The Relationship between Soil Carbon Sequestration, Dung Beetles and Grassland Management in the Korangadu Grasslands of Western Tamil Nadu

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DECLARATION

I declare that the project titled "The Relationship between Soil Carbon Sequestration, Dung Beetles and Grassland Management in the Korangadu Grasslands of Western Tamil Nadu" funded under WWF-India's Small Grant Program is my own work.

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ATREE – Ashoka Trust for Research in Ecology and the Environment

SKCRF – Senaapathy Kangayam Cattle Research Foundation

SOC – Soil Organic Carbon

Chapter 1: Introduction

Grassland management is an important aspect, pertaining to the health of the grasslands, and the ecosystem services surrounding it. With nearly 25% of the world's land mass covered with grasslands of various types (Abberton, Conant, & Batello, 2010), it becomes important to study grasslands, even more so under the ambit of climate change. Especially, grasslands can act as carbon sinks or carbon sources, depending on their management. In this context, the Korangadu grasslands, since are privatized, fenced grassland systems, offers a unique opportunity to study the effects of grassland management on the soil carbon pool and soil carbon sequestration.

Korangadu grasslands are present in the current districts of Erode, Tiruppur, Karur and Coimbatore of the Kongu region of western Tamil Nadu. The grasslands occupy the rain shadow region of the Western Ghats. Rainfall data from 2012 to 2017 shows a total average rainfall of 580.24mm in the districts of Erode, Tiruppur and Karur combined, with a standard deviation of about 190mm ("Customized Rainfall Information System (CRIS)," 2019). These private grasslands are owned and managed by many individual sedentary pastoralists. A single fenced paddock housing cattle or sheep, or both combined in rare cases, can vary in size from less than an acre, up to 200 acres.

Figure 1: Indigenous Kangayam Cattle in the Korangadu grassland system. On the right, live fencing of Commiphora beryii can be seen

The Korangadu grasslands also house variety of dung beetles, which play an important role in soil carbon cycle. They bury the dung biomass into the soil making the carbon available to be stored into the soil (Yamada, Imura, Shi, & Shibuya, 2007), rather than being released into the atmosphere in forms of greenhouse gases. Dung beetles also prevent the dung being occupied by parasites, effectively acting as parasite control of livestock, besides providing many ecosystem services (Nichols et al., 2008). Various studies show that dung beetles' activity positively correlate with increased soil carbon (Nichols et al., 2008; Scholtz, Davis, & Kryger, 2009; Yamada et al., 2007).

Also, carbon stock of grasslands in India are highly understudied, with focus more on forests (Kaur, Gupta, & Singh, 2000; Lal, 2004), crop fields (Manna et al., 2005) or reclaimed land regions. In this sense, studying the Korangadu grassland system, which has been actively used for pastoralism for more than 160 years (Vivekanandan, 2007) helps understand the soil carbon sequestration capacity of grasslands in India. With grasslands being predominantly seen as less productive wastelands and as prime grounds for development, studying the carbon sequestration potential and carbon stocks held by grassland soils, especially in the context of the threat of climate change becomes important for conservation and promoting sustainable usage and management.

The **primary objective** of this study is to delineate the varying management practices within the Korangadu grassland system and its influence on soil organic carbon (SOC), and dung beetles' richness and abundance.

Literature Survey:

The Korangadu grasslands of the Kongu region are tropical grasslands that are unique for their management methods. These grasslands were established during the British regime as they promoted pasture maintenance in the form of two *pillu taxes.* These two pillu taxes (*ayen pillu* and *paravu pillu*) were up to 75% less compared to taxes for land under farming, thereby economically incentivizing pasture maintenance (Kumar, Natarajan et al. 2011). These grasslands are now privately owned used for grazing native breeds of sheep (such as *Mayilambadi* and *Mecheri*) and the Kangayam breed of cattle known for their drought resistance (Vivekanandan 2007). The unique feature of these grasslands is that they have live fencing in terms of a thorny bush called as *Mullu kiluvai (Commiphora beryii) (FAO 2007).* This kind of a 'paddock' system enables the herders to practice sedentary pastoralism, reduces the management effort for the cattle and provides food security (Kumar, Biradar et al. 2011). The grassland is managed by a variety of methods such as – occasional tilling (once in 3-5 years), sowing of legumes and other grass breeds, managing and maintaining water source for the cattle, maintaining the paddock hedges, etc., (Kumar, Natarajan et al. 2011). However, the management methods are not uniform and vary widely both temporally and spatially. Recently the entire grassland system has been in flux due to a variety of socio-economic, political and ecological reasons.

Empirical results in other grassland systems suggest that moderate grazing and good management system improves carbon sequestration capacity of the soil and results in increased soil fertility and food security (Conant, Paustian et al. 2001, Reeder and Schuman 2002, Maia, Ogle et al. 2009). However, most of these studies focus on open grassland systems, where grazing takes place throughout the year. In contrast, the Korangadu grasslands are closed and privately-owned grasslands where sedentary grazing takes place for 7-8 months in a year (Kumar, Biradar et al. 2011). Their carbon sequestration ability and total carbon holding capacity is unknown, and could be affected by different management practices compared to open communal grasslands.

A simple google scholar search of "Korangadu grasslands" reveals only four relevant literature out of 8 results. Research on carbon sequestration ability of grassland soils are predominantly done in the US rangelands (Schuman, Janzen, & Herrick, 2002; Schuman, Reeder, Manley, Hart, & Manley, 1999) in Australia (Chen, Hutley, & Eamus, 2003), and in Europe (Smith et al., 2005), but not many literature on tropical grasslands. However, tropical grasslands provide numerous ecosystem services in terms of fodder for livestock (Wrage, Strodthoff et al. 2011), carbon sequestration (Sala and Paruelo 1997), preventing soil erosion, ameliorating weather at various scales (Sala and Paruelo 1997) and maintaining food security (O'Mara 2012).

Similar to grasslands, soil arthropods are not given primary importance in conservation efforts despite being the most diverse phylum in the animal kingdom and providing numerous ecosystem services (Erwin 1991, Perfecto, Vandermeer et al. 1997). Soil arthropods such as dung beetles directly involve in carbon sequestration and nitrogen accumulation in the soil by dung burial and increasing soil porosity (Losey and Vaughan 2006, Nichols, Spector et al.

2008). Most of the studies on grasslands have examined the effects of management on carbon sequestration, but have not investigated the role of dung beetles in having a potential interlink between the management practices and carbon sequestration. It is possible that certain management practices in the Korangadu grasslands could facilitate optimal dung beetle activity by providing them a conducive micro-environment.

Dung beetles can be of three types – paracoprid (tunnelers), telocoprid (rollers) and endocoprid (dwellers) (Nichols et al., 2008). Data from 1990-2000 shows that nearly 12 to 30 million tonnes of Nitrogen was excreted by livestock, most of which are lost as ammonia, which is a greenhouse gas. Out of which, nearly 22% of nitrogen is sequestered in the soil, mostly by the dung beetles. Besides enhancing soil carbons storage, they also facilitate nitrogen mineralization, enhanced pH and cation exchange. Dung of cattle contains indigestible carbon, consisting of lignocellulose (Scholtz et al., 2009), which is also not water soluble (Yamada et al., 2007). Therefore, by facilitating dung burial in soil, dung beetles play an important role not only in soil carbon sequestration, but in general, soil health, especially in grasslands.

An estimated 12% of soil organic matter is captured in grasslands, which accounts for nearly 25% of world’s land area (Abberton et al., 2010). By quantifying the carbon sequestration ability of the Korangadu grasslands, the project aims to challenge the prevailing colonial consensus that “grasslands are wastelands”, and are prime grounds targeted for developmental projects (Whitehead 2010, Tian, Banger et al. 2014).

Chapter 2: Study Area and Methodology

The overall study area was chosen to focus on the Korangadu grasslands of Kangayam Taluk of Tiruppur district. Based on variation in management practices, size of the paddock, accessibility, cattle stocking density and other parameters, 5 grassland paddocks of various sizes were selected for sampling (Table 1)

Though there are many differences between the different Korangadu grassland paddocks, they share many similarities. Almost all of the paddocks contain the native *Acacia leucophloea* trees (In Tamil: *Vella Velamaram*), which lower branches are usually cut to allow better movement by the cattle. Besides that, cutting of the lower branches enables the Acacia trees to grow more linearly, which are of more value as timer. These trees are harvested for lower-grade timber once every 10 years or so. Since Acacia trees grow naturally in these grasslands, the management of the Korangadu grasslands can be categorized as sedentary silvi-pastoralism. *Cenchrus ciliaris* (In Tamil: *Kolukkattai Pul*) is the most common grass species in the grassland.

Table 8: Characterization of the different field sites

Study site	Number of data points	Cattle stocking density	Type of cattle	Area of the paddock (in acres)	Predominant fencing type
SK	7	4 cows/acre	Kangayam breed	10	Live fencing using *Commiphora berryi* along all boundaries except 2 boundaries, which is shared with paddock AK. This is fenced by metal fencing
AK	10	0.1cow/acre	Kangayam Breed and Hybrid Cattle for Milch	70	One long fence with *Commiphora*. Rest of the boundaries are fenced with metal fencing.

RF	9	1 cow/acre	Kangayam Breed and Hybrid Cattle for Milch	30	One boundary of this paddock is fenced completely by *Prosopis* that naturally grows along the riverside. Other fences are all enclosed by *Commiphora*
KD	6	~1 sheep/acre and < 0.05 cow//acre	Hybrid Cattle for Milch and *Mecheri* breed sheep	70	This paddock, though privately owned is not fenced. Only paddock in the study site that has common access, and sheep grazing. The predominant grass species here is not *Cenchrus*, but *Aristida.*
PV	10	0.1 cow/acre	Predominantly Kangayam Cattle with 2 hybrid milch cows	40	Irregularly shaped paddock with about 7 boundaries. Only one of them is fenced with metal, while the rest are fenced with *Commiphora*

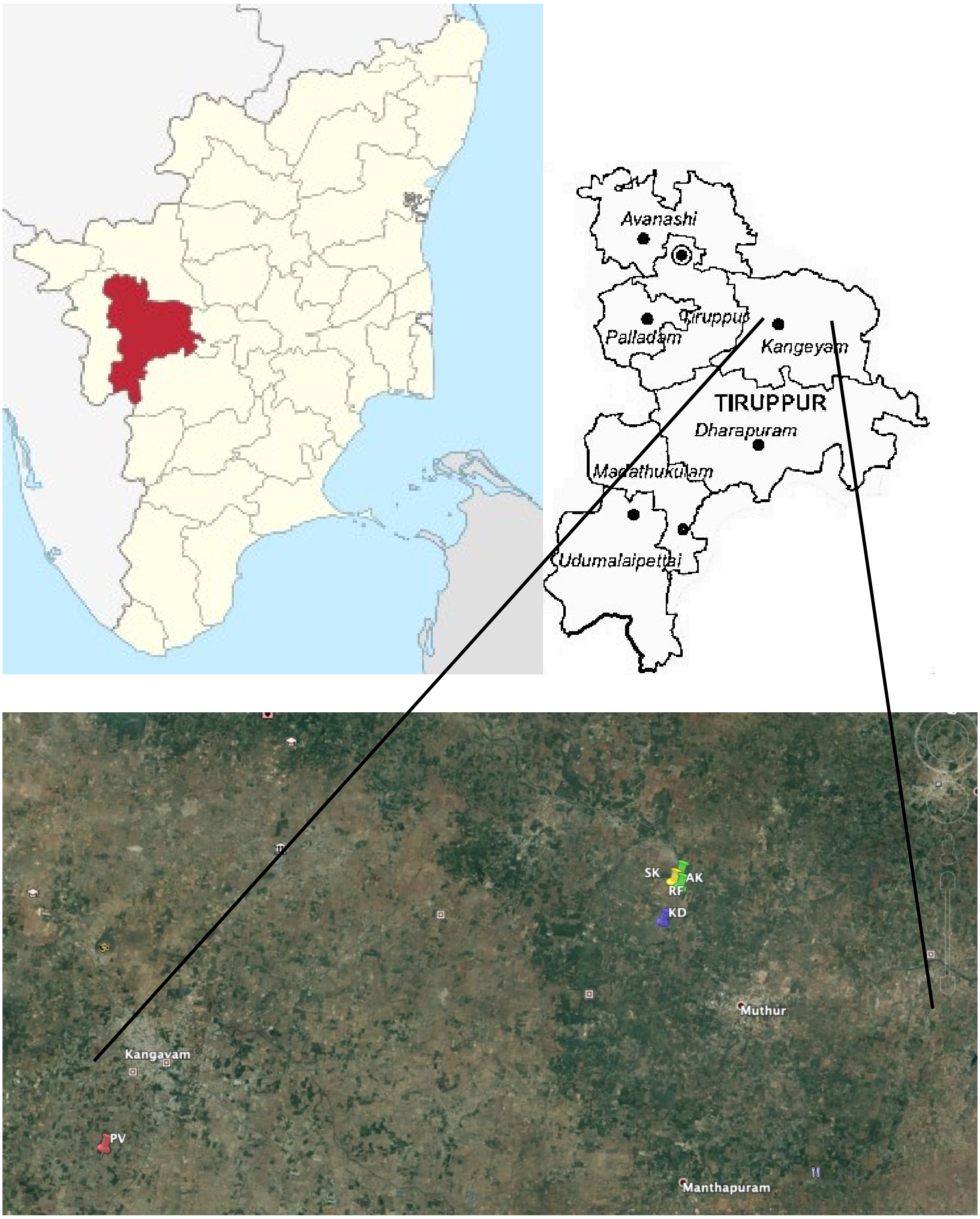


Figure 2: Clockwise from top: 1. Tiruppur district 2. Kangayam Taluk in Tiruppur District 3.

Soil sampling was carried out with a stainless steel core cutter about 25cm in height, and 5cm in diameters. The core cutter was hammered into the soil with up to 20cm first to get the 0-20cm layer of the soil, and then hammered in again to get another layer of sample from 20cm- 35cm. Since the topsoil of the grassland was found to be shallow (very rocky after about 50- 60cm), the originally proposed single sampling of 30cm was modified into two layers of 0- 20cm and 20-35cm.

Figure 3: Cenchrus ciliaris is the dominant grass species in the Korangadu grasslands. Just after the North-East monsoon (October-January) season, the grass growth is at its highest

Initially the first sampling point inside the paddock was chosen about 5-10m perpendicularly away any one of the fence – usually near the gate of the paddock. The type of fence – live fencing using Commiphora berryi or using metal fencing was noted down. For one paddock (SK), one of the live fencing was made of *prosopis*, which grew along the adjacent river bank. Once soil sampling was performed, a small ball of freshly collected cattle dung was placed near where the soil was taken, for sampling the dung beetles. Since no roller dung beetles were found in the field, the originally proposed idea of dung baited pitfall traps were replaced by simpler dung ball sampling. After 24 hours, the dung balls were bagged inside a polythene Ziploc bag along with some underlying soil to account for any tunneler beetles. Once the dung ball was placed, using a calibrated pedometer app in the smartphone, a point 100m away was selected from the initial sampling point, along the fence. The sampling was continued till the whole perimeter of the paddock is covered. Once the perimeter is covered, a sampling point in the center of the paddock is chosen, and the methods were repeated again. Suitable samples away from the fence of the paddock, and more towards the center, 100m apart from each other were also chosen.

Figure 4: Vegetation sampling with field assistant. A 10m x 10m quadrat was laid with the soil sampling point at the center using ropes that is marked at every 5 meter using a ribbon. The smaller quadrat measuring 50cm x 50cm was used to identify grass and herbs species.

For a single paddock, sampling was carried out usually in 2 days. In the first day, the soil sampling and placing of the dung ball traps were done. On the second day, a 10mx10m quadrat

Figure 5: Tunneler dung beetles have hollowed out a dung pat. These beetles tunnel the soil, and lay their eggs inside the dung, which they bury into the soil

was laid using pre-calibrated rope, with the soil sampling point at its center. Using a smaller 50cm x 50cm quadrat, the four corners of the bigger quadrat were analyzed for vegetation data including plant cover percentage, richness and abundance of grass species, richness and abundance of herbs species. Herbs and grass species were identified with the help of Ms. Ovee Thorat, PhD student at ATREE, as well as using Botanical Survey of British Museum Keys (Hooker, 1890). Unidentified species were kept in labelled Ziploc bag, transported back to ATREE, Bengaluru after completion of a season to be identified.

Vegetation in two diagonal smaller quadrats (50 cm x 50 cm) were cut, bagged in paper bags, dried in hot air oven in the field for about 6 hours at 80°C for above ground biomass calculations. In the bigger quadrat (10 m x 10 m), abundance and richness of trees, tree saplings, tree DBH, tree height as well as the number of dung pats were measured. The dung pats were measured as a sign of grazing activity in that particular quadrat.

The soil samples were brought to the field station, and a small subsample was weighed before and after drying in the hot air oven at 100°C for nearly 3 hours for calculation of soil moisture. The difference in weight was measured in a sensitive weighing scale with accuracy of 0.01 g (10mg). The dried soil subsamples were dumped back into the original polythene Ziploc bags, and delivered to the Mobile Soil Testing Lab, Government of Tamil Nadu at Pongalur, Tiruppur District for soil analysis. Total weight of the core sample was also measured. The weight was divided by the volume of cylinder corresponding to 5cm diameter and 20 or 15cm height to the 1^{st} and 2^{nd} soil depth respectively to obtain the soil bulk density.

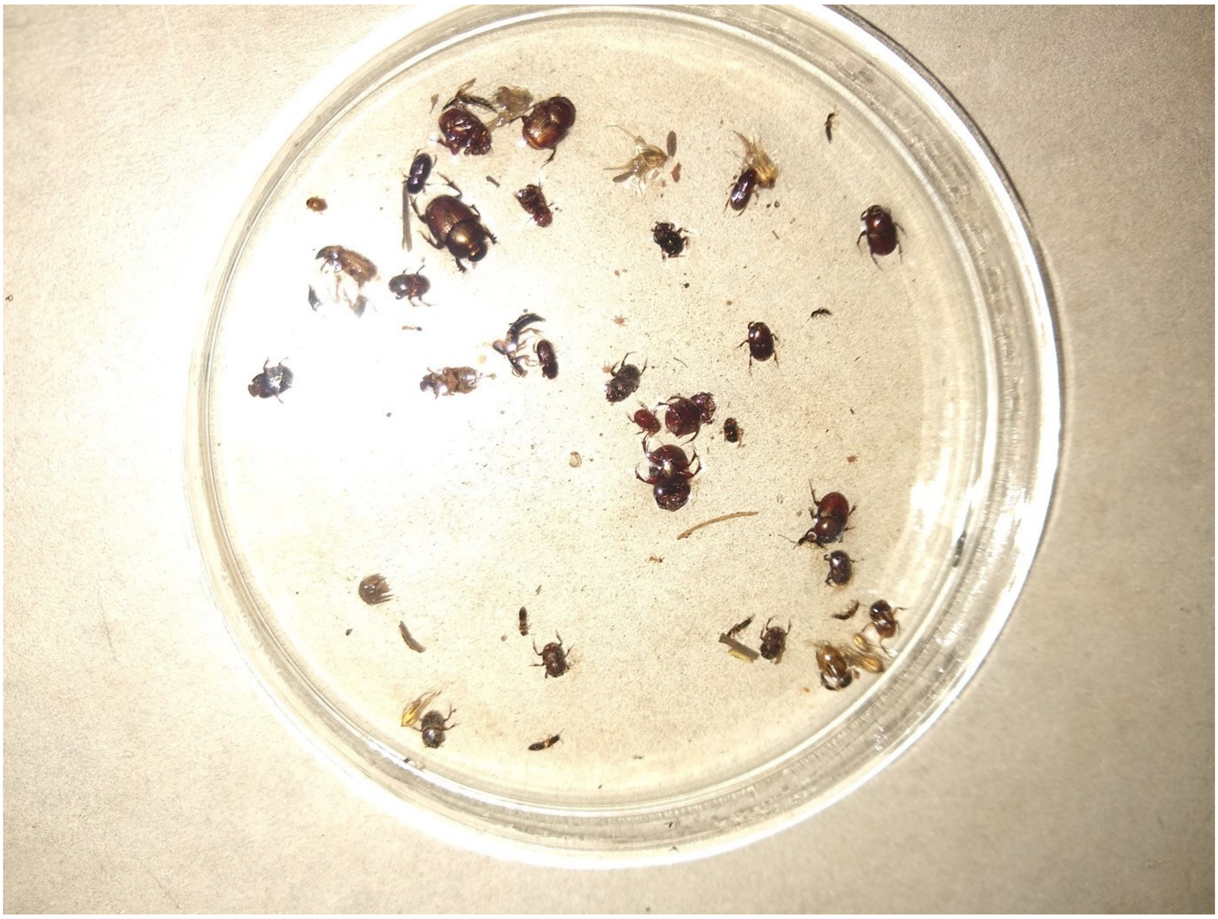


Figure 6: Dung beetles in 90% alcohol - After collecting the dung balls in a polythene ziploc bag, it was immersed in a bucket of water. The buoyant dung beetles are then collected in 90% ethanol in a petri dish, and then transferred to labelled falcon tubes for further identification

The soil parameters analyzed include available soil nitrogen by alkaline permanganate method, available phosphorous by Olsen's method, available potassium by Ammonium Acetate method, soil organic carbon by a previously calibrated measure of available Nitrogen, pH, electrical conductivity, iron, manganese, zinc and copper.

Figure 7: Measuring dried above ground biomass using hot air oven. The enclosed plant material is heated for 6 hours at 80 degrees, and then weighed.

Figure 8: Soil samples and soil sub samples. From the soil samples collected, sub samples of 15-20 g were taken, weighed before and after drying in the hot air oven to calculate soil moisture.

Figure 9: The soil samples were transported to the Mobile Soil Testing Lab at Pongalur, using saddle bags

Chapter 3: Results and Discussion

Table 2 presents the different data collected in the study under different variable groups, and at different scales. Three management variables that were given primary importance in analyses with the other parameters are – nearby fence type (live or metal), type of soil sample point (near the fence or not), and the paddock level cattle stocking density.

Scale	Variables analyzed	Variable Group
At the soil sample collected	Soil pH	Soil
	Soil Organic Carbon	
	Soil Phosphorous	
	Soil Potassium	
	Soil Available Nitrogen	
	Soil Bulk Density	
	Soil moisture	
	Dung beetles abundance	Dung beetles
	Dung beetles richness	
At the 50cm x 50cm quadrat	Grass abundance	Grass
	Grass richness	
	Herbs abundance	Herbs
	Herbs richness	
	Vegetation cover percentage	Grass and Herbs combined
	Above ground biomass	
At the 10m x 10m quadrat	Trees richness	Trees
	Trees abundance	
	Dung pat density	
	Nearby fence type	Management type
	Edge/Center	
At the paddock level	Cattle Stocking Density	

Table 9: Data collected at different scales

Soil Organic Carbon and Management:

All the analyses were performed in RStudio unless mentioned otherwise. Total Organic Carbon (Tonnes/hectare) was obtained by multiplying organic carbon (%), bulk density (g/cm3) and depth of the column (cm). It was multiplied by a conversion factor of 404.69 to convert it into kilogram/acre units. All the data distributions were checked for normality using a Shapiro Wilk test. If any one distribution was found to be non-normal, then non-parametric tests were used for the statistical analyses.

Table 3 shows the p-values of Kruskal-Wallis test (non-parametric equivalent of ANOVA) for Total Organic Carbon and different management parameters. The data were divided for Season 1 and Season 2 first, and then individually into the corresponding depths as well. Out of the 24 tests done, 6 tests showed a statistically significant difference ($p\text{-value} < 0.05$, green shaded), and 1 test showed a marginal statistical difference ($p\text{-value} < 0.1$, yellow shaded).

Ordinal variable/Organic Carbon (p-values) – Kruskal Wallis Test	Monsoon (both depths)	Post-monsoon (both depths)	Monsoon (20cm)	Post-monsoon (20cm)	Monsoon (35cm)	Post-monsoon (35cm)
Fence type (live, metal and center)	0.1611	0.2394	0.7588	0.4091	0.05564	0.3246
Center or Fence (Center or Fence)	0.4841	0.8033	0.8893	0.9556	0.497	0.5523
Data with only Fences (live vs metal – center data removed)	0.0525	0.09882	0.5292	0.1504	0.01943	0.3931
Cattle Stocking Density	0.00901	0.02347	0.05534	0.1549	0.1519	0.1983

Table 10:Kruskal Wallis test - Organic Carbon and Management

Average SOC values	Monsoon (20-35cm)	Monsoon (both depths)	Post-monsoon (both depths)
Fence type – Metal	2014.647	3306.274	3666.573
Fence type – Live	3522.84	4243.483	4830.285
Center/away from fence samples	3393.536	3909.06	4241.149

Table 11: Average Organic Carbon values for different fence types

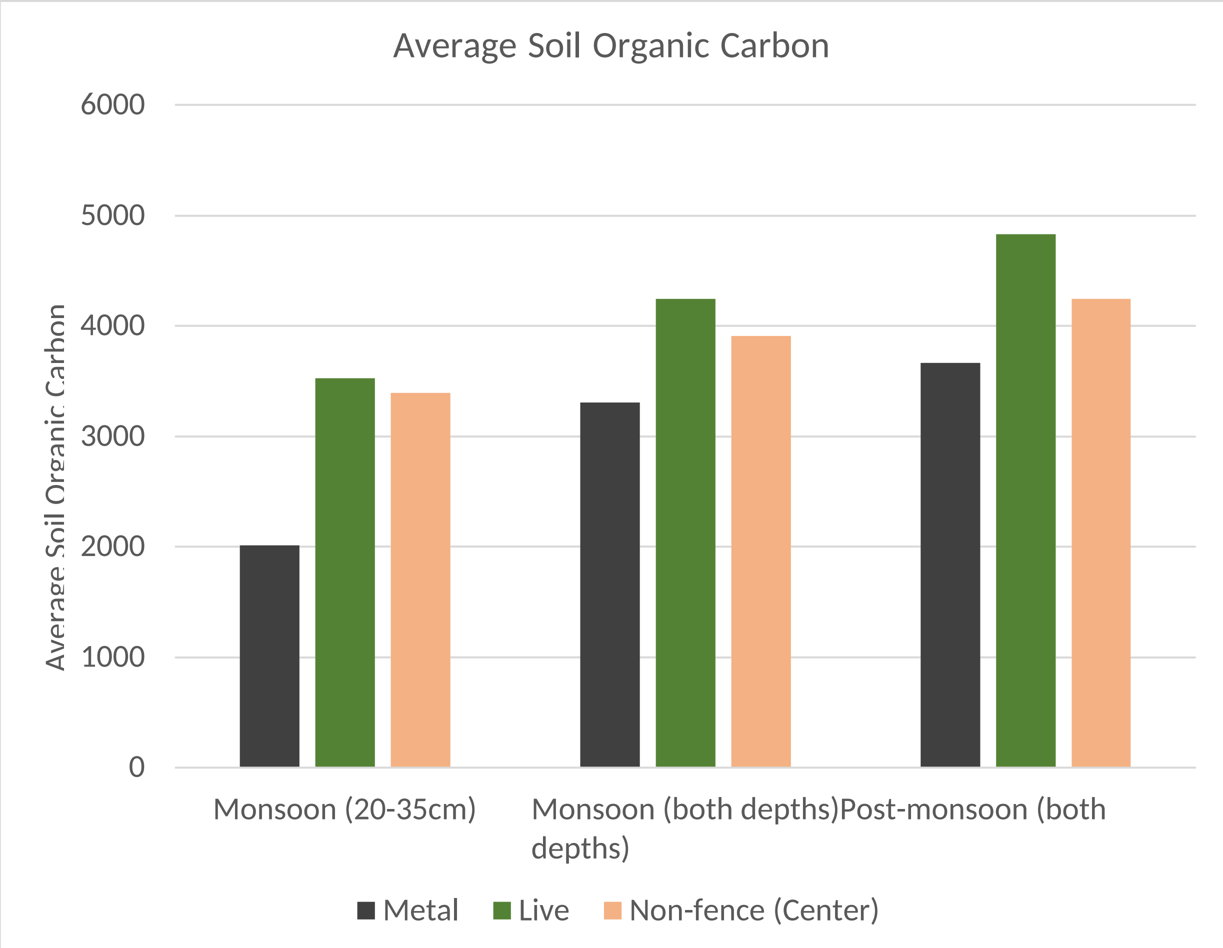


Figure 10: Average soil organic carbon values for the different fencing sampling.

Table 4 (and figure 9) suggests that there is a significant difference between live and metal fences, when both depths for both the sampling seasons are considered, and for the 20-35cm soil column when pre-monsoon was only considered. Table 5 shows that across both the depths for both the seasons, and for the 20-35cm soil column in pre-monsoon, the average SOC value is significantly lower in samples close to the metal fences, compared to the samples closer to the live fences. Similarly, though there was no statistically significant difference between samples collected close to live fences and samples collected near the center of the paddocks, average organic carbon values were significantly higher in samples collected from near the live fences, compared to samples collected from near the center. These results suggest that the live fencing is most conducive to higher SOC in the Korangadu grassland systems. However, other confounding variables, which could affect the SOC other than the fence types should be identified and corrected for.

During interactions with the Korangadu grassland owners, one respondent said that for making organic fertilizer called *Amirthakarasal* (a mixture of cow dung, cow urine, soil and other organic manure), traditionally, the soil near the live fences of the Korangadu paddocks are taken, as they were considered the most fertile. However, due to increasing labor cost of maintenance of the live *Commiphora* fencing, they are being converted into open metal fences.

With respect to inter seasonal variation, Organic Carbon values significantly did not vary, however, across both the depths, the average SOC increased. The average value increase when both the depths were considered was 457.606 kg/acre (1.13 tonnes/ha) of carbon in the second sampling season, compared to the 1st sampling season.

Inter-seasonal variation (p-values – Wilcoxon signed rank test)	Both Depths	20cm	35cm
	0.2378	**0.5944**	**0.192**

Table 12: p-values for Wilcoxon signed rank test for inter seasonal variation between soil organic carbon values

Average Organic Carbon Values (kg/acre)	Monsoon (both depths)	Post-monsoon (both depths)	Monsoon (20cm)	Post-monsoon (20cm)	Monsoon (35cm)	Post-monsoon (35cm)
	3893.392	4350.998	4582.978	4886.708	3088.876	3726.002
Increase	457.606		303.73		637.126	

Table 13: Average Organic Carbon values (kg/acre) for seasons across depths, and their corresponding average increase

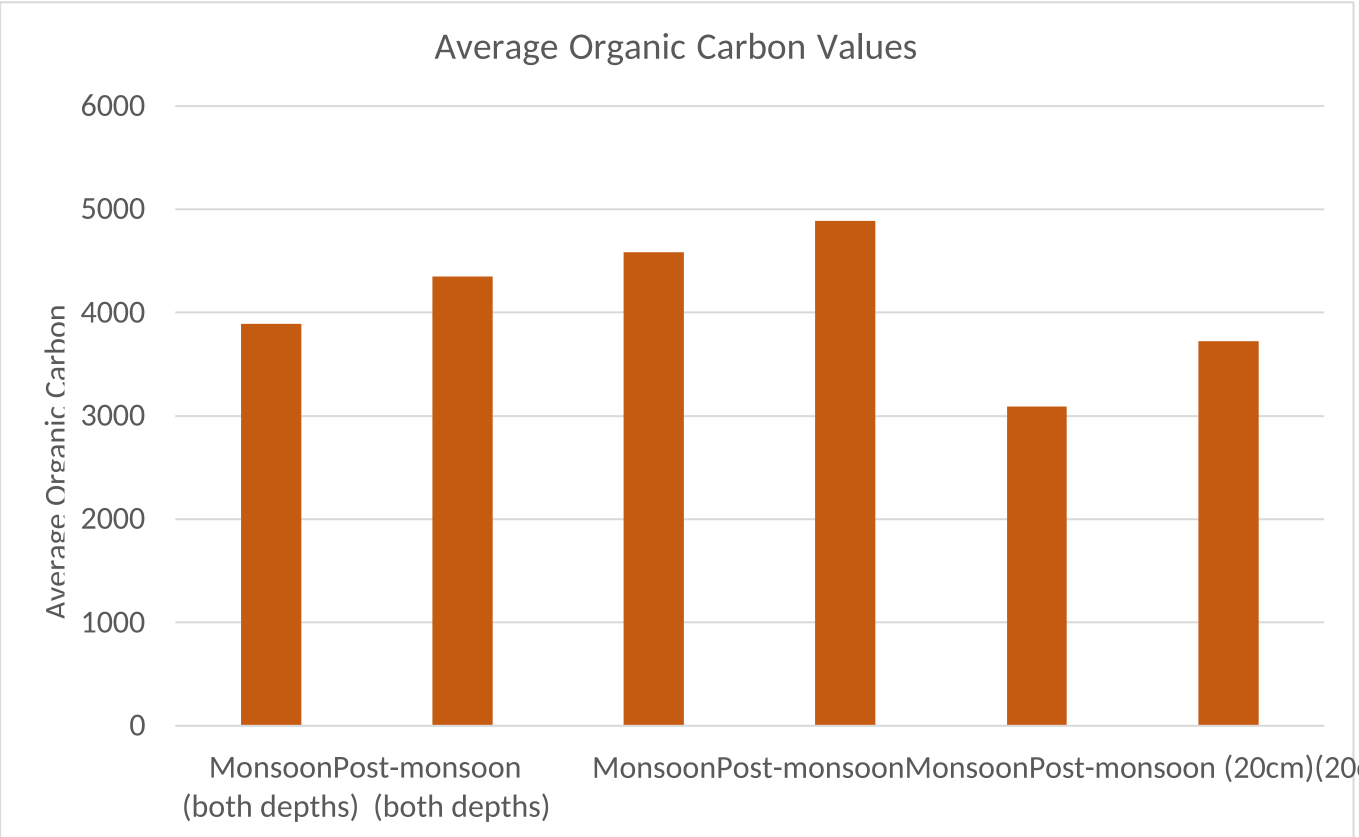


Figure 11: Average organic carbon values for different monsoons across different depths

Dung Beetles and Management

Dung beetles abundance and richness from every dung ball trap was summarized, and compared between the two sampling seasons. A Shapiro-Wilk test was first performed to check the normality of the distributions. Since, the normality was rejected with very low p-values ($p<0.01$), a non-parametric equivalent for paired t-test, Wilcoxon Signed Rank test was performed to check if abundance and richness significantly change between the same sites. However, no statistical significance ($p<0.05$) was validated by the test, showing that abundance and richness of dung beetles does not vary significantly between the two sampling seasons, despite a marked drop in abundance and richness in the post-monsoon season.

Descriptive Statistics – Dung Beetles	Season 1	Season 2	Total
Genus	5	5	5
Number of Morphospecies (Richness)	23	11	24
Abundance	863	676	1539

Table 14: Descriptive Statistics of Dung Beetles

However, during the pre-monsoon season, the dung beetle abundance significantly varies with respect to the fence type as well as the cattle stocking density, though no significant difference was found with respect to richness. In pre-monsoon season, the dung beetles abundance was significantly higher when sampled near live fences, compared to metal fences. Compared to samples near metal fences, dung beetles abundance was higher in samples away from the fences, and towards the center. This also suggests that dung beetles abundance is highly correlated with the presence of live fences in the Korangadu paddocks.

Dung-Beetles and management (p-values) – Kruskal Wallis Test	Monsoon		Post-monsoon	
	Abundance	Richness	Abundance	Richness
Fence type (live, metal and center)	0.009694	0.1584	0.1887	0.2872
Center or Fence (Center or Fence)	0.4246	0.2734	0.0691	0.1558
Data with only Fences (live vs	0.00203	0.1478	0.8318	0.5246

metal – center data removed)				
Cattle stocking density	0.02883	0.4921	0.676	0.5208

Table 15: Kruskal-Wallis test for dung beetles and management

Dung-Beetles – Average Abundance and Richness by Trap	Monsoon		Post-monsoon	
	Abundance	Richness	Abundance	Richness
Total	21.65	3.225	14.225	2.775
Live	30.5882			
Metal	11.1			
Center	18.5			

Table 16: Average abundance and richness of dung beetles across seasons, and different fences

Vegetation parameters:

A Wilcoxon signed rank test shows that vegetation cover percentage, herbs richness and abundance significantly reduces in the post-monsoon season compared to the pre-monsoon season. However, grass abundance and richness did not significantly reduce in the post-monsoon season. Above ground biomass also significantly reduced in the post-monsoon season.

Wilcoxon signed rank test: Variation between the two seasons: p-values	Vegetation cover percentage	Grass abundance	Grass richness	Herbs abundance	Herbs richness
	<0.00001	0.6656	0.9892	<0.00001	<0.00001

Table 17: Wilcoxon signed rank test for variation in vegetation parameters between the two seasons

The full potential of the vegetation parameters for analysis, especially with respect to SOC and grassland management is not fully explored yet. A non metric multi dimensional scaling analysis will be performed to check if the vegetation composition significantly varies between the different paddocks, with respect to their varying cattle stocking density.

Figure 12: Closeup picture of Crotalaria globosa. One of the prominent herbs found in the monsoon season, but not in the post-monsoon season.

Species Name	**Local Name**
Cenchrus ciliaris	*Kolukkattai pul*
Indigofera linnaei	*Cheppu nerinji*
Tephrosia purpurea	*Kolinji*
Tribulus terrestris	*Nerinjil*
Phaseolus trilogus / Vigna trilobata	NA
Crotalaria globasa	NA
Chloris barbata	*Kuruttuppul*
Merremia tridentate	NA
Brachiaria mutica	NA
Sporobolus coromandelianus	NA
Aristida funiculate	NA

Gallium aparine	NA
Pupalia lappacea	*Ottumpul / Forest burr*
Evolvulus alsinoides	NA
Emilia sonchifolia	*Muyal seevi*
Portulaca quadrifida L	NA
Tephrosia vogelii	*Kal Kolinji*
Leucas aspera	*Thumbai chedi*
Ocimum tenuiflorum	*Tulasi*
Aerva lanata	*Poolappoo*
Chrysopogon	NA
Parthenium sp.	NA
Acacia leucophloea	*Vella vela maram*
Commiphora beryii	*Mullu Kiluvai*

Table 18: Vegetation including grasses, herbs and trees identified at the Korangadu grasslands

Chapter 4: Conclusions

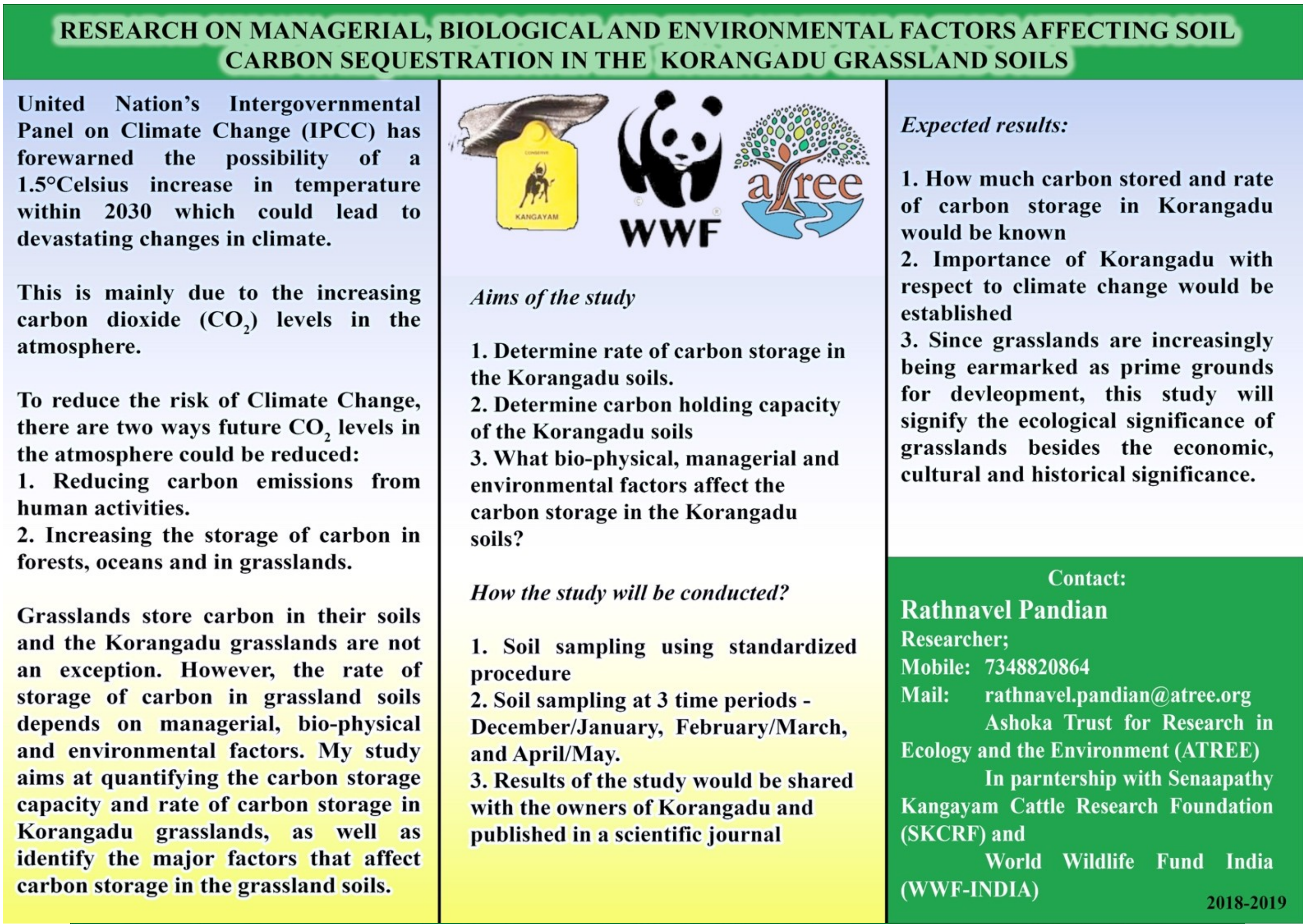
As part of the project, 21 variables have been collected so far across two sampling seasons to check the overall objective of - delineating the varying management practices within the Korangadu grassland system and its influence on soil organic carbon, and dung beetles' richness and abundance.

The management practices identified within the study system were - fence type – live or metal fencing and cattle stocking density (number of cattle stocked inside the paddock divided by area of the paddock in acres). It was found from the analyses that the type of fencing has a significant effect on both SOC and the dung beetles abundance, with live fencing supporting more SOC and dung beetles compared to metal fencing. Presence of live fencing could potentially help holding the top soil together, besides contributing to the SOC itself through root exudates. Besides that, live fencing provide more shade, and act as a wind breaker as well compared to the more open metal fencing (Prasad, 2010).

Figure 13: A Korangadu paddock with only one metal fencing. Due to the differential cattle stocking density (higher in the left paddock, lower in the right paddock), the vegetation changes accordingly.

The two sampling seasons conducted were in the months of - end of December, and beginning of March. Though the sampling seasons were spread out only in a time span of about 2 months, the landscape in terms of vegetation, and management are its most dynamic during this time. After the sparse North-East monsoon rains in the month of November, the vegetation cover significantly increases providing good quality fodder to the cattle inside the Korangadu. Starting from the month of February, however, the vegetation becomes sparse, and the temperatures begin to rise as well. This assertion is corroborated - by field interviews with Korangadu owners, as well as the statistically significant reduction in vegetation cover percentage, and herbs abundance and richness in the post-monsoon season (Table 10). Interviews further revealed that the lower vegetation cover continues further throughout the year till another sparse bout of summer rains during the month of June. Paddocks with lower cattle stocking density could continue to afford grazing in the paddock. However, paddocks with lower cattle stocking density also showed more presence of *Tephrosia* species, which are woody in nature, and are consumed less by the cattle. However, this was noticed only in two localized paddocks, and more evidence is needed to see if lower cattle stocking density inside the Korangadu leads to growth of the woody *Tephrosia* species. Due to the dynamic nature of the paddocks during these four months, compared to the rest of the year, one could assume that the SOC undergoes major changes – either increase or decrease during these months compared to the rest of the months, where more or less uniform weather (hot and dry), and management (very low cattle stocking density or no cattle stocked) remains.

Also, as part of the project, two pamphlets – one in English, and one in Tamil, with respect to the importance of the current project were distributed to the Korangadu owners, whose paddocks were used for the project.



RESEARCH ON MANAGERIAL, BIOLOGICAL AND ENVIRONMENTAL FACTORS AFFECTING SOIL CARBON SEQUESTRATION IN THE KORANGADU GRASSLAND SOILS

United Nation's Intergovernmental Panel on Climate Change (IPCC) has forewarned the possibility of a 1.5°Celsius increase in temperature within 2030 which could lead to devastating changes in climate.

This is mainly due to the increasing carbon dioxide (CO_2) levels in the atmosphere.

To reduce the risk of Climate Change, there are two ways future CO_2 levels in the atmosphere could be reduced:
1. Reducing carbon emissions from human activities.
2. Increasing the storage of carbon in forests, oceans and in grasslands.

Grasslands store carbon in their soils and the Korangadu grasslands are not an exception. However, the rate of storage of carbon in grassland soils depends on managerial, bio-physical and environmental factors. My study aims at quantifying the carbon storage capacity and rate of carbon storage in Korangadu grasslands, as well as identify the major factors that affect carbon storage in the grassland soils.

Aims of the study

1. Determine rate of carbon storage in the Korangadu soils.
2. Determine carbon holding capacity of the Korangadu soils
3. What bio-physical, managerial and environmental factors affect the carbon storage in the Korangadu soils?

How the study will be conducted?

1. Soil sampling using standardized procedure
2. Soil sampling at 3 time periods - December/January, February/March, and April/May.
3. Results of the study would be shared with the owners of Korangadu and published in a scientific journal

Expected results:

1. How much carbon stored and rate of carbon storage in Korangadu would be known
2. Importance of Korangadu with respect to climate change would be established
3. Since grasslands are increasingly being earmarked as prime grounds for devleopment, this study will signify the ecological significance of grasslands besides the economic, cultural and historical significance.

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கொரங்காடு மண் பரப்புகளில் கரியமிலவாயு சேமிக்கும் விகிதத்திற்கு மேலாண்மை, உயிரியல் மற்றும் சுற்றுசூழல் காரணிகள் கண்டறியும் அறிவியல் ஆய்வு

ஐக்கிய நாடுகள் சபையின் (United Nations) பருவநிலை மாற்றத்திற்கான சர்வதேச குழு 2030க்குள் புவி 1.5 டிகிரி செல்சியஸ் வரை வெப்பமாகக்கூடும் எனவும் இது பல்வேறு நாசவிளைவிக்கும் தட்பவெப்பங்களை உண்டாக்கும் எனவும் எச்சரித்துள்ளது.

வளிமண்டலத்தில் கரியமிலவாயு (Carbon Dioxide) அதிகமாகுவதே இதற்க்கு ஒரு முக்கிய காரணமாக திகழ்கின்றது.

பருவநிலை மாற்றத்தின் ஆபத்துகளை குறைக்க 2 வழிமுறைகளை கையாளலாம்.

1. புதிதாக உருவாகும் கரியமிலவாயுவினை குறைத்தல் (தொழிற்சாலைகள்).
2. கரியமிலவாயுவினை இயற்கையாக காடுகளின் மரங்களிலும், கடலிலும், புல்வெளி மண்ணிலும் சேமிக்கப்படும் விகிதத்தை அதிகப்படுத்தல்.

புல்வெளி நிலங்களில் இயல்பாகவே கரியமிலவாயு சேகரிக்கப்படும். கொரங்காடு நிலங்களும் இதற்க்கு விதிவிலக்கல்ல. எனினும் மண்ணில் சேரும் கரியமில வாயுவின் விகிதம் மேலாண்மை, உயிரியல் மற்றும் சுற்றுசூழல் காரணிகளால் பாதிக்கப்படுவதாகும். இதில் எந்த காரணிகள் அதிக பங்காற்றுகின்றன என்பதும் இந்த

ஆய்வின் குறிக்கோள்கள்:

1. கொரங்காடு நிலங்களில் கரியமிலவாயு சேகரிக்கும் விகிதத்தினை கண்டுபிடித்தல்.
2. கரியமில வாயுவினை சேகரிக்கும் கொரங்காடு மண்ணின் கொள் திறன் எவ்வளவு?
3. கரியமிலவாயு மண்ணில் சேர்க்கையில் எந்தெந்த மேலாண்மை, உயிரியல் மற்றும் சுற்றுசூழல் காரணிகள் முக்கிய பணியாற்றுகின்றன?

ஆய்வு எப்படி மேற்கொள்ளப்படும்?

1. வரையளவுபடுத்தப்பட்ட செயல்முறைகள் மூலம் மண் மாதிரிகள் எடுக்கப்பட்டு அவை தமிழ்நாடு வேளாண்மை பல்கலைக்கழகத்தில் ஆய்வு செய்யப்படும்.
2. மண் மாதிரிகள் மூன்று காலக்கட்டங்களில் ஆய்வு செய்யப்படும் - ஜனவரி, மார்ச் மற்றும் மே மாதங்களில்.
3. ஆய்வின் முடிவுகள் கொரங்காட்டின்

ஆய்வில் எதிர்பார்க்கப்படும் முடிவுகள்:

1. கொரங்காடு புல்வெளிகளில் எவ்வளவு கரியமிலவாயு சேகரிக்கப்பட்டுள்ளது என்றும் அதனின் சேகரிக்கும் விகிதமும் மற்றும் அதன் முக்கிய காரணிகளும் அறிவியல் ரீதியினில் தெரியவரும்.
2. பருவநிலை மாற்றத்தினை தடுக்க கொரங்காடு எவ்வாறு பணியாற்றுகிறது என்பது தெரியவரும்
3. இக்காலங்களில் உலகம் முழுக்க புல்வெளிகள் வளர்ச்சிப்பணிகளுக்காக அடையாளப்படுத்தப்பட்டுள்ளது. இந்த ஆய்வின் மூலம் புல்வெளிகளுக்கு வரலாற்று, கலாச்சார மற்றும் பொருளாதார முக்கியத்துவம் மட்டுமின்றி சுற்றுசூழலுக்கு முக்கியத்துவம் உண்டு என்பது புலப்படும்.

தொடர்புக்கு

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Figure 14: Informational Pamphlets distributed to the Korangadu owners

Figure 15: Paddock AK: The top picture shows the monsoon season with newly grown grass, while the bottom picture shows the post-monsoon season - more drier and grazed grass.

With respect to the total SOC sequestered in the study areas, there was a total average increase of 457.606 kg/acre (1.13 tonnes/ha) across both depths, with more increase in the 20-35cm column (637.126 kg/acre increase) compared to the top soil (303.73 kg/acre increase).

Chapter 5: Recommendations and the Way Forward

The current project that has analyzed five different Korangadu paddocks, over two seasons is a pilot project, and should be expanded to include more paddocks, over a longer period of time. Besides that, bulk density measurements heavily influence the carbon stock of the soil (Throop, Archer, Monger, & Waltman, 2012). Therefore, independent bulk density measurements using different techniques could also be employed to correct any potential error that could arise out of bulk density data, especially in rocky and silty soils in the grasslands.

As part of this project, two scientific papers will be produced – one on the rich environmental history of the Korangadu grasslands, and another on the Soil Organic Carbon Sequestration potential of the grasslands.

The environmental history paper focuses on the privatization of the grasslands through an historic lens through comprehensive literature search, combined with the unstructured interviews conducted with the Korangadu owners in the field. The paper explores the arrival of pastoralists from the Kodagu region to the Kongu region in 1st and 2nd century AD, the pre-colonial land revenue system of the Paalayakkarars, which paved way for the tax remission (*ayen pillu vari*) and reduced grass taxes for newly acclaimed lands (*paravu pillu*) under the colonial regime. After Independence, the grasslands were given exemption under the Tamil Nadu Land Ceiling Act of 1961, which led them to exist unbroken in large swatches. The paper also explores the effect of technology, and other socio- cultural effects such as the importance of the Kangayam breed to the Korangadu grasslands. The second paper relating to soil carbon sequestration will be expanded with further analyses, especially with respect to the inter-relationship of vegetation, management parameters, dung beetles, and soil organic carbon. Non-metric multi-dimensional scaling analyses, and general linear models would be produced to better understand these relationships.

Statistical analyses had shown that live fencing supports more SOC as well as dung beetles in the Korangadu grasslands. However, mainly due to increased cost of labor in maintaining and mending live fences, more paddocks are converted to metal fences (personal interviews).

Mapping of the Korangadu grasslands over a period of time would help in understanding the land use and land cover change pattern in the region. Since the rise of the textile market, and increased availability of water through the Lower Bhavani Canal Project, and through newer borewells in the districts of Tiruppur, and Erode, already many grasslands were converted either into industrial areas or into agriculture (personal interviews). The existing grasslands are also under threat – especially with increased variability in climate, increased cost of labor, and other cultural and economic issues. Mapping of the grasslands would help better understand the land use pattern changes.

Besides that, carbon credits for grassland systems could also be explored in the Korangadu grasslands. Since these grasslands are privately owned, and the paddocks mostly individually managed, carbon credit systems could be more easily developed and distributed compared to commonly owned and managed grassland systems.

Figure 16: At Senaapathy Kangayam Cattle Research Foundation. Kuttapalayam, Tiruppur.

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