Dr Marion Pfeifer
Assoc Prof, Landscape Ecology and Management
Director of TROPs lab, SNES, Newcastle University
Ridley 2 Building, NE1 7RU, Newcastle Upon Tyne, UK
marion.pfeifer@newcastle.ac.uk

Report on subset of data important in the context of river habitat restoration on KSC grounds and outgrowing area.

Marion Pfeifer[2], Susannah Sallu[1], Eleanor Moore[2], Lauren Barnes[2], Esther Kioko[3], Deo Shirima[4]

[1]University of Leeds, [2]Newcastle University, [3]National Museums Kenya,[4]Sokoine University of Agriculture

Key message 1: The intensification of sugarcane production and extension towards small holder farmed land will have detrimental effects on the number of bird species unless it is carefully managed for. Management needs to focus on retaining access to trees and other natural / seminatural habitat features. These currently are primarily found along water ways (rivers, creeks, channels).

Key message 2: The intensification of sugarcane production and extension towards small holder farmed land may likely have detrimental effects on birds that could control insect pests on crops.

Key message 3: Mammals require natural habitats and are primarily found in forests or similar environments. They are likely to need riparian zones that at least in some areas have tree cover (e.g. riparian forests) to meet their resource needs. Restoring tree cover habitats along rivers or along farm boundaries will benefit overall mammal diversity in the landscape. That is the true for species considered beneficial (e.g. pest controls = carnivores) but also for crop pests (herbivores).

Key message 4: Conversion of small-holder farms to sugarcane monocrops will likely benefit greater cane rat and negatively affect presence of carnivores that could control the cane rat. Management based on nature should involve improvement of riparian habitats for vertebrate feeding mammal species. Of six carnivore species in total that we detected across habitats, three use the estate and small-holder farms, beside grasslands and forests: Common genet, Marsh mongoose, and *Leptailurus serval*.

Key message 5: Phosphorus addition would improve the fertility of soils o both estate and smallholder farmed land.

Key message 6: Management on the estate does not have negative impacts on soil organic carbon stocks relative to other types of management (small-holder farms) or land use (forests, grasslands).
Soil organic carbon stocks in cropland are comparable to levels reported for other cropland systems in tropics under active crop management but perhaps on the lower side.

Key message 7: Small-holder farmed land has a higher proportion of sandy loam soils. Sandy soils are more prone to erosion and thus requires attention to measures preventing erosion, in particular in risk prone areas like along water channels, creeks and rivers.

Key message 8: Including trees on the estate ground will dampen extreme temperatures of surfaces (leaves, ground). The plants on the estate are getting hottest compared to all other habitat types with average temperatures exceeding 35 degree Celsius. The ground surfaces are also getting very warm, with temperatures that compare to small-holder farmed land and grassland habitats.

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Technical report with data underlying key messages

This report builds on data collected in the Agrisys Tanzania project (BBSRC GCRF funded) and impact projects subsequently funded as CORRESTOR (SNAPP funded) and Newcastle University managed funding. Our interactive map for data check can be found on:
https://www.mapss.solutions/agrisys/Agrisys_Landing_Page/

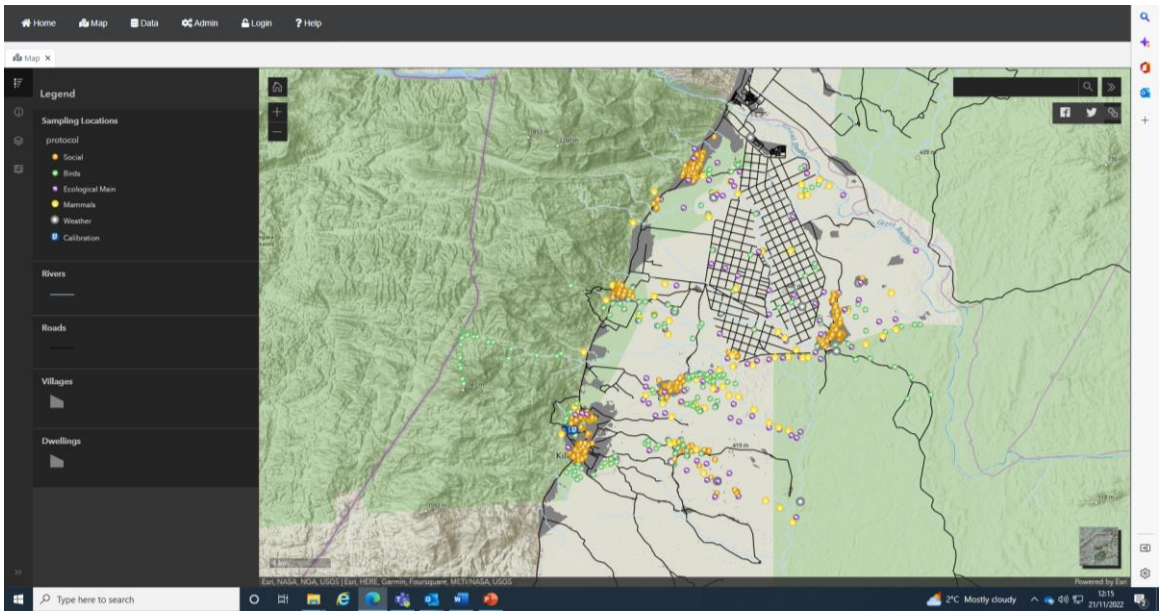

Fig 1 Web interface of the Agrisys Tanzania research project (funded by BBSRC GCRF, Project Number: BB/S014586/1), with further support by Science for Nature and People Partnership (CORRESTOR project) and Newcastle University Impact funding.

Key message 1: The intensification of sugarcane production and extension towards small holder farmed land will have detrimental effects on the number of bird species unless it is carefully managed for. Management needs to focus on retaining access to trees and other natural / seminatural habitat features. These currently are primarily found along water ways (rivers, creeks, channels).

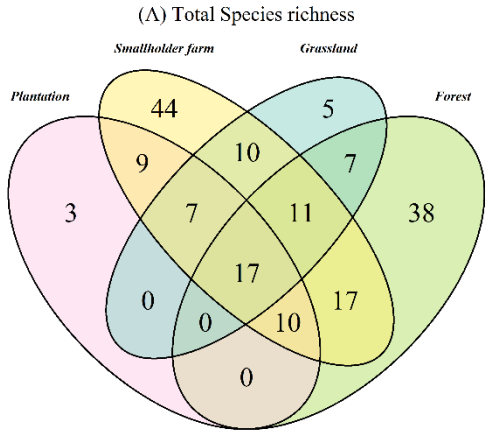

Fig. 2 Distribution of species across the different habitat types in the study landscape. For example, there are 44 unique species in small-holder farms (only observed there). 9 species use both estate grounds and small-holder farms.

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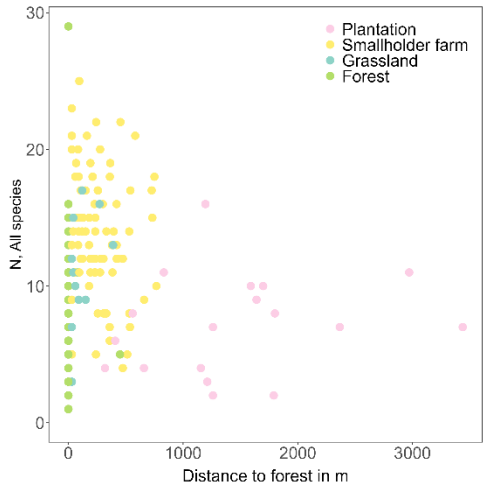

Fig. 3 Total number of bird species measured at different distances to larger forest areas.

For several survey points, the number of bird species observed per survey point on the estate is lower compared to survey points on small-holder farms.

As indicated in Fig. 2, the estate grounds are not great habitats for birds. Just 3 of the species we observed across the landscape are only found on the estate grounds: *Pogonornis melanopterus* (Brown-breasted barbet), *Bostrychia hagedash* (Hadada ibis) and *Merops bullockoides* (White-fronted bee-eater). The latter two are invertebrate feeding and thus likely important as insect pest controls. For all other species: on the estate we can find 53 species, but these also frequent small-holder farms and/or grasslands and forests. Forests and small-holder farms provide resources for unique sets of bird species: 44 on the small holder farms, 38 in the forests.

Considering all species found at survey points on the estate (Fig. 4) it was apparent that species numbers are higher in locations that are closer to rivers and creek and water channels. It's likely that these are spaces that retain different levels of natural and semi-natural vegetation features. Several explorative drives around the estate since 2019 confirm that observation but also suggest that field verges are used by some bird species.

We suggest that if you want to retain higher number of birds, whether insect feeding or not, you will want to improve/restore riparian habitats.

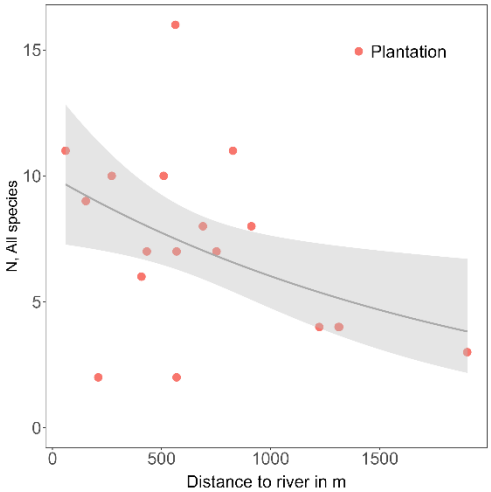

Fig. 4 Total number of bird species observed on the estate (sugarcane plantation) and their decline in locations further away from rivers and creeks.

Dr Marion Pfeifer
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Ridley 2 Building, NE1 7RU, Newcastle Upon Tyne, UK
marion.pfeifer@newcastle.ac.uk

Key message 2: The intensification of sugarcane production and extension towards small holder farmed land may likely have detrimental effects on birds that could control insect pests on crops.

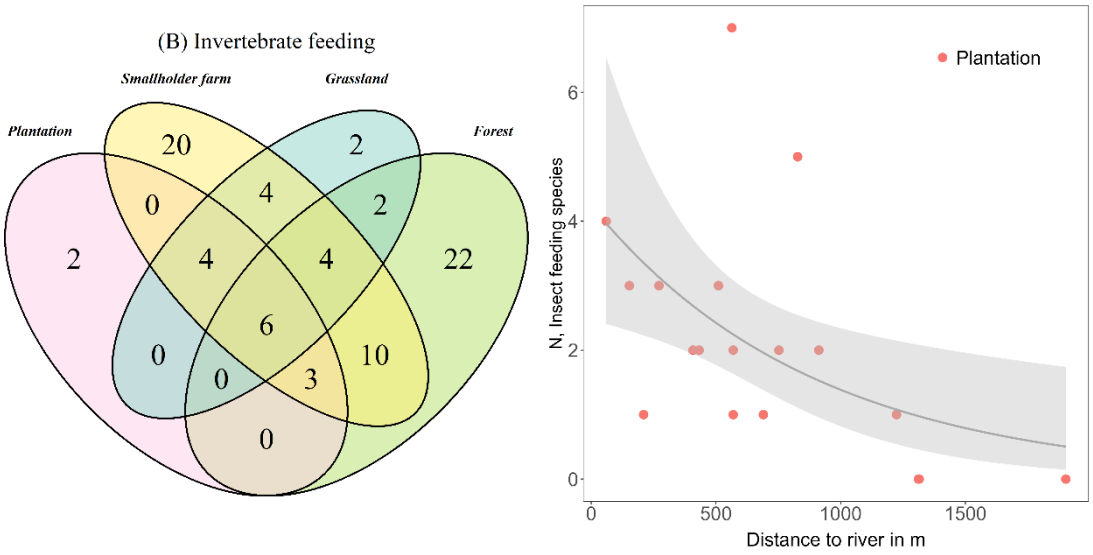

Fig. 5 Total number of invertebrate feeding birds (potential insect pest control species) and their distribution across the habitat types (left) and their decline on the estate further away from rivers and creeks.

Insect feeding birds are very common on small-holder farms, presumably benefitting from a diversity of habitat (trees, shrubs, flowering plants supporting insects) and resources (food). As shown in the figure on the left, the majority of insect feeding birds are found on small-holder farms, and 20 of these are only found in this habitat type, whilst 13 are shared with the estates and/or forests. The number of species that could potentially act as insect control declines with increasing distance from riverine areas.

Key message 3: Mammals require natural habitats and are primarily found in forests or similar environments. They are likely to need riparian zones that at least in some areas have tree cover (e.g. riparian forests) to meet their resource needs.

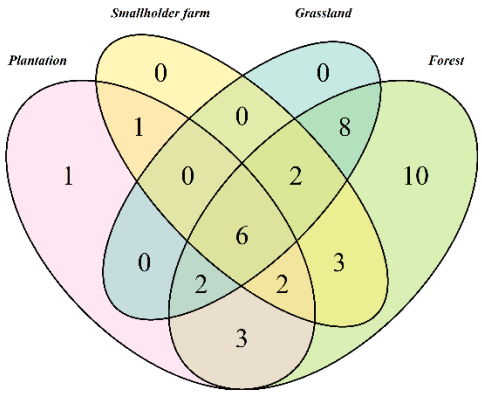

Fig. 6 Total number of mammal species distributed across habitat types in the study landscape. Forests are the preferred habitat type for many mammal species and ten of the species are only observed there.

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Looking across the different habitat types, we know that most species are found in forests (Fig. 6).

For the estate: just one species was found solely on the estate: *Thryonomys swinderianus* (Greater cane rat). One species was using small – holder farms and estate grounds*: Canis adustus* (Side Striped Jackal). 3 species were shared between the estate and forests include *Cercopithecus mitis* (Blue monkey), *Cephalophus sp* (one of the duiker species), and *Cephalophus harveyi* (Harvey's duiker).

This implies that restoring tree cover habitats along rivers or along farm boundaries will benefit overall mammal diversity in the landscape. That is the true for species considered beneficial (e.g. pest controls = carnivores) but also for crop pests (herbivores).

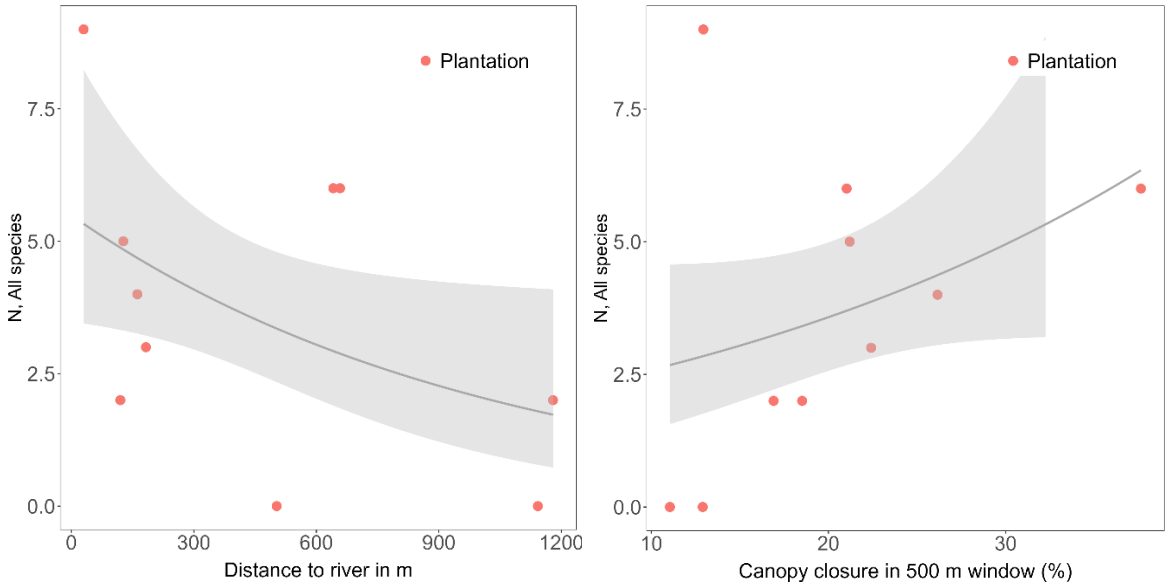

Fig. 7 Total number of mammal species observed on the estate and their decline in locations further away from rivers and creeks (left) and their increase with increasing tree canopy coverage (right).

Mammals on the estate are more likely to be near riverine areas and they prefer tree cover habitats (Fig. 7) suggesting that restoration of riparian buffer zones requires a mix of habitat types but at least to some extent will need to have tree cover patches if the target is to maintain mammal communities on the ground.

Key message 4: Conversion of small-holder farms to produce sugarcane as monocrop will likely benefit greater cane rat whilst negatively affecting presence of key carnivores that could potentially control the cane rat. Management based on nature should involve improvement of riparian habitats for vertebrate feeding species (e.g. carnivores).

The estate seems to be the preferred habitat for the Greater cane rat, a key crop pest on sugarcane and other crops including maize, wheat and cassava. The species likes river banks. Ideally, the species is controlled by carnivores. In some regions, the species is used as preferred bushmeat.

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Ridley 2 Building, NE1 7RU, Newcastle Upon Tyne, UK
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There are six carnivore species in total that we detected at our camera traps across habitat types (Fig. 8): *Genetta genetta* (Common genet), *Panthera pardus*, *Atilax paludinosus*, *Leptailurus serval*, *Crocuta crocuta*, *Felis silvestris*. Three of these use the estate as well as small-holder farms, grasslands and forests: *Genetta genetta* (Common genet), *Atilax paludinosus* (Marsh mongoose), and *Leptailurus serval*.

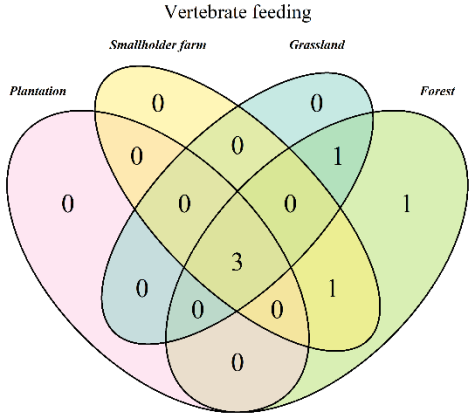

Fig. 8 Number of carnivores, (potentially feeding on cane rats) across the habitat types.

Their overall number is low and they are habitat generalists. 3 of the species are observed in all four habitat types.

Of the three carnivorous mammals observed on the estate: the genet eats small mammals, birds and insects. It prefers areas with denser cover of trees for resting. The mongoose requires water and feeds on rodents, snakes and insects. And the serval is a wild cat that prefers areas close to water bodies which provide cover (e.g. reeds). It preys on rodents (including the cane rat), small frogs, insects, birds and reptiles.

Key message 5: Phosphorus addition would improve the fertility of soils o both estate and smallholder farmed land.

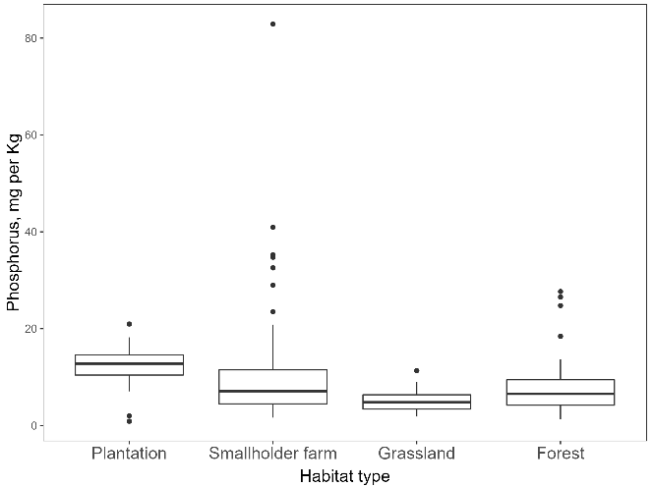

Fig. 9 pH levels of soil as measured in plots across the habitat types.

Phosphorus was below the expected threshold of 20 mg per kg in most plots sampled in our study, with the exception of some smallholder farms and a couple of forest plots. This threshold is considered as optimal for plant growth (Bai et al. 2013 Plant Soil 372). Critical levels of Olsen P values (above which crop yield does not respond to P application) are estimated at 18 mg per kg for maize, 14 mg per kg for wheat and 11 mg per kg for rice. These threshold values are based on the Olsen method for quantification of Phosphorus levels. However, we used the Bray 1 P method, given the PH levels of the soils, which indicate non-calcareous soils. Its worth noting here that a comparison of Olsen and Bray 1

Dr Marion Pfeifer
Assoc Prof, Landscape Ecology and Management
Director of TROPs lab, SNES, Newcastle University
Ridley 2 Building, NE1 7RU, Newcastle Upon Tyne, UK
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methods indicates that Olsen produces lower values compared to Bray 1 on soil with PH < 7 (Malharino 1995, Proceedings Soil Fertility Conference) so the values displayed in the graph below are likely to be overestimates and even lower than expected compared the 20 mg / kg threshold. Applying fertilisers and exceeding thresholds of 40 mg per kg likely runs the risk of run-off, erosion and leaching into waterways.

Soil pH levels are highly important for crop productivity. They affect the ability of crop plants to uptake essential plant nutrients and for most of these nutrients, the **pH should be between 6 and 6.5**. For half of the plots measured on the estate and on the small-holder farmed land that is not the case (soil pH too low) (Table 1). Importantly, acidic soils may affect uptake of toxic elements (e.g. cadmium) and may benefit soil borne pathogens (e.g. Plasmodium brassicae that causes clubroot in vegetable brassicas).

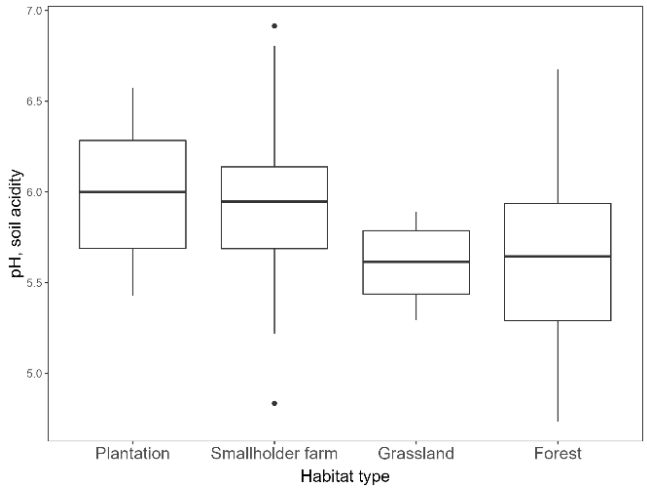

Fig. 10 pH levels of soil as measured in plots across the habitat types.

Table 1 Key soil attributes measured across plots (n – Number of plots sampled) in different habitat types in the landscape.

	N	N, pH < 6.0	N, P < 20 mg per kg	Soil Organic C t/ha (Mean ± SD, Minimum and Maximum)
Estate, crops	18	9	17	36.5 ± 10.4 [Min 20, Max 56]
Small-holder farm	82	41	73	33.8 ± 11.6 [Min 0, Max 55]
Grassland	12	11	12	34.1 ± 15.1 [Min 12, Max 70]
Forest	28	20	23	32.3 ± 12.79 [Min 13, Max 61]

Notes: P extraction by Bray 1 method includes extraction 0.03 N NH4F and 0.025N HCl extraction ratio 1:7 SOIL: BRAY 1 SOLUTION, colour development by ascorbic acid method. Soil Organic Carbon was measured as soil organic carbon by Black and Walkley method Mach 2022. pH was determined in water at 1:2.5 soil:water ratio.

Key message 6: Management on the estate does not have negative impacts on soil organic carbon stocks relative to other types of management (small-holder farms) or land use (forests, grasslands).

Soil organic carbon stocks in cropland are comparable to levels reported for other cropland systems in tropics under active crop management but perhaps on the lower side. The stocks appear low for natural habitat types. Sugarcane and tomato are expected to have high attainable soil organic carbon stocks due to higher yields and production of residues, the latter being twice the yield. This differs from maize, which has lower plant residue for example (Morais et al. 2019 Plos One).

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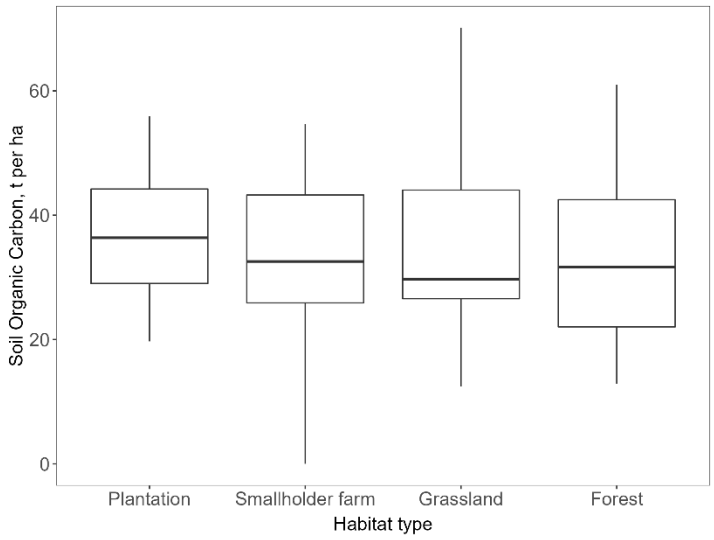

Fig. 11 Soil Organic carbon of soil as measured in plots across the habitat types.

Key message 7: Small-holder farmed land has a higher proportion of sandy loam soils. Sandy soils are more prone to erosion and thus requires attention to measures preventing erosion, in particular in risk prone areas like along water channels, creeks and rivers.

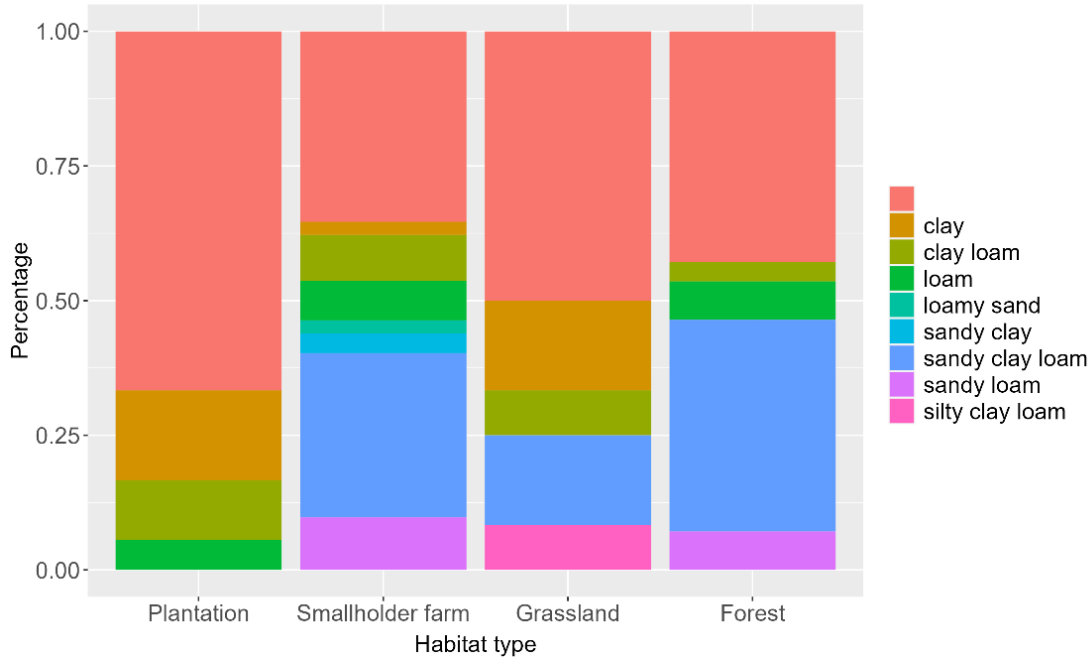

Fig. 11 Soil type as measured in plots across the habitat types.

Key message 8: Including trees on the estate ground will dampen extreme temperatures of surfaces (leaves, ground). The plants on the estate are getting hottest compared to all other habitat types with average temperatures exceeding 35 degree Celsius. The ground surfaces are also getting very warm, with temperatures that compare to small-holder farmed land and grassland habitats.

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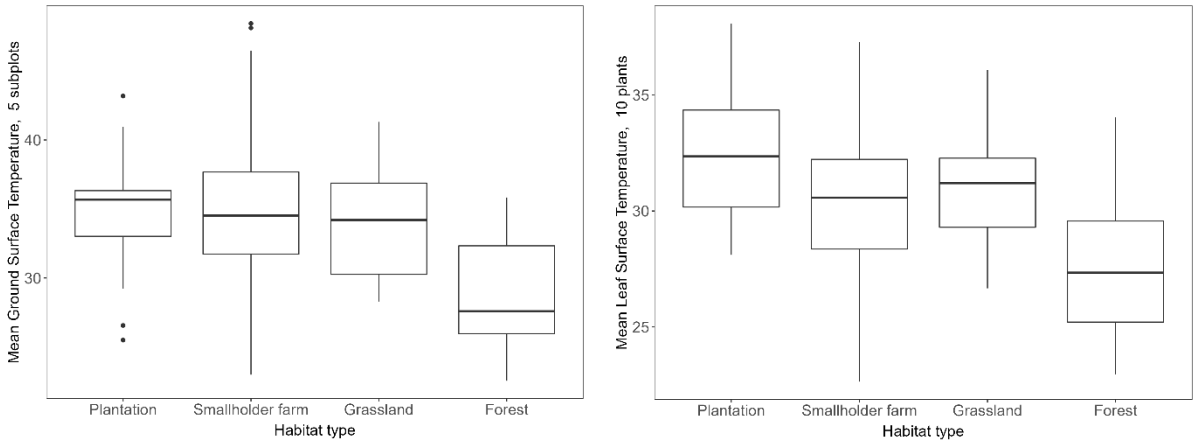

Fig. 12 Variation in ground and leaf surface temperatures (left and right) across plots in the four habitat types.

High temperatures may ultimately have an effect on health of people or livestock and crops. During the time of measurements (snapshots in time), surface temperatures exceeded 30 degree C in various areas of the landscape (Fig. 12). That surface temperature is a direct function of canopy closure (trees above the ground, Fig. 13).

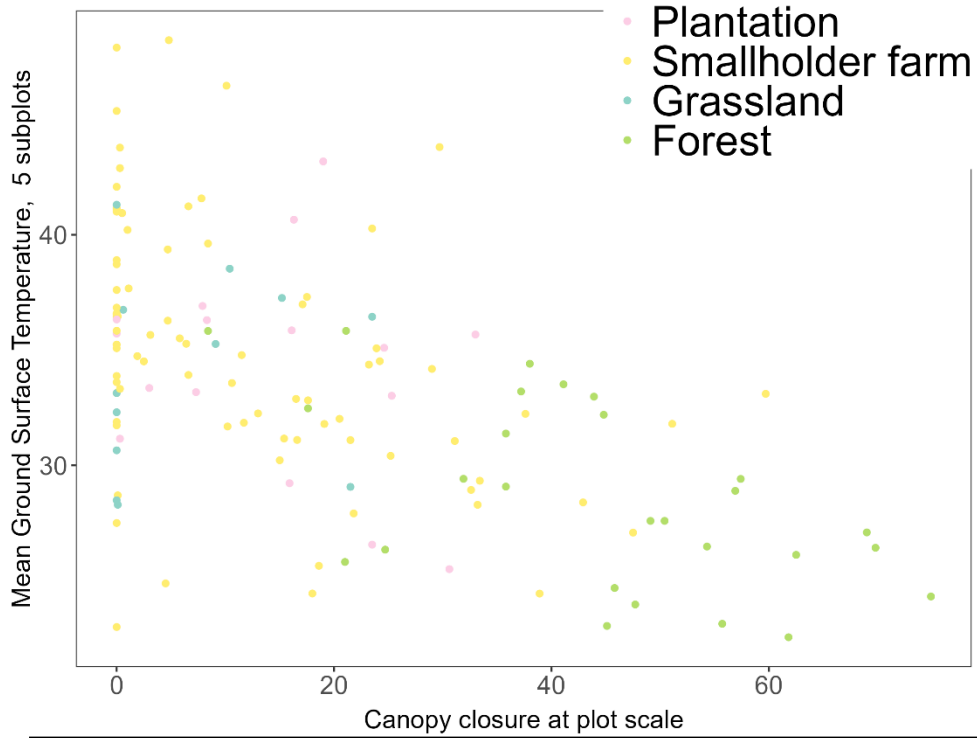

Fig. 13 Variation in ground surface temperatures across plots in the four habitat types as a function of tree canopy closure (in %, from 0 to 100 % with 100 indicating very dense tree canopy cover). Surface temperatures decline as tree canopies become closer.