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RESEARCH PAPER

Spatiotemporal distribution and diversity of plant communities in post-fire sites of Mt. Iglit-Baco Natural Park (MIBNP), Occidental Mindoro, Philippines

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ABSTRACT

The existing monitoring strategy of Mts. Iglit-Baco National Park (MIBNP) employ extensive use of fires. These practices are hypothesized to hinder the natural succession from grassland to forest. To address these concerns, a biodiversity assessment utilized incidence-based sampling with nineteen repetitions from 2020–2021 across five sites within the Core Zone of Monitoring. A total of 77 species belonging to 27 families were documented. Spatiotemporal post-burning biodiversity trends exhibit the pattern of dominance of certain introduced and native plant species such as *Themeda gigantea* for site 1, *Chromolaena odorata* for site 2, *Themeda triandra* for site 3, and *Imperata cylindrica* for sites 4 and 5. These results facilitated a deeper understanding of the progression of changes in species composition as an impact of burning practices through space and time.

Keywords: disturbance, landscape ecology, plant regrowth, protected area, pyroecology, successional diversity gradient

РЕЗЮМЕ

Собрамонте-Маглипон П.А., Луис Хоакин М. Ракиза Л.Х.М., Пунонгбаян-Канделария Н., Клаудио-Парагас С.И., Рейес Ф.М.М, Гил Ф.Г., Шютц Э., Дагамак Н.Х.А. Пространственно-временное распределение и разнообразие растительных сообществ на участках после пожаров в природном парке горы Иглит-Бако (MIBNP), Оксидентал Миндоро, Филиппины. В рамках существующей стратегии мониторинга Национального парка Горы Иглит-Бако (MIBNP) широко используются выжигания. Предполагается, что такая практика препятствует естественной сукцессии от луга к лесу. Для решения этих проблем в ходе оценки биоразнообразия использовался метод выборочного контроля на основе частоты встречаемости с девятнадцатью повторами в 2020–2021 годах на пяти участках в основной зоне мониторинга. Всего было зарегистрировано 77 видов, относящихся к 27 семействам. Пространственно-временные тенденции биоразнообразия после выжигания демонстрируют доминирование некоторых интродуцированных и местных видов растений, таких как *Themeda gigantea* на участке 1, *Chromolaena odorata* на участке 2, *Themeda triandra* на участке 3 и *Imperata cylindrica* на участках 4 и 5. Эти результаты позволили глубже понять динамику изменения видового состава под влиянием практики выжигания в пространстве и времени.

Ключевые слова: нарушение, ландшафтная экология, восстановление растений, охраняемая территория, пироэкология, градиент сукцессионного разнообразия

Mindoro is known for having a vast array of biodiversity, with high endemism and a unique biogeographical identity (Lit Jr. et al. 2011). The floral composition of Mindoro was initially studied by Merrill (1907). Upon her assessment of Mt. Halcon, she established a preliminary list of the existing plant species on the island. However, there were only a few studies about the flora assemblages of Mindoro that followed despite the growing interest in the island because of restrictions on the conservation of endemic tamaraws and their habitats. These studies include Merritt's (1908) characterization of Mindoro's Forest, Merrill's (1946) fern and flowering plant identification, and a fieldwork report on the island by Conklin (1949), to name a few. Fortunately, by the 1970s, botanical studies, such as the study on common plants mainly used by the Tau-Buid tribe (Pennoyer 1977) and the ethnobotanical study by Mandia (1987), among others (Buot et al. 1990, Gascon 1998, Mandia 1998) had significantly increased as the flora and fauna diversity, as well as abundance on the island, came into light. However, the natural habitat of these organisms was steadily declining

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because of various detrimental anthropogenic practices; due to this, Mts. Iglit-Baco Natural Park (MIBNP) was proclaimed as a Protected Area (PA) in November 1970, taking into account that it is a tamaraw reserve by virtue of Republic Act No. 6148. MIBNP was also declared one of the 32 national parks in the Philippines by the National Integrated Protected Area System (NIPAS) Act of 1992. In relation to this, a recent study by Malabrigo, Jr., and colleagues (2022) identified plant species, determined the number of noteworthy species, and described the forest structure. Similarly, Villanueva & Buot (2015) were able to publish two separate studies, one of which established a list of threatened plant species in Mindoro, and the other investigated documenting valuable plants of the Alangan Mangyan community, which had direct implications for ethnobotanical research (Villanueva & Buot 2021).

Along the PAs of MIBNP, different studies whose main goal is to assess the different types of habitats present and their dynamics under current management to prepare, predict, and guide local authorities toward a shift in habitat management, especially a phase-out of grassland burning inside the area of the annual tamaraw population count and the elaboration of a habitat restoration plan (see report of Monge 2019). As of this date, challenges posed by invasive plant species have led to emphasizing the importance of conserving the remaining forest habitats within MIBNP. Specifically, the study by Bonefant et al. (2019) identified two particularly concerning invasive species: *Saccharum spontaneum*, and *Chromolaena odorata*. Both are widespread, allelopathic (Tadios-Ayson et al. 2024, Dogra et al. 2009, Sinha et al. 2022, Ooka & Owens 2018), and unpalatable to herbivores (Mligo 2006). These allelopathic properties negatively impact the growth and survival of other plants, posing a significant threat to traditional Tau-Buid agricultural practices that rely on these lands (Pertin et al. 2018). Their American origin (similar to hagonoy) suggests a potential introduction pathway, and further investigation into their dispersal mechanisms and potential control methods is warranted.

Another introduced species, lantana (*Lantana camara*), known for its invasive tendencies across various regions (Day et al. 2003, Gooden et al. 2009, Kohli et al. 2006, Sharma et al. 2007), was fortunately only found in one quadrat at a higher elevation (465 meters). This limited distribution suggests that elevation might be a natural barrier for this species. However, observations of lantana clumps near lower-elevation footpaths and Indigenous kingpins warrant further monitoring to prevent its potential spread. While grasslands dominated the MIBNP landscape, the ecological significance of these areas deserves reevaluation. The project identified cogon (*Chromolaena*), talahib (*Saccharum*), and various *Themeda* grasses (*T. triandra*, *T. arguens*, and *T. gigantea*) as the dominant species based on measurements like species dominance index (SDI) and cover. The extensive coverage of these grasslands resulted in nearly three-quarters of the sampled areas being classified as such, even with a stratified random sampling approach employed. However, despite the larger sampling effort dedicated to grasslands due to their prevalence, statistical analysis revealed a clear pattern: forested habitats supported significantly higher species richness than grasslands, particularly after fire events. Interestingly, the number of species recorded in grasslands was slightly lower than that of forests and secondary forests. This seemingly contradictory finding highlights the limitations of relying solely on species richness as a measure of biodiversity. The primary difference likely lies in the dominance patterns within these habitats. Furthermore, forested habitats harbored one more habitat-restricted species despite their smaller size. This observation, coupled with *ad libitum* observations that documented a wider variety of species within forest fragments (including trees, flowering shrubs, lilies, orchids, and parasitic plants), suggests that a more extensive sampling of forested areas, limited by both geographical extent and indigenous access restrictions, would likely reveal a significantly higher species count.

The species composition was deemed fundamental to relevant issues. It was subject to investigation to better grasp both the tamaraw ecosystem and the protected area management, as well as a key reference to baseline information on their fire-disturbed habitat diversity and structure. Furthermore, previous records of MIBNP flora are limited. Because of the concurrent work of the same parties in preparing the Protected Area General Management Plan, recognizing the park's floral diversity, species composition of its habitats, and community dynamics are greatly necessary. Thus, the main goals of this study are to (i) determine the plant communities occurring within the plots, (ii) quantify the diversity among different sites and periods of collection by calculating for diversity indices, and (iii) investigate the pattern of dominance among plant species across the five accessible sampling sites of MIBNP.

MATERIAL AND METHODS

Study site

Mindoro, the seventh-largest island in the Philippines, is bounded by two provinces: Oriental Mindoro and Occidental Mindoro. Because of its distinctive vegetation and wildlife, the island is considered a diverse biogeographic region. Specific areas within the province are protected under the National Integrated Protected Areas System (NIPAS) Act of 1992 to safeguard the unique biological species thriving in their respective habitats (DENR-Biodiversity Management Bureau 2013). One is MIBNP (12°54'N 121°13'E), located at the central spine of Mindoro Island. It was designated as a protected area (PA) in 1970 as declared under Republic Act No. 6148. Moreover, it is an ancestral domain to the Tau-buid, an indigenous tribe, and an ASEAN Heritage Park. It stretches through four municipalities in Occidental Mindoro, namely Sablayan, Calintaan, Rizal, and San Jose, and five municipalities in Oriental Mindoro, those being Pinamalayan, Gloria, Bansud, Bungabong, and Mansalay (Fig. 1). The lowland dipterocarp flora species, grassland communities, and montane rainforests on the higher slopes comprise most of the park's vegetation. In total MIBNP spans 97 000 ha. Within this total land area, five sampling sites were established, namely: (1) "Anyayos", (2) "Magawang", (3) "Tangle", (4) "Lanas", and (5) "Namara",

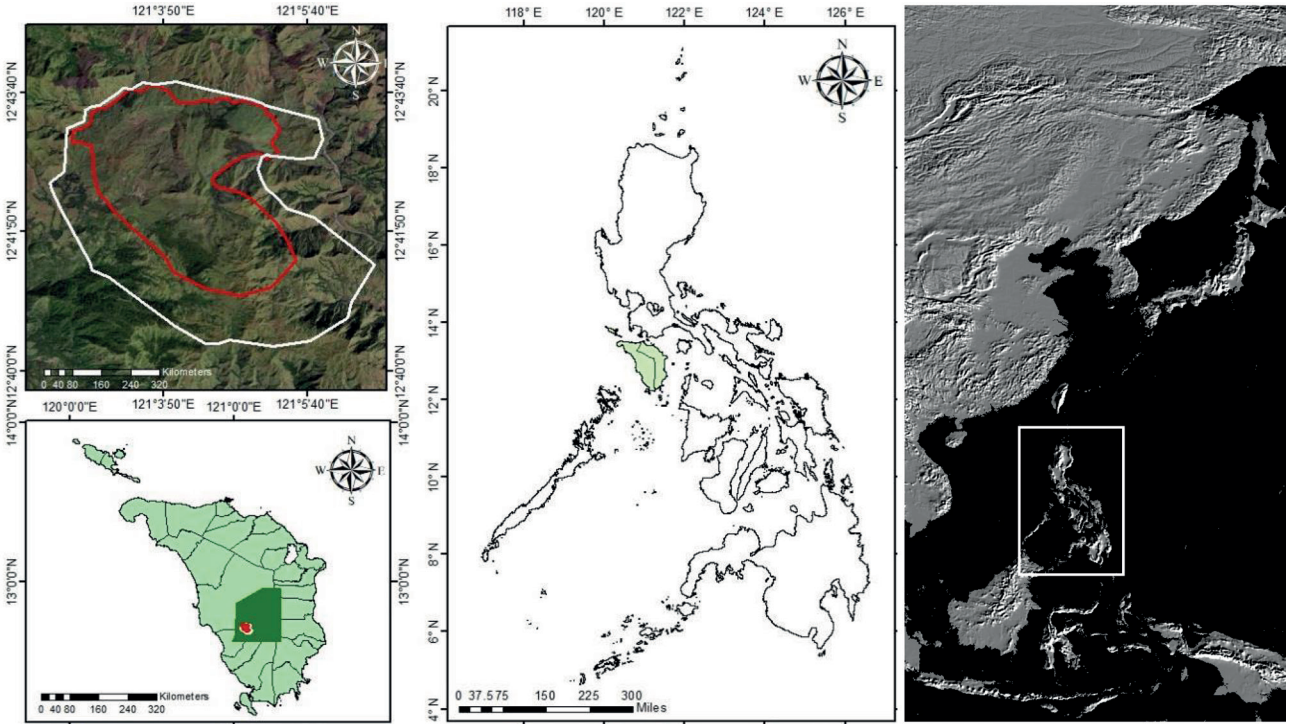

Figure 1 Map showing the study area in Mindoro Island

which represent the Northern, Central, and Southern areas of CZM that spans 2200 hectares (ha) (Fig. 2).

Photo documentation of plant species

The documented plant species were first verified against the established reference database curated in 2019 by D'Aboville Foundation. The comprehensive catalog included scientific names, their respective Tau-Buid vernacular designations, as well as photo voucher specimens exhibiting either or both vegetative and reproductive features of the plant. Second, photo documentation was carried out during two field surveys in September 2023 and April 2024. The plant species listed in the habitat assessment of DAF were photo-documented to create a separate comprehensive visual database of plant species within the five sites in MIBNP, with the assistance of local guides, including a tribal elder and two forest rangers, who possess extensive knowledge of the study area and expertise in the local flora. Standardized photographic techniques in accordance with Gómez-Bellver et al. (2019) were followed to establish consistency in image quality, including considerations for lighting, framing, and angles. A systematic organizational system to categorize and manage the photographs effectively was established to facilitate data management. The photo database was designed as a structured system that stores plant images alongside associated metadata, including species' local and scientific names, coordinated, and the documentation date (Joly et al. 2016). In terms of data management, a secure data backup and storage system to safeguard against data loss ensured the longevity of research efforts.

The photo analysis phase involved organizing images according to their photo code to ensure clarity and accuracy. The identified plants were initially determined based on the given local names alongside plant images, which were cross-

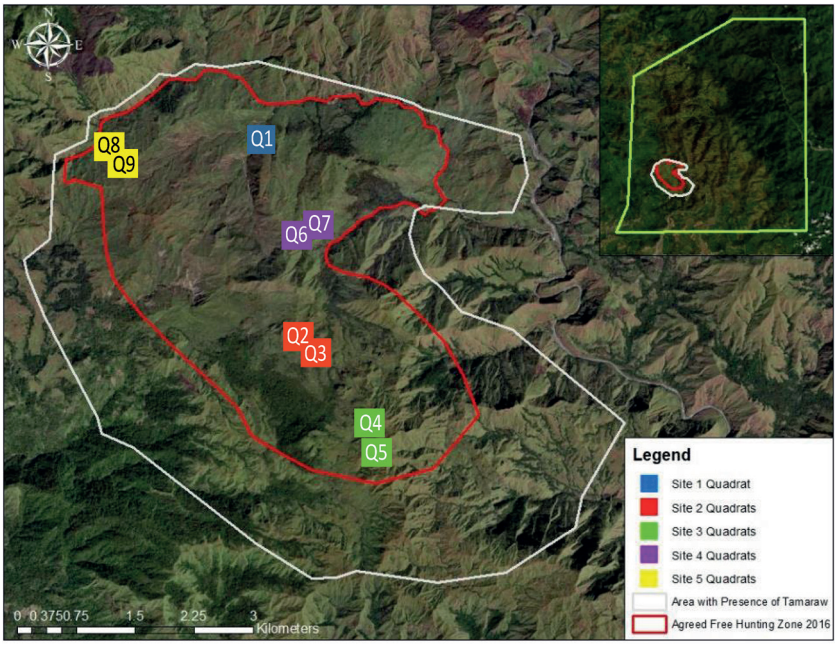

Figure 2 Sampling map in Mts. Iglit-Baco National Park shows the five collection points where the quadrats were established in the Free-hunting zone

referenced. To match the local name to its universal scientific name, the recorded plant species were uploaded to Pl@ntNet, a citizen science platform for plant identification. It is a web-based system designed for image recognition to enable non-specialists to have a two-way means to contribute valuable botanical data (Joly et al. 2016). Succeeding this, online botanical databases guided the identification and reference works such as Caton et al. (2010), Donayre et al. (2016), Merrill (1903), and Quisumbing (1951). Acquiring physical plant sampling within the study site was strictly prohibited per the Indigenous communities' rules and regulations. This application served as a supplementary medium to support the identification process by providing potential matches based on image recognition algorithms. Ethical considerations played a significant role in the research, considering the study site is protected. Plant photography documentation practices were guaranteed to align with ethical and conservation principles. Obtaining necessary permits and permissions for data collection will be a priority. The confidentiality and intellectual property entitlements of the authorities, indigenous communities, and experts involved in the research will be honored and upheld.

The final verification of documented plant species involved confirmation by a licensed forester with expertise in the local flora. The methodologies employed to carry out the multi-step verification process which combined reference database checks, plant photo voucher specimen from field surveys, and citizen science through the use of application assistance, as well as expert verification, all aimed to limit identification errors and ensure the accuracy of the species inventory.

Temporal species turnover

The foliar cover, or cover index, of each species within respective quadrats per site, was assessed using a visual estimation method that utilizes a numerical scale of 5 categories, each corresponding to a particular range of vegetation cover. 1 denotes cover index of 1–5 %, 2 for 6–25 %, 3 for 26–50 %, 4 for 51–75 %, and 5 for 76–100 %. Plant cover estimation was numerically standardized by quantifying the extent to which a particular plant species covers the vegetation plot. This, in turn, was used to generate a series of heat maps. A similar approach was used by Mucina et al. (2005) and Seabloom et al. (2014) to estimate the percentage of the species' ground cover over a specific quadrat by assigning a similar scale of 1–5.

Data analyses

The species composition in each site was initially documented by considering existing species determined on the sampling date to account for their diversity. Microsoft Excel sorted and organized the incidence-based data across the five sites. Following this, the Paleontological Statistical Software (PAST 3.20) (Hammer et al. 2001) and vegan package in R Studio were utilized to calculate several alpha diversity indices, including the Margalef richness index [eq. 1], the Shannon-Weiner index, and the Simpson's index. Margalef index takes into account richness rather than the abundance of the individual per species – this suggests that the higher the index value, the greater the number of species (Gamito 2010). The second index denotes the degree of uncertainty in predicting a species community at random; hence, when the Shannon-Weiner index is high, species prediction is deemed lacking (Shannon 1948, Ludwig et al. 1988, Magurran 2021). Simpson's index, by contrast, is the likelihood of encountering two separate individuals in a community. As a result, a high value for this index indicates a high probability of encountering two different species (Simpson 1949) [eq. 2].

$$\text{Margalef Richness Index} = (S\text{-}1)/\ln(n) \quad \text{[eq. 1]}$$

$$D = 1 - \sum_{i=1}^{S} \mathrm{P_i^2} \quad \text{[eq. 2]}$$

S denotes the number of species present per quadrat; *N* represents the total of the number of the presence of a species throughout all the replicates; Pi is the relative incidence of a particular species (Gamito 2010, Shannon 1948, Simpson 1949). In addition to this, neighboring joining cluster analysis based on Jaccard index [eq. 3] was performed in the PAST software as well to account for the beta diversity.

$$\mathrm{C_j} = \frac{\mathrm{j}}{(\mathrm{a+b-j})} \quad \text{[eq. 3]}$$

The symbol j represents the number of species shared by different sampling units or replicates; a and b are the number of species in varying samplings, respectively. Jaccard's index, denoted by Cj, explicates $0 < Cj < 0.25$, which indicates significant dissimilarity, whereas $0.25 < Cj < 0.50$ indicates moderate dissimilarity, followed by $0.50 < Cj < 0.75$, indicating a moderately similar clustering, and $0.75 < Cj < 1$ denoting significant similarity (Baselga & Orme 2012). Species accumulation curves were constructed for each site and all sites combined using EstimateS software. Through such visualization, the exhaustiveness of the sampling effort captured the total number of species present in the study area. The curves were generated using the rarefaction method with default settings within the software.

RESULTS

Species richness

This study investigates the short-term changes in plant communities in a frequently fire-disturbed landscape. Through such assessment, a total of 77 plant species across the five investigated sites within the CZM of MIBNP were documented, of which 11 (14.29 %) could be identified with Tau-Buid names only and are yet to be given proper scientific designations. These are Alsyawe, Famotos, Loblob, Meot, Nangura, Okra-okrahan, Pino, Tagbal, Talawak, Talinga, and Upos bulaho. From this, 66 species (85.7 %) were positively identified at least until genus level. These documented species belong to 27 families and 59 genera. To facilitate a clearer interpretation of this data, this aspect of the study was partitioned into two equal aspects, namely, spatial (focusing on the sites) and temporal (focusing on the replicates) dimensions. Of the 66 species, 44 were native, and 21 were introduced (see Table 1).

The Poaceae family has the highest number of species with 11 species representing the family. The asters (Astera-

Table 1. Species identification and their status, native (Nat) or introduced (Int), across five sampling sites in the CZM within MIBNP

Taxon	Tau-buid Name	Status	Site				
			1	2	3	4	5
Poaceae							
Themeda arguens (L.) Hack.	Agyon	Nat		+	+		
Chrysopogon aciculatus (Retz.) Trin.	Amorsikos	Nat		+			
Setaria parviflora (Poir.) Kerguélen	Bayotbot	Int		+	+		+
Sorghum nitidum (Vahl) Pers.	Busareg	Nat	+	+	+	+	+
Imperata cylindrica (L.) Raeusch.	Cogon	Int	+	+	+	+	+
Miscanthus sinensis Andersson	Ene	Nat			+	+	
Miscanthus floridulus (Labill.) Warb. ex K.Schum. & Lauterb.	Falto	Nat	+				+
Saccharum spontaneum L.	Sigbo / talahbib	Nat	+	+	+	+	+
Themeda gigantea (Cav.) Hack. Ex Duthie	Tanglad-tangladan	Nat	+				
Cenchrus ciliaris L.	Turbo	Int		+		+	
Themeda triandra Forssk.	Yago/ Samongsamong	Nat	+	+	+	+	+
Asteraceae							
Galinsoga parviflora Cav.	Budbulay	Int	+				+
Mikania micrantha Kunth	Budbuyo	Int	+				+
Chromolaena odorata (L.) R.M.King & H.Rob.	Bungarngar	Int	+	+		+	+
Elephantopus mollis Kunth	Bunglay	Int	+	+	+	+	+
Crassocephalum crepidioides (Benth.) S.Moore	Furangat	Int		+			
Ageratum conyzoides L.	Makmak Basong	Int	+	+		+	+
Ageratum houstonianum Mill.	Makmak Tangda	Int	+	+	+	+	
Emilia sonchifolia (L.) DC.	Salong Bulaho	Nat	+	+	+	+	+
Blumea balsamifera (L.) DC.	Sambong	Nat		+			
Mikania cordata (Burm.f.) B.L.Rob.	Saong	Nat		+		+	
Erigeron sumatrensis Retz.	Tagamfong	Int				+	
Fabaceae							
Senna occidentalis (L.) Link	Alongang	Int					+
Abrus fruticulosus Wall. Ex Wight & Arn.	Amutos	Int					+
Albizia procera (Roxb.) Benth.	Anapla	Nat		+		+	
Centrosema plumieri (Turpin ex Pers.) Benth.	Bangas	Int				+	+
Lablab purpureus (L.) Sweet	Lablafat	Int	+	+	+	+	+
Aeschynomene indica L.	Makahiya-makahiyan	Int	+	+	+	+	+
Galactia striata var. villosa (Wight & Arn.) Verdc.	Mani-mani	Nat	+	+	+	+	+
Calopogonium mucunoides Desv.	Mongo-mongo/Tagbal	Int				+	+
Vigna oderniza (Thunb.) Ohwi & H.Ohashi	Tapto	Nat	+				+
Lamiaceae							
Achyrospermum densiflorum Blume	Banglo	Nat	+	+	+	+	+
Mentha sp.	Fulatlat	*	+	+	+	+	+
Leucas R.Br.	Kolantro	Nat		+			
Hyptis brevipes Poit.	Star-staran	Int	+	+	+	+	+
Uraria lagopodioides (L.) DC.	Tagyangfet	Nat	+	+	+	+	+
Scutellaria indica Roxb.	Talingabot	Nat		+		+	+
Cyperaceae							
Cyperus cyperoides (L.) Kuntze	Alidas	Nat	+	+	+	+	+
Paspalum scrobiculatum L.	Barere	Nat	+	+	+	+	+
Scleria ciliaris Nees	Baret	Nat		+	+	+	+
Fimbristylis dichotoma (L.) Vahl	Fungo	Nat	+	+	+	+	+
Euphorbiaceae							
Jatropha curcas L.	Aglomfang	Int	+				
Sapium haematospermum	Agufet	Int		+	+		
Melastomataceae							
Osbeckia chinensis L.	Bolso-bolsoan	Nat	+	+	+	+	+
Melastoma malabathricum L.	Bulso	Nat		+	+	+	
Apocynaceae							
Urceola brachysepala Hook.f.	Dalet	Nat		+		+	
Cynanchum loheri Schltr.	Magloko	Nat		+			
Vitaceae							
Vitis flexuosa Thunb.	Agrangfes	Nat	+	+		+	+
Malvaceae							
Grewia laevigata Vahl	Bagyuhan	Nat				+	+
Cucurbitaceae							
Diplocyclos palmatus (L.) C.Jeffrey	Barukadya	Nat		+			
Araceae							
Alocasia macrorrhizos (L.) G.Don	Bega	Nat		+			
Polypodiaceae							
Goniophlebium pseudoconnatum (Copel.) Copel.	Etos	Nat		+	+		
Hypoxidaceae							
Curculigo orchioides Gaertn.	Fangketot	Nat	+	+	+	+	+
Orchidaceae							
Peristylus intrudens (Ames) Ormerod	Kosol-kosolan	Nat	+	+	+	+	+
Dipterocarpaceae							
Anisoptera thurifera (Blanco) Blume	Lakwan/Lagwan	Nat		+	+		
Menispermaceae							
Cissampelos pareira L.	Lanlanos	Nat		+			
Dioscoreaceae							
Dioscorea alata L.	Liyagan	Nat	+	+			
Thymelaeaceae							
Wikstroemia androsaemifolia Hamaya	Loblofak	Nat		+			
Rubiaceae							
Mitragyna speciosa Korth.	Mambog	Nat	+			+	

ceae) also represent 11 species, followed by the legumes (Fabaceae) with 9 and the mints (Lamiaceae) with 6 species representing their family, and sedges (Cyperaceae) with 4 species. Whereas plant families Euphorbiaceae, Melastomataceae, Cyperaceae, and Apocynaceae were each represented by only 2 species across the study sites.

A consistent pattern of species richness emerged across all five sites. Site 4 is observed to have the highest Margalef index among all the sites, followed by Site 2. Sites 1, 3, and 5 have the lowest Margalef index values, indicating that these sites have the lowest species richness. The graphs displayed a relatively low initial species richness, indicated in the first replicates for sites 1–5, which are 0, 7, 14, 0, and 1, respectively. This is followed by a rise in the number of species, and a slight decrease towards the end. This pattern suggests a potential post-disturbance regrowth phenomenon. Initially, a limited number of colonizing species establish themselves. This entails that diversity increases as more species become established in the recovering habitat. The slight decrease at the end might be attributed to species turnover or competitive interactions among established species.

Spatial analysis

Across the five study sites, the most dominant species, spatially, were *Themeda arguens*, *Cyperus cyperoides*, *Achyrospermum densiflorum*, *Paspalum scrobiculatum*, *Osbeckia chinensis*, *Elephantopus mollis*, *Sorghum nitidum*, *Imperata cylindrica*, *Curculigo orchioides*, *Mentha* sp., *Fimbristyis dichotoma*, *Perystilus intrudens*, *Lablab purpureus*, *Aeschynomene indica*, *Galactia striata* var. *villosa*, *Emilia sonchifolia*, *Saccharum spontaneum*, *Hyptis brevipes*, *Uraria lagopodioides*, and *Themeda triandra*. These 20 species were present across all sites; however, the frequency of their occurrence for each species per

site varies all through the 19 sampling repetitions.

Temporal analysis

The use of cover or coverage index is a practical method to quantify the percentage of ground area occupied by a particular species considering that it incorporates both spatial and temporal aspects (Fernández-Mena et al. 2021). Heat maps using the six classifications in the cover index were created to visualize spatial patterns of plant cover and identify temporal shifts in dominant species across sites (heat maps of Figs 3–7). These heat maps effectively displayed variations in plant cover across the five sites, revealing a clear shift in dominance by *Themeda arguens*, *Achyrospermum densiflorum*, *Paspalum scrobiculatum*, *Chromolaena odorata*, *Imperata cylindrica*, *Saccharum spontaneum*, *Uraria lagopodioides*, *Ludwigia octovalvis*, and *Themeda triandra*.

Analysis of the 19 sampling replicates within each site also showed significant heterogeneity in plant cover. Dominant species differed across these replicates, visualizing the patchy nature of post-fire vegetation recovery. While these visualizations depict variations in the percentage occupancy of various species, a distinct pattern of dominance is observed. Few species consistently displayed the darkest color on the heat map, indicating its overwhelming dominance throughout the end of the sampling. These species displayed a remarkably consistent presence and high cover index across all sites, suggesting its persistent dominance within the post-fire recovering communities. Interestingly, a distinct pattern emerged regarding the dominance of native versus invasive species. All five study sites experienced a fire event within the past two decades and reside within 2200 ha. Sites 1 and 3 exhibited dominance by native grasses, specifically *Themeda gigantea* and *T. triandra*, respectively. These findings suggest that these sites may be recovering more naturally, with native species recolonizing the burned areas. Conversely, Sites 2, 4, and 5 were dominated by invasive species: *Chromolaena odorata*, a known problematic weed (Zachariades

Table 1. Continued.

Taxon	Tau-buid Name	Status	Site				
			1	2	3	4	5
Zingiberaceae							
Curcuma longa L.	Reyamang	Int	+				+
Lycopodiaceae							
Lycopodiella cernua (L.) Pic.Serm.	Sakfo	Nat		+	+		
Pteridaceae							
Adiantum capillus-veneris L.	Talilis	Nat	+	+	+	+	
Onagraceae							
Ludwigia octovalvis (Jacq.) P.H.Raven	Taris-taris	Nat		+	+		+
Moraceae							
Ficus septica Burm.f.	Tyagtag	Nat		+			
Convolvulaceae							
Ampelopsis glandulosa (Wall.) Momiy.	Wat Bangon	Nat					+
Leucobryaceae							
Campylopus introflexus	Segyo bato	Nat		+	+		

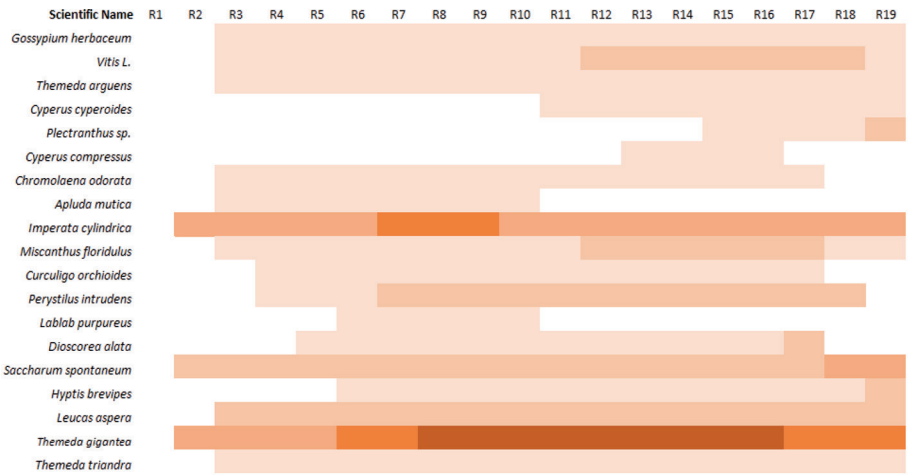

Figure 3 Cover index heat map of site 1 (Namara)

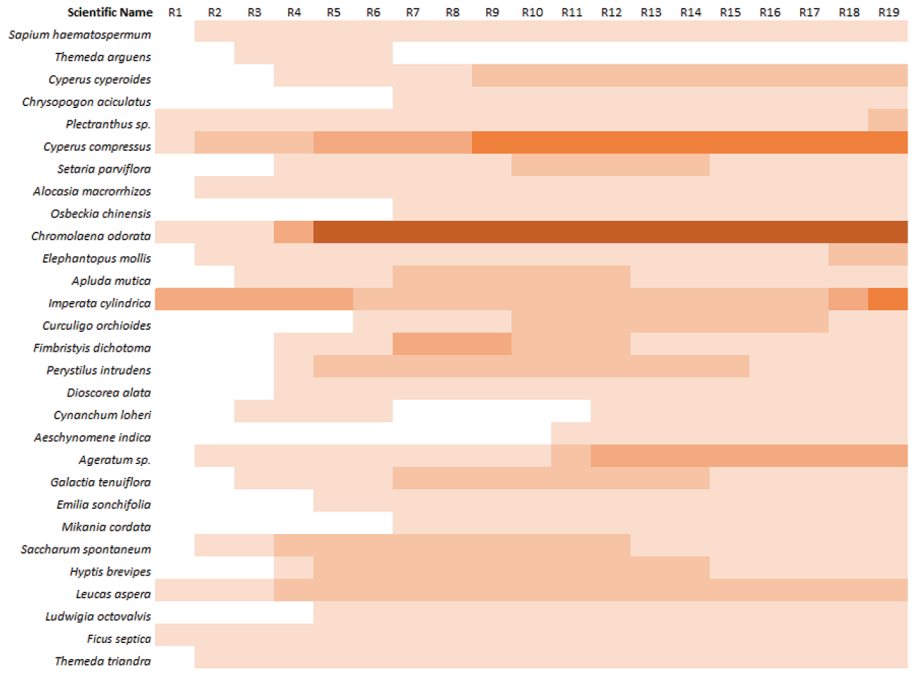

Figure 4 Cover index heat map of site 2 (Magawang)

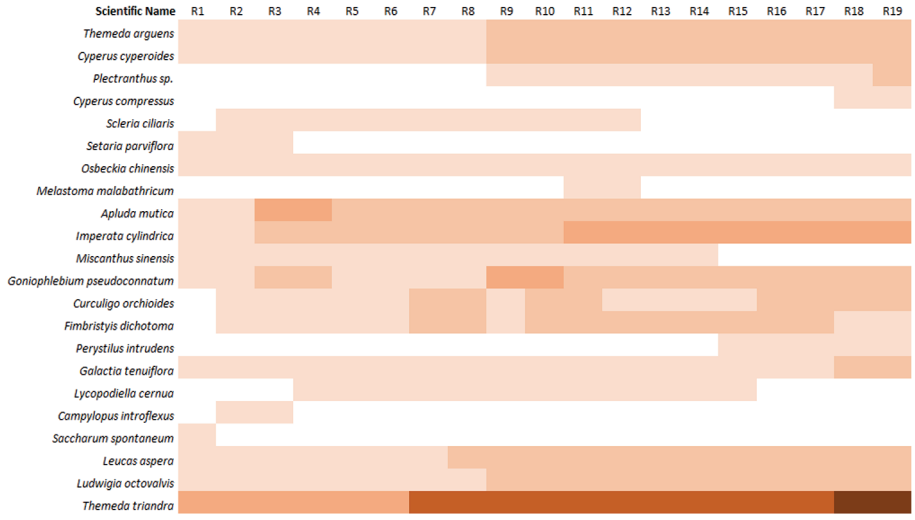

Figure 5 Cover index heat map of site 1 (Namara)

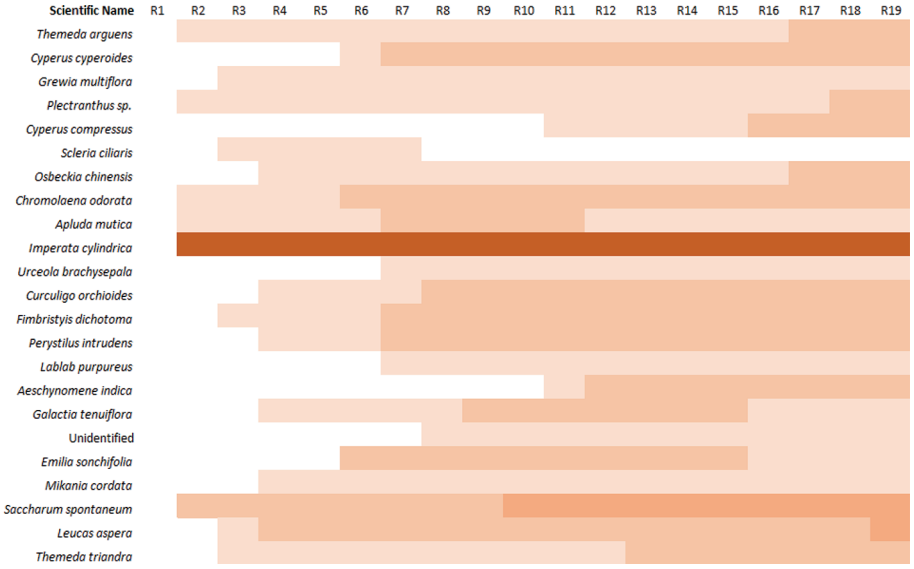

Figure 6 Cover index heat map of site 1 (Namara)

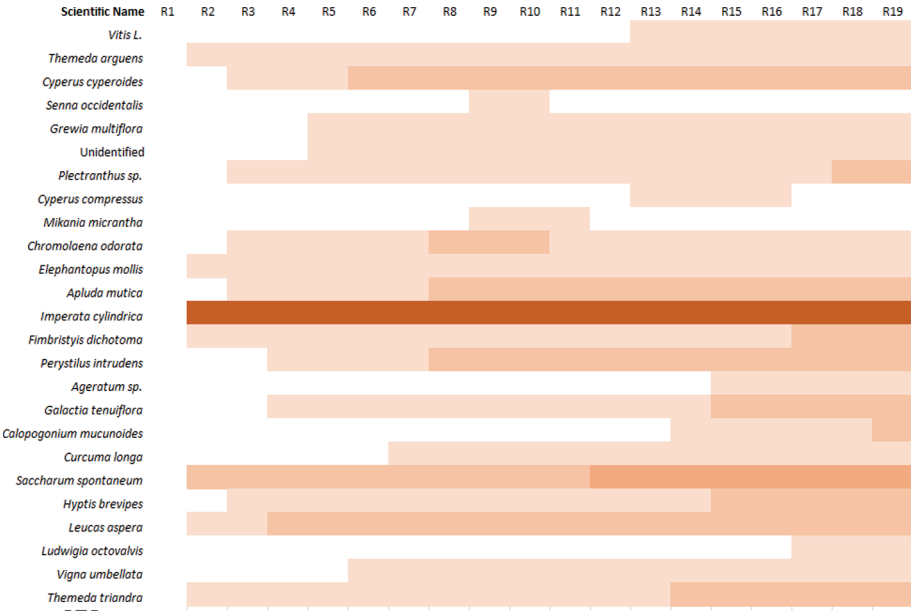

Figure 7 Cover index heat map of site 1 (Namara)

2009), and *Imperata cylindrica*, an aggressive invader with a history of displacing native vegetation (Daneshgar & Jose 2009). This spatial heterogeneity in dominant species highlights the potential challenges invasive plants pose in the landscape's post-fire recovery.

Spatiotemporal diversity trends

The Shannon-Weiner (Fig. 8A–E) and Simpson diversity (Fig. 8F–J) indices were employed to evaluate diversity trends across the nineteen sampling replicates within each site. These trends exhibit 0–0.947, 0.857–0.952, 0.929–0.938, 0–0.933, and 0–0.95 for Simpson and 0–2.94, 0–3.045, 2.64–2.77, 0–2.71, and 0–94 for Shannon in replicates 1–19 in sites 1–5, respectively. Both indices revealed a consistent pattern: an initial phase with low diversity, a significant increase, and a relatively stable diversity level. This observed pattern aligns with the initial colonization by a limited number of species after the disturbance, followed by a rise in diversity as more species establish themselves. However, the lack of a subsequent decline in diversity, typically observed in later successional stages, suggests a deviation from the classical successional diversity gradient (SDG) hypothesis.

The SDG hypothesis proposes a gradual shift in diversity following a disturbance: low diversity initially, followed by an increase as new species colonize, and then a slight decrease as the landscape matures towards a climax community (Whittaker 1972, Chraibi et al. 2021). While the findings align with the initial stages of the SDG hypothesis, the absence of a decline in diversity suggests the plant communities have not reached the late-successional stage.

Plant regrowth patterns / Temporal species turnover

Species accumulation curves (SACs) were constructed to esti-

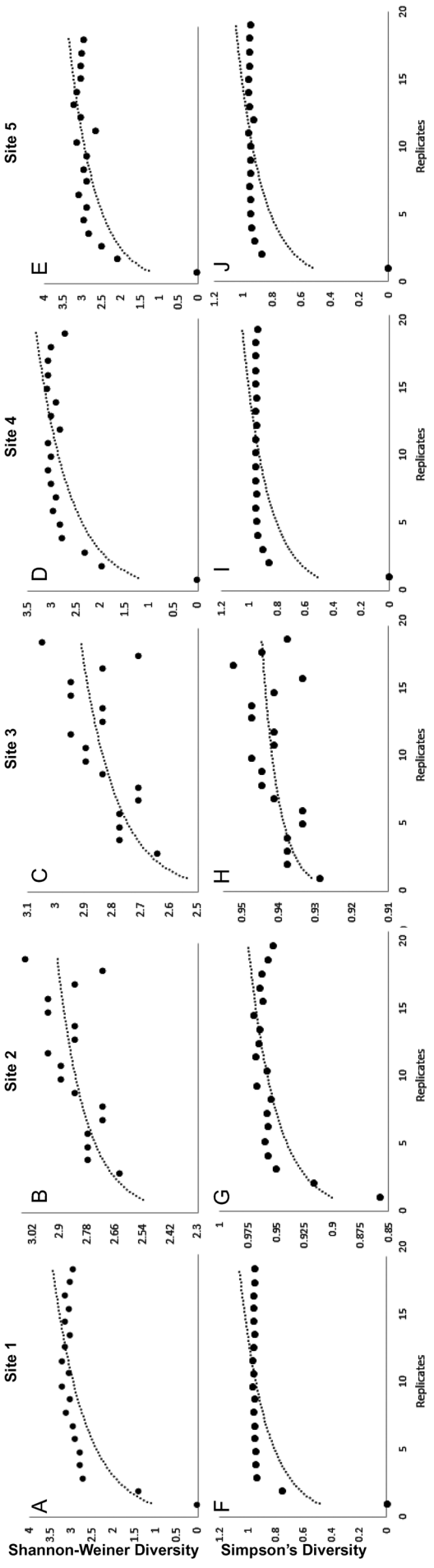

Figure 8 Temporal variation of Shannon-Weiner Diversity and Simpson's Diversity indices in Sites 1–5

mate the expected cumulative number of species discovered to the increasing sampling effort (replicates). The SAC graphs exhibited similar trends, with a steep initial rise indicating a rapid increase in observed species (Fig. 9). This further supports the notion of post-disturbance plant regrowth, where new species are readily colonizing the disturbed area. As additional samples were collected, the curves began to flatten, suggesting a decrease in the rate of documenting new species, potentially indicating a nearing saturation point for the current sampling intensity.

Neighbor-joining cluster analysis (Fig. 10) using the Jaccard index further corroborated the regrowth patterns observed in the results. The analysis grouped replicates based on the similarity of their species composition. The groupings, reflecting the similarity of species composition among replicates, show replicates: 1–5, 6–8, and 9–11 for early sampling, 12 and 15 as well as 13–16 for mid-sampling, 17–19 for late sampling (Fig. 10). This pattern aligns with the expected trajectory of plant communities undergoing regrowth after a disturbance event.

The pattern of grouping may be attributed to several factors, such as the initial plant community composition (Hooper et al. 2004, Körner et al. 2008), the microhabitat conditions influencing early successional plant establishment (Menges & Hawkes 1998), or the variation and intensity of disturbances for each site (Kuss 1986, Means et al. 2017). Future studies investigating soil properties and pre-fire vegetation surveys within each sampling site could shed light on the specific factors driving these observed groupings.

DISCUSSION

Overall findings indicate that grass species, the pioneering species subsequent to a disturbance, are the most dominant across the study area; even so, this is the consequence of heavy human-induced influence from previous anthropogenic activities such as cattle ranching, and the current fire regime maintained and employed by park authorities, along with the Tau-Buid communities residing in the area. The landscape of MIBNP is characterized as being dominated by an assortment of plant species, indicating that it is a savanna, rather than a grassland (Oesterheld et al. 1999). This dominance likely results from past and ongoing human influences. The area's history as a cattle ranch, combined with the annual fire disturbance practiced have likely shaped the current vegetation composition (Schult 2001). This is evident in the dominance of pioneering grass species like *Imperata cylindrica*, *Saccharum spontaneum*, *Chromolaena odorata*, and *Themeda triandra*. Notably, these grasslands are more susceptible to invasion by introduced species compared to other potential habitats within MIBNP, such as in the secondary forests near the Oriental region.

A status review conducted by Long et al. (2018) revealed that deforestation, along with poor soil, frequent fire, and a prolonged dry season, has contributed to the growth and development of habitats dominated mainly by grasses, which was previously mentioned, in Occidental Mindoro's middle altitudes. Consequent to the abrupt habitat transformation at the start of the twentieth century, private landowners, including foreign corporations, established cattle ranches

on these mid-elevation grasslands. Cattles were considered competitors of tamaraw; because of this, their population decreased, and lowland habitats were destroyed, relegating the species to more mountainous terrain, including Mounts Wood, Baco, Sinclair, Halcon, as well as Calavite. The decrease in ranching activities in the 1970s provided a chance for indigenous Mangyan groups to re-occupy their Ancestral Lands, resulting in conflict with tamaraw over territory and thereby limiting the species' distribution (Kuehn 1975, Schult 1991, Lawas et al. 1996)

The conversion of land, initially from natural habitats into agricultural fields, was most likely the primary factor of tamaraw's dwindling population. Mindoro was formerly a heavily forested area. However, by 1988, merely around 70 % of the forest remained. Commercial logging and subsequent conversion to agriculture have resulted in the loss of forest cover (Gonzalez et al. 1998). Between 1988 and 2015, an additional 30 000 acres of forest was also lost (Long et al. 2018). Because of such, a comprehensive logging ban was imposed. In 2011, the Department of Environment and Natural Resources (DENR) launched a large-scale reforestation effort (National Greening Program), which included multiple sites in Mindoro (Von Kleist et al. 2021). Regardless, the forests continue to be susceptible to various threats (Israel & Lintag 2013).

The main findings of habitat assessments and preliminary field observations conducted before this study imply that grasses and shrubs dominate the study area and other areas within the boundaries of MIBNP. Additionally, historical records point out that the savanna landscape is not a natural habitat but a result of anthropogenic disturbances, such as the regular fire regime that has taken place for decades. This hinders the natural regeneration process of the forest, which is evident in the dominance of pioneer grasses such as cogon (*Imperata cylindrica*), tagyangfet (*Uraria lagopodioides*), hagonoy (*Chromolaena odorata*), and talahib (*Saccarum spontaneum*), as observed from the results. Furthermore, the landscape presented more native species of plants but with a relatively denser population of introduced species, such as the makmak basong (*Ageratum conyzoides*). The current fire regime employed at the study site has plausibly played a substantial role in expanding these species. All of these findings do not directly point that *Imperata cylindrica* brings about significant threats to tamaraws, as it occurs naturally in the environment, especially in the Philippines as well as adjacent Southeast Asian savannahs and grasslands (Peet et al. 1999, Garrity et al. 1996). However, the constant burning of vast expanses of land destroys other forms of vegetation in the grassland. This facilitates the rapid re-colonization of burned regions by the above-mentioned pioneering grass species, especially since these species develop rapidly in their environment, hence, crowding out other species (Lunt 1990).

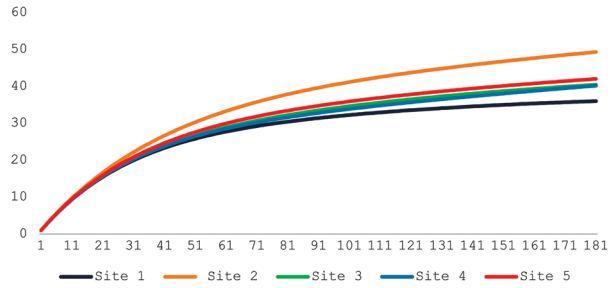

Figure 9 Species accumulation curves of the Sites 1–5

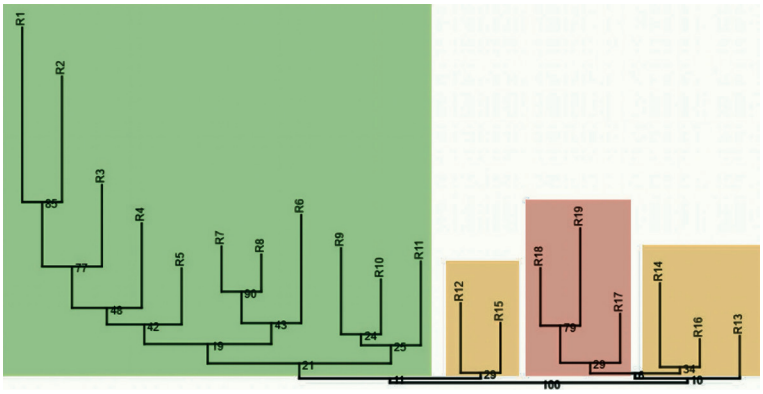

Figure 10 Community Clustering Analysis through Bootstrap Method (PAST) based on Jaccard Index. Green are replicates done during the early sampling, red for mid-sampling, and yellow are late sampling periods

The observed dominance of *Imperata cylindrica* is particularly concerning. Local Park rangers and indigenous communities report its ongoing expansion, suggesting a potentially invasive pattern. Studies by Howison & Coulon (2009) highlight the negative consequences of *Imperata cylindrica* expansion, including reduced habitat-carrying capacity and suppression of other plant growth. However, it is important to consider the broader ecological processes at play. Natural ecosystems experience changes in species composition over time, particularly following disturbances like fire. This phenomenon, known as temporal turnover (Magurran & Henderson 2010), describes the shift in dominant species as an ecosystem recovers through successional stages.

The concept of temporal turnover is governed by a framework that provides an in-depth understanding of the changes in ecological communities' dynamics over time. By means of applying this to post-fire succession, insights regarding species diversity, and further modification in the changes of the function of the community are gained (Norden et al. 2012). The concept of species turnover is also directly related to the successional model established by Whittaker (1970). In this model, a humped-shaped trajectory can be observed – this illustrated the increase in diversity during the early stages of the succession sequence because this reflects the rapid colonization of pioneering species right after the fire disturbance where the area has been cleared out; thus, more advantageous to capitalize available resources without competition. However, as time progresses, a shift in diversity can be observed. This is attributed to several factors, but mainly, the change in the diversity rate is due to some species outcompeting others (Guo 2003, Chalcraft et al. 2004). Towards the end, where the climax community has been reached due to the maturity of the landscape, a slight decrease towards the end of the hump is apparent – and

this is because of species turnover or the interplay between the availability of resources and the competitive exclusion principle (CEP) (López-Gómez & Molina-Meyer 2006). As the landscape matures towards a stable state, resulting in increased biomass, dominant species who tend to have more advantageous traits than other species have increased their chance of survival and reproductivity. This inevitably leads to the overall decline in community diversity (Tilman 1994).

Unique habitats such as grasslands and savannas offer a distinct aspect in the overall concept of ecological succession compared to other ecosystems (Sun et al. 2021). These habitats, characterized by their open nature, facilitate faster growth rates in plant communities because of the emergence of pioneering species like grasses and herbaceous species, providing the opportunity to allow researchers to observe succession and its changes over a shorter period (Czarniecka-Wiera et al. 2019). In relation to this, frequent disturbances, such as fire, drought, or the like, that reshape vegetation are a medium for a natural successional reset that provides prospects to other species to colonize the area (Longo et al. 2014). This intricate interaction impedes single-species dominance, resulting in more diverse and rapidly evolving successional trajectories. Moreover, grasslands are highly susceptible to changes in the environment, whether it may be temperature, precipitation, and the like. The environmental changes drive the composition of plant communities, thus allowing researchers to initiate associations between biotic and abiotic factors (Knapp et al. 2015).

While natural succession is crucial in restoring vegetation, it can be slow, particularly in disturbed ecosystems. In areas facing issues like grazing or significant erosion, achieving a stable plant cover through natural succession alone may take over 20 years (Sun et al. 2017). The result from this study entails that even though the study sites are changing species composition, they are not undergoing succession yet. Rather, it exemplifies temporal turnover due to its short timeframe, suggesting that the landscape is undergoing earlier stages of recovery before the reset caused by annual fire disturbance. A critical consideration for the long-term health of MIBNP's ecosystem is the annual occurrence of burning practices. This frequent fire disturbance disrupts the natural successional processes that would otherwise guide the recovery of plant and animal communities. Succession describes the predictable changes in species composition following a disturbance as an ecosystem progresses toward a stable state, often called the climax community (Krebs 2008). By repeatedly disrupting the landscape before it reaches a stable state, the frequent fires in MIBNP may prevent the full recovery of these communities. This phenomenon is not distinct from MIBNP. Studies conducted by Guo (2001) in the Santa Monica Mountains of California, another landscape subject to frequent fire disturbances, demonstrated similar disruptions to natural successional pathways. This suggests that the annual burning practices in MIBNP likely impede the natural progression from grasslands towards a forested climax community.

Given the observed deviations from the SDG hypothesis, the study explored the potential influence of annual burning practices within MIBNP. The analysis proposes that the frequent fire disturbance disrupts the successional process before the plant communities can reach a stable state. This continuous disruption might prevent the establishment of late-successional species, leading to the observed pattern of relatively constant diversity. Similar findings have been documented in frequently fire-disturbed landscapes (Guo 2001).

The dominance of invasive species in some sites further complicates the regeneration process. Invasive species can outcompete native vegetation, hindering the establishment of late-successional communities. If left unchecked, this pattern could lead to a progressive reduction in habitat-carrying capacity, potentially impacting native fauna like the tamaraw, a critically endangered ungulate found in MIBNP. Future research efforts may delve into temporal expansion by means of designing a long-term monitoring project that aims to track changes in species turnover, community structures, as well as vegetation succession patterns succeeding the cessation of the current tamaraw monitoring strategy that employs extensive burning.

A unifying governance structure for the Tamaraw, with processes in place for gathering key information, evaluating options, and making decisions will aid in achieving the primary objective of moving forward towards a common goal: the conservation and protection of life. In light of the projected natural regeneration process that drives the changes in the vegetation composition as a result of annual prescribed burning, vegetation monitoring programs are in dire need to be established prior to the burning practice to create baseline information that may be used for comparative analysis for future vegetation. Through investigating the regeneration process, future researchers may be able to draw out invaluable inferences centered on the ecological processes that have taken place after the complete phase-out of the fire-based monitoring strategy for tamaraws.

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Data availability: The data used in this research is available from the corresponding author upon reasonable request.

Ethics approval: The authors confirm that this article is original research and has not been published or presented previously in any journal or conference in any language in whole or in part.

Consent for publication: All the authors consented to publish this manuscript.

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