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Biodiversity monitoring as a baseline for PROPER biodiversity protection program of PT. Geo Dipa Energi Dieng, Central Java, Indonesia

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Abstract. *Hadisusanto S, Purnomo, Trijoko, Reza A, Eprilurahman R, Yudha DS, Sudibyo P, Asti HA, Fauzy NH, Pranoto FS, Priyono DS, Mufti S, Rabbani A, Putri DM, Syamsumin, Tampubolon APC, Abdullah FN. 2022. Biodiversity monitoring as a baseline for PROPER biodiversity protection program of PT. Geo Dipa Energi Dieng, Central Java, Indonesia. Biodiversitas 23: 4466-4472.* Anthropogenic activities drove an unprecedented rate of land-use change in the last century. Corporate is one of the most highlighted sectors due to the extent of the impact on the environment. Therefore, PROPER (Corporate Performance Rating Assessment for Environmental Program) was developed by the Ministry of Environment and Forestry as a safeguard to halt biodiversity loss due to corporate-related development in Indonesia. The present study analyzed the flora and fauna composition, structure, and trend in PT. Geo Dipa Energi Dieng well pad surrounding area from 2019-2021, as a critical part of the PROPER assessments. The study revealed that the study area was homogeneously dominated by shrubs-herbaceous plants, contributing to 60% of total species richness and abundance. Two dominant species were the introduced wild species *Ageratina riparia* and the cultivated plant *Solanum tuberosum*. Moreover, despite tree individual scarcity, the tree growth form was primarily constituted by introduced species with a mean abundance of 347 individuals, or 5-fold higher than native species. *Acacia decurrens* and *Cupressus sempervirens*, the introduced tree species planted during the rehabilitation program, dominated the area. The homogeneous floristic composition led to a homogenization of the fauna community, particularly birds, dominated by cosmopolitan insectivorous species. NMDS analysis and Shannon-Diversity Index also revealed that the pattern and trend among sites and years were similar, and there was an insignificant change, showing the urgency of the long-term revegetation programs to rehabilitate the ecosystem. Moreover, the presence of protected species in the study area showed that ecosystem rehabilitation is critical.

Keywords: Agriculture, biodiversity, biotic homogenization, land conversion, monitoring

INTRODUCTION

Over the recent decades, numerous studies highlighted several human activities that severely changed the terrestrial landscape, including agriculture and monoculture plantation (Seymour and Harris 2019; Lezzi et al. 2021), urbanization (Knop 2016), landscape simplification (Gámez-Virues et al. 2015), road development (Haider et al. 2017), mining (Sonter et al. 2017), and airport development (Alquezar et al. 2020) that often lead to biotic homogenization and the replacement of the specialized, rare native, and endemic species by the cosmopolitan and generalist species, which frequently thrive in disturbed ecosystems (Solar et al. 2015; Holl et al. 2022). Furthermore, the spread of cosmopolitan species into newly accessible areas expands their range and population, accelerating the colonization process (Dyer et al. 2016). Due to their small ecological niche, specialized species are disproportionately eliminated from the ecosystem (Socolar et al. 2016; Vatani et al. 2017; Reside et al. 2019)

There is a growing body of evidence showing the anthropogenic impact on several taxa homogenization, including birds (Mitchell et al. 2022), herpetofauna (Palmeirim et al. 2017), insects (Knop 2016), freshwater fish (Bezerra et al. 2019), river and lake macroinvertebrates (McGoff et al. 2013; Liu et al. 2022), mammals (Lezzi et al. 2021; Arce-Penna et al. 2022), also vegetation (Haider et al. 2017). These simplifications potentially adversely impact the ecological services since the loser species potentially serve critical roles in the ecosystem (Holl et al. 2022). Therefore, several countries have developed instruments, such as Biodiversity Assessment on Environmental Impact Assessment, to minimize and forecast biodiversity loss in the face of development (CBD 2006; Bigard et al. 2017). The instruments are compliant with the Convention on Biological Diversity (CBD), which recommend assessment and monitoring of the impact of human-driven development on biodiversity in the relevant sector, and the industrial or corporate sector is a critical sector due to the extent of the impact to the environment (CBD 2006; Rainey et al. 2014).

In Indonesia, the biodiversity safeguard for the industrial sector is PROPER (Corporate Performance Rating Assessment for Environmental Program), which was conceptualized and implemented by the Ministry of Environment and Forestry of the Republic of Indonesia in the early 1990s (Reliantoro 2012). The PROPER overarching aim is to mitigate, monitor, evaluate, and take action on any company activities-related environmental impact. The essential biodiversity protection programs include in situ and ex situ conservation and rehabilitation or restoration. Furthermore, the company is required to develop an information system to gather, analyze, and assess the state and trends of biodiversity in the managed area (Reliantoro 2012) as regulated by the Regulation of the Minister of Environment and Forestry (*PERMEN LHK No 1 Tahun 2021*)

Evaluation of the PROPER program in 2021 was carried out on 2,593 companies, and 75% achieved compliance level, with 117 out of 697 biodiversity-inclusive innovations. The innovations include the establishment of community-based conservation areas, catchment area conservation, conservation education camp, high conservation value, native tree seeding, degraded land revegetation, endangered species conservation, and honeybee breeding (Anugrah 2021), as reported in Regulation of the Minister of Environment and Forestry (*KEPMEN LHK SK-1307*). One company that already holds a high level of compliance is PT. Geo Dipa Energi Dieng (GDE Dieng) is located in the Dieng Mountains area, one of the Important Bird Areas (Birdlife International, 2022), but severely degraded due to massive conversion into settlement and agriculture in the past (Smiet 1990; Griffin 2019). Therefore, as part of the company biodiversity protection program, this study aimed to analyze the flora and fauna composition, structure, and trend in GDE Dieng Well Pad surrounding area over the years as the evaluation and the baseline for future intervention in rehabilitation or restoration program.

MATERIALS AND METHODS

Study area

The research was conducted in the surrounding area of the eighteen GDE Dieng Well Pad, Dieng Plateau area. Most of the study area is agricultural fields, mainly potatoes and carrots, although sites 14, 15, and 18 consisted of agricultural fields-remnant forest, and sites 3 and 13 consisted of agricultural fields-remnant forest-cemetery area (Figure 1).

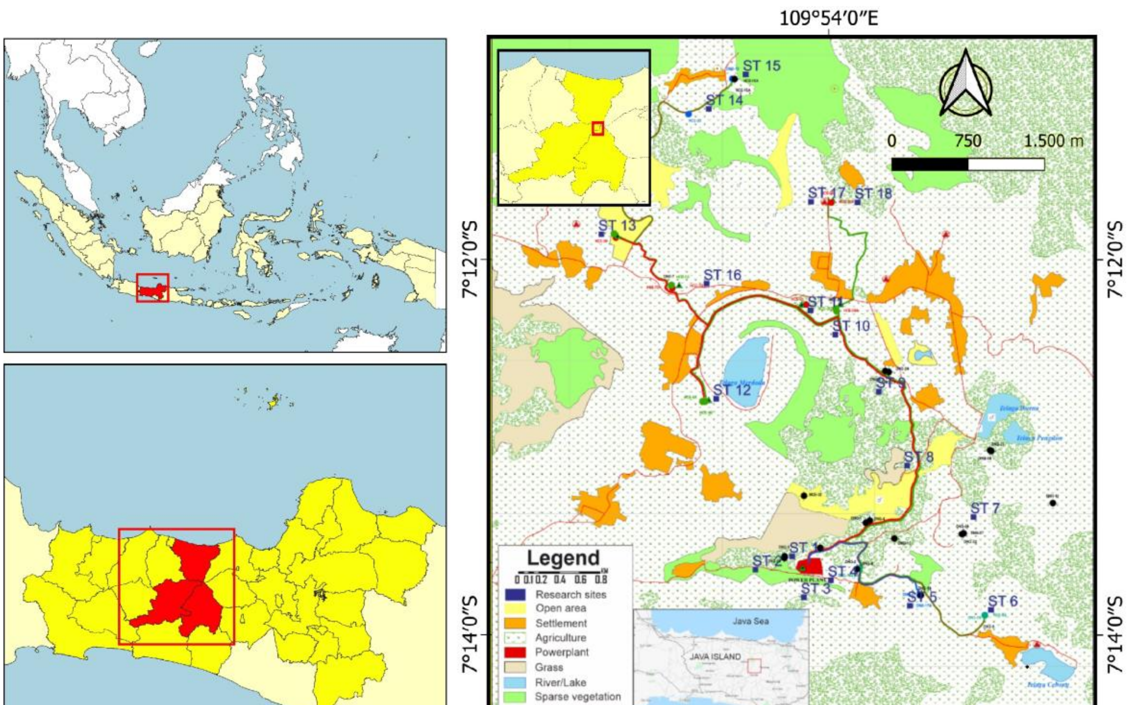

Figure 1. Land use map and eighteen study sites (blue square) on GDE Dieng well pad that are highly distributed in agricultural areas

Data collection and analysis

Data were collected a minimum of two times a year during the dry and rainy seasons from 2018-2021. However, the data in 2018 were excluded due to dataset differences. Therefore, only 2019-2021 data were analyzed. Floristic data were collected using purposive random sampling around the well pad. The data were sorted based on growth form: Trees, Shrubs-Herbs, and Grass. Furthermore, tree species were mainly sorted into two groups, namely native to Java's mountain and introduced species, following van Steenis (1972), Setyawati et al. (2015), and Invasive Species Compendium https://www.cabi.org/isc (CABI 2022). Data on mammals, birds, reptiles, and amphibians were collected using a combination and modification of visual encounter survey and point count (Yudha et al. 2022) in both the edge and interior of vegetated areas, mainly in the morning 07:00 AM to 10:00 AM and afternoon 2:00 PM to 5:00 PM, additional to night observation without rain. In addition to the encounter, traces of residual activity (trace, feces, scratch, nest, or vocalization) and local people information were also recorded. Furthermore, the observed bird is categorized into dietary guilds following Schulenberg (2020), namely insectivores, frugivores, granivores, piscivores, and omnivores, to investigate the guild-level response to floristic composition and vegetation structure.

Data were analyzed for mean abundance and frequency per species and functional group (growth form, feeding guilds). The similarity of fauna communities among 18 sites over three years was analyzed and visualized using Bray-Curtis Non-Metric Multidimensional Scaling (NMDS) and performed on PAST ver 4.03. Furthermore, the Shannon-Wiener diversity index (H') was calculated using a formula according to Krebs (2014) to analyze trends in flora and fauna species diversity and evenness over the years.

RESULTS AND DISCUSSION

Floristic composition and structure

The species richness of the shrubs and herbs was the highest with 123 species, constituting over 60 percent of total species and almost 3 and 4 times higher than that of the tree (44 species) and grass (36 species), respectively (Figure 2). Species abundance was also dominated by shrubs and herbs, ranging from 53.08-80.32% or 67.37% on average (Figure 2) or 3-8 folds higher than that of the tree and grass. The shrubs-herbs community was the mixture of wild and cultivated plants homogeneously dominated by introduced species mistflower *Ageratina riparia* and Potato *Solanum tuberosum*. The grass community was also dominated by the introduced giant reed *Arundo donax*, which comprised 11.79% of the total grass individuals. The proportion of shrubs, herbs, and grasses contributed to more than 80% of the total abundance. The richness and relative abundance revealed that the vegetation in the study sites was a non-tree-dominated landscape, although the ecological unit of the study area was a tropical montane rainforest. In addition, cemetery areas were found to be less converted and dominated by the tree. The non-tree-dominated flora community resulted from the long history of deforestation that has persisted for hundreds of years, particularly in the 14th-15th. Furthermore, the land conversion intensified during the colonial period and in the mid-1980s when Potato was cultivated in the Dieng mountains and provided a significant yield (Smiet 1990; Griffin 2019). Moreover, the economic crisis that struck Indonesia from 1997-1998 drove a significant conversion of forests, including the protected forest, into agricultural fields (Setyowati and Hardati 2009; Griffin 2019).

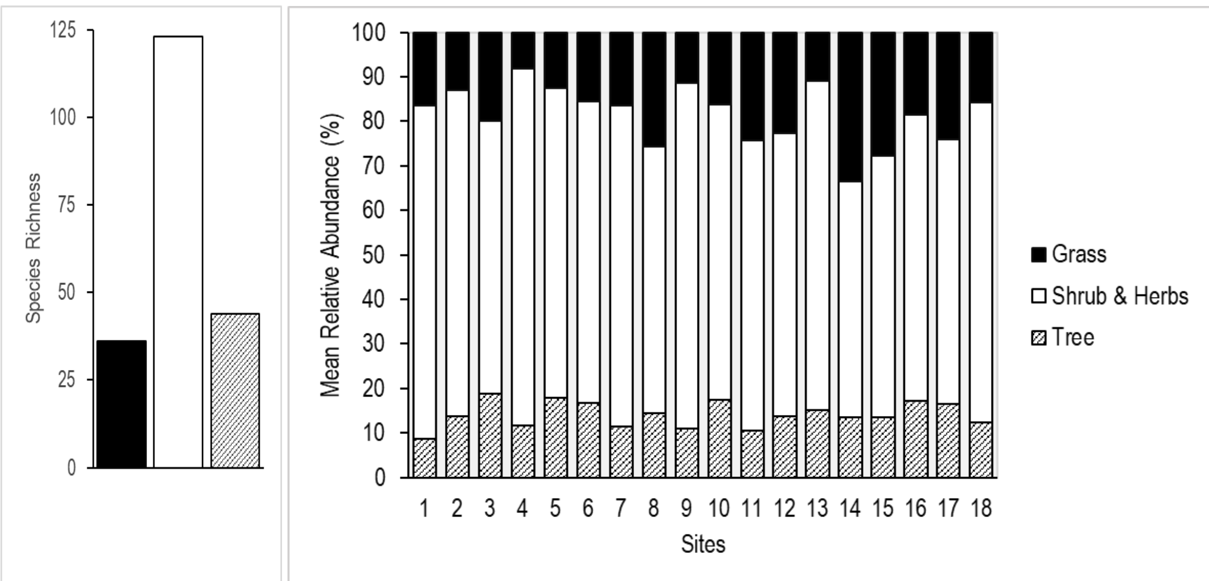

Figure 2. Species richness and relative abundance of grass, shrubs-herbs, and tree

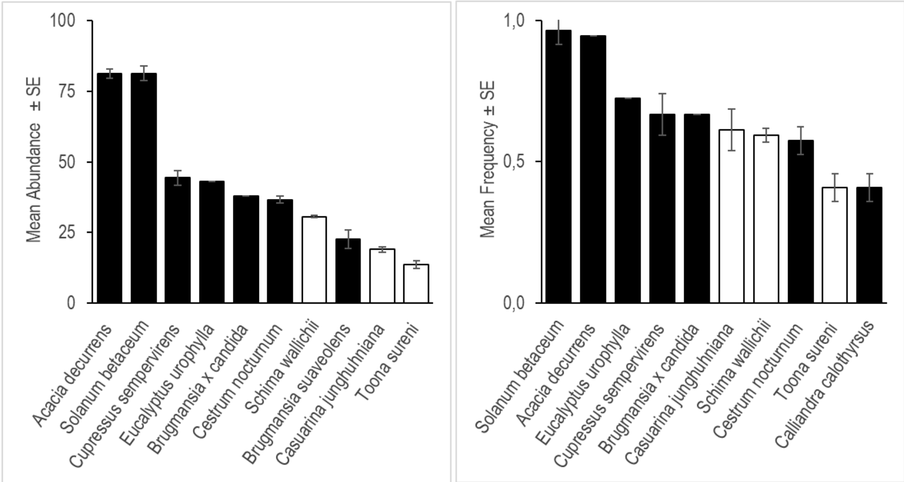

Figure 3. Relative abundance and frequency of dominant tree species consisting of introduced and Java native

The domination of introduced species was found in not only the shrubs-herbs and grass but also the tree community (Figure 3). The graph shows the ten most abundant and highest frequency tree species, contributing to approximately 70% of tree abundance and frequency. The tree communities were largely constituted by introduced species with a mean abundance of 347.3 individuals, contributing to more than two-thirds of the tree community or 5-fold higher than native species (63.3 individuals). The relative frequency trends were also similar since the introduced species comprised 47.51%, or almost half of the study sites were colonized by the species, while the native species were only a third of the introduced species (15.48%). Furthermore, four introduced species, namely *Acacia decurrens*, *Cupressus sempervirens*, *Solanum betaceum*, and *Eucalyptus urophylla*, contributed almost two-thirds of the abundance and half of the frequency of the ten most dominant species.

The presence of the introduced species is highly interrelated with the crisis-driven deforestation and the national movement of forest and land rehabilitation (GNRHL) program, particularly in 2002-2004 (Setyowati and Hardati 2009; Marliana and Ruhe 2014). *Acacia decurrens*, *C. sempervirens*, *E. urophylla* were the commonly selected species for land rehabilitation due to their tolerance to the degraded soil, rapid growth, and additional economic benefits (Setyowati and Hardati 2009; Sunardi et al. 2017). Therefore, those species possibly provide a substantial supply of seeds to rehabilitated and non-rehabilitated areas in the Dieng plateau. Recently, *A. decurrens* and *C. sempervirens* were used to rehabilitate the 30.5 Ha area in the Dieng Plateau area despite its invasiveness and tendency to form a dense thicket, outcompete and inhibit other species, including the native species (Marliana and Ruhe 2014; Sunardi et al. 2017). Even though three native species of Java, namely *Schima wallichii*, *Casuarina junghuhniana*, and *Toona sureni*, were present, their abundance and frequency were significantly lower than those of the introduced species (Figure 3). The finding regarding the dominance pattern is similar to Marliana and Ruhe (2014), which investigated post-reforestation vegetation development on abandoned highland fields in Dieng Plateau and found tree species planted during the reforestation programs, *A. decurrens, C. sempervirens,* and *S. wallichii* co-dominated the study area. A similar result regarding the dominance of these species in the rehabilitated area was also reported by Setyowati (2009). In the present study, *S. wallichii* was among the ten dominant trees, but its abundance was significantly lower than that of *A. decurrens* and *C. sempervirens.*

Fauna communities

Three years of observation cumulatively recorded 48 bird species, 11 mammal species, and three herpetofauna species. Several protected animals by Presidential Regulation (*Peraturan Pemerintah No. 7/1999*) or Regulation of the Minister of Environment and Forestry (*Peraturan Menteri Lingkungan Hidup dan Kehutanan Republik Indonesia No. P.106/MENLHK/SETJEN/KUM.1/12/2018*) were also recorded, including Black Eagle *Ictinaetus malayensis*, Javan kingfisher *Halcyon cyanoventris*, White-throated kingfisher *Halcyon smyrnensis*, Collared kingfisher *Todiramphus chloris*, Spotted kestrel *Falco moluccensis*, black-banded barbet *Megalaima javensis* (*Psilopogon javensis*), Sunda pied fantail *Rhipidura javanica*, white-bellied fantail *Rhipidura euryura*, rufous-tailed fantail *Rhipidura phoenicura*, Australasian grebe *Tachybaptus novaehollandiae*, Sunda porcupine *Hystrix javanica*, Sunda pangolin *Manis javanica*, and southern red muntjac *Muntiacus muntjak*.

Birds were the most frequently encountered fauna and constituted 90.06% of the total individuals. Furthermore, 86.40% of the bird abundance was represented only by ten dominant species, and more than two-thirds (75.10%) of the dominant species guild were insectivorous and ubiquitously distributed (Figure 4), showing a homogeneous community pattern. Similar results were also reported by Mitchell et al. (2022), that investigated the bird guild turnover across a gradient of deforestation and found the proportion of insectivores negatively correlated with the forest cover in Talaud and Seram Island, with an approximately 2.5% proportion increase per 10% forest cover loss. In contrast, the frugivore, the essential forest seed dispersers, and the fruiting tree-dependence guild were positively correlated with the forest cover.

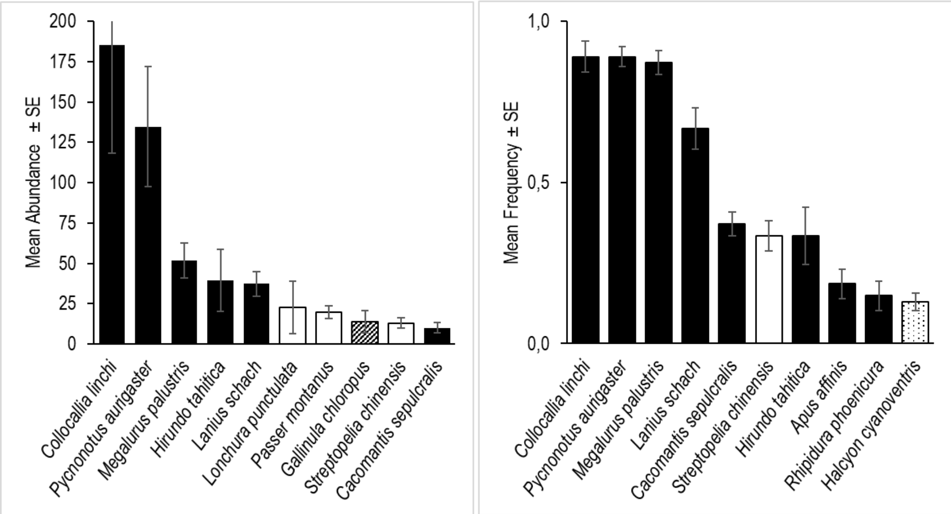

Figure 4. Mean abundance and mean frequency of dominant bird species and feeding guilds

In the present study, frugivores only contributed 0.002% of the total individuals. The dominance of insectivorous and the low abundance of frugivores may interrelate with the floristic composition and structure dominated by non-tree vegetation, hence less suitable for frugivores that depend on the fruiting trees (Marliana and Ruhe 2012). In addition, another plausible cause for the low number of frugivores may be the hunting pressure, such as that exerted on species of Wallacean parrots that are popular in the cagebird trade (Setiyani and Ahmadi 2020). Furthermore, insectivores presumably thrived because the guild has a lower degree of dietary specialization, thus less susceptible to habitat degradation (Mitchell et al. 2022). However, the insectivorous species-specific sensitivities variation should be noted (Hamer et al. 2015; Stratford and Stouffer 2015), requiring further investigation.

The high abundance of cosmopolitan insectivores, and low abundance of diet specialist frugivore, may exacerbate the damage to ecosystem function and forest regeneration (Brodie and Aslan 2012; Gardner et al. 2019), particularly in the Dieng Mountains, where forest regeneration is heavily determined by human intervention due to the scarcity of climax native tree species seeds (Marliana and Ruhe 2012).

The fauna composition and abundance were further analyzed using NMDS, which showed no clear separation or cluster. Hence the community was relatively similar among sites and years (Figure 5). The fauna community homogenization may be correlated to the homogeneous agricultural and shrub-dominated vegetation in all sites. Moreover, most of the encountered fauna was the bird, highly dependent-vegetation taxa due to its habitat provision and diet. The biotic homogenization of birds and its interrelation with land-use change was also reported by Karp et al. (2017), that investigated bird community patterns and species turnover in Costa Rica rainforest and found the bird in the agriculture contribute 7-11% less turnover than in forests due to uniformity of the vegetation structure as one of the factors. Another study by Liang et al. (2019) found that taxonomic, phylogenetic, and functional similarities of bird communities were consistently higher in the planted woodland, farmland, and village than in the natural grassland. This biotic homogenization was also reported by Newbold et al. (2018), which revealed that cosmopolitan or generalist bird species are more dominant in disturbed habitats such as agriculture and settlements. In the present study, the cosmopolitan species, including sooty-headed bulbul *Pycnonotus aurigaster*, the striated grassbird *Megalurus palustris*, and the cave swiftlet *Collocalia linchi* were the dominant species in almost every site (Figure 4).

In addition, the separation of two sites (13 and 17) from the ellipsoid on NMDS (Figure 5) was strongly caused by the approximately 2 to a 6-fold decrease of fauna mean abundance on these sites in the 2021 observation. During the observation in 2019-2020, the mean abundance of fauna was 73 and 50 on sites 13 and 17, respectively, and it dramatically decreased to 13 and 22 in 2021. Moreover, *P. aurigaster*, *C. linchi*, and *Hirundo tahitica* was dominant in these sites in the 2019-2020 observation, with a total of 31 individual but decreased to 2 individuals in 2021, even with zero encounters with *C. linchi*. There are several assumptions to explain the dramatic decrease of the bird, such as the immediate effect of weather that directly affect the behavior of the bird, or the decrease in insect abundance due to wind speed, cloud cover, or precipitation, thus indirectly affecting the bird abundance through prey-predator interactions since *P. aurigaster*, *H. tahitica*, and *C. linchi* are insectivores (Weegman et al. 2017; Møller 2018).

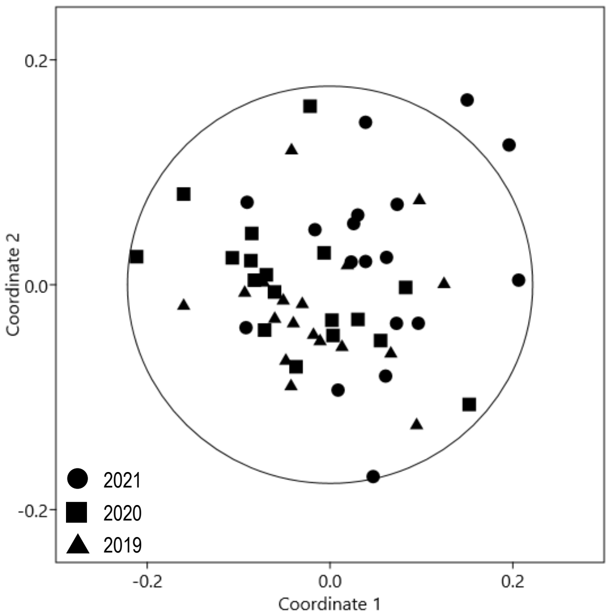

Figure 5. Bray-Curtis-based non-metric multidimensional scaling plot of all observations (stress 0.18) showing no apparent clustering among sites and years. Ellipsoids represent a 95% confidence interval

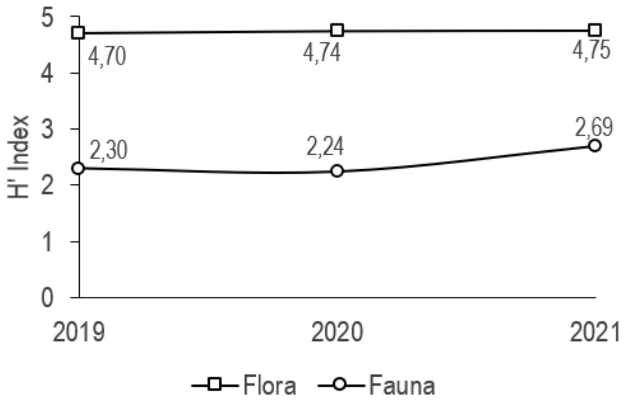

Figure 6. Shannon-Wiener diversity index (H') trends of flora and fauna

The biotic homogenization pattern was also reflected in the Shannon-Wiener trend, showing an insignificant change (Figure 6) since the flora and fauna community structure and composition were comparably similar over the years (Figure 2; Figure 5). Even though the diversity index of flora was relatively high, ranging from 4.70-4.75, it should be noted that the high index does not indicate the healthy state of the vegetation but is due to the high richness and evenness of the shrubs and herbs (Figure 2). Moreover, the stable trend also reflected the unchanged floristic composition and abundance over the years.

In conclusion, the study revealed that vegetation was dominated by a shrubs-herbs and introduced species. The homogenous vegetation and tree scarcity strongly drove the biotic homogenization of fauna communities among sites and years and led to the domination of cosmopolitan insectivores. The insignificant change in the flora and fauna patterns over the years shows the urgency of long-term intervention of tree plantation, particularly native trees, if the overarching aim of the GDE Dieng PROPER biodiversity protection program is to rehabilitate the ecosystem and its ecological services.

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