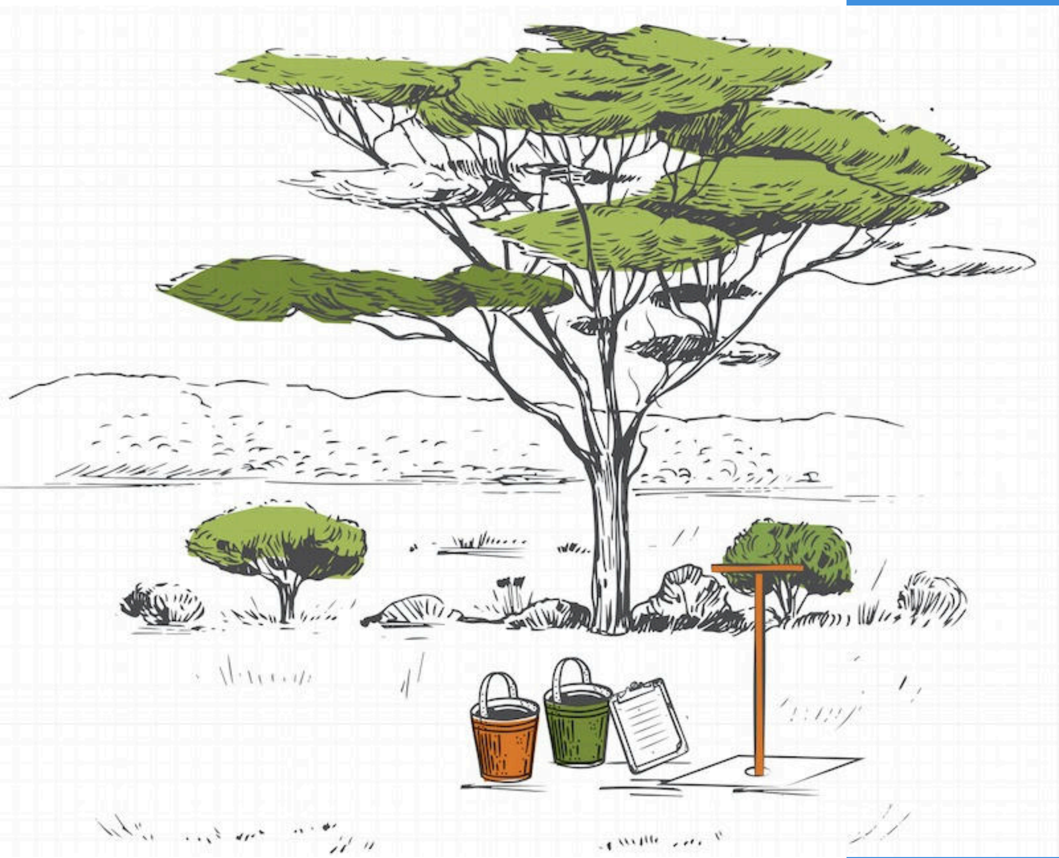
THE LAND DEGRADATION SURVEILLANCE FRAMEWORK

BRCiS LDSF Soil Report
v1 - February 2025
v2 - April 2025



LDSF

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This report

is version two of the addendum to the report Ecosystem Baseline Report for BRCiS III. It presents results from the LDSF surveys conducted in Kismaayo and Guriel, particularly the results of the soil analyses for the two sites, which were not part of the baseline report given the time it took to complete the analyses.

Contents

About the LDSF

The LDSF was developed in response to the need for a simple, low-cost and flexible framework for monitoring and assessing soil and land health. It is designed to be used by a wide range of stakeholders, including government agencies, non-governmental organizations, research institutions, and local communities. The LDSF is based on a set of simple, standardized protocols for collecting data on land cover, land use, soil health, and land degradation. These protocols can be adapted to local conditions and are designed to be used by people with limited technical expertise. The LDSF is designed to be used in a wide range of ecosystems, including forests, grasslands, croplands, and rangelands. It is currently being used in more than 40 countries.

About the BRCiS LDSF soil surveys

The BRCiS LDSF surveys were conducted in eight areas (clusters) within the programme area, with soil sampling conducted in two of these areas (Kismaayo and Guriel). Results from the eight surveys were presented in the baseline report submitted separately. In this report, we present more in-depth results for Kismaayo and Guriel, with particular focus on the soil analyses results. We also discuss the implications of the soil health results for land management and restoration in the two programme areas. The results of the soil analysis is highly consistent with the predictions produced as part of the project based on the global LDSF database. However, the soil health maps produced as part of the project, and reported on in the baseline report, will be updated with the new data presented here and updated on the online land health dashboard created for the project (see: https://dashboards.cifor-icraf.org/app/somalia).

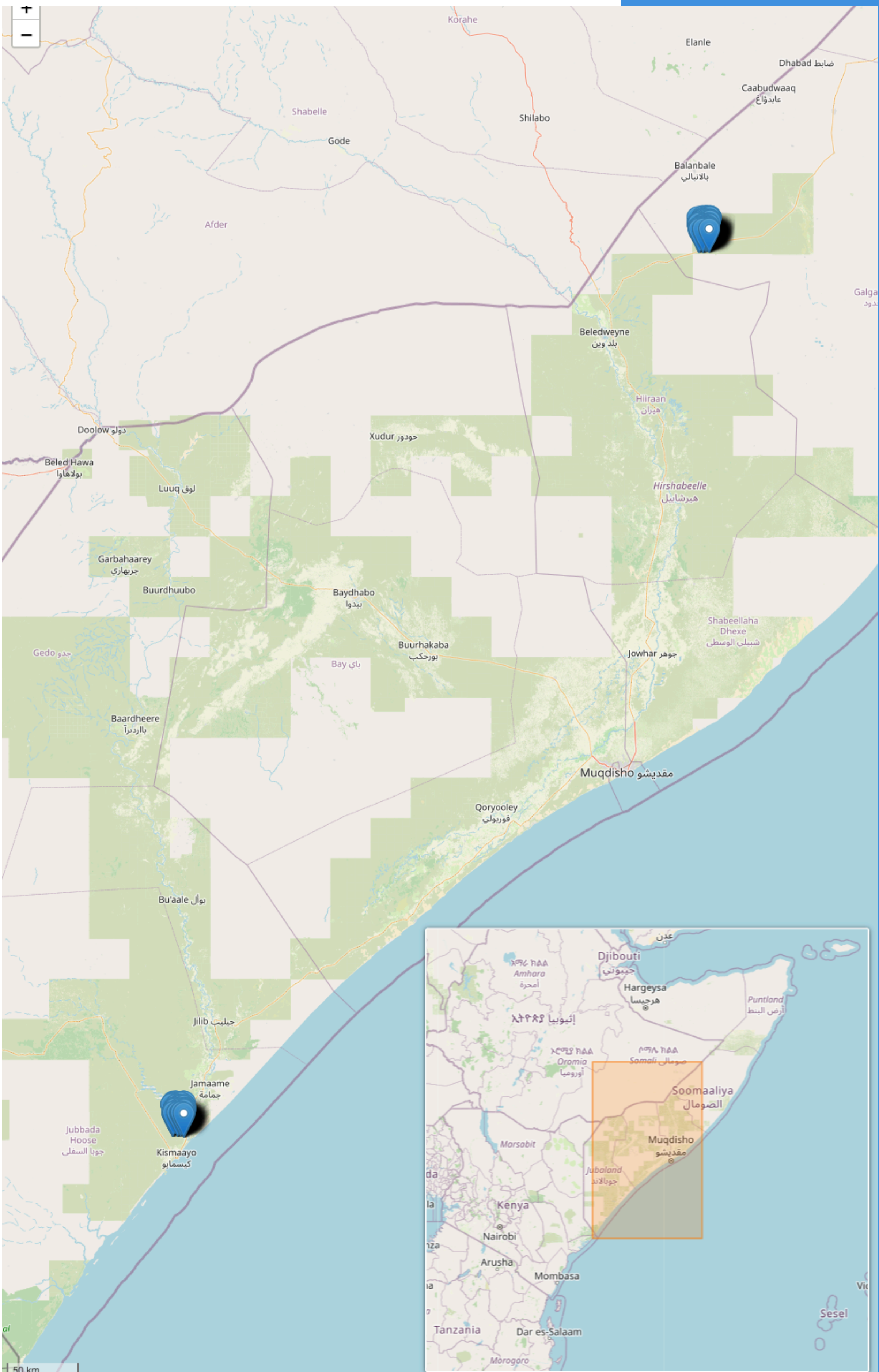

Figure 1: Map showing the locations of the Kismaayo site in the south and Guriel to the north.

1. Land cover and land use

In the LDSF, we capture dominant land use through the field data collection (Vågen & Winowiecki (2023)). The data collected shows how people use a given area or landscape – whether for development, conservation, tree planting, cropping, or mixed uses. Agroforestry, for example, is a mixed land use system that combines trees and/or shrubs with crops and/or livestock. In both Guriel and Kismaayo, pasture/rangeland are the most dominant land uses (99% of the surveyed plots in Guriel and 75% of the surveyed plots in Kismaayo). In Kismaayo, there were annual crops in about 20% of the surveyed plots (mostly in LDSF cluster 1 (Figure 3)), while Guriel only had 1% annual crops (in sampling cluster 13).

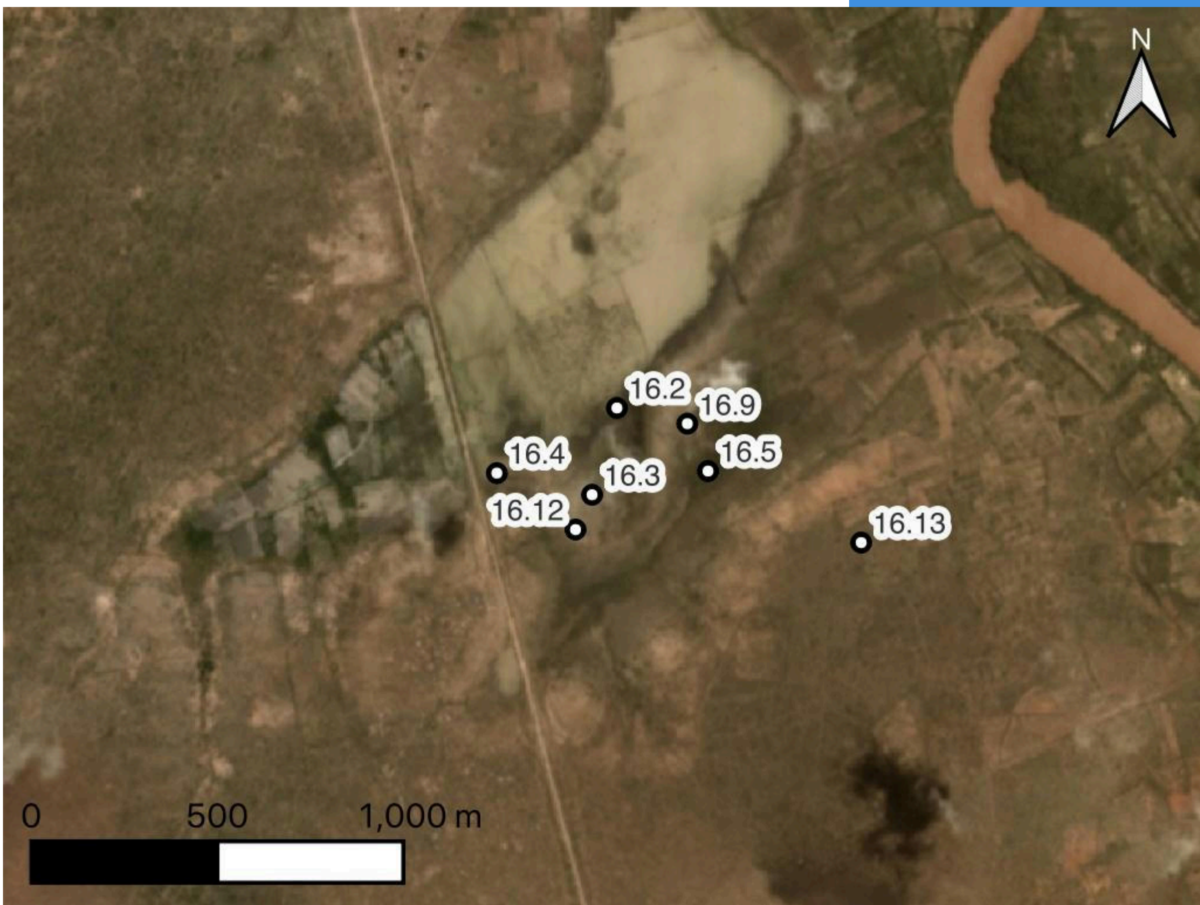

Figure 2: Planet satellite image showing LDSF sampling cluster 16 in Kismaayo.

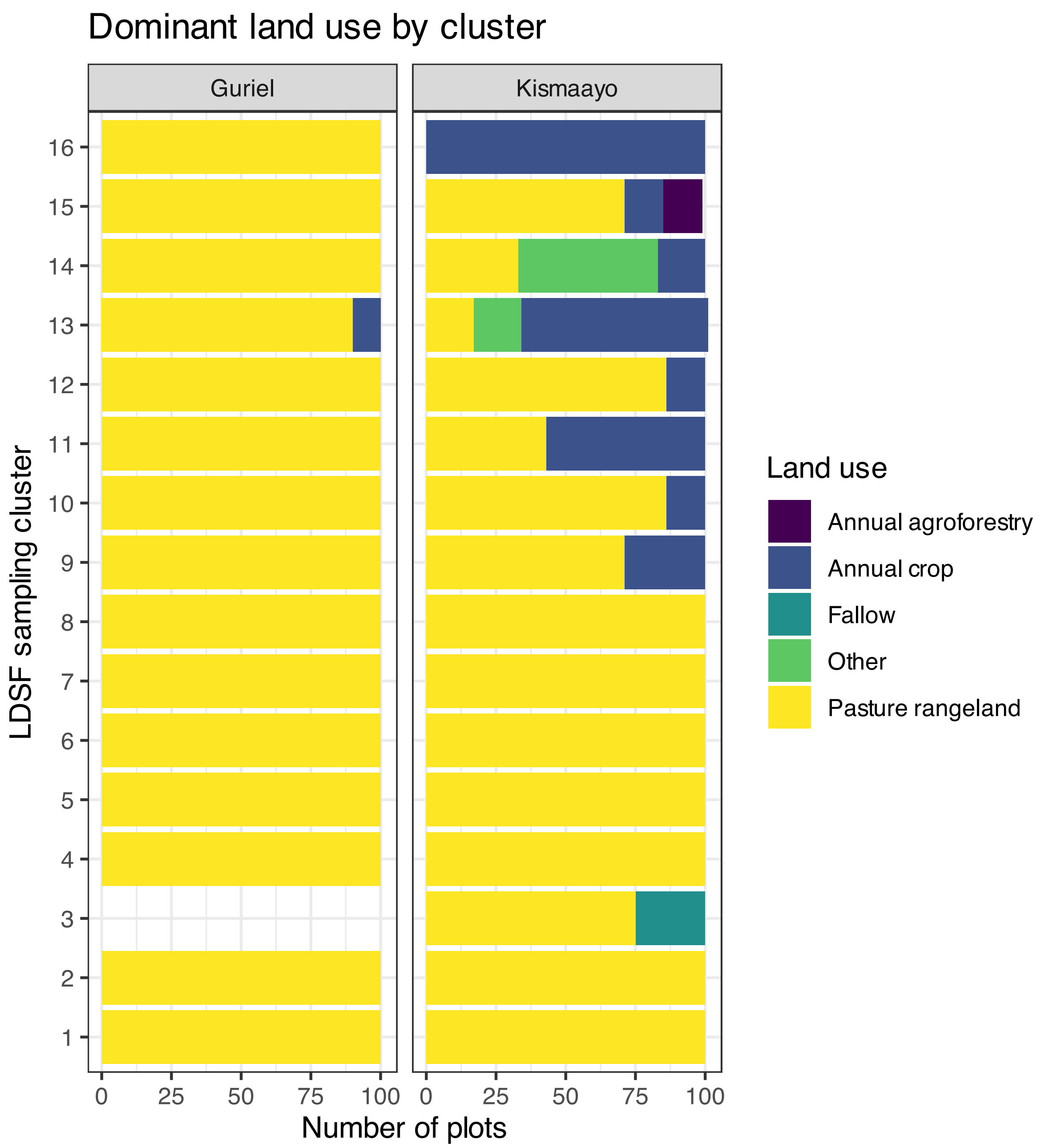

Figure 3: Dominant land use types in the BRCiS LDSF sites.

Land cover or vegetation structure data reflect how much of an area or region is covered by agriculture (croplands), grasslands, forests, wetlands, impervious surfaces, and other land and water types. Water types include wetlands or open water. In terms of vegetation structure classification, the most common vegetation structure class in Kismaayo was Bushland (36%), followed by Shrubland (23%), Cropland (18%), and Grassland (12%). In Guriel, Bushland was also most dominant with 68% of the sampled plots, followed by Shrubland (26%). No grassland plots were recorded in Guriel. The results are shown in Figure 4.

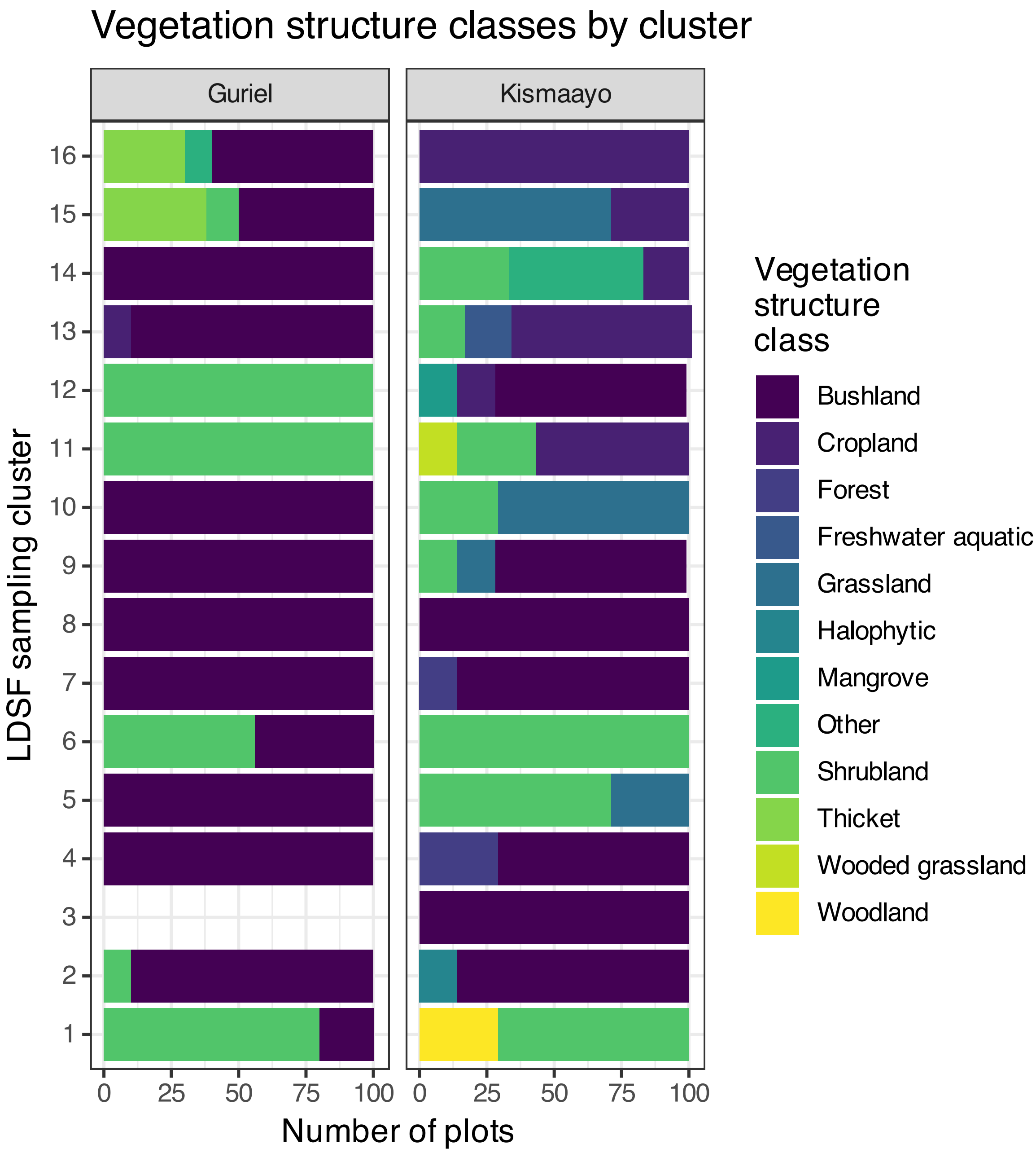

Figure 4: Vegetation structure classes in the BRCiS LDSF site.

1.1. Tree and shrub densities

Tree densities are relatively low with Kismaayo having an average tree density of almost 18 trees ha^{-1} and Guriel having an average tree density of 24 trees ha^{-1}. Shrub densities are higher with Kismaayo having an average shrub density of 149 shrubs ha^{-1} and Guriel having an average shrub density of 124 shrubs ha^{-1}. As shown in Figure 5 and Figure 6, shrub densities are also generally more variable between clusters than tree densities.

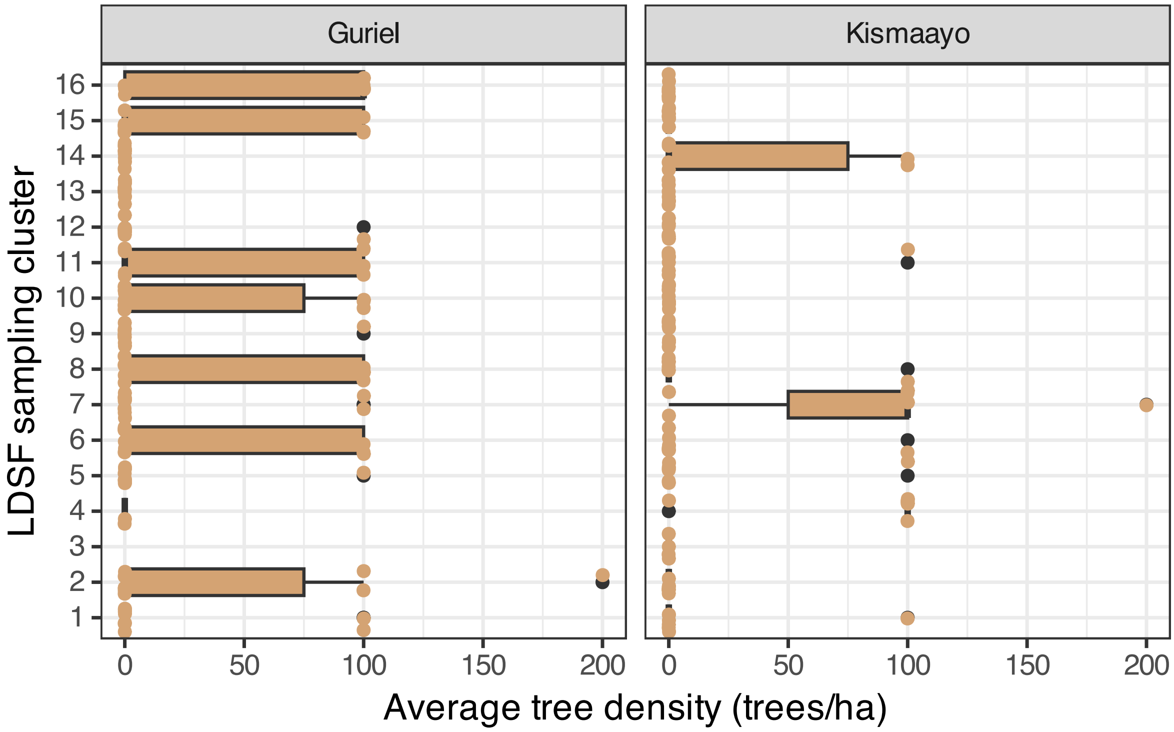

Figure 5: Tree density by cluster.

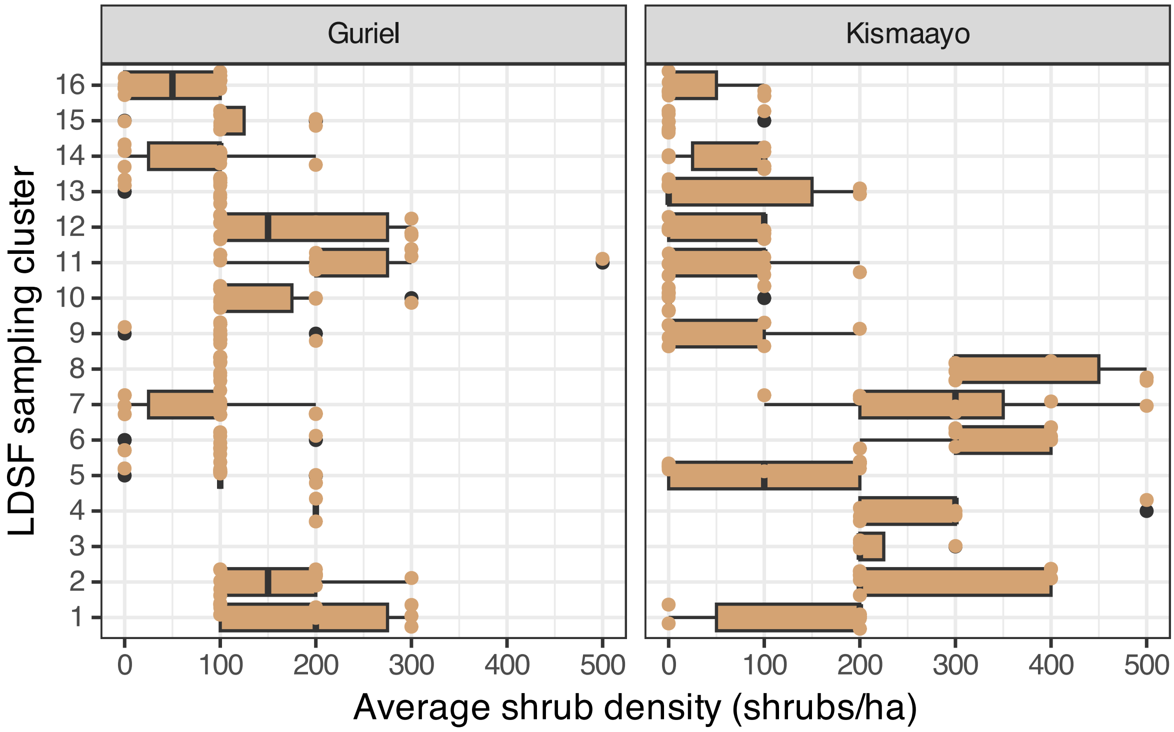

Figure 6: Shrub density by cluster.

2. Land degradation

Erosion is arguably the most widespread form of land degradation in the tropics. There are many forms of soil erosion as illustrated in Figure 7. In the LDSF, each sub-plot (n=4) is classified according erosion status as None/Sheet/Rill/Gully (Vågen & Winowiecki (2023)). Based on this, a visible erosion score is calculated by aggregating the erosion observations (0 - no erosion, 4 - all subplots have erosion). We model the prevalence of soil erosion for each plot by considering plots with three or more subplots with erosion as eroded and then predicting the probability of erosion in each plot.

As shown in Figure 8, erosion prevalence is very high in Guriel and high, but more variable, in Kismaayo. For example in cluster 7 in Kismaayo, no erosion was observed in any of the plots, while in cluster 2, 3 and 10, all plots had erosion. In Guriel, erosion prevalence is high in all clusters. Cluster 3 in Guriel was missing from the data submitted. We discuss the implications of the high rates of erosion for management in Section 4.1.

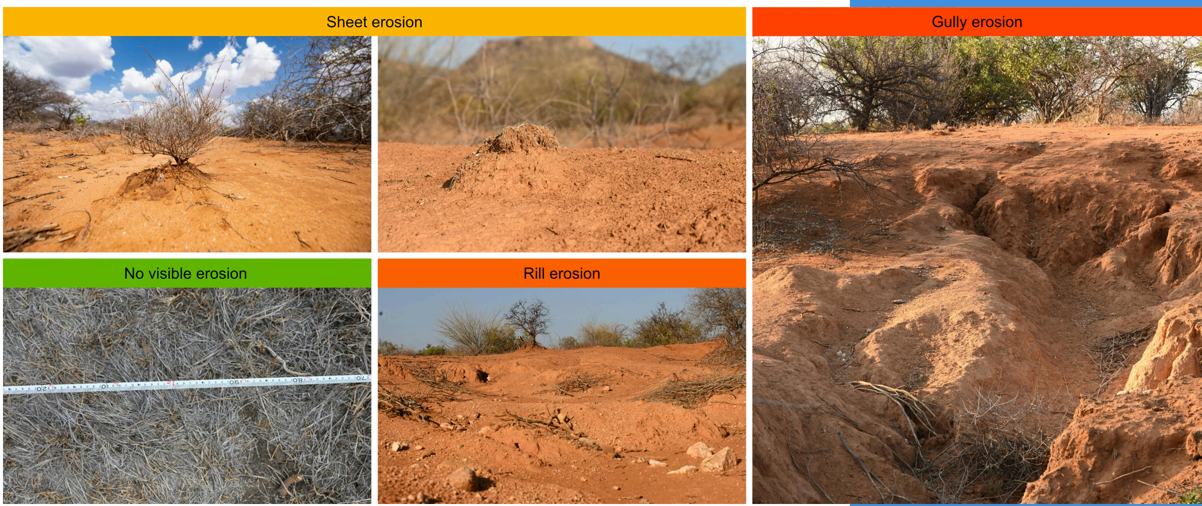

Figure 7: Illustration of different types of soil erosion recorded in the LDSF.

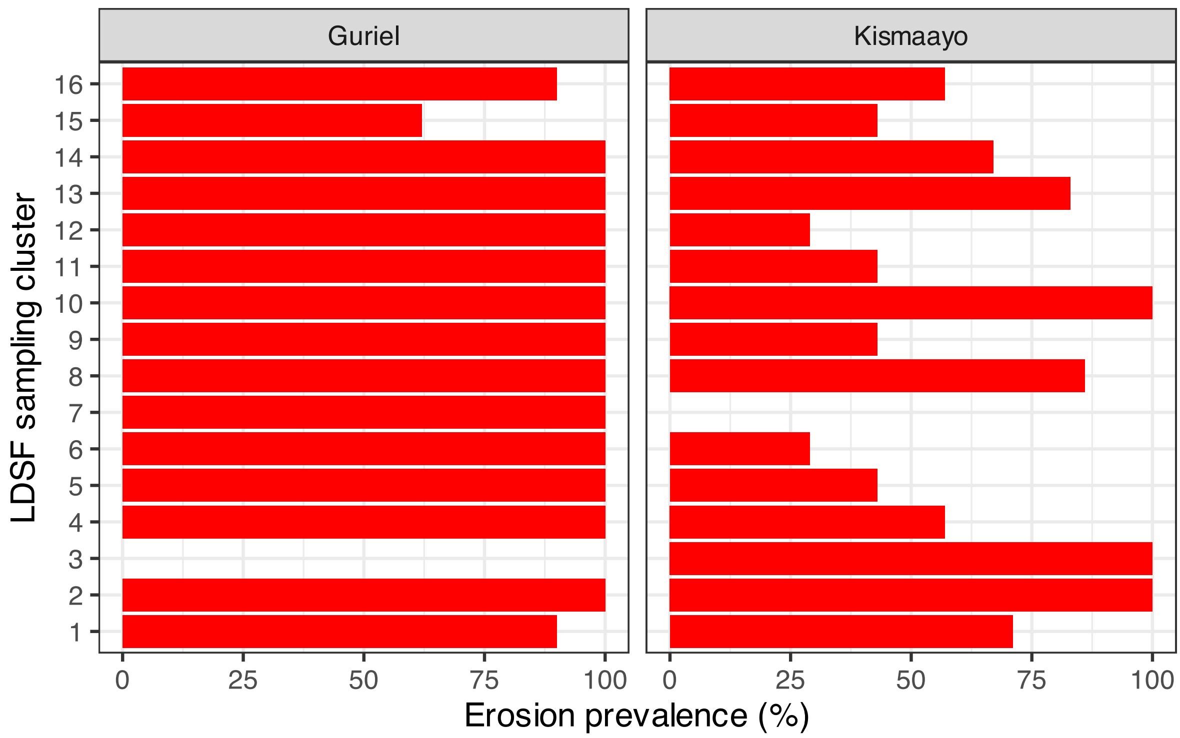

Figure 8: Erosion prevalence by cluster.

3. Soil health

We define soil health as an "integrative property that reflects the capacity of soil to continue to support both agricultural production and the provision of other ecosystem services". We use a number of indicators to assess soil health (Figure 9), including soil organic carbon (SOC), soil pH, and soil texture. Soil health is a key focus of the LDSF given its influence on a range of different ecosystem services, and its importance for landscape resilience (Winowiecki et al. (2016), Massawe et al. (2017), Vågen et al. (2013)). For example, SOC is important for agricultural and rangeland productivity, water retention and regulation, and climate change mitigation and adaptation. Soil pH is important for nutrient availability and plant growth. Soil texture is important for water retention as well as for SOC and nutrient dynamics. Taken together, these different indicators give us a picture of the overall health of the soil in a given area.

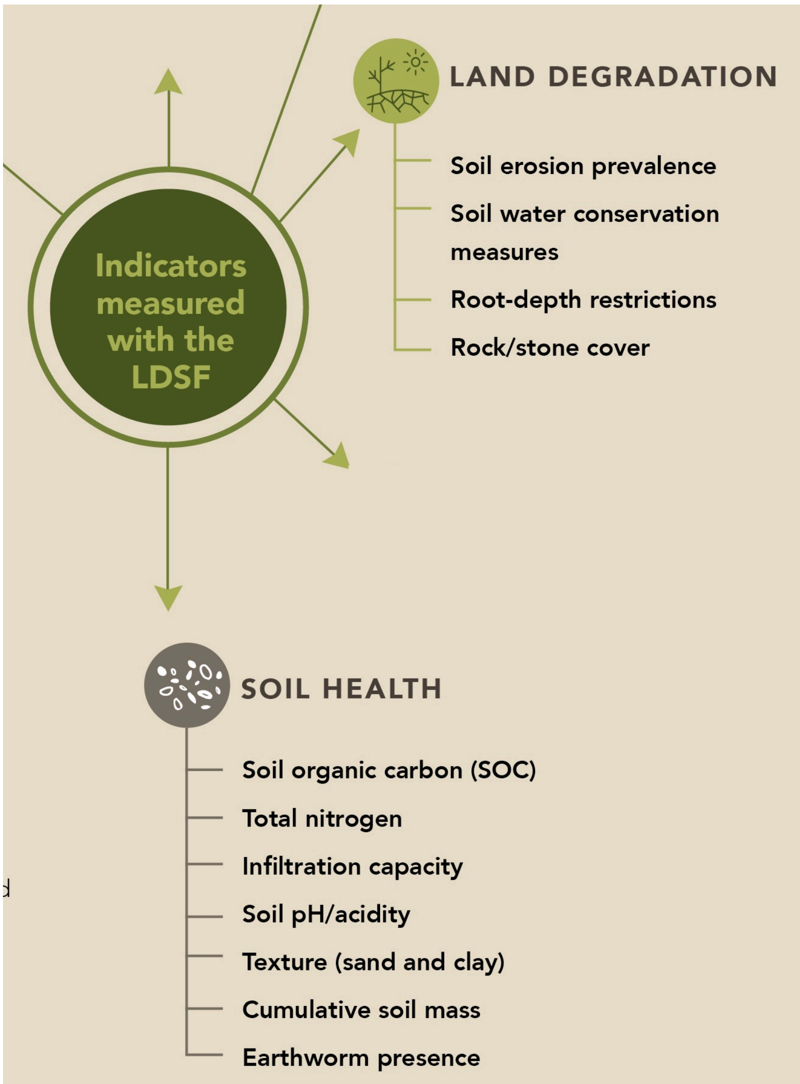

Figure 9: Soil health indicators assessed in the LDSF.

3.1. Soil organic carbon

Soil organic carbon (SOC) is a key indicator of soil health. It is a measure of the amount of carbon, which provides the energy that drives the soil system (Kibblewhite et al. (2008)), stored in the soil in the form of organic matter. SOC is important for soil fertility, water retention, and climate change mitigation and adaptation. Hence, the resilience of ecosystems and the services they provide are closely linked to SOC levels.

As shown in Figure 10, SOC levels are very low in Guriel (<5 g/kg), and more variable in Kismaayo. Topsoil SOC is highest in grassland areas (Figure 11) in Kismaayo, followed by bushland, cropland and shrubland.

The extremely low SOC in Guriel means that the soil is likely to be very poor in terms of fertility and water retention, strongly impacting rangeland productivity. Hence, management interventions to increase SOC sequestration will be critical. Given the high sand content in this site (Figure 15), management strategies to reduce soil erosion and increase water retention will be key, including active land restoration interventions such as soil and water conservation measures combined with reseeding of perennial grasses (see Section 4.1).

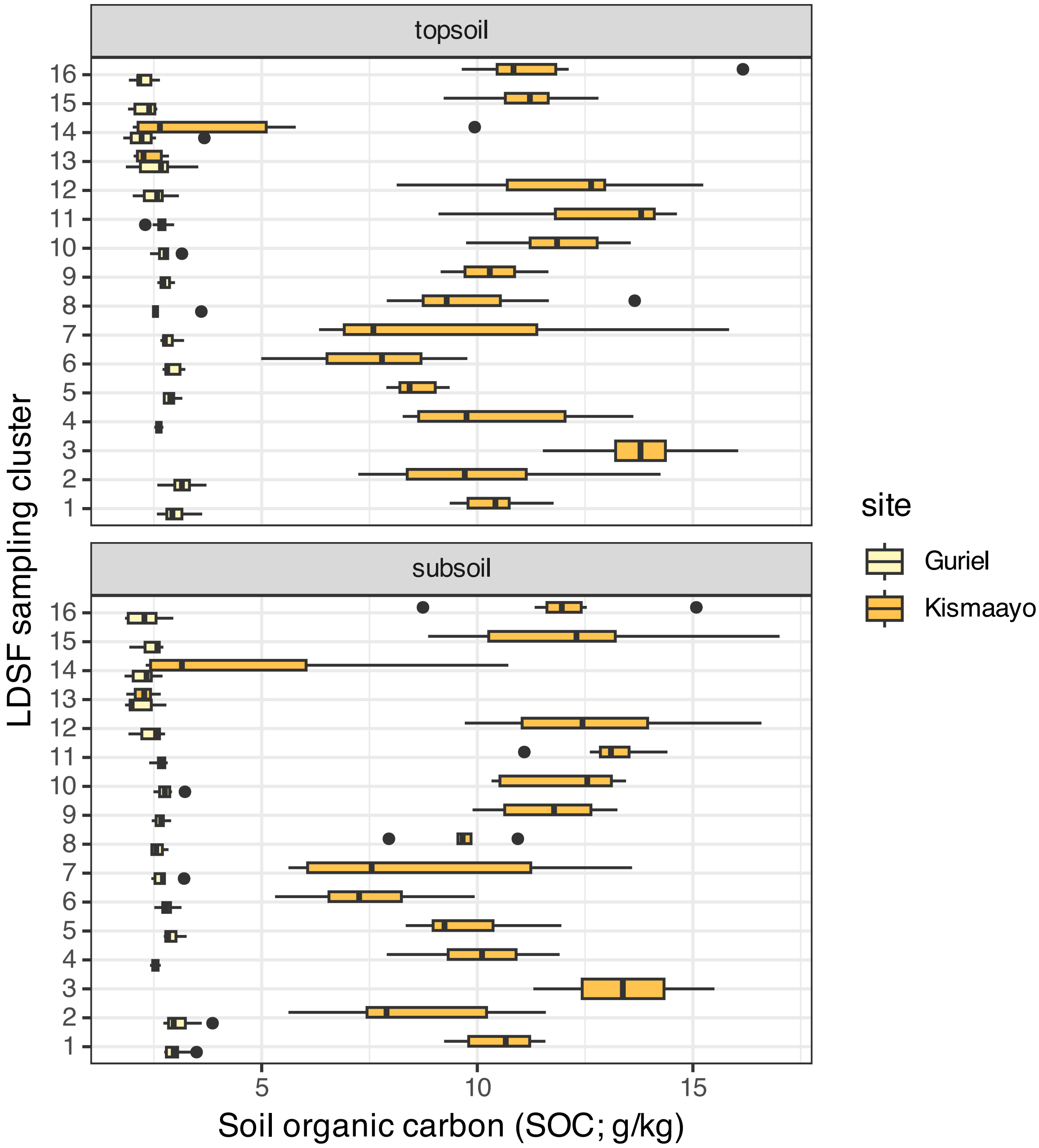

Figure 10: Soil organic carbon levels by site and cluster. We generally have higher SOC in Kismaayo and very low SOC in Guriel (below 5 gC/kg).

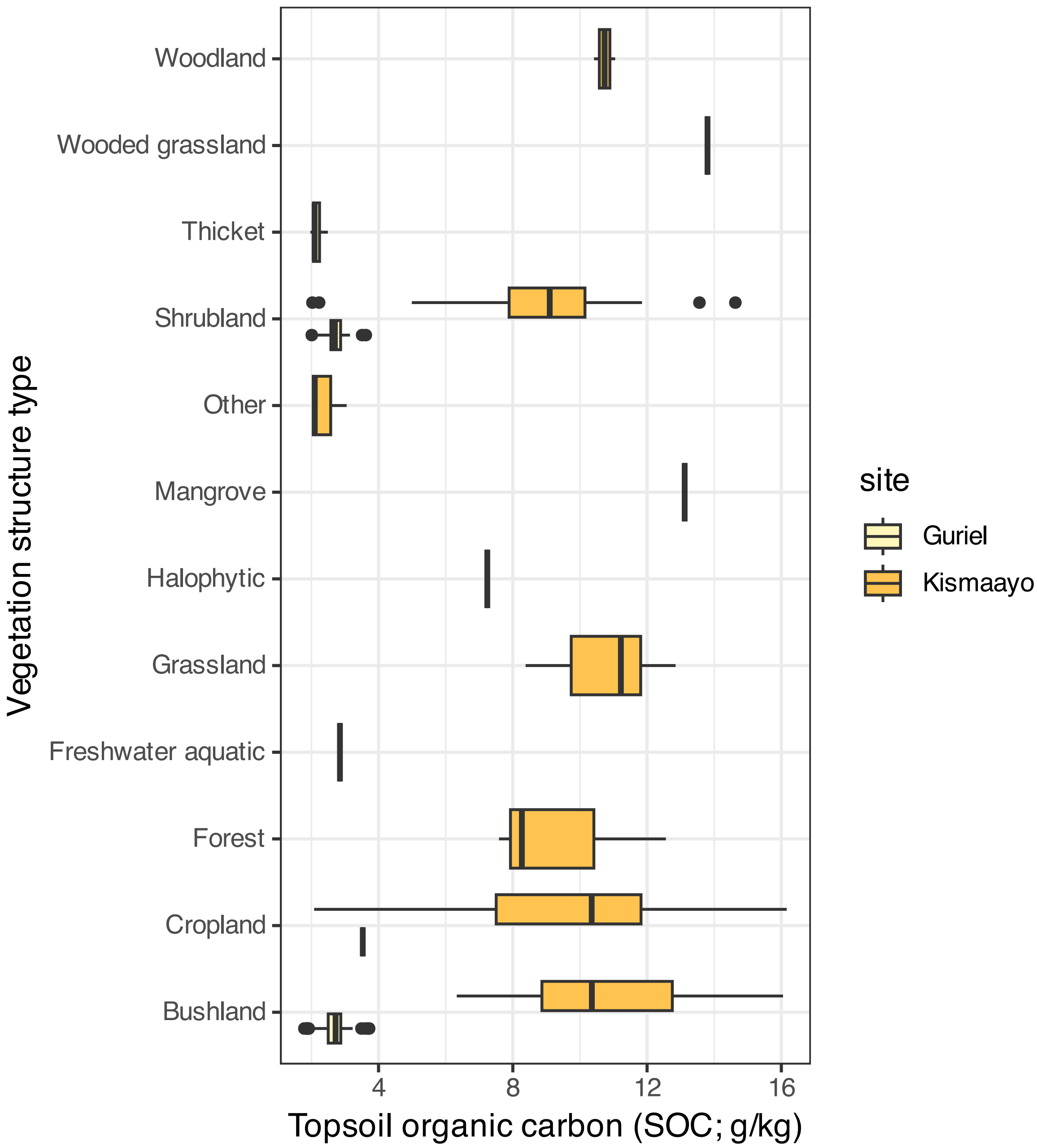

Figure 11: Soil organic carbon levels in topsoil (0-20cm) by vegetation structure type/class.

3.2. Soil pH

Soil pH is in the neutral range in Guriel and highly alkaline in Kismaayo (Figure 12). This means that the risk of salinization is high in Kismaayo, which can be a major constraint to crop productivity in the area. In Guriel, soil pH is more neutral. As shown in Figure 13, the high pH (alkaline) soils in Kismaayo also have higher SOC and lower sand (more clay) content (Figure 16). This relationship between soil pH and SOC is not necessarily universal as it depends on a range of factors, including climate, vegetation, and land use. As shown in Figure 14, soils with higher pH also have higher contents of base cations such as Ca, Mg, K, and Na. In cases where Na is high, the risk of sodicity is high, which can present a number of challenges for management.

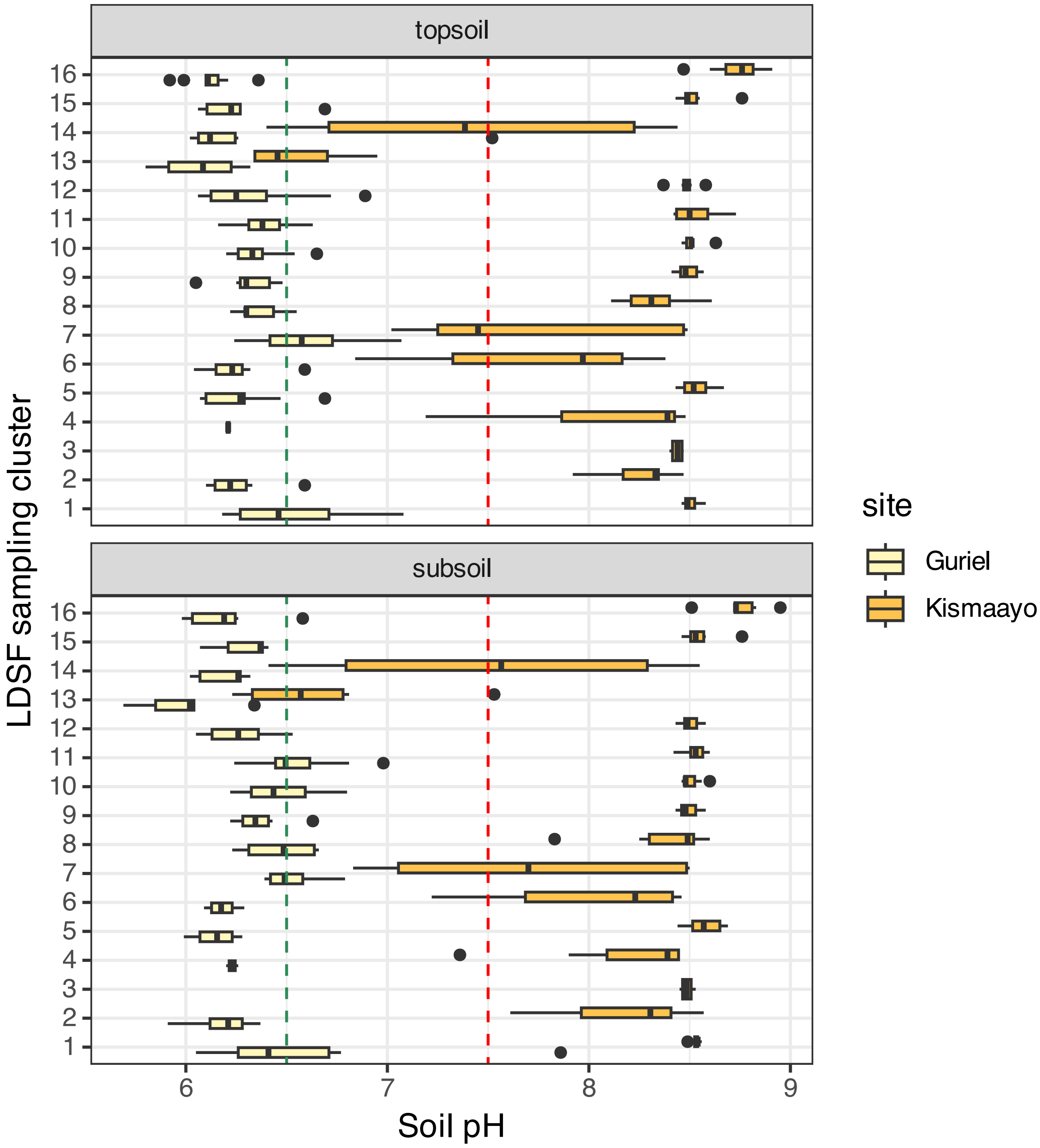

Figure 12: Soil pH levels by cluster. The red dashed line represents pH 7.5, above which the soil is considered to be alkaline. Where soil pH exceeds 8, alkalinity is very high and represents a major constraint to crop production. Soil pH is generally somewhat higher in subsoil.

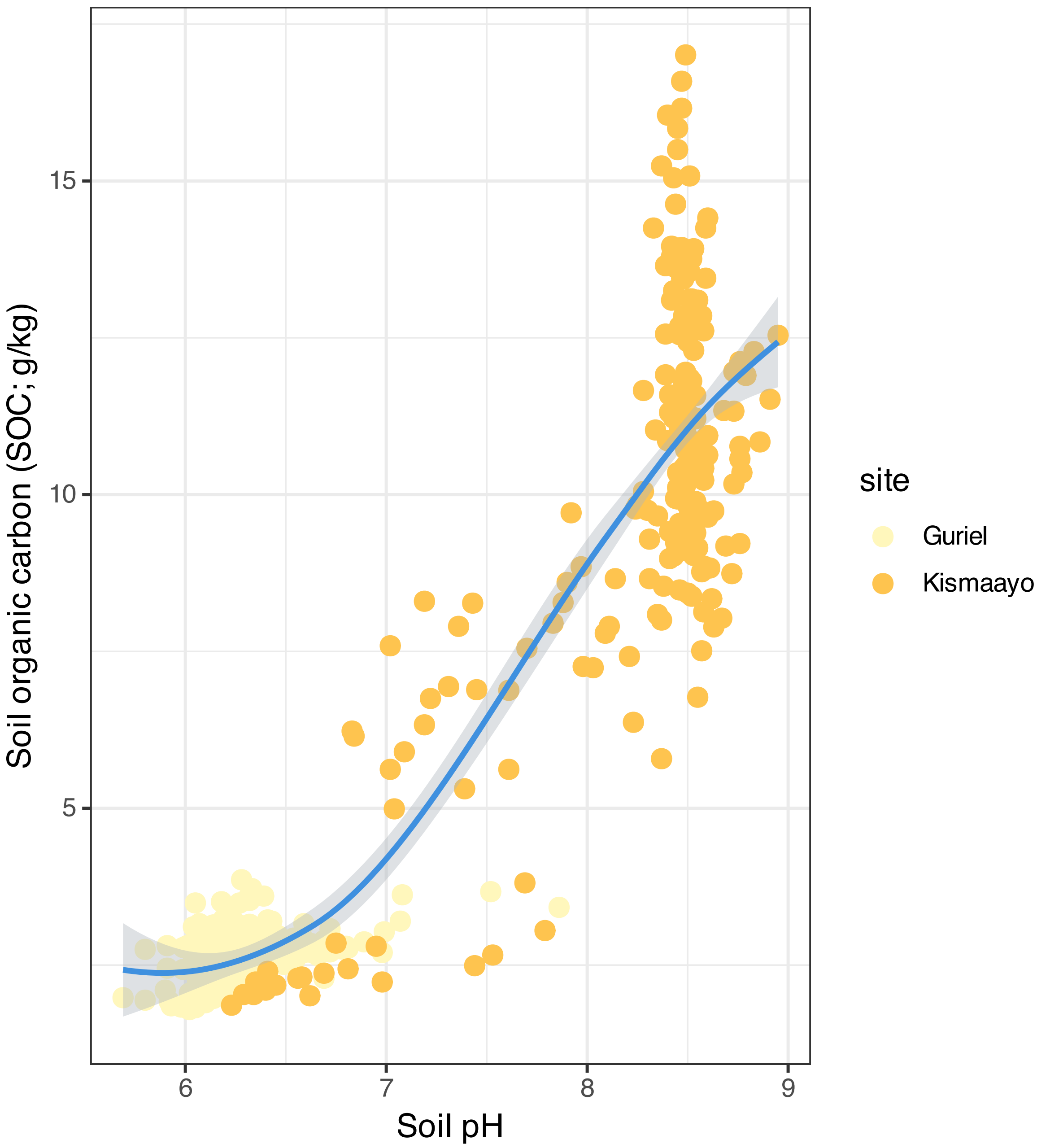

Figure 13: Soil pH levels and organic carbon content in Guriel and Kismaayo. As we saw earlier, soil pH and SOC are higher in Kismaayo overall. This explained in part by the soil types in the two sites, with Kismaayo having lower sand and higher clay contents, which means that soils in Kismaayo have an inherent ability to store more carbon than the sandier soils in Guriel.

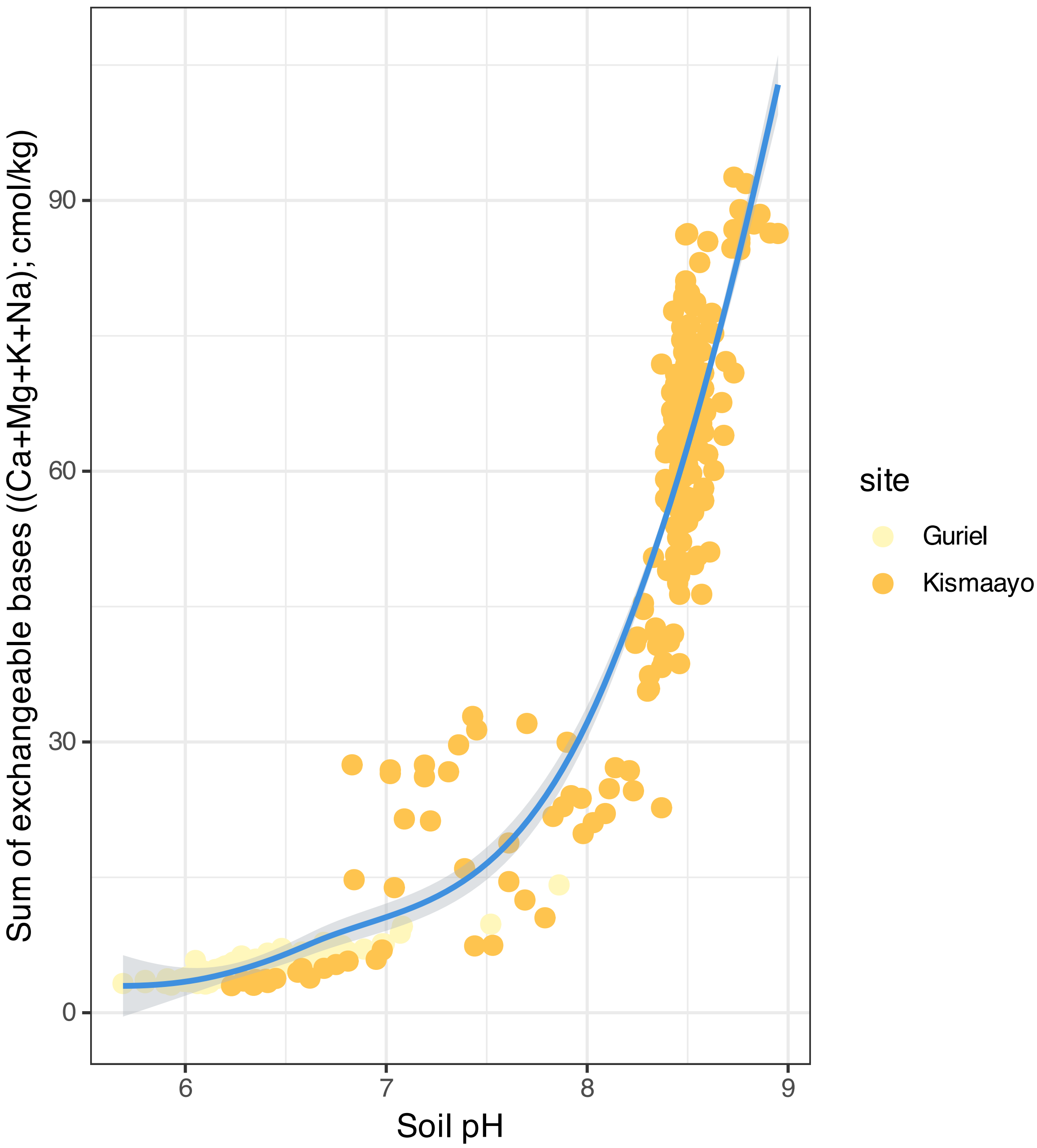

Figure 14: Soil pH sum of exchangeable base cations (Ca+Mg+K+Na) in Guriel and Kismaayo. This is a pattern that is commonly observed and is related to texture (e.g. clay content) and mineralogy, among other things.

3.3. Soil texture

Soil texture varies strongly between Guriel and Kismaayo with Guriel having high sand content in general, while most clusters in Kismaayo have less than 30% sand (Figure 15), except clusters 13 and 14, which have high sand contents. These are also the clusters with the lowest SOC contents (Figure 10). This relationship is common as sandier soils generally have lower capacity to store SOC, and can be observed for the two sites surveyed here (Figure 16). The coarse texture of the soils in Guriel therefore partially explains the low SOC levels in this area, combined with other factors such as low rainfall (aridity), high temperatures, and high rates of soil erosion (degradation).

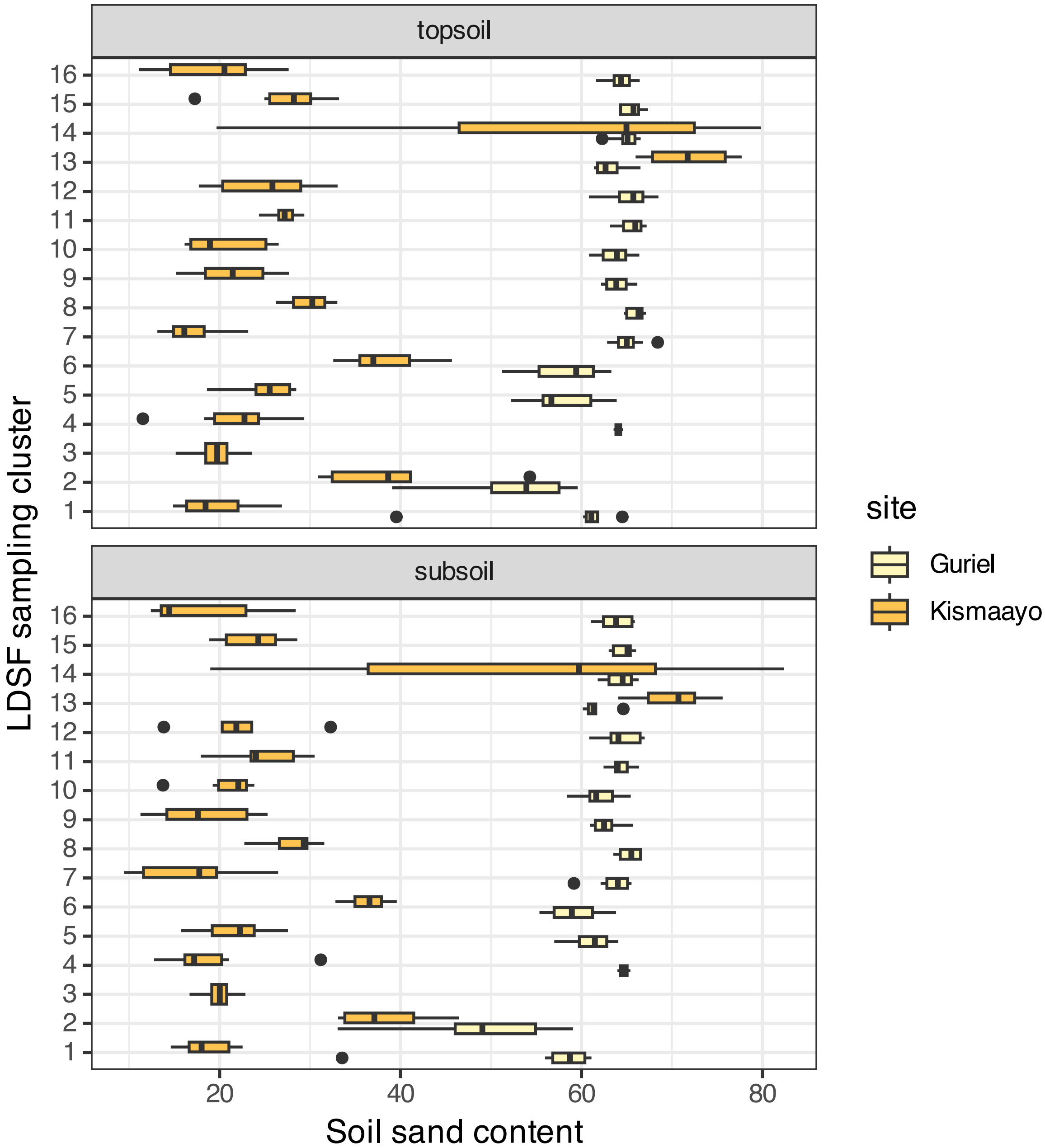

Figure 15: Soil sand content by cluster. Guriel generally has very sandy soil (>50% sand) while sand content is more variable and lower in Kismaayo, with the exception of clusters 14 and 15.

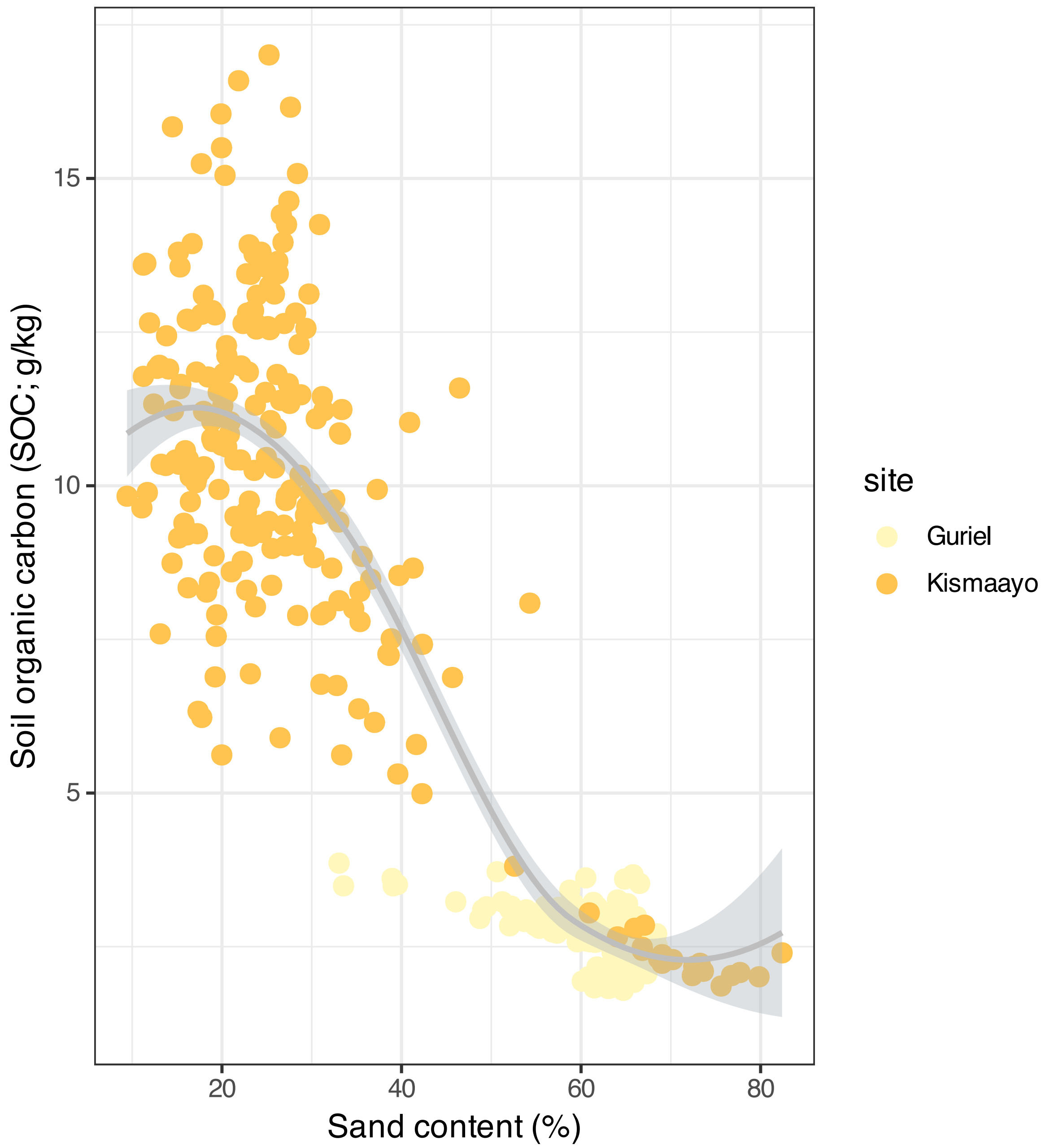

Figure 16: Soil organic carbon levels and sand content in Guriel and Kismaayo. When sand content is higher there are fewer surfaces that SOC can attach to due to the coarse soil matrix, while vise-verca is true for soil with higher clay content. This is explains the shape of this curve. In other words, sand content is an inherent soil property that strongly determines the potential of the soil to store carbon. Also, when sand content is high, infiltration rates also tend to be higher while water retention is lower.

(a)

(b)

Figure 17: In the LDSF, infiltration capacity is measured using single-ring infiltrometers. The result of the test is a curve showing the rate of infiltration over time, which we can use to calculate the rate of infiltration at saturation (KfS). This is an important indicator that tells us a number of things, including how well the soil is drained, and the risk of surface runoff when rainfall exceeds certain thresholds.

3.4. Infiltration capacity

Results on infiltration capacity were presented in the baseline report, but we highlight a few additional aspects of these data for Guriel and Kismaayo here. As presented in the baseline report, infiltration rates were much higher in Guriel than in Kismaayo (Figure 18). This is due to the higher sand contents (coarser texture) in Guriel, which generally leads to higher infiltration rates (Figure 19). In other words, soils in Guriel are well drained, while soils in Kismaayo are more poorly drained, which means that different management strategies are needed for the two areas. In Guriel, management practices to increase water holding capacity will be important, including a combination of physical and biological interventions to enhance soil structure and fertility. In Kismaayo, management practices to enhance drainage should be implemented. The latter is also critical to reduce the risk of salinisation, which is significant in Kismaayo.

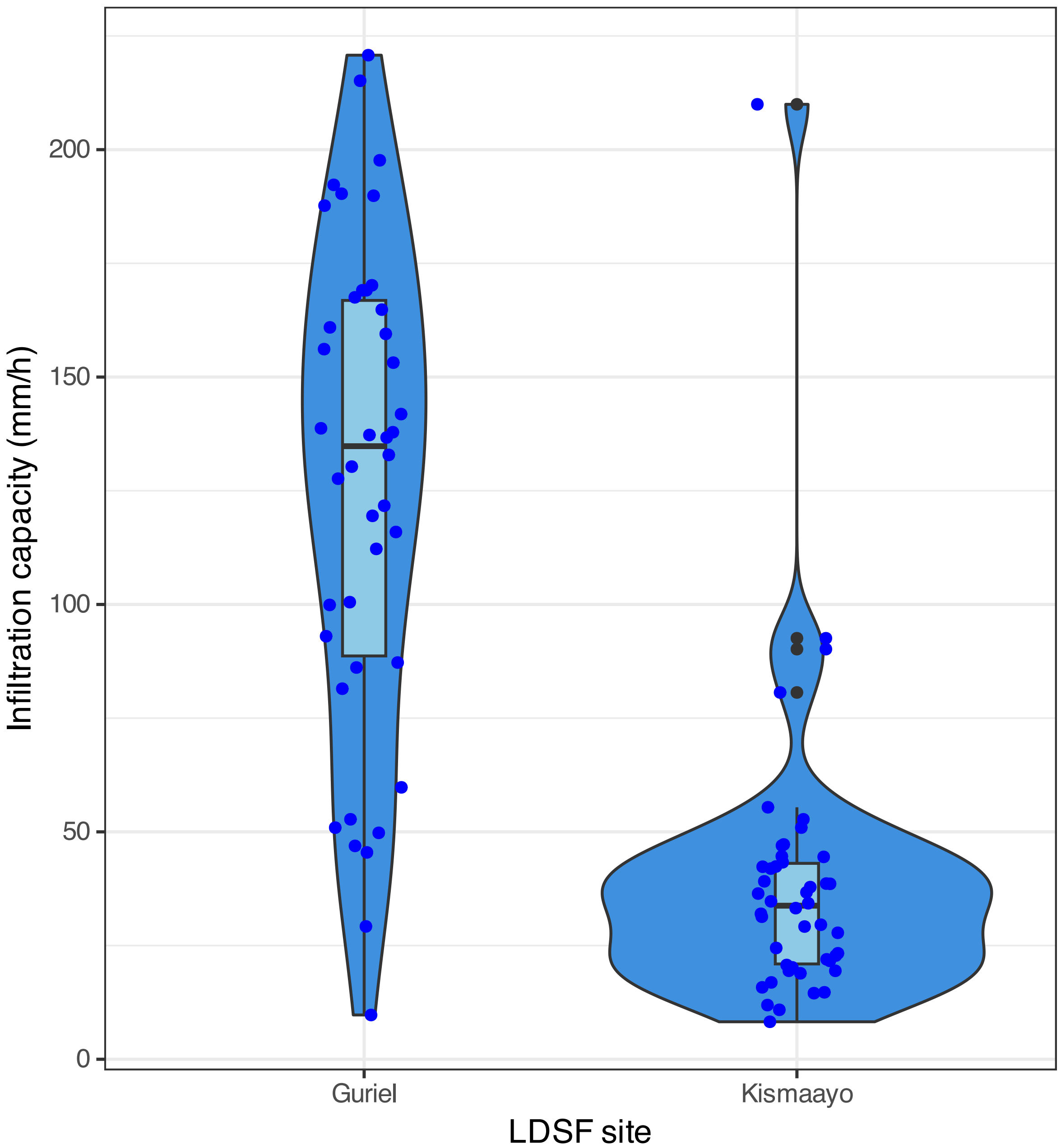

Figure 18: Infiltration capacity by site. As expected, Guriel has much higher infiltrtation rates than Kismaayo, as indicated by the median infiltration rate in the boxplot. The 'violin plot' is another way to show the distribution of KfS values for each site. This (and the boxplot) shows that infiltration is much more variable in Guriel than in Kismaayo, ranging from less than 20 mm/h to over 200 mm/h.

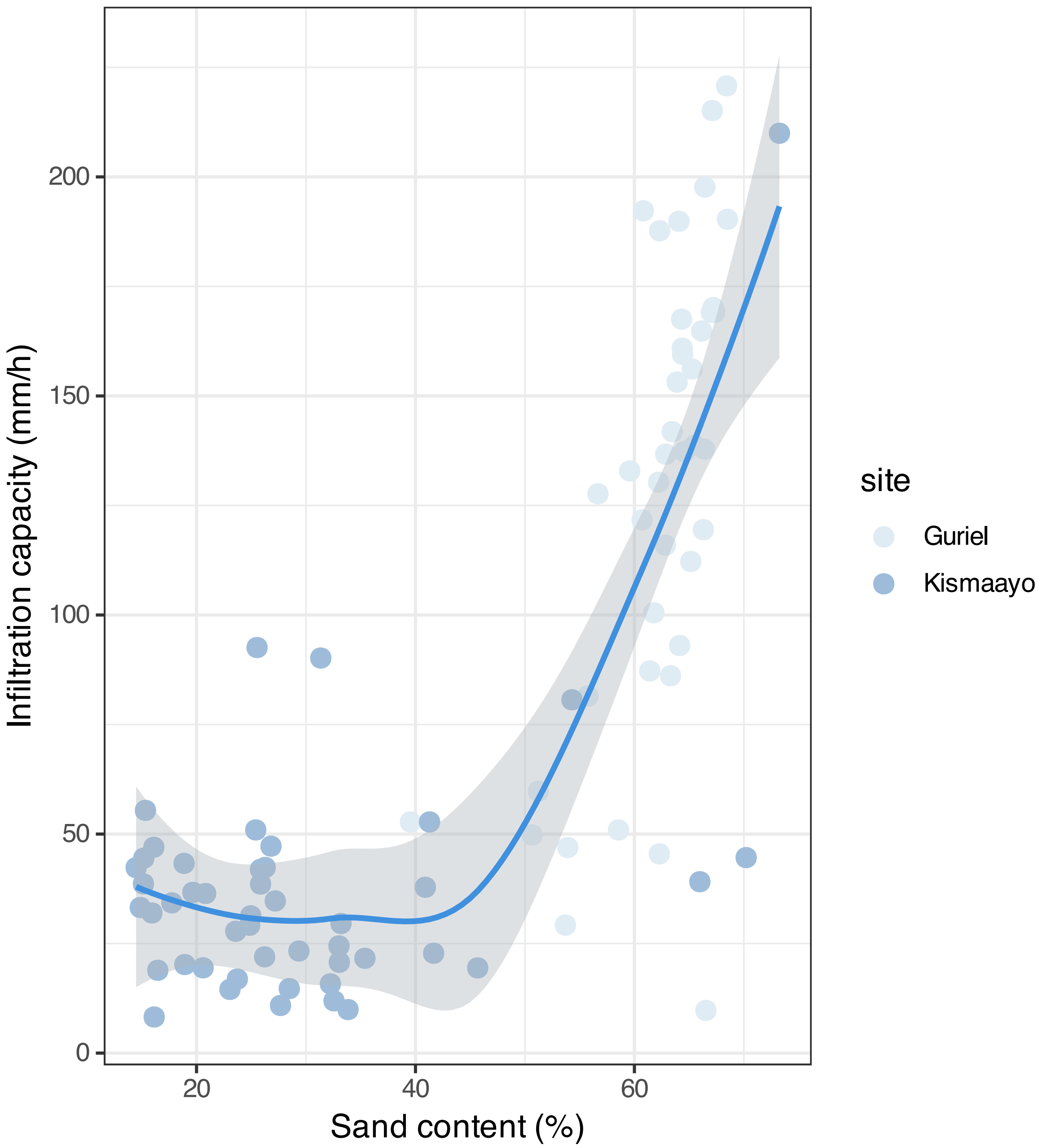

Figure 19: Infiltration capacity and sand content in Guriel and Kismaayo.

4. Conclusions and recommendations

The results of the LDSF surveys in Kismaayo and Guriel show that both areas are facing significant challenges in terms of land degradation and soil health constraints, with very high rates of land degradation in Guriel in particular. This is reflected in the high levels of erosion in both areas, but particularly in Guriel. In terms of soil health, low to moderate SOC levels observed in Kismaayo and very low SOC in Guriel are of concern. High soil pH levels were found in Kismaayo, representing challenges in terms of salinization, meaning that interventions to enhance soil infiltration capacity (drainage) will be important. In Guriel, soil pH is more neutral and not of concern, but the low SOC levels are a major constraint to rangeland productivity. The high sand content in Guriel also means that management strategies to enhance SOC and water retention will be important.

4.1. Implications for land restoration and management

Given the severity of soil erosion in both sites, soil and water conservation measures will need to be implemented at scale, taking into consideration local context. In other words, knowledge of erosional processes in each of the sites will be critical (Morgan (2005); Nur et al. (2024)) while also taking into consideration local or indigenous knowledge to ensure that the measures are appropriate for the local context (Critchley et al. (1994)). Historically, many soil and water conservation projects have been implemented in Somalia, including during the period from the end of world war two to 1953 when measures such as stonelines, grass strips or steps, contour stone walls, and simple basin listers (McCarthy et al. (1985)) were implemented at scale. While some of these were relatively succesful, many were not due to lack of maintenance and often hard to replicate design criteria, or because they were not popular with local communities.

Below, we discuss measures such as half-moons, which have been shown to be effective within rangelands in the region. They are relatively simple to implement and maintain and can also be readily adapted to local conditions, which makes them more likely to be adopted by local communities. By reducing runoff and soil erosion, these interventions can help increase soil organic carbon levels and improve soil health, while also increasing water retention. This is particularly important in the context of climate change, where increased rainfall variability is expected to lead to more frequent and severe droughts and floods.

(a)

(b)

Figure 20: Soil erosion is the most common process of land degradation in the rangelands of East Africa. When erosion is very severe, it leads to loss of soil organic carbon and a decline in soil health, as well as reduced resilience of the ecosystem overall.

In the context of rangelands, which represents the most dominant form of land use in both sites, interventions specific to these systems are needed. Half-moons (Figure 21) combined with terraces or soil/stone bunds or infiltration trenches can slow down the flow of water and reduce erosion. When combined with reseeding of grasses, and in some cases removal of invasive species, these interventions have the potential to be both effective and scalable. Grass species such as *Sporobolus helvolus*, *Oropetium minimum*, *Microchloa kunthii*, *Aristida adoensis*, *Aristida mutabilis*, and *Enneapogon cenchroides* are grasses that are able to grow in disturbed dryland soil to prevent soil erosion. A number of other grasses can also be used for active restoration, as outlined by for example Mganga et al. (2021).

(a)

(b)

Figure 21: Half-moon pits are similar to Zai pits and can be an effective technique to harvest rainwater, enhance water retention, reduce soil erosion, and re-establish perennial grasses in degraded rangeland areas. They can be implemented in combination with grass strips, as shown in (a) above, infiltration trenches and other soil and water conservation measures. Given that they are relatively easy to establish, these interventions can be scaled effectively across landscapes, as illustrated in (b) above (from Kenya).

Figure 22: When implemented well, soil and water conservation measures such as half-moons can be effective in re-establishing perennial grasses in rangelands.

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