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RESEARCH PAPER

Ecology of Grasslands of Central Nicobar: Commons in a Sea of Change

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Abstract: The tropical grasslands of the Central Nicobar Islands have long been perceived as anthropogenic formations, which has influenced their conservation and management in the region. Despite their ecological and cultural significance, these grasslands have received limited scholarly attention, rendering them vulnerable to alternative land uses and conversion. This study aims to address these knowledge gaps through an extensive vegetation survey, soil analysis, and ethnographic research. The outcomes of the vegetation survey and soil analysis reveal that these grasslands are the result of serpentine soil formations, managed by Nicobari communities by fire. The ethnographic research reveals the cultural importance of the grassland commons and its governance through the *tuhet* system. Further, the study shows that the access regimes have undergone a rapid transformation during post-tsunami resettlement, endangering local instuitions and the sustainability of the grassland commons of the Nicobars.

Keywords: Tropical Grasslands, Vegetation Analysis, Serpentine Soils, Cultural Ecology, Nicobar Islands, Grassland Commons

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1. INTRODUCTION

The tropical grasslands of Southeast Asia stretch from the Arakan ranges in Myanmar to Papua New Guinea and Réunion Island in the Far East (Whitmore 1984). These grasslands harbour a vast biological diversity, a substantial chunk of which is endemic to different subregions of Southeast Asia (Corlett and Primack 2011). Home to diverse flora and fauna, these grasslands provide millions of people—mostly indigenous societies—with a livelihood (Dove 2004). This study is focused on the grasslands of the central Nicobar Islands, which are located in the Andaman and Nicobar archipelago and are considered to be part of the Sundaland biodiversity hotspot (Myers *et al.* 2000). These islands are also the critical commons of the local Nicobari communities.

1.1. Ecology of Tropical Grasslands

The tropical grasslands of Southeast Asia are unique ecosystems that present an ecological paradox. According to Schimper's classical definition of grassland ecosystems, grasslands occur only in low rainfall regions and in climatic conditions that are windy, dry, or where frost prevails, which prevents woody species from taking over (Schimper 1903). In contrast, these tropical grasslands occur in humid and damp conditions, wherein annual rainfall reaches above 180 cm with very little or no dry period (Kricher 2011; Osborne 2000). According to Beard (1953), tropical grasslands are not confined to any single climate, challenging the very idea of vegetation classifications based on climatic conditions.

In Southeast Asia—where regional climax formations are forested—grasslands are predominantly considered to be maintained by fire (Richards 1996). However, some studies indicate they persist as edaphic climaxes (Pemadasa 1990) or are maintained by frost (Joshi, Ratnam, and Sankaran 2020). Therefore, the distribution and persistence of tropical grasslands in Southeast Asia are loosely understood to be related to climatic conditions, human activity, and edaphic features (Pletcher, Staver, and Schwartz 2022), which makes it difficult to assign a singular determinant to these formations.

Based on the factors that govern their persistence, tropical grasslands are broadly categorized into two types: "derived" and "natural" (Gibson 2009). Many tropical grasslands are anthropogenic in origin, as they are created and sustained by human activities and are thus classified as derived. Regular maintenance and constant human intervention are required to sustain derived grasslands and prevent them from reverting to woodlands.

The other, more stable grasslands found in tropical rainforests are mainly edaphic in origin and are classified as natural. The determining factor in the

formation and sustenance of natural grasslands is the soil—or edaphic conditions—which acts as a limiting factor in preventing the development of forests (Richards 1996). Although these grasslands are also maintained by fire and human activity, they do not decline once anthropogenic activities cease. Natural grasslands are typically inhabited by more endemic species and are richer in species diversity than derived savannas (Garrity *et al.* 1996). Recent studies demonstrate that regardless of the nature of grasslands, they require more conservation attention owing to high endemism and because they are seen to be maintained by endogenous disturbance regimes (Nerlekar *et al.* 2022; Nerlekar and Veldman 2020; Sankaran 2009).

Several studies have been conducted to understand the origins of these grasslands and investigate the role of biotic and abiotic factors in the persistence of these ecosystems, and, yet, the debate continues (Meadows and Linder 1993; Moravek *et al.* 2013; Rogers 1994). Most of these studies describe these grasslands as anthropogenic grasslands, referring to the idea of landscapes created by humans for specific use (Goudie 1990). Those who do not support this theory instead describe these grasslands as Pleistocene glacial vegetation, which was maintained by early humans through burning practices (Bowman *et al.* 2013; Ellis 1985).

Another theory on the origin of these grasslands emerges from recent palaeoecological investigations conducted in the Southeast Asian region, which provide insight into the land bridges connecting Southeast Asian islands during the Last Glacial Maximum (LGM). During this period, the Sundaland landmass was significantly larger than its present-day configuration. These land bridges primarily featured savanna corridors that connected these islands. It has been proposed that after the LGM, as sea levels rose and these land bridges were submerged, remnants of ancient grasslands persisted in isolated pockets on certain islands (Voris 2000; Bird, Taylor, and Hunt 2005).

1.2. Grassland Commons of the Tropics

While there is extensive literature on grasslands as common property resources, most of the existing research is associated with grasslands as grazing commons or as a resource for livestock management. While this stands for most temperate and arid grasslands, tropical grassland commons are entirely different. Tropical grasslands, particularly those in Southeast Asia, are rarely utilized for livestock rearing. Thus far, these have mostly been referred to in the context of swidden practices and hunting (Dove 1984, 1983; Sherman 1980).

Unlike the temperate grasslands, the biocultural adaptations of indigenous societies here are not aimed at capturing sparse productivity through pastoral

practices, as the moist tropics are already high on primary productivity (Grace *et al.* 2001; Nangendo *et al.* 2002). Tropical grasslands from Southeast Asia to the Shola grasslands of Peninsular India are mostly managed by fire by indigenous societies by one method or another (Richards 1996; Whitmore 1984). These uses constitute grazing, foraging, and hunting commons, and they are reserved for local communities that have collective rights over these grasslands. These activities are managed through social institutions that earmark boundaries and usufruct rights that are assigned according to season and resource availability (Cordero *et al.* 2018). Most of these societies have been disenfranchised through the creation of protected area systems, as slash-and-burn practices are seen as unsustainable and destructive for ecosystems by conventional conservation biologists (Thung 2016; Vliet *et al.* 2013).

The sustainability of commons is governed by several variables, and of particular importance is the condition of the social institutions that manage them (Ostrom 1990). The social institutions that govern tropical grassland commons have hardly been studied. While cultural anthropological descriptions of the local uses of the grasslands of Southeast Asia exist (Dove 2004), these grasslands have not been adequately researched to explore the "agent-based" theories that are pervasive in the commons literature or the "structure-based" theories that emphasize the role of supra-individual groups on the forces that govern these commons. As Fairhead and Leach (1996) eminently demonstrate, the anthropogenic nature of these grasslands has been consistently misrepresented, disenfranchising the local communities and their active role in sustaining them.

Grasslands in the tropics are managed by controlled fires, which are often associated with swidden and hunting and organized by communities as part of festivals, usually before the onset of rains (Stott 2009; Wharton 1968). Direct benefits include the removal of brushwood, an increase in soil nutrients that benefit agriculture, and the harvesting of meat through the communal hunt, which forms a critical resource for the entire community (Marean 1997). This pattern seems to hold across the humid tropics (Fortier 2014). The burn season, burn area, and other rituals surrounding the process are usually controlled through traditional institutions, sanctions, and restrictions (Barnard 2002). The role of swidden practices in establishing "fire-climax" grasslands and the decline in forests and biodiversity is well studied (Henley 2011). The related decline in biodiversity is often attributed to the intensity of fires, fallow cycles, and invasive species.

The entire discussion on the tropical grasslands of Southeast Asia emphasizes their "improvement". Tragically, the most researched subject on the grasslands of South Asia is their elimination (Bagnall-Oakeley *et al.* 1996; Dove and Kammen 2015). An array of methods for the removal of these

grasslands have been deployed for the "improvement" of these areas ranging from herbicides and mechanical tillage to replacement plantations. The governance of these commons is least studied, and the local institutions and property rights associated with them have hardly been highlighted.

1.3. Tropical Grassland in the Western Ghats and Central Nicobar

In 1938, Ranganathan wrote an article on a similar kind of issue in the tropical grassland mosaic situated in the Nilgiri plateau, India, stating that frost acts as a hindrance to the establishment of montane forests—locally called *shola*s—in these grasslands. He argued that the saplings of evergreen forests cannot tolerate the frost and perish, creating space for grassland species (Ranganathan 1938). These findings have been rejected by Bor (1938). Several studies have been conducted to understand the ecosystem structure and vegetation dynamics of shola grasslands and forest ecosystems (Robin and Nandini 2012). Studies conducted by Ranganathan and Bor presented two distinct theories on the origin of the shola grasslands. Ranganathan (1938) classifies them as a natural grassland ecosystem where the vegetation has reached its climax stage, whereas Bor (1938) classifies them as anthropogenic grasslands created by indigenous communities (the Toda people).

Apart from this, several paleo-historical studies have also been conducted to identify the origins of these grasslands. Their findings suggest that although the grasslands existed before human habitation (Thomas and Palmer 2007), the present vegetative structure is influenced by human activities (Chandran 1997; Nayak, Vaidyanathan, and Krishnaswamy 2014). Recent studies have, however, re-established frost as a key determinant of the shola mosaic in Southern India (Joshi, Ratnam, and Sankaran 2020).

Apart from the shola grasslands, and other climatically determined grasslands of the Deccan plateau and north-western India in the Indian mainland, tropical grasslands are also found in the Nicobar group of islands in the Andaman and Nicobar archipelago. The origins of the grasslands of central Nicobar are shrouded in mystery and there are several theories and myths surrounding them. The most widely accepted theory, which is endorsed by government documents, posits that these grasslands are anthropogenic and relatively recent in origin. According to this prevailing theory, substantial modifications were made in land use by Danish settlers during the mid-nineteenth century, when the Danes held sway in the region, before British occupation. According to some authors, vast expanses of forested land were transformed into pasturelands, serving as cattle ranches to meet the demand for meat and dairy products (Saldanha 1989; Singh *et al.* 2001). However, other authors provide a contradictory view on the origins of these grasslands

and consider them to be permanent features maintained by constant human interventions (Kurz 1876; Nair 1979), pre-existing the Danish period (Haensel 1812).

The Nicobari community, which is native to the Nicobar Islands, has very little documented historical utilization of the grasslands in question. The Nicobari people predominantly inhabit coastal regions and their livelihoods are primarily dependent on activities such as hunting, gathering, fishing, and pig and chicken husbandry as well as the cultivation of coconut plantations and horticultural gardens for sustenance. While some of the central Nicobar Islands do host small populations of cows and wild water buffalos left by Danish people, these animals exist in a feral state (Imperial Gazetteer of India 1909). The Nicobari community does not engage in any systematic dairy or meat production as people do in mainland India, but, occasionally, they hunt these animals. The lack of discernible social and cultural ties between the Nicobari people and these grasslands has contributed to the classification of these habitats as unproductive in the eyes of the authorities and other organizations, rendering them susceptible to land-use changes.

1.4. Outline of Research Objectives

The ecology of the grasslands of central Nicobar, and their cultural ecology in particular, have never been studied in detail. This study has the following broad objectives:

(i) To understand the ecology of the grasslands of central Nicobar through a systematic investigation of the region's biogeographic affinities, soil chemistry, and traditional management systems.
(ii) To understand and document the cultural embeddedness of the grasslands in Nicobari society and the socio-political processes that drive their transformation in present times.

2. STUDY AREA AND METHODOLOGY

The study was conducted in the Nicobar Islands in the Andaman and Nicobar Islands, India. A detailed description of the study area and the methodology used in this study are provided in the section below.

2.1. Study Area

Located in the Indian Ocean, the Andaman and Nicobar Islands form an arc stretching approximately 550 km. These islands, characterized as oceanic, were uplifted during the tertiary period and have remained geographically isolated from the Asiatic mainland (Bandopadhyay and Carter 2017). Among these, the Nicobar group, consisting of 22 islands, is situated to the south of the Andaman Islands. Twelve of these islands are inhabited. The Nicobar

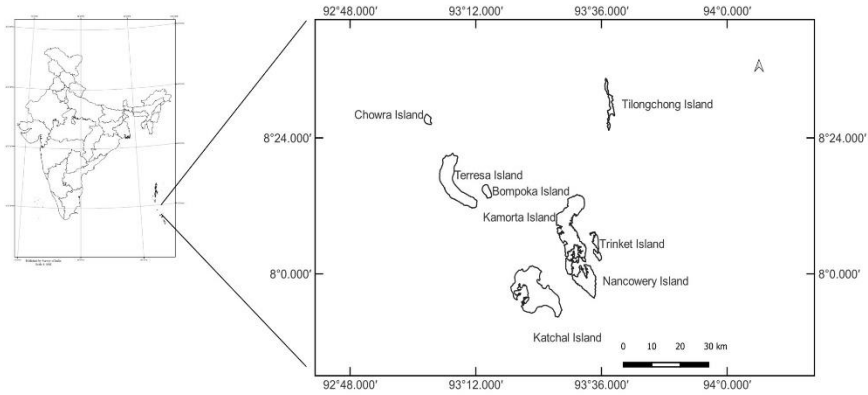
group of islands is divided into three administrative blocks/*tehsil*s: Car Nicobar, Nancowry, and Great Nicobar (Tehsil Statistics 2023).

The Nicobar group of islands hosts significant floral biodiversity, and its vegetation can be divided into two broad categories: a) a littoral zone, which comprises beach forests and mangrove forests, and b) an inland zone, which has three types of habitats: evergreen forests, deciduous forests, and grasslands (Hajra, Rao, and Mudgal 1999). The grasslands can only be found in five islands of central Nicobar, namely Chowra, Terresa, Bompoka, Kamorta, and Trinket—all located in the Nancowry tehsil (Kurz 1876) (Figure 1).

All five islands are inhabited by the Nicobari community, with 1,270 people living in Chowra, 1,934 people in Teressa, and 3,688 people in Kamorta (ORGI 2011). According to official sources, Bompoka and Trinket were assumed to be devoid of human population in the aftermath of the 2004 tsunami, but field visits conducted for this study showed evidence to the contrary.

All these islands fall under the purview of the Andaman and Nicobar Islands (Protection of Aboriginal Tribes) Regulation, 1956 (ANPATR), which supports the rights of indigenous communities over their land and natural resources, and allows outsiders to only visit these islands with a valid tribal area permit (The Andaman and Nicobar Gazette 1956).

Figure 1: Map of the Central Nicobar Islands



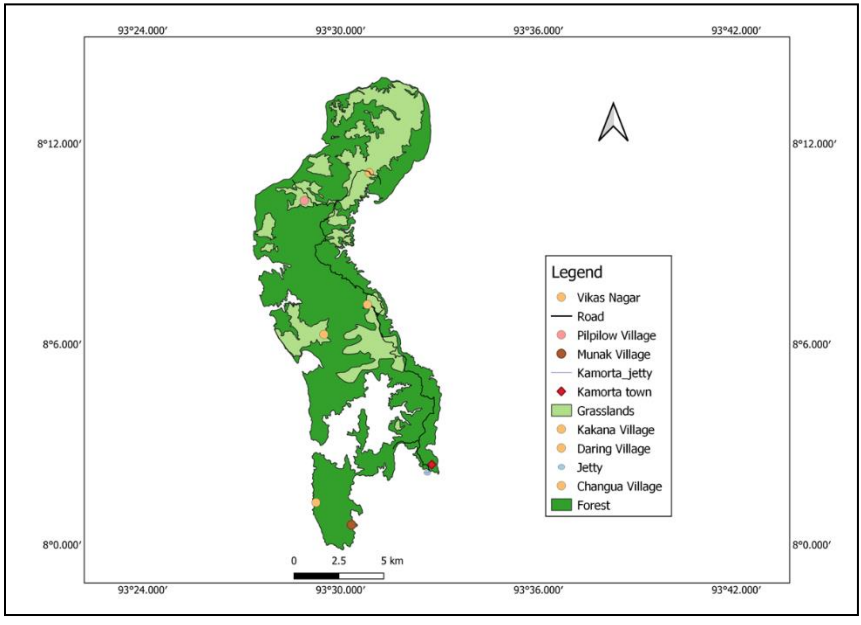
Source: Authors

Kamorta Island holds significant importance as it lies between the Trinket and Katchal islands, with Nancowry situated to its south, which makes it the safest harbour for anchoring ships in any kind of weather. The total area of

this island is 188.2 km², of which 38% area is covered in grasslands (Figure 2). The southernmost point of the island has been converted into a small township. It hosts the assistant commissioner's office, a police station, a hospital, a school, and a housing colony for government employees and holds a small floating population of government employees, migrant labourers, and small businessmen. Additionally, Kamorta functions as a naval forward operating base for INS Kardip of the Indian Navy, which is also based on the southern side of the island. Except for this southern area, the rest of the island has sparse Nicobari settlements, and the area under tropical forests, mangroves, and grasslands is divided between villages/*tuhet* (the Nicobari family structure has been explained in Section 3.4).

The natural harbour at Nancowry, created by this group of islands, has historically attracted traders and travellers who used Kamorta Island as a stock refilling station during their long journeys. In 1756, the Danes colonized the island group, establishing their headquarters on Kamorta Island, and made an early attempt to create a dairy and a settlement on the grasslands. However, their efforts were thwarted by several malaria outbreaks. Subsequently, when the British took over from the Danes, they initially attempted to establish a penal settlement in the Nicobar Islands—in the Kamorta–Nancowry harbour—before relocating it to Port Blair.

Figure 2: Map of Kamorta Island Showing Grasslands and Forested Areas along with Other Important Features



Source: Authors

Over time, Kamorta Island has undergone various changes due to regular contact with the outside world through travellers, merchants, colonial influences, Japanese occupation in the Second World War, and, finally, the Indian government. The tsunami of 2004 and the consequent relief efforts have had a dramatic impact on the islands; the islands and their people have struggled to revive their economy even after two decades.

2.2. Methodology

The objectives of this study were addressed through a mixed-methods approach, utilising primary survey data and secondary data from reports and other such resources. The detailed methodology used in this study is described in the following sections.

2.2.1. Vegetation Analysis and Soil Chemistry

A systematic, plot-based sampling method was employed to assess vegetation characteristics in Kamorta Island. Two areas were selected for the sampling based on a primary survey: the grasslands near Pilpilow village, which are managed by fire annually, and the grasslands near Kakana, where fire management practices were discontinued after 2004. The sampling design involved the use of wireframe plots, each measuring 1 m × 1 m. These wireframe plots were further subdivided into a grid of 16 equally spaced points. A total of 800 plots (400 each across burnt and unburnt areas) were systematically laid out within the study area, ensuring a consistent distance of 10 m between adjacent plots (Krebs 1999; Mueller-Dombois and Ellenberg 1974; Sutherland 2006).

Soil samples were collected from three strata of the grasslands—hill, slope, and valley from Pilpilow (burnt) and Kakana (unburnt). Samples were collected by maintaining a 50-m distance between each sample and using a soil corer to maintain uniformity between the samples. Although physicochemical properties and nutrients were analysed for all soil samples, the objective of this specific study was to test the soils for their 'serpentine' nature as a possible cause for the maintenance of grasslands. The soils were subjected to high-precision, inductively coupled plasma–mass spectrometry (ICP-MS), specifically focusing on calcium/magnesium and heavy metals. A total of twelve elements were analysed; however, in this paper, we present data for five elements—magnesium (Mg), calcium (Ca), iron (Fe), copper (Cu), and cobalt (Co)—which were integral to the study. Details of soil sample preparation and workflow for ICP-MS have been provided as supplementary information (Appendix 1).

2.2.2. Data Analysis

The field-based vegetation and soil data were subjected to statistical analysis using R Studio (Version 4.3.1)—with *Biodiversity R* and *vegan* packages—following standard ecological methods to estimate species diversity. Diversity indices—including Simpson's diversity index, Shannon's diversity index, and Pielou's evenness index—were used to analyse the species diversity of the plot-based data (Krebs 1999; Magurran 2009; Ricklefs 2000).

2.2.3. Ethnographic Survey

The social and cultural relevance of grasslands for the Nicobari community was studied primarily through ethnographic interviews supplemented with participant and non-participant observations (Atkinson *et al.* 2007; O'Reilly 2012). Field work for this study was conducted in three villages of the Kamorta Island—Pilpilow, Kakana, and Daring—for about 180 days across five years (2018–2023). The sample island and villages were selected following a preliminary survey in 2018, keeping in mind three key considerations: the presence of extensive grasslands, the existence of historical records, and cultural indicators of grassland management.

Key informants were identified for the survey after informal interviews and spending time with the community in all three villages. The first phase consisted of familiarization with the overall landscape and village activities through participant and non-participant observation, followed by resource mapping exercises. Subsequently, in-depth interviews were conducted in a mix of Hindi and Nicobari with the help of a local translator, who was bilingual and familiar with local Nicobari dialects (to adjust for local variations in the language since different islands use different dialects of the language). The field notes and interviews were recorded through conventional journals and, in some cases, the interviews were recorded with the permission of the resource persons (Atkinson *et al.* 2012).

Resource maps were made with the help of handheld GPS and key informants. These maps helped understand the location of resources and the division of habitats between families. All the data recorded through in-depth interviews were transcribed and processed through inductive coding. This research method was preferred because the interviews were taken without any prior notions about grasslands. Through the coding process, the data relevant to this study was extracted and the remaining data was coded and marked for future work (for details on the method see Saldaña 2016). Although the interpretation of ethnographic data for this study is presented through an emic approach, other perspectives on the implications of traditional resource management have been highlighted in the discussion section (Bergman and Lindgren 2018).

3. RESULTS

This section summarizes our observations based on the results of a primary survey conducted in the Nicobar Islands. We explore the vegetation ecology and cultural ecology of the grasslands, including specific details on vegetation composition, aspects of soil chemistry, biogeographic affinities, and the centrality of grasslands to the resource management systems of Nicobari communities.

3.1. Vegetation Ecology of the Grasslands of Kamorta Island

The grasslands of Kamorta encompass 38% of the island's land area; the remaining portion is characterized by tropical forests and mangroves. These grasslands extend over significant hilly and undulating terrains situated within the island's central region, occasionally interspersed with patches of tropical forests. Kamorta Island's grasslands prominently feature members of the Poaceae and Cyperaceae families. In total, the grasslands host a diverse ecosystem comprising 56 distinct species, consisting of both herbaceous and woody species.

The grasslands of Kamorta Island were historically maintained by regular fire management practices. However, after the 2004 tsunami, these practices were discontinued in certain areas and are still practised annually in others. In this study, we compare burnt and unburnt habitats to understand how a change in land management practices affects vegetation composition and the influence of edaphic factors in maintaining grasslands.

Table 1: Vegetation Composition Comparison Between Two Types of Grasslands: One Was Maintained Through Fire and the Other Discontinued the Fire Management Regime After the 2004 Tsunami

	Fire-managed	**Unburnt for 18 years**
Total species richness	42	37
Number of grass species	22	20
Grass cover (%)	85.19	73.85
Herbaceous and woody plant cover (%)	10.98	21.71
Species diversity (Simpson)	0.71	0.77
Species diversity (Shannon)	1.84	1.98
Evenness	0.48	0.54

Source: Authors

As shown in Table 1, we divided the Kamorta Island grasslands into two categories: one managed by fire annually and the other, which has been

unburnt for the last 18 years. Both areas have somewhat similar species richness, with 42 species in the fire-managed region and 37 species in the unburnt region; there was a similar number of grass species comprising the Poaceae and Cyperaceae families in both.

However, in the case of grassland cover, there were some dissimilarities between the habitats—the regularly burnt habitats seemed to support more grass cover (both Poaceae and Cyperaceae) compared to the unburnt grassland. A greater presence of other herbaceous and woody plant species was observed in the unburnt grasslands. However, the comparisons of grass cover and woody vegetation were not statistically significant (Kruskal Wallis test; grass cover $N = 400$; $p = 0.928$, and herbaceous and woody cover $N = 400$; $p = 0.58$). The difference in cover can be attributed to one species of fern (*Dicranopteris pedate*), which covers almost 10% of the land in unburnt habitats as compared to regularly burnt areas, where it covers only 1% of the area.

The diversity indices of both areas show similar results, with high diversity recorded in both habitats. Similarly, both areas reported similar levels of evenness, indicating that most of the species are evenly distributed, except for a few grass species such as *Imperata cylendrica* and *Scleria sumantresis,* which dominate the landscape in both habitats.

Figure 3: Grasslands with Bordering Forests on Kamorta Island. The Nicobari Refer to This Area as *Ryakhhipot* and It Is Managed by Fire Annually

Source: Authors

3.2. Chemistry of Serpentine Soils

The average concentration of select chemical components and heavy metals in 37 soil samples collected from different strata within the grasslands of Kamorta Island are presented in Table 2. The samples had distinctively low

levels of calcium and high levels of magnesium. As a result, all the soils sampled had extremely low Ca/Mg ratios, which is characteristic of ultramafic serpentine formations. Moreover, the samples showed high concentrations of heavy metals—Fe, Cu, and Co—in all three strata. All these characteristics point towards the serpentine nature of the soil, which is very low in essential elements and high in concentrations of heavy metals. which can restrict plant growth.

Table 2: Average Concentration of the Chemical Components of the Soils of the Kamorta Grasslands Divided into Three Strata, Showing Attributes Characteristic of Serpentine Soils

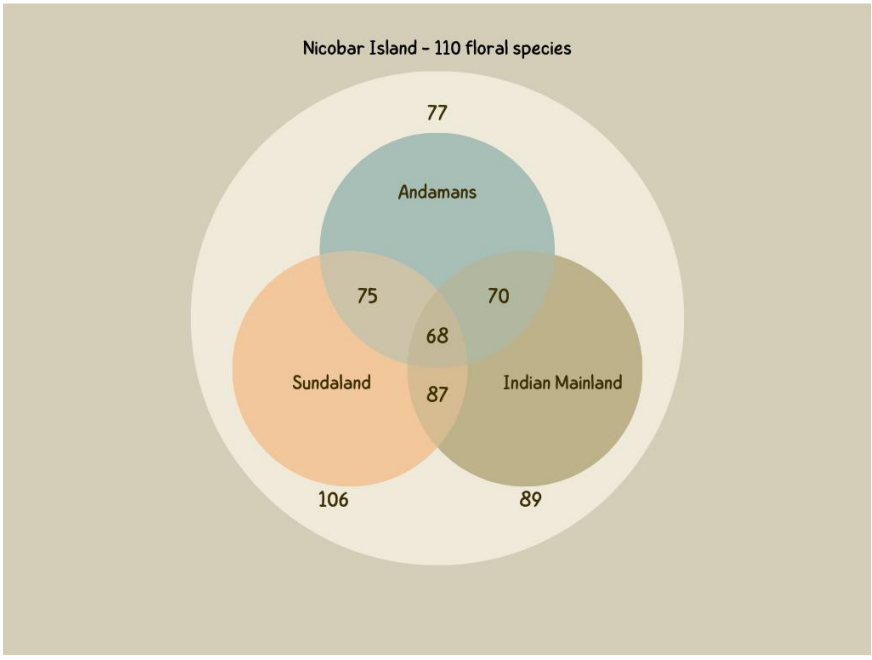
Locality	**No. of Samples**	**Mg µg/g**	**Ca µg/g**	**Ca:Mg ratio**	**Fe µg/g**	**Cu µg/g**	**Co µg/g**
Grassland Hill	11	8,429.4±731.99	275.9+34.17	0.033 ±0.01	68,004±14268.81	76.3±6.96	85.6±35.63
Grassland Slope	13	8,328.8±643.7	332+41.63	0.039 ±0.01	43,130.7±2423.58	65.9±4.94	37.9±11.42
Grassland Valley	13	8,083.4±1,196.55	566.3+34.49	0.070 ±0.01	38,689.9±4182.35	44.8±2.53	37.1±6.95

Source: Authors

3.3. Species Composition and Biogeography

The flora in the central Nicobar grasslands comprises 110 species, dominated by the Poaceae and Cyperaceae families. We distributed these 110 species across three biogeographical zones to understand the biogeographical affinities of the flora (for instance, as seen in Figure 3): Sundaland (consisting of the Southeast Asian regions of Sumatra, Java, Bali, the Malayan peninsula, and Indonesia), the Indian Mainland, and the Andaman Islands. Of the 110 species recorded in the grasslands of Nicobar, 89 species were found to be in common with the Indian Mainland, 77 with the Andaman Islands, and 106 with Sundaland. The grassland flora of Nicobar demonstrates a significant affinity to the Sundaic region, although 68 species of the 110 recorded were found to be common to all three regional floras (Kew 2023). These results indicate that the grasslands of central Nicobar are part of a larger, continuous formation of tropical grasslands across South and Southeast Asia.

Figure 4: Biogeographical Affinities of the Central Nicobar Grasslands



Source: Authors

3.4. Cultural Ecology of the Grasslands of Central Nicobar

Contrary to what has been reported thus far, this study demonstrates the centrality of the grasslands for the Nicobari community. In the Nicobari language, grasslands are referred to as "*kuisen*", a composite term derived from the combination of "*kui*", signifying "place", and "*sen*", denoting "grass". Within the Nicobari language, there exists distinct terminology for identifying various grass species as well as other nomenclature for defining activities related to grasslands. The traditional Nicobari village administration is organized in the following manner:

(i) Every village is headed by a chief who is referred to as the "captain".
(ii) Within the village, clusters of households form an aggregation called the *tuhet*, headed by a tuhet chief or the *mah-chyonyi*.
(iii) Within tuhets, family clusters are organized as *nyi*, which forms the basic household unit of the village.

The captains and "second captains" are elected much like the panchayat system in mainland India. Captains coordinate village-level activities with the formal administration—the *tehsildar* and the assistant commissioner of the sub-division. However, tuhet chiefs are the operational heads and are selected among the elders and active members of the community. Tuhet chiefs have

final authority on management decisions regards horticulture, forests, grasslands, and coastal resources, which they oversee through their traditional knowledge and skills as well as the collective wisdom of the tuhet. Tuhets are dynamic units and may be small or large and may have several households. Previous tuhets can lead to the creation of new tuhets because households may decide to start their own settlement.

The grasslands are managed as common property resources, with the tuhet chief settling territorial rights and dividing the area between tuhets. For example, in the Pilpilow, Kakana, and Daring villages, the tuhet acts as the primary social institution that regulates hunting, fishing, and other harvesting processes, which are managed according to the Nicobari calendar. The Nicobari calendar has two prominent seasons: *alfool*—the fair weather season when venturing into the sea is preferred, with a consequent harvest of resources from the sea (coastal and marine)—and *alsumaho*—which marks the beginning of the southwest monsoon wherein the sea becomes rough and coastal harvesting declines. During alfool, tuhet chiefs enforce restrictions on hunting in the grasslands as well as gathering specific resources from the land. With the onset of alsumaho, these restrictions are lifted, and people can start harvesting the land-based resources that had been restricted; this is usually initiated by burning grasslands (locally referred to as *ussah/issoh*).

Access to various resources is regulated, and there are taboos and restrictions on the use of grasslands. There are specific rituals that must be performed before the initiation of burning practices and the annual hunt. Violations are reported to the tuhet chiefs and often attract verbal reprimands and minor fines. In other words, a well-developed institutional structure exists for overall governance and natural resource use across the three villages surveyed for the study. In one of the interviews with a tuhet chief, it was revealed that post-tsunami resettlement has become a major hindrance in the management of the grasslands by fire (ussah/issoh). The village of Daring, in particular, has not been able to burn its grasslands for 18 years owing to the permanent shelters and other infrastructure that have come up on the grasslands.

Further, another captain of the Pilpilow village recounted the hardship the residents encountered because the permanent shelters had been built far from the original location of their homes, owing to perceived risks of future tsunamis. Yet another respondent from this village recounted how permanent shelters were designed differently from their traditional huts, which are constructed on props; this allows residents to keep poultry and pigs near the house. He explained that this was the main reason for the households to return to the coast and rebuild their traditional houses.

Figure 5: A Traditional House (nyi hupul) on the Island of Chowra; the Roof of the House Is Made of Grass Material Collected from the Community-owned Grasslands

Source: Author

3.4.1. *Nyi hupul* and the Importance of Grasslands

In Nicobari society and culture, the *nyi hupul* (Figure 4) assumes a pivotal role. Essentially, the term refers to a traditional circular dwelling constructed exclusively from locally sourced materials, abstaining from any foreign components. This ancestral edifice serves as a focal point for organizing significant festival ceremonies, hosts travellers arriving from various islands,

and serves as a communal meeting centre. According to a former captain of Kakana village, the construction of nyi hupul entails the utilization of diverse tree species found within the island's forests, mangroves, and grasslands. In cases where a specific tree species is not readily available on their island, the inhabitants embark on inter-island journeys to request a loan of the requisite timber. The traditional roofing of the nyi hupul predominantly comprised either the leaves of the nypa palm (*Nypa fruticans*) or a combination of indigenous grass species. As elucidated upon by the chief of Chowra island, the process of roof construction may necessitate the collection of grasses over three consecutive years, which are then meticulously secured to form the roof of newly erected nyi hupuls or for repair purposes. This grass-harvesting activity is exclusively undertaken by the women of the island; men refrain from participation. The captain of Pilpilow expounded that the grass roof, when compared to the nypa palm alternative, boasts greater durability, requiring fewer repairs over time.

3.4.2. Wild Pig Hunting and Grasslands

The Nicobar Islands harbour a species of wild pig (*Sus scrofa andamanica*) that lives in coastal, mangrove, forest, as well as grassland ecosystems. In central Nicobar, the females of the species use the burrows and grooves in tall grass found in the grasslands for breeding and rearing young ones. The high density of wild pigs in the grasslands provides Nicobaris with hunting opportunities, which they avail of by using an array of traps. In one of the traditional festivals celebrated annually—*kafas*—communal hunts are organized by tuhets and are an important activity, as the number of animals hunted on that day is seen as an estimate of productivity in the coming year. According to Abelson (name changed), a resident of Pilpilow village, people regularly visit the grasslands and search for the burrows made by female wild pigs to gather the young piglets and domesticate them. He clarified that when they go to capture the piglets, they do not take their hunting dogs with them, since they can injure or kill the young ones before they reach the burrows.

3.4.3. Management of the Grasslands by Fire

On the island of Kamorta, Nicobaris celebrate traditional annual festivals called kafas and *hinyan* (Tonol Sayeuh). Both festivals are performed when the season changes and the southwest monsoon approaches the Andaman and Nicobar Islands in June. Both the festivals focus on the theme of the changing season but are performed by different tuhet groups. The second captain of Pilpilow explained the backdrop of the festival. Nicobari people mostly depend on marine resources for their daily food consumption and a small dugout canoe made by traditional craftsmen is used for fishing activities. This canoe is reliable and can travel in open waters in fair weather.

In bad weather, especially during the monsoon season, when heavy winds prevail in the region, taking out the canoes in open waters is not possible. Therefore, in the monsoon season, which stretches from June to October, access to marine resources is limited. To avoid resource crunch during the monsoons, traditionally, restrictions are enforced on inland resources in the fair season—particular areas of the forests and grasslands are earmarked, and hunting wild pigs is restricted in particular areas. In this period, people were not allowed to consume, hunt, and collect certain species from particular areas, and it is believed that doing so would create some deformity in the body of the consumer. Kafas and hinyan are celebrated when the restrictions on particular food items are lifted; Nicobaris can consume any type of food in this season.

The festivities go on for a whole day, but the most important part of the festival is when a group of people go hunting and gathering. As a part of this process, a group of hunters visits the grasslands and performs ussah/issoh. Consequently, two things happen. First, the wild pigs hiding in the grasslands venture out and become easy targets for hunters. Second, since the smoke is visible throughout the island, it signals to the nearby islands that the festival is complete and the restrictions may be lifted. The Nicobari community believes that discontinuing ussah/issoh will lead to a decline in the productivity of the grasslands vis-à-vis the hunt and the resources of the freshwater streams that emerge from the grassland.

3.5. Post-tsunami Resettlement

The earthquakes and tsunami that occurred in the region on December 26, 2004, had a profound impact on many islands in the Indian Ocean, particularly on the Nicobar Islands. The earthquake that triggered the tsunami, measuring M_w 9.3 on the Richter scale, resulted in waves reaching up to 1,000 m inland, causing devastating destruction to coastal zones. The government data reported a staggering loss of over 3,500 lives as well as the destruction of coastal villages and plantations (Ramanamurthy *et al.* 2005; Sankaran 2005). The Nicobari villages, in particular, were severely affected, with many being completely washed off. Their crucial coconut plantations were also obliterated by the calamity.

This catastrophe left the affected communities heavily reliant on government agencies and organizations for relief and support. In response to the disaster, the Government of India formulated an extensive tsunami rehabilitation package for the Andaman and Nicobar Islands (Murty *et al.* 2006). A crucial element of this package was the construction of permanent shelters for the coastal villages that had been devastated by the tsunami. A total of 9,714 houses were built across the Andaman and Nicobar Islands in the following

years by the Central Public Work Department (CPWD) and the Andaman Public Works Department (APWD) (Press Trust of India 2006; Rawal, Desai, and Jadeja 2006).

The process of selecting suitable sites for constructing new houses for Nicobari communities involved seeking recommendations from the Department of Science and Technology (DST), Ministry of Science and Technology. Based on the DST's report, an elevation-based setback line for establishing new settlements was adopted. Consequently, all the new settlements were built on elevated land, maintaining 1.5 km from the high tide line to ensure safety against potential future tsunamis (Rawal, Desai, and Jadeja 2006). In the case of the central Nicobar Islands, that high tide line fell within grassland ecosystems in most of the cases. Consequently, permanent shelters—with other infrastructure such as schools, hospitals, and community centres—were built on the grasslands.

4. DISCUSSION

The observations from the previous section are analysed in light of the published literature to identify the nature of the grasslands of Central Nicobar, their embeddedness in the traditional resource management systems of the Nicobari, and the ramifications of the socio-economic transformation of the region after the tsunami of 2004.

4.1. Biogeographic Affinities and Vegetation Ecology

The vegetation composition of the Nicobar archipelago—where all the islands come under similar climatic conditions—typically supports tropical forests as climax formations, and the presence of grasslands in some of the islands has been a source of mystery for a long time (Hochstetter 1866). The demarcation between the forested areas and the grasslands displays a distinct and sharp boundary, which remains impervious to determination through climatic factors (Beard 1953) as mentioned earlier.

The grasslands of central Nicobar show floristic affinity to neighbouring regions, particularly Sundaland, with which it shares a significant proportion of species. The grassland vegetation is dominated by *Imperata cylindrica* and *Scleria sumtrensis*, which occur commonly across the South and Southeast Asian regions. Furthermore, the biogeographical affinity of the Kamorta grasslands in particular is high with Borneo (65%) and Sulawesi (60%)—both islands support serpentine outcrops similar to our study area (Galey *et al.* 2017). This is in line with botanical research observations on Nicobar Islands, which indicate that the overall flora of the islands has a stronger affinity to Sumatra than Andamans or mainland India (Hajra, Rao, and Mudgal 1999). Consequently, these grasslands may indeed constitute remnants of an

otherwise continuous distribution of such grassland habitats that occurred across Southeast Asia, formerly connected by land bridges during the LGM, which dates back to 20,000 years ago (Bird, Taylor, and Hunt 2005)(Bird *et al.* 2005). Some of these grasslands may have emerged during previous periods of arid climatic conditions and have persisted over time due to recurrent fire occurrences (Bird *et al.* 2005; Eden 1974; Voris 2000).

The soil analysis conducted in this study demonstrates that the grasslands of Kamorta are serpentine formations, which are characterised by extremely low Ca/Mg ratios and high concentrations of heavy metals, such as Fe, Cu, and Co, which are known to limit primary productivity (Brady, Kruckeberg, and Bradshaw Jr 2005; Galey *et al.* 2017; Mizuno *et al.* 2009; Whittaker 1954). In other words, as a primary condition, edaphic factors limit the development of forests in these grasslands, and these formations are indeed an edaphic climax (Jose *et al.* 1994).

The vegetation analysis conducted in this study demonstrates that annually burnt grasslands show higher, but comparable, grass cover and diversity parameters when compared to unburnt grasslands, which have been left fallow for over 18 years. This indicates that serpentine formations indeed prevent the development of forests even if grasslands are not managed by fire, further corroborating the hypothesis that the grasslands of Kamorta are edaphically determined and are not of recent anthropogenic origin.

In the case of the Southeast Asian grasslands, maintenance of these ecosystems by fire is common and has been practised widely by indigenous communities for thousands of years (Stott 2009; Wharton 1968). This disturbance regime controls the encroachment of woody species in the grassland system. However, in this process, species adapted to fire benefit over others and dominate the landscape in the process. For instance, *Imperata cylindrica* is a fire-tolerant aggressive species that dominates most of the tropical grasslands of the Southeast Asian region (Garrity *et al.* 1996). The grasslands dominated by *Imperata cylindrica* are often seen as unproductive wastelands in the eyes of authorities and government agencies. Thus, they mark these grasslands as available for development projects. This perspective overlooks the profound significance of the grasslands for local communities, as these ecosystems not only sustain livelihoods but also play integral roles in the social and cultural fabric of the society (Dove 1997).

4.2. Embedded Cultural History

This study demonstrates that the ecology and management of grasslands are deeply embedded in Nicobari culture. We see that the grasslands are a critical component of the coastal, horticultural, forest, and grassland resource base that Nicobari society depends on. We see that grassland management

activities—including burning—are managed by the tuhet and administered as a CPR (common property resources). The tuhet, as a social institution, regulates resource use, mitigates conflicts, and manages the Nicobari calendar of activities such as kafas. The festivities associated with the seasonal calendar, observed synchronously by tuhets, involve resource-sharing across villages and managing land and sea-based resources equitably. The entire grasslands of Kamorta were divided between the villages of Pilpilow and Daring and have historically been managed using traditional practices that are a part of the Nicobari calendar, beginning with the onset of alsumaho. This period is marked by synchronized burning of the grasslands and hunting, which were—and still are—practised in Pilpilow.

The cultural embeddedness of the grasslands and the traditional knowledge systems associated with their use and management make it amply clear that these grasslands are neither recent in origin nor decoupled from the "coastal culture" of Nicobari society. Research on tropical grasslands shows that these grasslands are maintained by human actions even though their origins may vary, except in the case of Kamorta.

Nonetheless, the ecological classification of the landscape as natural or anthropogenic seems futile and renders grasslands political and contested. It is noteworthy that past research on the region has failed to sufficiently highlight the role of these grasslands and their biocultural significance for Nicobari society, and, as a result, there is a conscious decoupling of Nicobari society in defining them as a coastal/horticulture stereotype. For instance, the importance of kafas and the way Nicobari society incorporates grassland management into their otherwise coastal/horticulture lifeworld has not previously been recorded in the literature. This omission, although regional, has been far from benign as we demonstrate in the next section.

The discourse on tropical grasslands in the last century has mostly focused on their lack of productivity and attempts to repurpose them for commercial plantations. Dove and Kammen (2015) lament the appalling lack of empirical research on the ecology of tropical grasslands, which has led to all forms of mythmaking and misappropriation all across South Asia. Further, they assert that "the needful grassland research has not been done or has been done in error or has been done correctly but without impact, is sociologically meaningful" (Dove and Kammen 2015, 64). This becomes particularly relevant for grasslands and the indigenous communities that depend on them all across the region, and for Nicobars as we observe in this study.

The anthropogenic nature of tropical grasslands has been the point of focus from which all ideas of betterment emerge. The grasslands of Southeast Asia have been victims of a "forest bias" that prevailed from the mid-nineteenth

to the mid-twentieth century—originally through colonial forestry—but persisting even in present-day imaginations of grassland management. Deleuze and Guattari (1987) point out that "arboreally oriented" western imaginations are in stark contrast to "rhizome-oriented" eastern thinking. From the standpoint of developmental agencies, both governmental and non-governmental, tropical grasslands offer an attractive avenue for resource allocation and investment in development initiatives. This trend has persisted since the colonial era and continues to be a prominent feature of contemporary governance. Many government policies and strategic plans, past and present, have framed tropical "anthropogenic" grasslands as problematic and have sought to supplant them with alternative land use practices (Anderson 1969; Buttel 2010; Coomes, Grimard, and Burt 2000; Greller 1995; Nyerges 1989; Stott 1991).

4.3. Resource Politics and Transformation of the Kuisen

As outlined in the results (Section 3.4), the grasslands of Kamorta are managed as CPR through an intricate system of rights involving the tuhets of Pilpilow and Daring. However, these arrangements have not been documented previously and, as a result, there is a knowledge gap amongst the research community as well as planners. Traditional management activities in these locations occur far from the visitors to Kamorta, as Pilpilow and Daring are among the farthest from the administrative headquarters. In short, the connection between Nicobari communities and the grasslands remained invisible not just to government officials but also to the research community. Consequently, the popular notion that these grasslands are anthropogenic and of recent origin prevailed and was perpetuated, and the fact of these being actively managed CPRs remained obscure.

Although ANPATR (1956) provides blanket protection to tribal communities and prevents their lands from being diverted to developmental purposes, the apparent non-use of these grasslands projected them as wastelands or unproductive lands that require active management and agricultural efforts. It is interesting to note that while the Forest Protection Act provides an umbrella of protection against unbridled development, it strictly applies to "forests" and not grasslands. As such, the act is only applied with mild intent since these are notified as tribal areas. While conservation biologists have regularly conducted research on wildlife and biodiversity in the region, significant attention has not been given to the grasslands. Hence, no one attempted to dispel the myths about these anthropogenic grasslands. In short, the functional and cultural dimensions of grasslands were simultaneously invisible to state agencies as well as to the research community.

Under these circumstances, the earthquakes and tsunami of 2004 unleashed mayhem in Nicobars. Survivors were moved to higher ground, in this case, into the grasslands, where temporary shelters were erected to secure their lives. As a national emergency was declared, the relief operation took precedence and the focus shifted entirely to rehabilitating the displaced people. Permanent shelters were built on the grasslands, along with roads and supporting infrastructure that did exist in the pre-tsunami era.

These resettlements have not only disconnected the Nicobaris from the coastline, increasing their hardship, but they have also disrupted the grassland commons and territorial arrangements. The settlers were now expected to engage in developing productive plantations in the grasslands, which they knew to be not productive and hence never attempted to raise plantations historically. The settlements (six villages with 360 houses and amenities) came up on the tuhet grasslands of Daring and Pilpilow and transformed the management of the kuisen forever. Daring tuhets had to stop the annual ussah completely and several Pilpilow tuhets had to restrict ussah to protect the new infrastructure that had come up on their grasslands. In short, over 18 years, the land tenure arrangements of the CPR have been transformed completely, with possible long-term consequences for the Nicobari villages of Kamorta. Similar changes have occurred in the neighbouring islands of Teressa, Chowra, and Trinket in the central Nicobar Islands that harbour grasslands.

The sustainability of grassland commons in the Nicobar Islands will be at risk if institutional arrangements and resource management regimes are not revived. As observed in this study, the Pilpilow grasslands that have not been burnt are now mostly dominated by hardy grasses and forbs, including *Dichranopteris*, an aggressive fern which has now taken up about 10% of the unburnt area. The access regimes of the tuhets of Pilpilow and Daring have been altered drastically, disenfranchising communities from critical grassland resources. The experiences of the other communities inhabiting tropical grasslands in Southeast Asia have mostly been one of dispossession due to agroforestry projects and other improvement efforts, most of which, notably, have failed (Keijiro, Suyanto, and Tomich 1997)

Simultaneously, these efforts fail to recognize these grasslands as products of human society sustained through conscious will and not merely depauperate ecosystems (Dove 2019). As has also been shown in the case of the forest grassland mosaic of Southern India, colonial policies of "foresting the grassland" indicate misrepresentation and poor understanding of grassy biomes and have resulted in large-scale transformation of these ecosystems (Joshi, Sankaran, and Ratnam 2018). It would be useful to understand the complex relationship of the Nicobaris with kuisen in terms of the space–

society dialectic where each shapes and transforms the other (Soja 1980). With the arrival of built infrastructure and settlements in the grasslands, the "bundle of powers" (Ribot and Peluso 2003) now moves to the administration, indicating a permanent shift in the management of Nicobar's grasslands.

5. CONCLUSION

This study examined the ecology of the grasslands of the central Nicobar Islands, in general, and Kamorta Island, in particular, to understand the species composition and origins and their cultural significance for the Nicobari community. Through a detailed analysis of species composition and biogeographical affinities, we conclude that these are part of an extensive formation of tropical grasslands that are in continuity with similar formations in the rest of Southeast Asia. In line with contemporary thinking that classifies grasslands as biomes, we concur that physiognomic classifications are limiting in their ability to describe such formations; compositional analysis is much more insightful in inferring history and biogeography (Veldman 2016).

Through a detailed high-resolution analysis of soils, we conclude that the Kamorta grasslands are located on a serpentine outcrop, which has resulted in edaphic conditions with very low Ca/Mg ratios and high concentrations of heavy metals that limit plant productivity. We conclude that the grasslands of Kamorta are edaphically limited and, hence, "natural" in origin (*sensu* Gibson 2009). Further, based on a comparison of grasslands under different management regimes (burnt annually versus unburnt for 18 years), in terms of their species diversity and composition, we conclude that even after forgoing fires for such a long time, the overall composition of these unburnt grasslands is comparable to burnt ones.

Ethnographic research on the Nicobari community reveals the centrality of grasslands in their resource management matrix, which demonstrates that these grasslands are indeed CPRs managed by the traditional tuhet system that regulates its access and use. Our results demonstrate the embeddedness of the grasslands in the Nicobari culture, suggesting a long history of co-evolution. We find that post-tsunami settlements in grasslands have changed the access and tenure arrangements of central Nicobar, with perhaps long-lasting impacts on the ecology and overall management of grassland commons.

The long-standing colonial forest bias that renders tropical grassy biomes "unproductive" and in need of improvement has been debunked in the last two decades through grassland research. Based on current thinking and observations made in this study, we recommend that there is a need to move

beyond natural/anthropogenic classifications and prioritize the conservation and sustainable use of Nicobar's grasslands regardless of their origins. Empowering the tuhet system and reviving traditional management practices could perhaps offset some of the recent tenurial rearrangements.

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Ethics Statement: I hereby confirm that this study complies with requirements of ethical approvals from the institutional ethics committee for the conduct of this research.

Data Availability statement: The data used to support this research is available in a repository and the hyperlinks and persistent identifiers (e.g. DOI or accession number) are stated in the paper.

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APPENDIX 1

Soil analysis through ICP-MS

Method developments and services in ICP-MS (Agilent 7800)

Inductively coupled plasma mass spectrometry (ICP-MS) is a type of mass spectrometry that is used for elemental analysis and detecting trace metals and non-metal ions in a sample. A summary of the instrument's profile and the workflow is provided here: https://www.agilent.com/Library/slidepresentation/Public/ASTS_2015_AtomicTour_7800_ICPMS.pdf

For this study, the workflow has been adapted to quantify macro and microelements in the plant/microbial samples.

Sample preparation with microwave-assisted digestion

Approximately 100–200 mg lyophilized/oven-dry homogenized plant tissue or soil sample was weighed and transferred to the digestion tube. 8 mL of ready-to-use 70% nitric acid was added. In the case of liquid samples, such as bacterial culture media/plant exudates, 5 mL of nitric acid was added to 5 mL of the sample. Vessels were then locked properly, arranged in the vessel rack, and placed in the microwave digestion system for the proper digestion of the samples. The parameters were optimized according to the sample type, as well as the number of samples.

Table A1: Method Optimized for Sample Digestion with 70% Nitric Acid in the Microwave Digestion System.

Vial	**Xpress**
Power	1600
Ramp Time	25:00 Min
Hold Time	40:00 Min
Temperature	180°C
TempGuard	210°C

Source: Authors

Upon completion of the digestion process, vessels were allowed 120 minutes. Digested samples were then transferred to 50 mL of falcon tubes. Volume make-up was done up to 50 mL with fresh MiliQ water. Further, 1:10 dilution was done using 2% nitric acid in MiliQ water. This diluted sample was then filtered using a 0.25µ filter to remove any undigested/contaminating particles.

For relatively hard tissues, 2 mL of hydrochloric acid was used along with 8 mL of nitric acid for the proper digestion of the sample.

Elements that can be measured in the sample with this digestion method: Ag, Al, As, Ba, Be, Ca, Cd, Cd, Co, Cr, Cs, Cu, Fe, Ga, K, Li, Mg, Mn, Na, Ni, Pb, Rb, Se, Sr, Tl, U, V, P.

3.2 ICP-MS analysis method development

The instrument utilizes extremely hot inductively coupled argon plasma for atomizing/ionizing any sample for trace element analysis. Operating conditions for plasma and ICP-MS were optimized as follows:

- RF flow: 1,550 W
- Nebulizer gas flow: 1.08L/min
- Nebulizer pump: 0.10 rps
- Omega lens: 8.4 V
- Helium gas flow: 4.0ml/min
- Count replicates: 3
- Energy discrimination: 30 V
- Extract 2: 190 V
- Xpress: 1,600; at 25:00 min, at 40:00 min, at 180 °C, at 210 °C

APPENDIX 2

Table A2: List of Permanent Shelters Made on Kamorta Island by the Andaman Public Work Department (APWD) in the Rehabilitation Process After the 2004 Tsunami

Village	**No of permanent houses**
Chotainak	36
Badainak	26
Vikas Nagar	53
Kakana	80
Pilpilow	101
Daring	64
Banderkari	23
Changua	32
Munak	45
Al uk Heak	7
Total	**467**

Source: Authors