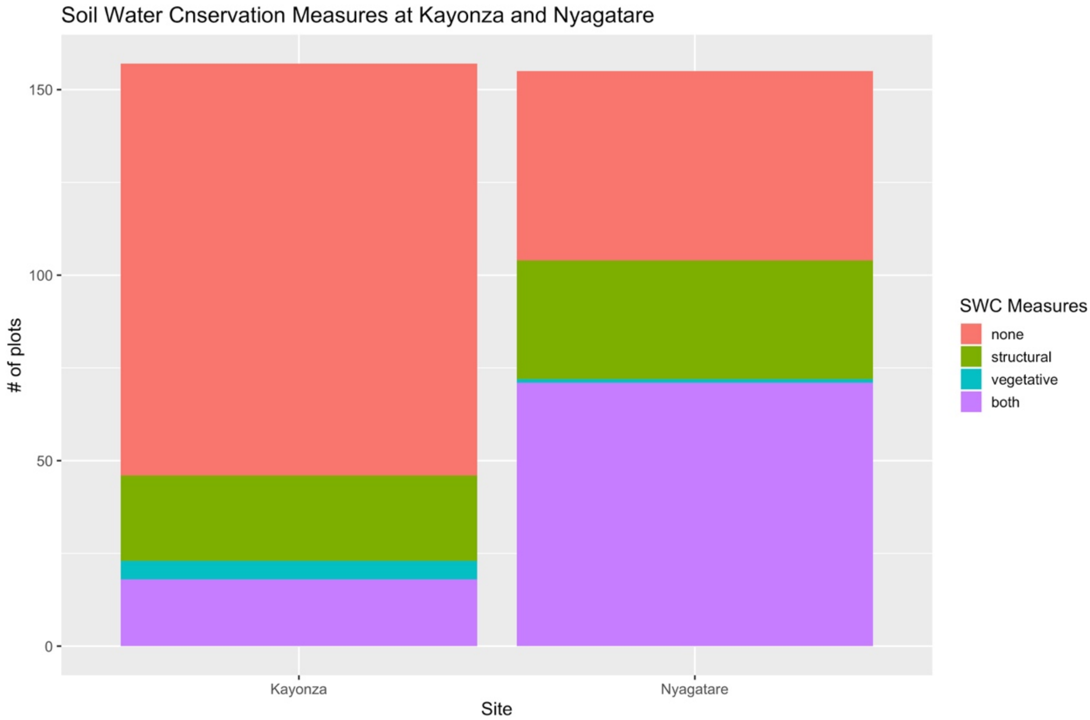


Figure 18: Presence of soil water conservation measures.

Infiltration Capacity

Infiltration capacity was measured at three plots per cluster in each site using single ring infiltrometers to assess variation across land uses and soil types. Soil infiltration capacity into dry soils follows a predictable temporal pattern: it is high in the early stages of infiltration and tends to decline gradually with time until it eventually approaches a nearly constant rate known as steady-state infiltration capacity.

Corrected infiltration capacity rates over time, and the modeled infiltration curves and steady-state infiltration capacity (which corresponds to the estimated soil saturated hydraulic conductivity, *i.e.,* K_s) for each plot in which infiltration was measured (Figures 18 &19).Note the variation across the sites, for example, RW.Kayon.2.5 and RW.Kayon.4.3 had faster infiltration rates compared to several other plots.


Figure 19: Photo of the single ring infiltrometer used to measure infiltration in the field. Photo: G. Koffi/ICRAF.

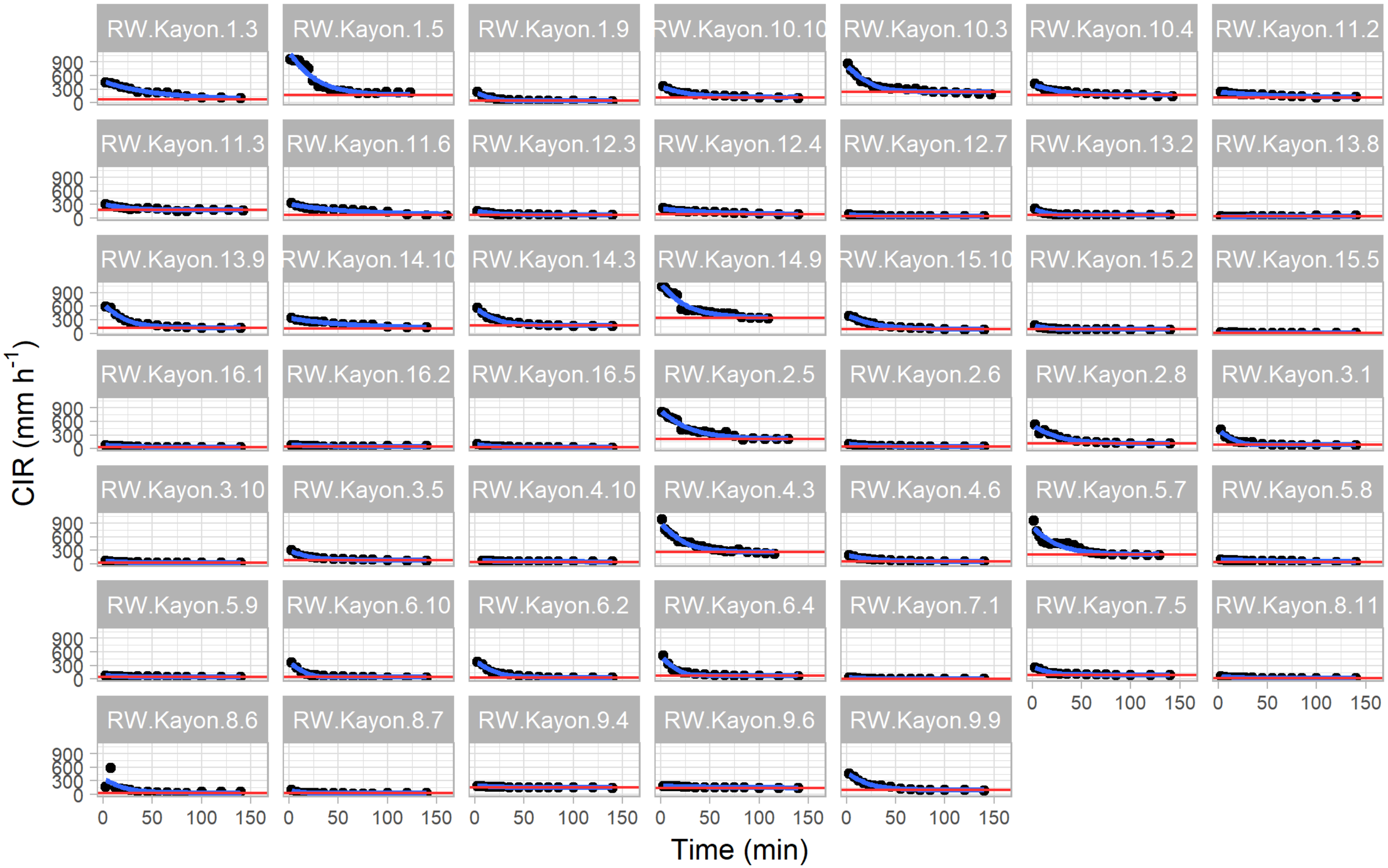


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Figure 20:Corrected infiltration rates (black dots), modelled infiltration curve (blue line) and modelled saturated hydraulic conductivity (red line) for each plot in which infiltration was measured in Kayonza LDSF site.

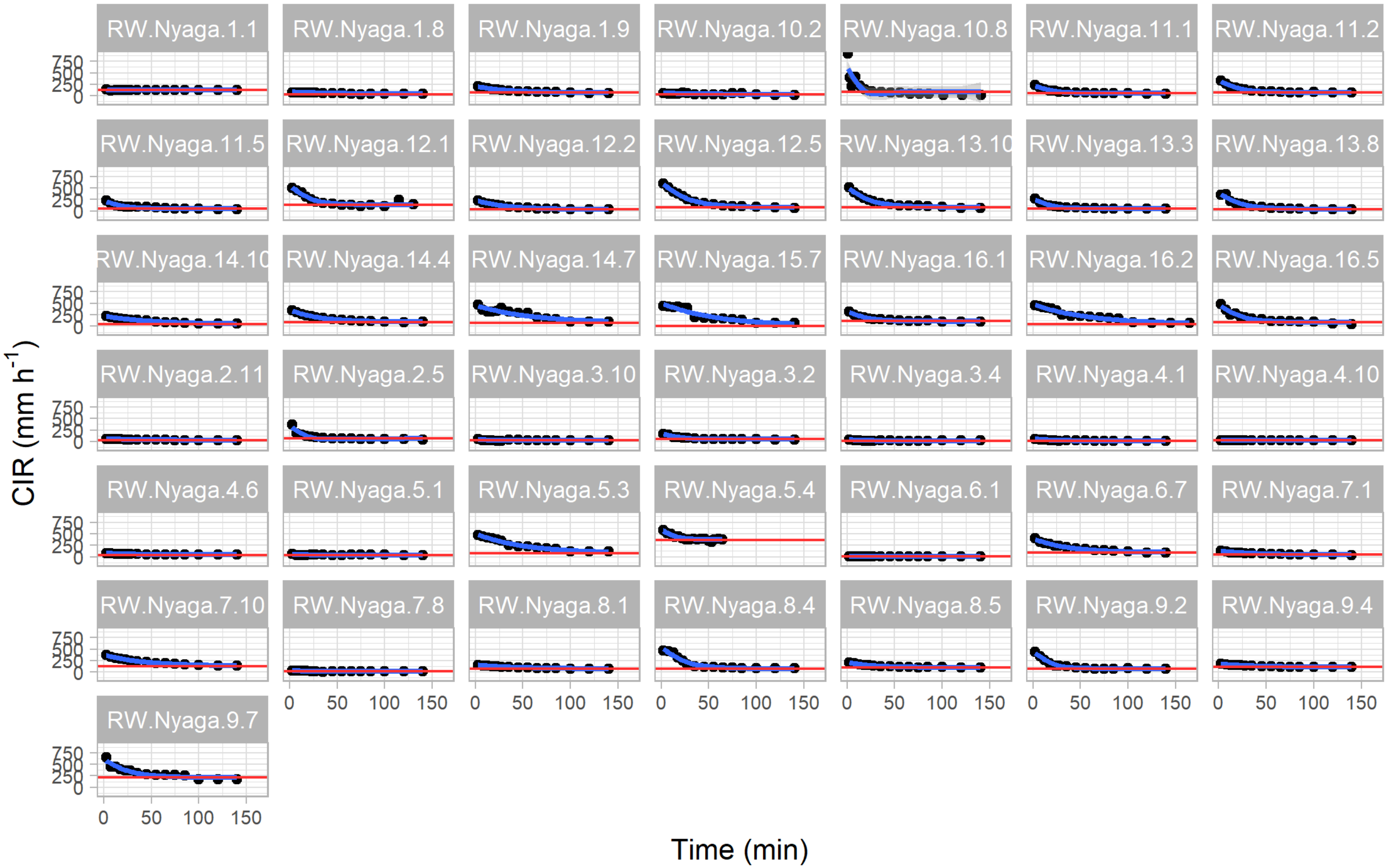

Figure 21: Corrected infiltration rates (black dots), modeled infiltration curve (blue line) and modelled saturated hydraulic conductivity (red line) for each plot in which infiltration was measured in Nyagatare LDSF site.

Modeled saturated hydraulic conductivity (K_s) ranged between 6 and 368 mm h^{-1}, and was higher in Kayoza compared to Nyagatare, with median values of 79 and 61 mm h^{-1} , respectively (Figure 20).

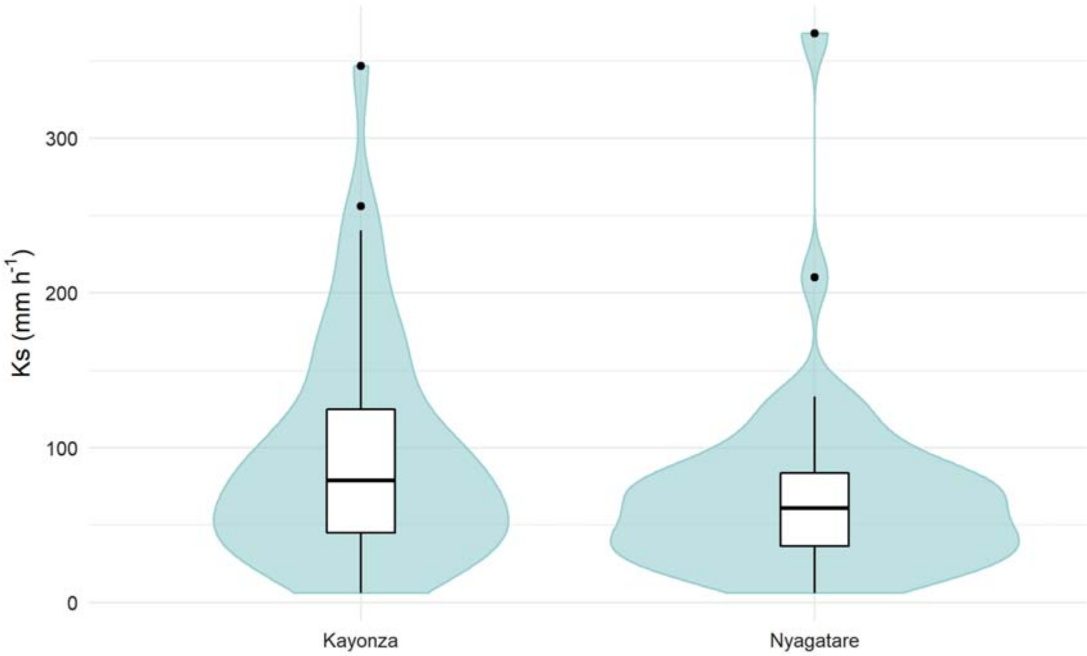

Figure 22: Box and violin plots of the modeled saturated hydraulic conductivity (Ks) for each site. The three horizontal lines in the box plot show the first quartile, the median, and the second quartile. Whiskers extend to the outer-most data point that falls within 1.5 box lengths. The violin plots show the distribution of the Ks data.

These data will be used to understand how land use and land management influence infiltration capacity of water into the soil.

Mapping Soil Erosion

Soil erosion prevalence was mapped at 30-m resolution for 2018. Hotspots of erosion are shown in red/yellow for each of the maps below.

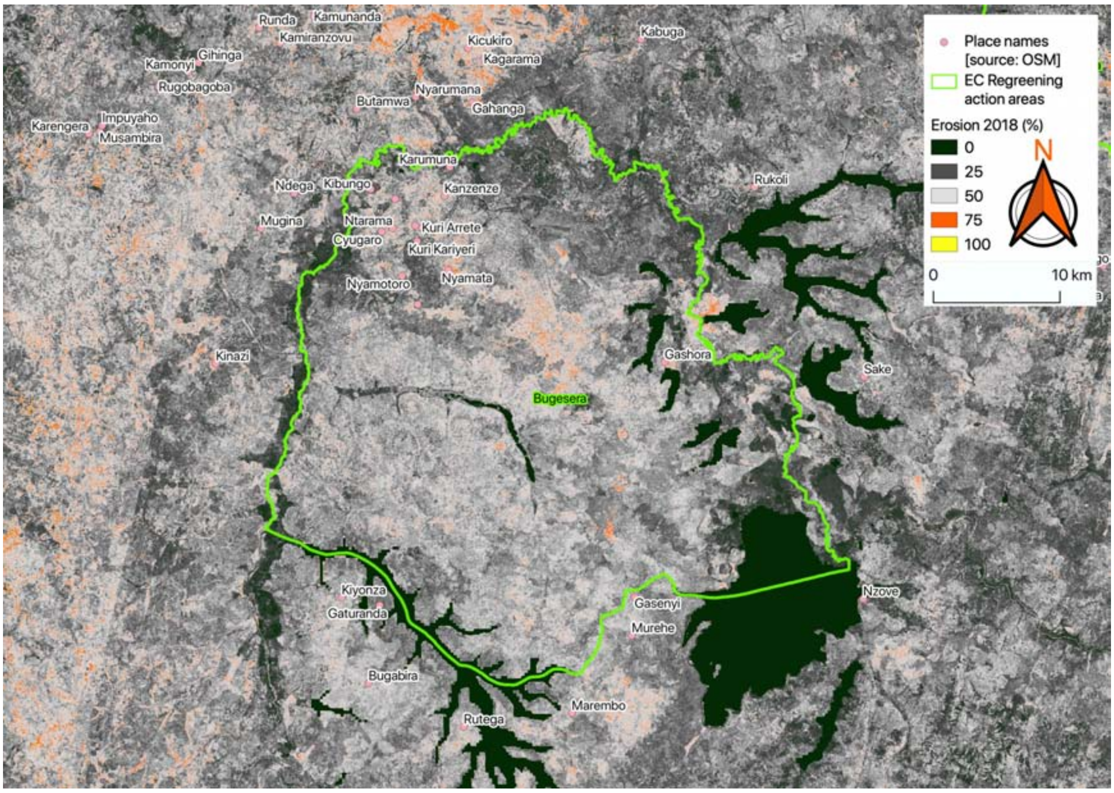

Figure 23: Soil erosion for Bugasera district.

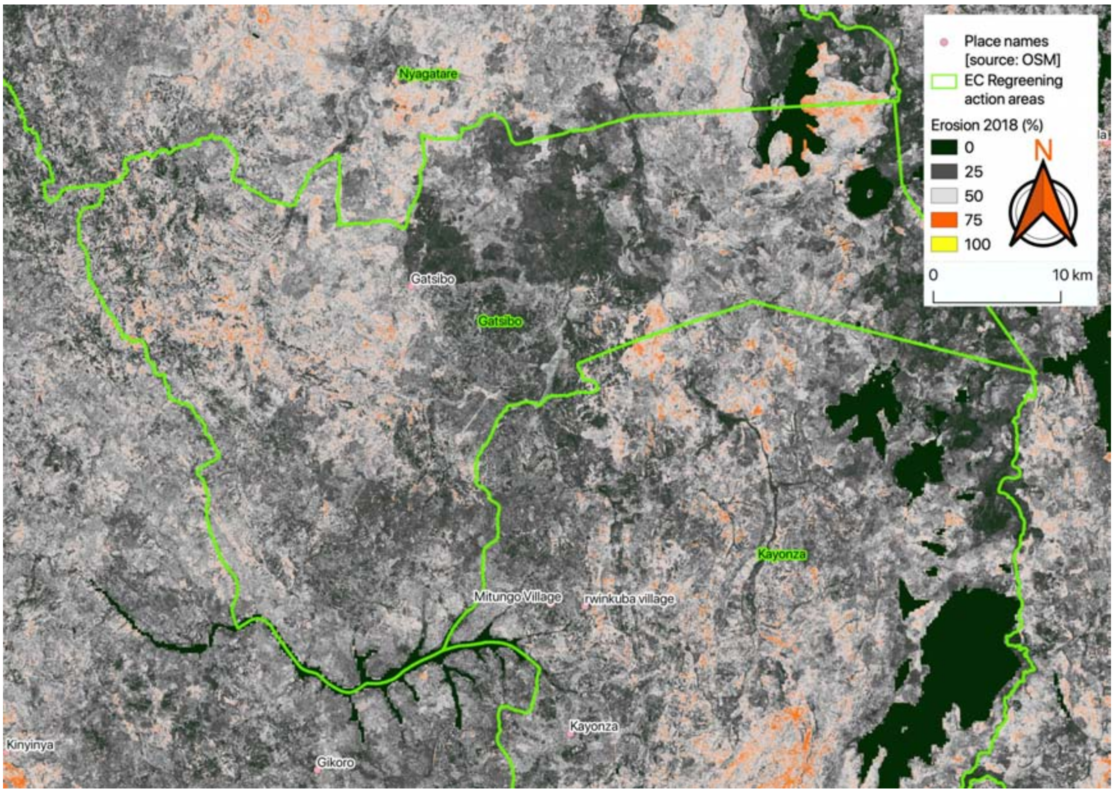

Figure 24: Soil erosion prevalence for Gatsibo district.

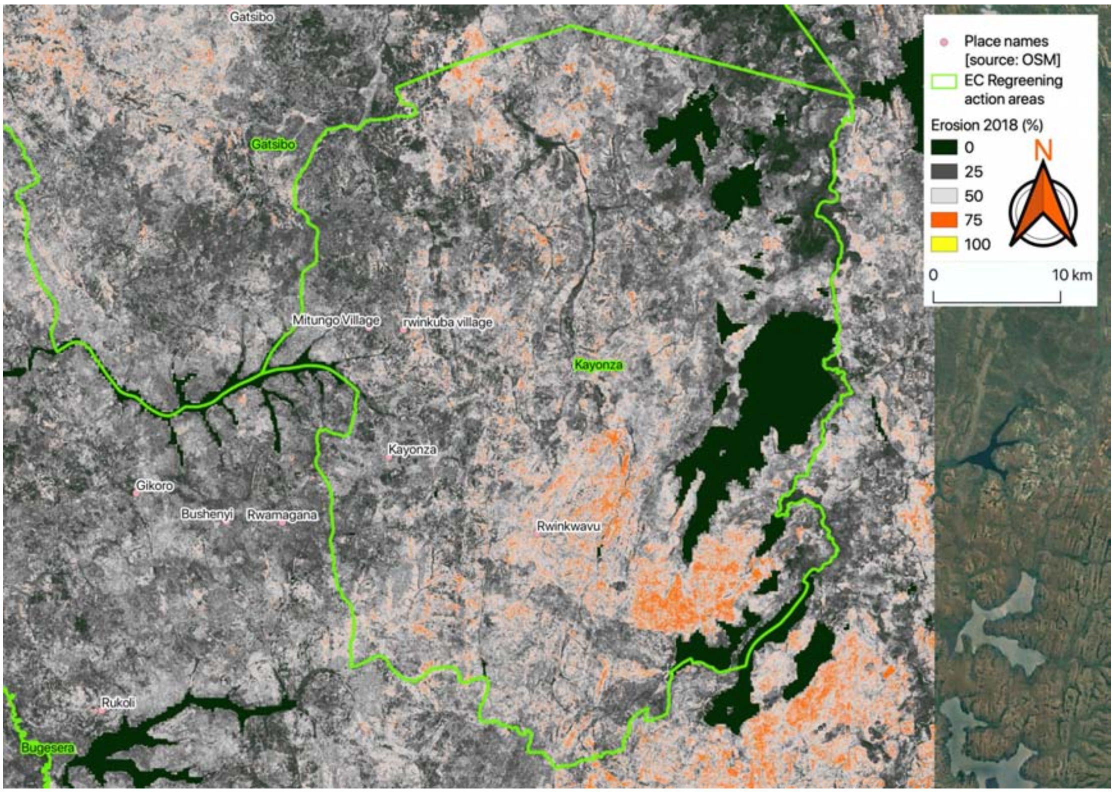

Figure 25:: Soil erosion prevalence for Kayonza district.

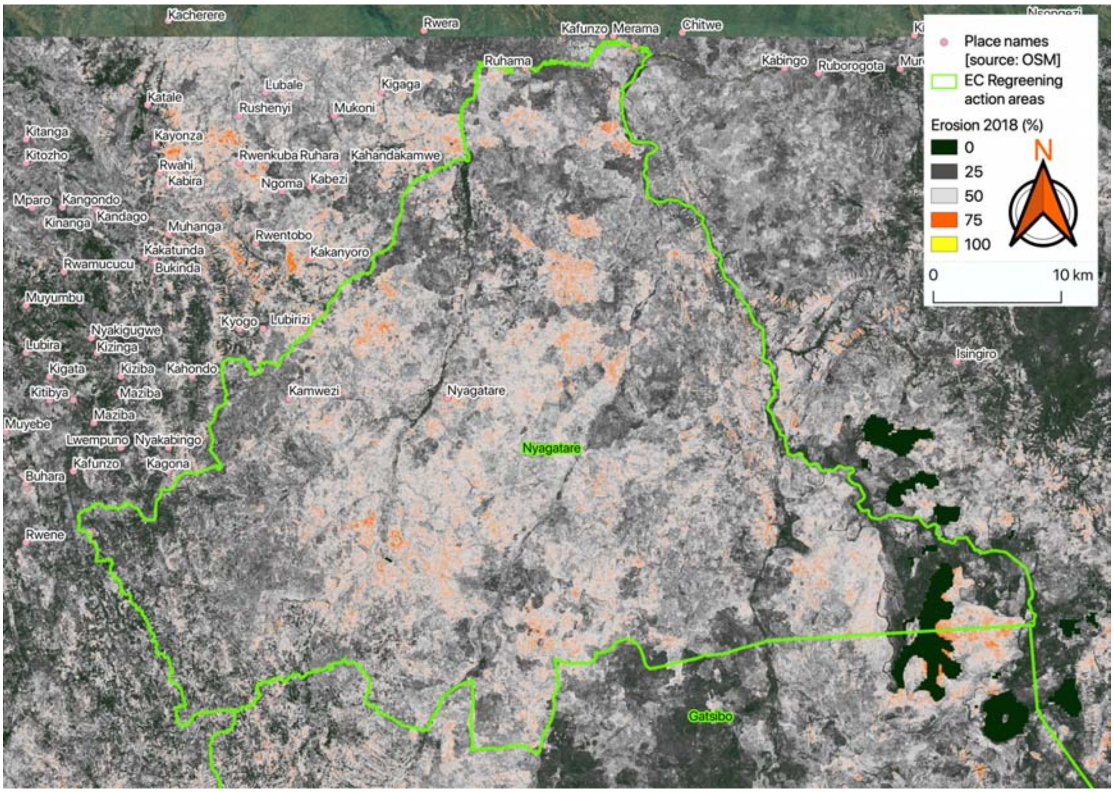

Figure 26:: Soil erosion prevalence for Nyagatare district.

Soil properties

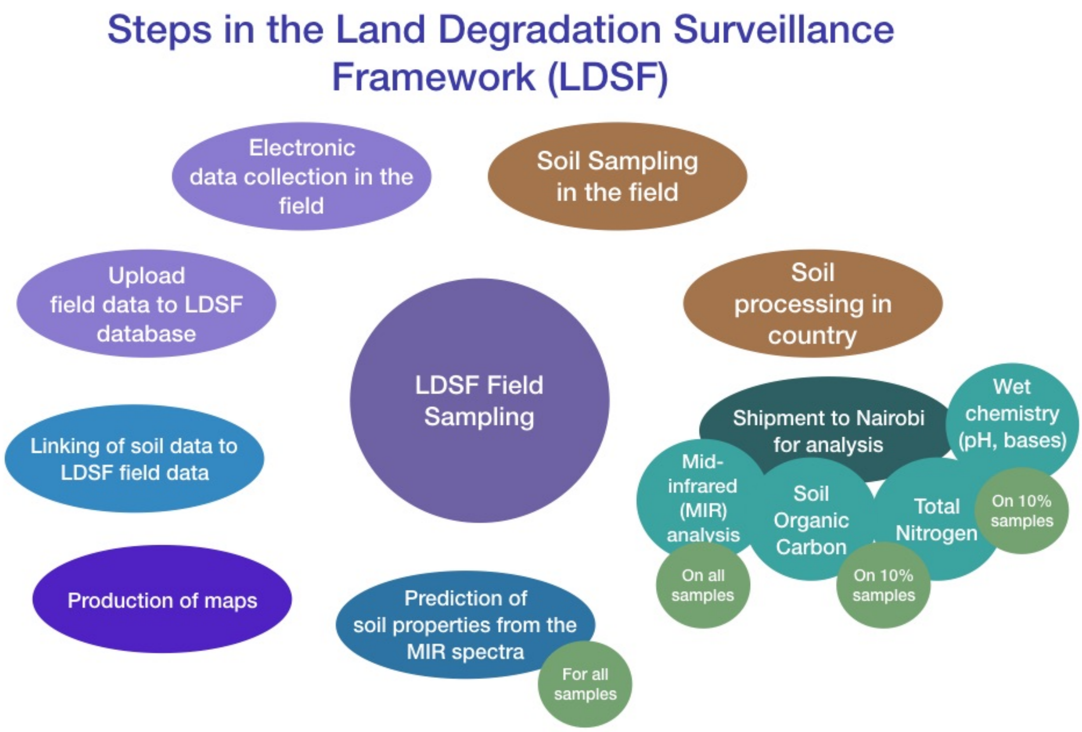

Figure 27: Steps in the LDSF data analysis.

Soil samples were collected at two depths (0-20 cm) referred to as topsoil and (20-50 cm) referred to as subsoil. In Kayonza 154 topsoil and 138 subsoil samples were collected. In Nyagatare, 153 topsoil and 147 subsoil were collected. The below table shows the mean and standard deviation (sd) for soil organic carbon (SOC), pH and Sand content (%).

Table 2:Soil properties for top and sub soil samples at the two LDSF sites.

Site	Depthcode	count	mean.SOC g.kg	sd.SOC	mean.pH	sd.pH	mean.Sand %	sd.Sand
Kayonza	Topsoil	154	21.66	9.36	5.64	0.68	21.86	9.89
Nyagatare	Topsoil	153	17.58	6.42	5.87	0.56	33.17	11.15
Kayonza	Subsoil	138	17.55	8.50	5.64	0.64	21.12	9.06
Nyagatare	Subsoil	147	13.47	5.70	5.86	0.54	33.07	11.45

Average pH across the two depths and the two sites was 5.75, as indicated by the dotted vertical line in the below plot. Interestingly, Kayonza has several plots with more acidic pH levels (between 4 and 5), as shown by the bimodal distribution in pH.

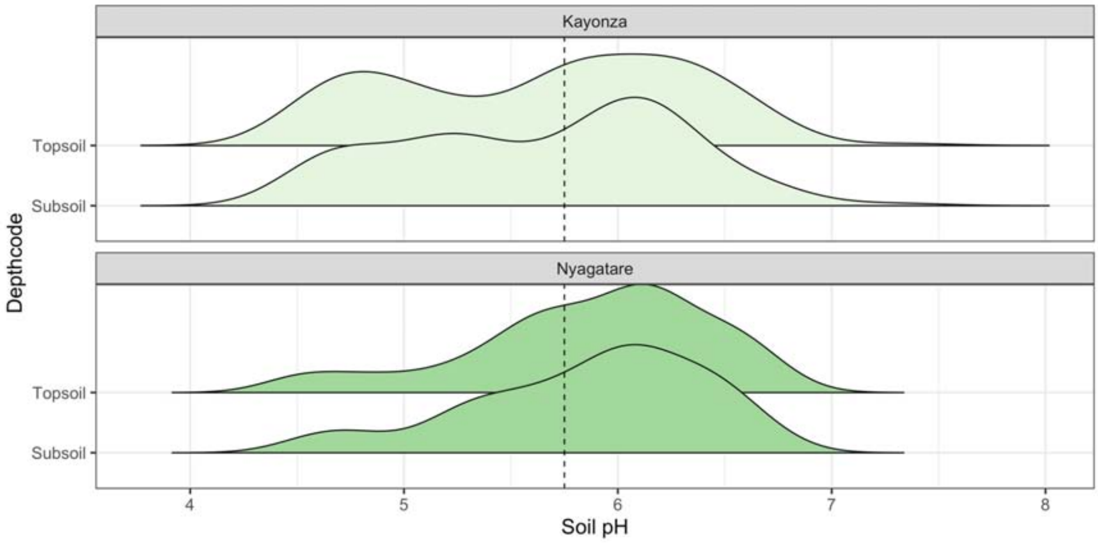

Figure 28: Density plots of soil pH, showing the distributions for each depthcode and site. Vertical dotted line indicates the average pH for the dataset (5.75).

Soil organic carbon (SOC) is a key indicator of soil health. An accepted threshold of SOC for agricultural production is around 20 g.kg (2%). In Nyagatare, most of the sampled plots are below this threshold.

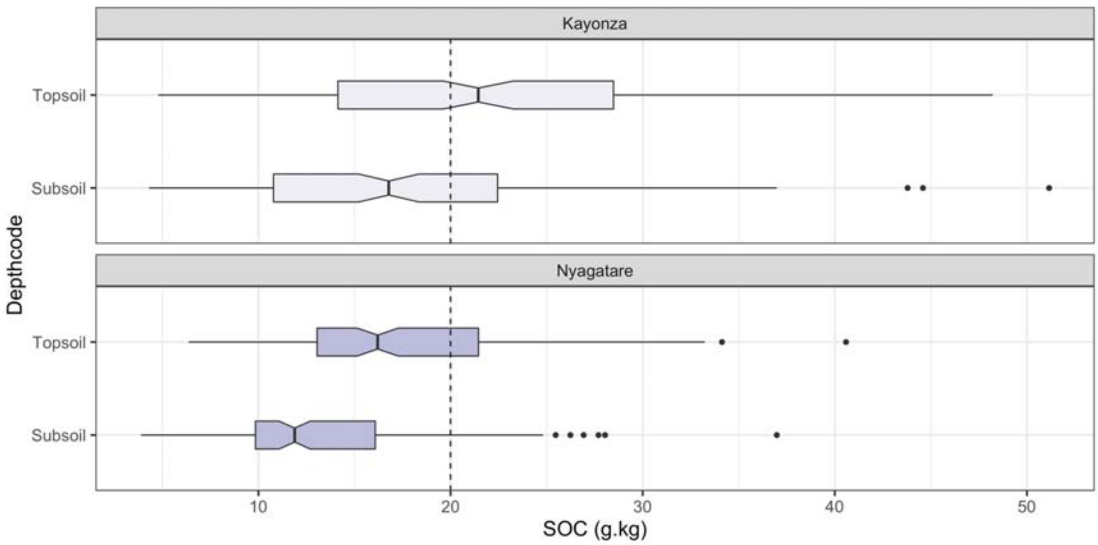

Figure 29: Boxplots of SOC by depthcode and site. Dotted vertical line indicates the 20 g/kg threshhold. The black line inside the box is the median.

Average topsoil sand context was 22% in Kayonza and 33% in Nyagatare.

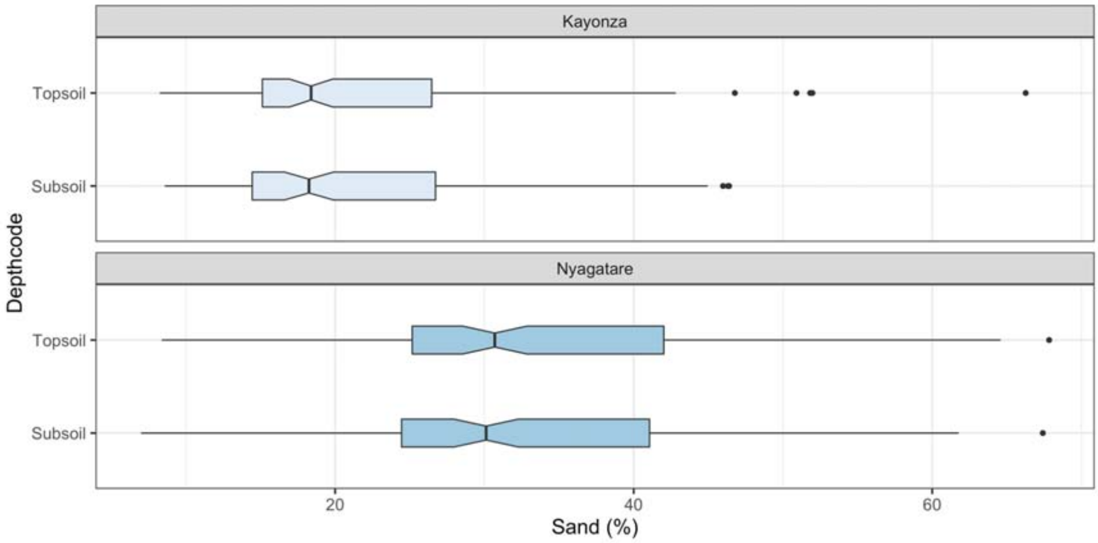

Figure 30: Boxplots of sand by depthcode and site.

The below figure shows the relationship between sand content and SOC. For example, as sand content decreases, SOC increases. This pattern holds, in general for both sites, with Kayonza having slightly higher SOC.

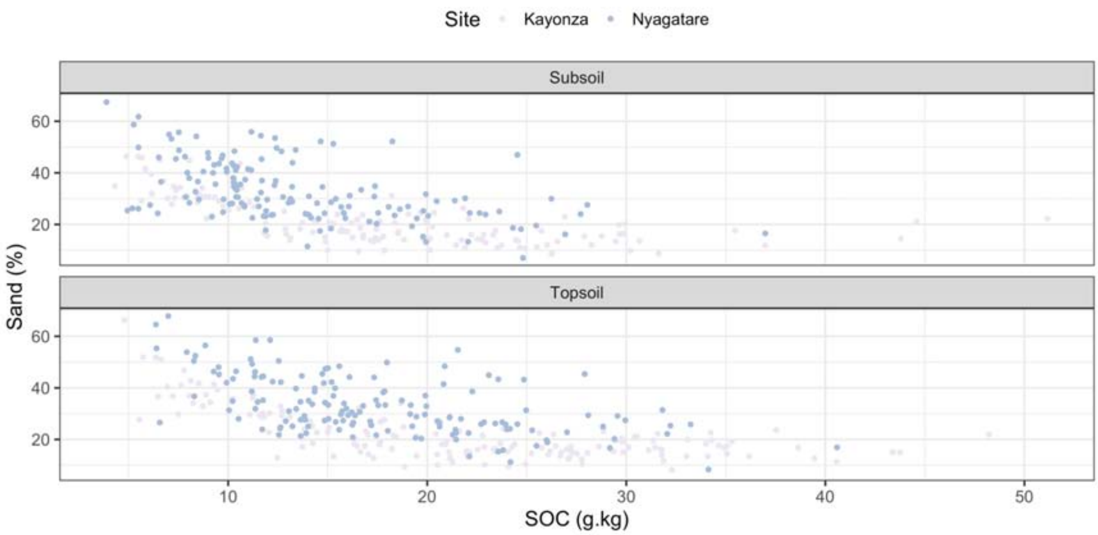

Figure 31: Relationship between Sand and SOC.

Total nitrogen content is low across both sites, below the suggested thresholds.

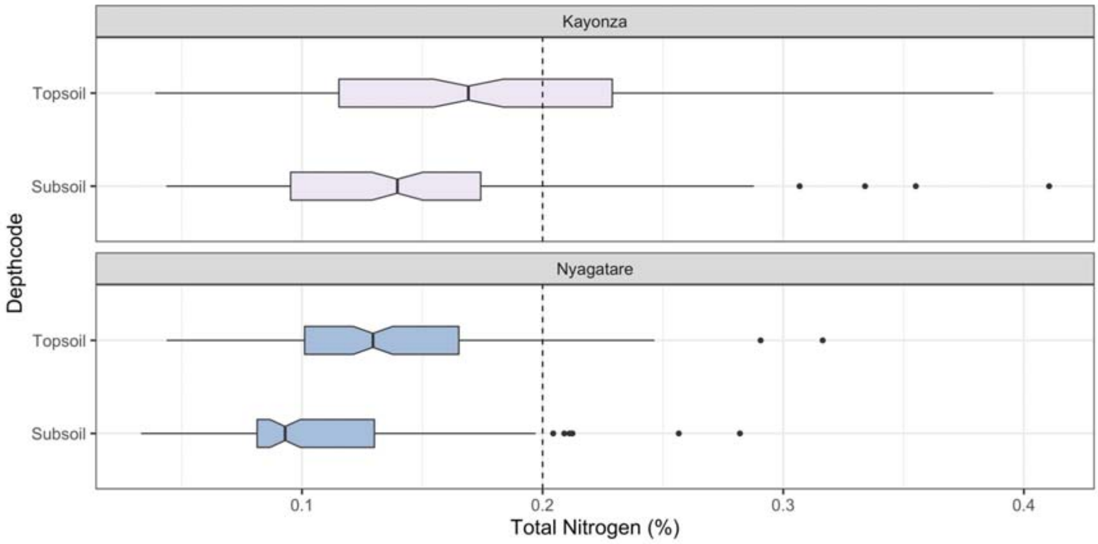

Figure 32: Boxplots of total nitrogen by depthcode and site. The dotted vertical line is the suggested threshhold for nitrogen.

Spatial Variation

The below images illustrate the spatial variation

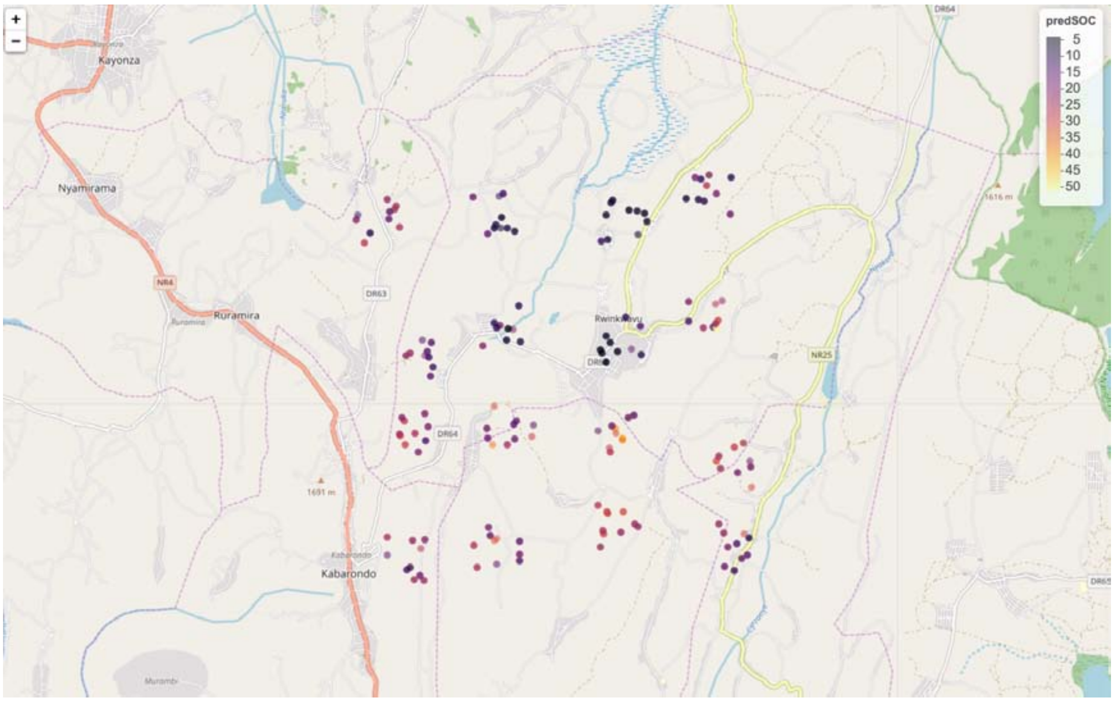

Figure 33: SOC content (g.kg) of each plot sampled in Kayonza LDSF site.

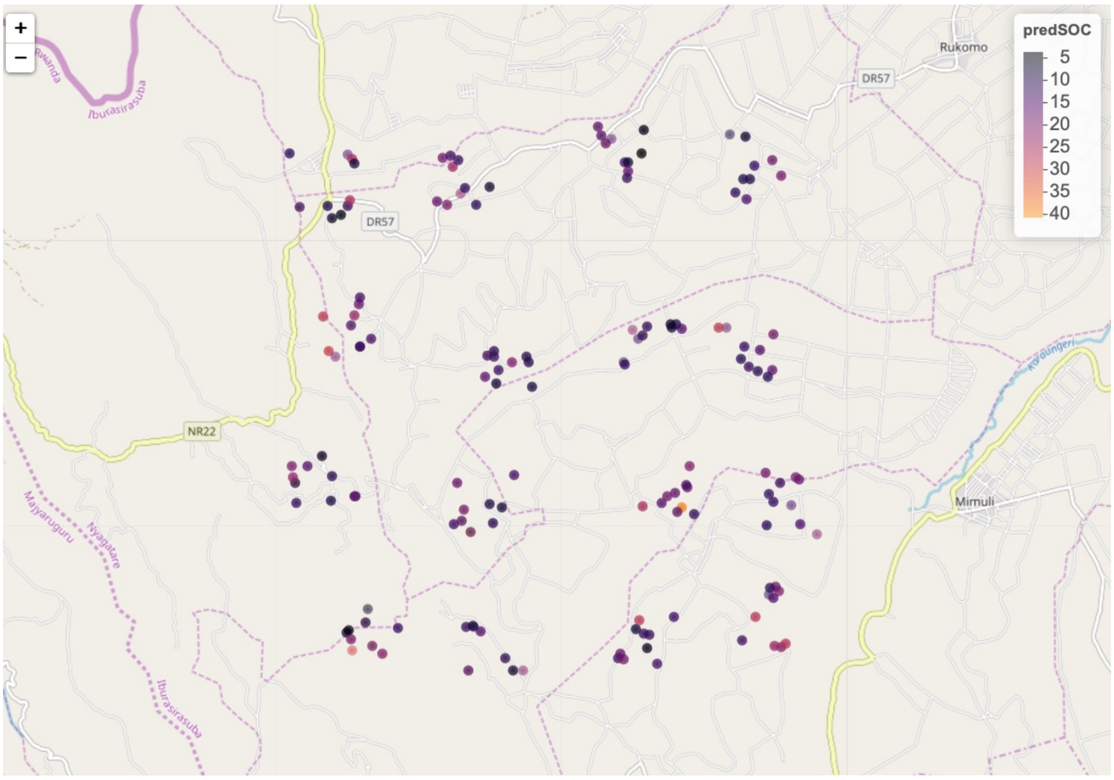

Figure 34: SOC content (g.kg) of each plot sampled in Nyagatare LDSF site..

SOC by Vegetation Structure

Cropland plots had the lowest SOC across the two sites. Bushland, woodland, wooded grasslands had the highest SOC content.

Table 3: SOC content by Vegetation Structure.

Site	Depthcode	VegStructure	count	mean.SOC g.kg	min.SOC g.kg	max.SOC g.kg
Kayonza	Topsoil	bushland	9	26.17	16.55	38.63
Kayonza	Topsoil	cropland	102	19.49	4.78	43.75
Kayonza	Topsoil	grassland	5	22.97	15.00	35.05
Kayonza	Topsoil	shrubland	18	26.41	8.05	48.22
Kayonza	Topsoil	wooded_grassland	3	31.73	29.48	35.30
Kayonza	Topsoil	woodland	14	26.11	14.22	34.92
Nyagatare	Topsoil	bushland	2	29.39	28.83	29.95
Nyagatare	Topsoil	cropland	133	17.07	6.37	40.59
Nyagatare	Topsoil	shrubland	2	25.06	17.89	32.22
Nyagatare	Topsoil	wooded_grassland	1	28.09	28.09	28.09
Nyagatare	Topsoil	woodland	11	18.41	11.38	22.85
Kayonza	Subsoil	bushland	7	23.82	17.15	29.95
Kayonza	Subsoil	cropland	100	16.64	4.31	44.59
Kayonza	Subsoil	grassland	4	16.05	8.79	22.53
Kayonza	Subsoil	shrubland	14	18.45	5.49	51.16
Kayonza	Subsoil	wooded_grassland	1	17.39	17.39	17.39

Kayonza	Subsoil	woodland	10	19.89	11.31	29.87
Nyagatare	Subsoil	bushland	1	14.84	14.84	14.84
Nyagatare	Subsoil	cropland	133	13.16	3.89	36.98
Nyagatare	Subsoil	shrubland	2	18.41	13.88	22.93
Nyagatare	Subsoil	wooded_grassland	1	23.62	23.62	23.62
Nyagatare	Subsoil	woodland	8	15.72	9.24	22.63

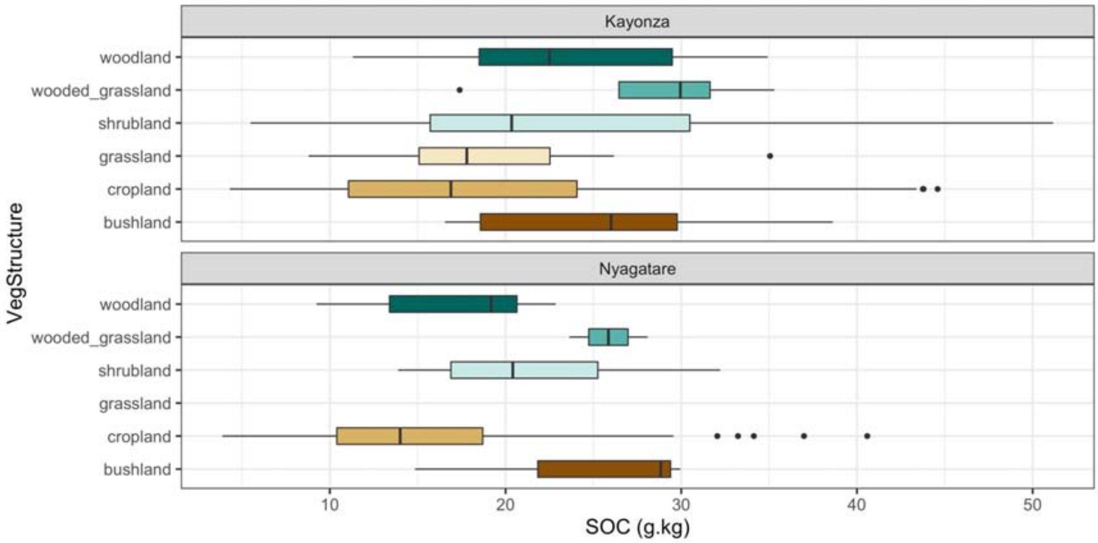

Figure 35: Boxplots of SOC content by Vegetation Structure.

Next Steps

This is a preliminary report summarizing some of the initial indicators from the LDSF field data. Further analysis of the LDSF field data will be carried out, including on the land degradation status and mapping and modelling of the infiltration data.

Maps of key indicators of land and soil health will be generated, including soil organic carbon, among other indicators.

Capacity development on data analytics will be scheduled in 2020.

Capacity Development with Partners using the Land Degradation Surveillance Framework (LDSF)

1

Field training includes all aspects of the LDSF such as: GPS navigation; electronic data entry and upload; LCCS vegetation classification; soil sampling; infiltration measurements; woody biodiversity measurements; and land degradation assessments. **Participants include** field technicians, members of the LDSF field team, partners interested in learning new techniques for land and soil health assessments.

2

Data analytics training to explore the LDSF data with R statistics. We will tidy and visualize data as well as apply mixed effect models to assess key indicators of land and soil health. We will also explore database development and data management. **Participants include** technical staff interested in data analysis and data management and those who will continue to work with the LDSF datasets.

3

Remote sensing (RS) training to explore key concepts, methods and applications of RS, including the use of open source GIS and remote sensing software. Conduct basic analysis using RS data (creation of image composites, image calculations, generation of vegetation indices and soil maps, etc). **Participants include** technical staff familiar with RS and GIS principles.

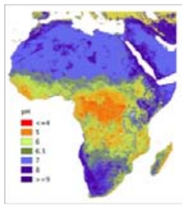

Figure 36: Opportunities for capacity development around the LDSF.

ANNEX 1: AGENDA for LDSF training 24th – 28th September 2018:

Venue: Nyagatare LDSF site
Accommodation: Nyagatare town
Contact person: Athanase Mukuralinda (ICRAF)

Date	Agenda	Activity
24th September 2017	**ICRAF colleagues to arrive in Kigali ~ 9 am**	Leigh and Tor arrive in Kigali. Meet participants, presentation and introduction on the LDSF methodology, organized field equipment with the team.
25th September 2017 Tuesday All day	**LDSF Field Training - Day One**	Travel to the field site programming GPS, GPS navigation and the randomized LDSF design, setting up the plot.
26th September 2017 Wednesday All day	**LDSF Field Training - Day Two** Closing Reception and certificates in the evening.	Training on LDSF field methods, soil sampling, labelling, plot and sub-plot measurements, tree and shrub biodiversity assessment
27th September 2017 Thursday All day	**LDSF Field Training for core team - Day Three**	Continued training on the LDSF methodology, core team should feel comfortable to continue the survey after the training. Discussion about methodology, data upload, data analysis.
28th September 2017 Friday	**Leigh and Tor travel back Kigali for meetings and then fly back to Nairobi**	Meeting with RAB staff and Permanent Secretary on the Rwanda Soil Information System. Internal discussion on the way forward – next steps for operationalizing the LDSF surveys.

ANNEX 2: LINK TO THE LDSF DATA WALL

During the Joint Reflection and Learning Mission (JRLM) in Kigali in June 2019, these data were presented and shared with partners.

The link to view and download the graphics and PowerPoint presentation is here: https://www.dropbox.com/s/3iznfo293v12t6w/ldd_Regreening%20Africa_JRLM%20data%20wall_Rwanda_sm.pptx?dl=0