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Native and alien plant species inventory and diversity in disturbed forests and its economic value

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ABSTRACT

The study was conducted to assess the native and alien plant species in one of the highly disturbed forest (S1) and less disturbed forest (S2) in Mt. Manunggal, Cebu Island, Philippines. Twenty-four quadrats with a size of 20mx20 m were established using a quadrat sampling technique to identify and record all plant species. Diversity indices were utilized to determine species abundance, richness, evenness, and diversity. There was also the characterization of sites concerning anthropogenic activities and economic uses of native and alien plant species. Results showed that there was apparent domination of alien plants in terms of species richness and abundance in both sites (S1; R=62 species; N=10519; S2; R=55; N=32739). However, there was higher species richness (S1; R=62 and S2; R=30) and diversity (S1; H'=2.76, D=0.10 and S1; H'=2.41, D=0.11) but lower abundance (S1; N=10519 and S2; N=32739) and evenness (S1; PE=0.67 and S2; PE=0.73) in S1 than in S2. The high abundance and evenness of alien plant species in S2 could be due to high anthropogenic activities and its economic value. These factors indirectly assist in the introduction and persistence of alien plant species in disturbed ecosystems by increasing alien plant invasion which usually results in a higher diversity of alien plant species in highly disturbed sites. Assessment on the negative impacts to native plant species by alien plant invasion, enhanced by anthropogenic activities, must, therefore, serve as bases in future directions and implication for restoration and conservation of the remaining forests of Mt. Manunggal, Cebu Island, Philippines.

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INTRODUCTION

Invasive Alien Species (IAS) are species that are non-native to an ecosystem whose introduction may cause or likely to cause economic or environmental threat as well as harm in human health and is considered as the second most significant threat to biodiversity next to habitat loss (Bellard *et al.*, 2018). Global impacts on the invasiveness of alien plants across spatial and temporal scales undoubtedly destroy species abundance and diversity (Sands *et al.*, 2011; Pysek *et al.*, 2010; Pysek *et al.*, 2017). In the Philippines, more than 475 plant species were recognized as IAS since prehistoric time (Sinohin and

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Cuaterno, 2002; Joshi, 2006). The introduction of IAS was first known from Malayan-Polynesian origin, may have included common crops; additional IAS tree species were introduced during the Spanish regime via Acapulco trade, and additional percentage of exotic plants were introduced after the Spanish-American war and still this introduction continues which later on become synonymous with reforestation (Baguinon and Miel, 2003). The associated impacts of these invasions involve a tremendous decrease in the diversity of native flora and fauna. These invasions have now displaced native plant species and alter their expansions worldwide (Chen *et al.,* 2019). The Philippines declares international acknowledgment for its floral-rich forests which show notable role in terms of climate mitigation. However, the Department of Environment and Natural Resources-United National Environment Program (DENR-UNEP) revealed that there are no known management plans for addressing the IAS of plants threat in the Philippines, particularly in Cebu Island, Philippines, where some of the unique fauna and flora exist (i.e., Cebu cinnamon, Cebu flowerpecker, and Cebu blueberry (Salares *et al.,* 2018; UNEP, 2012; DENR, 2007). Some articles related to the topic in Cebu are scarce and limited (DENR, 2007). In the study of Oyama *et al.* (2003), most tropical rainforests worldwide have higher plant species richness due to unique biogeographic characteristics, disturbance regime and habitat suitability. In turn, these species provide goods and services to humankind (Moreno *et al.,* 2018). Nevertheless, the presence of rich flora in the Philippines remains to be less studied, as well as the extinction of key species was overlooked. In the Philippines, the rate of biodiversity loss from Asia is alarming because of rampant anthropogenic activities leading environmental degradation (PCARRD, 2017). Moreover, IAS of plants as a biological pollutant has a severe impact on the ecosystem (UNEP, 2012; Cheng and Lai, 2018). It is therefore essential to study the potential effects of IAS on plants, especially in the Philippines being part of the biological hotspot (Conservation International, 2007; Agenda, 2018). The effect of IAS of plants is often severe and irreversible, and it usually takes several years before the impact of the problem can be recognized (UNEP, 2012; DENR, 2007). While these plant species are available, it is timely to create an inventory of plummeting flora documented in the past years. Failure to realize the potential ecological damage to IAS of plants to the country's biodiversity will result in devastating effects, consequent economic losses and possible hazards to human health (Sinohin and Cuaterno, 2002; Joshi, 2006). Floristic inventories of native and alien species are necessary for creating conservation plans and programs, as well as a basis in the formulation of effective policies regarding areas focusing on the conservation of forests (PCARRD, 2017; UNEP, 2012; DENR, 2007). This study aimed to provide a comprehensive list of native and alien plant species between Site 1 (highly-disturbed site) and Site 2 (less-disturbed site) in Mt. Manunggal, Cebu Island, Philippines, determine the species composition such as species richness, abundance, evenness and diversity and identify the anthropogenic activities and economic uses of alien and native plants. This study has been carried out in Barangay Sunog, Mt. Manunggal, Cebu Island, Philippines in 2016- 2017.

MATERIALS AND METHODS

A. Prior informed consent (PIC), gratuitous permit and selection of local researchers

To conform to the requirements of Executive Order 247 (Bioprospecting and Republic Act, 9147) (Wildlife Resources Conservation and Protection Act), prior informed consent was obtained from the villagers of Mt. Manunggal. This research has been presented to the Protected Area Management Board (PMB) of the Department of Environment and Natural Resources Region VII for the issuance of the Gratuitous Permit.

B. Research environment

An assessment of the species abundance, richness, evenness, and diversity of alien and native plants has been conducted in Barangay Sunog, Mt. Manunggal, Cebu Island, Philippines with geographic coordinates of 10° 27' 39.41" N latitude and 123° 46' 50.72" E longitude (Fig. 1). It has an area of about 717.87 hectares and rises 1003 meters above sea level, approximately 22 miles of northwest of Cebu City. The peak also has a secondary pocket forests, canyons, cliffs, caves, gullies, and creeks that lead the water to drain two main rivers: Combado River in Balamban which borders the Cebu Central Park in the north and Banban River which traverses the southern portion of the park. As articulated in Republic Act. 7586, also known as the National Integrated Protected Area System (NIPAS), it is within the enclave of Central Cebu Protected Landscape (CCPL).

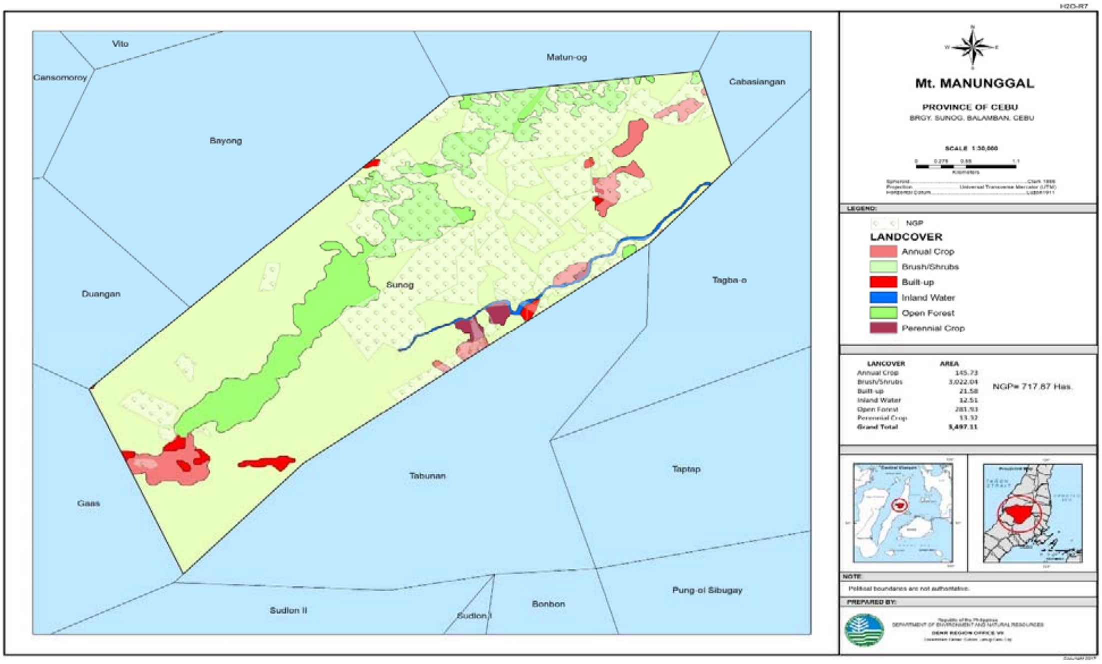

Fig. 1. Geographic location of the study area of Mt. Manunggal, Cebu Island, Philippines (DENR, 2017)

C. Survey, establishment of sampling sites, collection and processing of specimens

A dual-purpose reconnaissance survey was first carried out in Mt. Manunggal, Cebu Island, Philippines. Transect walks were done to identify the existing native and alien plant species found within the 20m x 20m quadrat. Species richness, abundance, evenness, and diversity for native and alien plant species were also determined, including different anthropogenic activities and its economic uses. These plants were only photographed and identified using consolidated printed manuals and databases: Global Invasive Species Database, Pacific Island Ecosystem at Risk, Global Compendium of Weeds and Asia-Pacific Forest Invasive Species Network and Co's Digital Flora of the Philippines. As a protected site and based on the recommendation of the DENR, no voucher specimen was collected and only a field camera was utilized in the documentation of native and alien plant species present in each quadrat of S1 and S2 in Mt. Manunggal, Cebu Island, Philippines.

D. Survey of anthropogenic activities and economic uses of native and alien plants

Consensus sampling was employed in all study sites, resulting in 77 villagers (head of household) being interviewed (Cheng and Lai, 2009). Data were collected from October 2016 to February 2017, using a semi-structured questionnaire, supplemented with a guided field survey. A semi-structured questionnaire (in local language) was used to determine the respondent's demographic profile, economic status and uses (used part/s and utilization category) of native and alien plant species. The economic uses of native and alien plant species were analyzed. As a limitation of the study, an inventory was only made to identify the scientific name, plant family, origin of introduction, anthropogenic activities and economic uses of each species of alien and native plants in Mt. Manunggal, Cebu Island, Philippines.

E. Diversity indices and statistical analysis

A 100x50 m area was established in each study site, where three 100 m-transect lines were laid out with a distance between 10 meters from each other. Four 20x20 m quadrats in each transect were laid out alternately from left or right with a 20m interval which are randomly distributed each study site. A total of 24 quadrats from the six transects of the two-study site were randomly selected for sampling. Within these quadrats, a 20x20 m quadrat was laid out to determine the species abundance and richness of native and alien plant species. Species abundance and richness of both native and alien plants was determined using Eqs. 1 and 2:

Species abundance= (Total number of species A/ Total number of all species) X 100 (1)

In terms of species richness (Scot *et al.*, 1987), both Site 1 and Site 2 were accounted as regions in this study where species richness is calculated using the formula:

Species richness= number of species found within a community or area (2)

To calculate species diversity, Shannon-Wiener Index (H') and Simpson' Index of Diversity (Wen *et al.*, 2010) were computed as Eqs. 3 and 4.

$$H' = -\sum_{i=1}^{S} \frac{ni}{N} \ln \frac{ni}{N} \quad (3)$$

Where, H'= diversity index; ni= number of individuals; ln= natural logarithm; N= total number of species.

$$D = 1 - \frac{\sum_{i=1}^{S} ni(ni-1)}{N(N-1)} \quad (4)$$

Where, D= Simpson's index; ni= number of individuals; N= total number of species

Table 1. List of all native and alien species surveyed in Site 1 and Site 2 of Mt. Manunggal, Cebu Island, Philippines

Taxa family	Plant species	Site 1	Site 2	Total	Abundance (%)
Family Asteraceae	*Mikania micrantha*	701	1420	2121	4.9
	Ageratum conyzoides	391	5203	5594	12.93
	Elephantopus mollis	1667	4226	5893	13.62
	Erechtites valerianifolius	67	0	67	0.15
Family Araceae	*Colocasia esculenta*	100	102	202	0.47
Family Convolvulaceae	*Ipomoea purpurea*	0	44	44	0.1
Family Cyatheaceae	*Cyathea contaminans*	95	963	1058	2.45
Family Euphorbiaceae	*Cicca acida*	10	0	10	0.02
Family Fabaceae	*Acacia mangium*	32	4	36	0.08
	Mimosa pudica	199	0	199	0.46
	Centrosema pubescens	38	0	38	0.09
	Samanea saman	11	0	11	0.03
	Albizia saman	33	0	33	0.08
Family Lamiaceae	*Hyptis capitata*	111	3211	3322	7.68
	Gmelina arborea	29	0	29	0.07
Family Lauraceae	*Persea americana*	5	0	5	0.01
Family Leguminosae	*Acacia aurei*	33	0	33	0.08
Family Malvaceae	*Theobroma cacao*	36	0	36	0.08
Family Melastomataceae	*Miconia calvescens*	123	1060	1183	2.73
Family Meliaceae	*Swietenia macrophylla*	108	332	440	1.02
Family Moraceae	*Broussonetia papyrifera*	0	27	27	0.06
	Artocarpus heterophylla	5	0	5	0.01
Family Myrtaceae	*Syzigium cumini*	0	41	41	0.09
	Psidium guajava	390	0	390	0.9
	Eucalyptus globulus	9	0	9	0.02
Family Muntingiaceae	*Muntingia calabura*	12	0	12	0.03
Family Oxalidaceae	*Oxalis corniculata*	112	0	112	0.26
Family Passifloraceae	*Passiflora incarnata*	0	68	68	0.16
Family Poaceae	*Axonopus compressus*	442	5571	6013	13.9
	Pennisetum purpureum	331	1709	2040	4.72
	Imperata cylindrica	1901	3611	5512	12.74
	Paspalum conjugatum	1500	3330	4830	11.17
	Bambusa sp.	39	39	78	0.18
	Cynodon dactylon	121	0	121	0.28
	Dendrocalamus giganteus	17	0	17	0.04

Table 1. (Continued)

Taxafamily	Plant species	Site 1	Site 2	Total	Abundance (%)
Family Rubiaceae	*Coffea arabica*	41	0	41	0.09
Family Rutaceae	*Citrus microcarpa*	19	0	19	0.04
	Citrus grandis	16	0	16	0.04
Family Verbenaceae	*Stachytarpheta jamaicensis*	1133	802	1935	4.47
	Lantana camara	301	741	1042	2.41
	Duranta plumerii	10	0	10	0.02
Family Casuarinaceae	*Casuarina equisetifolia*	35	14	49	0.11
Family Combretaceae	*Quisqualis indica*	18	10	28	0.06
	Terminalia nitens	17	7	24	0.06
Family Dilleniaceae	*Dillenia philippinensis*	23	12	35	0.08
Family Dipterocarpaceae	*Dipterocarpus grandiflorus*	30	13	43	0.1
	Parashorea malaanonan	10	5	15	0.03
	Pentacme contorta	5	8	13	0.03
	Pentacme mindanesis	10	5	15	0.03
	Shorea almon	23	9	32	0.07
	Shorea astylosa	7	7	14	0.03
	Shorea negrosensis	14	7	21	0.05
	Dillenia philippensis	0	12	12	0.03
	Dipterocarpus philippinensis	0	24	24	0.06
	Anisoptera thurifera	5	7	12	0.03
Family Fabaceae	*Pterocarpus indicus f. indicus*	30	18	48	0.11
	Ptercarpus indicus f. echinata	30	10	40	0.09
	Albizia ackle	13	3	16	0.04
Family Lamiaceae	*Vitex parviflora*	7	7	14	0.03
Family Lauraceae	*Cinnamomum mercadoi*	2	0	2	0
Family Lythraceae	*Lagerstroemia speciosa*	12	3	15	0.03
Family Malvaceae	*Bombycidendron vidalianum*	2	1	3	0.01
Family Meliaceae	*Aglaia rimosa*	5	7	12	0.03
Family Moraceae	*Ficus balete*	12	17	29	0.07
	Ficus minahassae	10	5	15	0.03
Family Rubiaceae	*Mussaenda philippica*	11	12	23	0.05
Family Simaroubaceae	*Quassia indica*	18	12	30	0.07
Family Urticaceae	*Leucosyke capitellata*	5	0	5	0.01

To calculate how evenly and equally the individuals of the plant species are distributed in both sites, Pielou's *evenness* (PE) was calculated per plot using Eq. 5.

$$J = \frac{H}{\ln(S)} \quad (5)$$

Where H'=Shannon Weiner diversity; ln= natural logarithm; S= total number of species in a sample, across all samples in a dataset (Pielou, 1966).

RESULTS AND DISCUSSION

Classification, identification, description, and diversity of native and alien plant species

A total abundance of 43,258 alien and native plants (S1-37 alien and 25 natives; S2-30 alien and 25 natives) (Fig. 1) were identified in the highly-disturbed (S1) and less disturbed site (S2) of Mt. Manunggal, Cebu Island, Philippines (Table 1). S1 had 10,519 individuals while 32,739 individuals were recorded in S2. Among these, dicotyledons were represented by 25 families, and 60 species; monocotyledons by two families and eight species; and fern by one species of the family Cyatheaceae (Table 1). Alien species *Mikania micrantha, Ageratum conyzoides, Elephantopus mollis, and Erechtites valerianifolius*, belonging to family Asteraceae in both sites had 13,675 individuals or 32.03% of total abundance (Table 1). These species under family Asteraceae have also been documented to be invasive in the Northern and Southern American forests (UNEP, 2013). Documented native and alien plants in Mt. Manunggal also included seven species of Poaceae, with 18,611 individuals (43.59%). Family Lamiaceae comprised two species with 3,351 individuals, making up 7.85% of total abundance and three species of family Verbenaceae with 2,987 individuals or 7.00% (Table 1). Majority of these plants were also reported as invasive alien species in most continents of North and South America, Europe, Africa, Asia, and Australia and are also included in the Global Compendium Weeds and 100 Most Invasive Species of the World (Pysek *et al.,* 2017). Selection of species for these databases was based on their impacts on biological diversity, and human-mediated activities and their relevance to issues on biological invasion.

The Dipterocarpaceae had the highest number of native species at 201 individuals or 0.46% of total family abundance. Moreover, this was followed by the three species of family Fabaceae, two species of Combretaceae, one species of Casuarinaceae and two species under family Moraceae, with 104 individuals (0.46%), 52 individuals (0.24%), 49 individuals (0.12%), 44 individuals (0.11%) (Table 1), respectively. The least dominant species of the native plants belong to Lauraceae, Malvaceae, and Urticaceae, had a total abundance of 0.004% and 0.006%, and 0.011%, respectively. Native trees such as *Pterocarpus indicus, Dillenia philippinensis* and *Casuarina equisetifolia* were reared by the local villagers, as required by the DENR (Table 1). Wildlings of these native trees are collected from the forest and are immediately reared in nurseries created by some of the local villagers. Studies indicate that alien plant species can outnumber native plant species in terms of species abundance and diversity due to morphological, physiological, and ecological factors (Pysek *et al.,* 2016). There is also a relation between seed morphology and the biological processes associated with native plant species. It is thus necessary to try to understand how the morphological or genetic characters (e.g., seed morphology, leaf arrangement; vegetative structure) are related to the survival of native and alien plants in a given habitat, particularly under final modifications (Mooney *et al.,* 2001). For physiological and ecological factors, native and alien plant species are considered to be light-demanding species which are adaptable to open areas (Tata *et al.,* 2008). Moreover, land preparation for enrichment planting with native plant species in secondary forests is also a main requirement for these plants to proliferate. These shade-tolerant species need moderate light for early growth which demands care in nurseries when grown (Gratani, 2014). Other challenges that may be faced when planting native plant species are the production of shoot cuttings, species and site matching, planting distance, potting seedlings, seedlings maintenance and harvesting techniques. These demanding requirements are not needed by alien plant species (Pysek *et al.,* 2013). In terms of species richness, S1 has 62 plant species, made up of 37 (59.67%) alien plant species and 25 (40.32%) native species (Fig. 2). In contrast, S2 had 30 (54.55%) alien and 25 natives (45.45%) species for a total of 55 plant species (Fig. 2). However, in terms of abundance, there were more alien plants in S2 at 32, 504 individuals (76.18%) compared with 10, 165 individuals (23.82%) in S1. Native plant abundance was also higher in S1 at 354 individuals (60.10%) while S2 had 235 individuals (39.90%). Both sites varied in terms of the number of individuals per species within and across the study sites. The most invasive plant species found in both sites were *Axonopus compressus, Elephantopus mollis*, and *Ageratum*

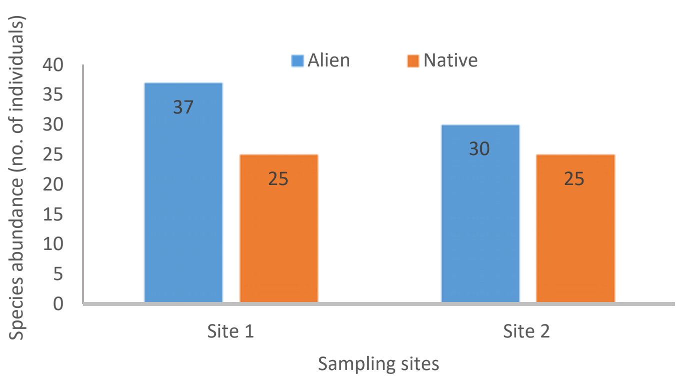

Fig. 2. Number of alien and native species found in S1 and S2 of Mt. Manunggal, Cebu Island, Philippines

conyzoides with 6013 (13.90%), 5893 (13.62%), and 5594 (12.93%) individuals, respectively (Table 1). These three found in all the study sites have been classified as invasive alien species (IAS). The invasion success of *Axonopus compressus* depends on certain morphological and physiological adaptation, as well as to environmental conditions. As a vigorous and aggressive weed, its seeds reproduce prolifically, with a seed germination rate of 45% after two weeks under alternating temperatures of 15°C (16h) and 35°C (8h) daily. Also, this species thrives in a moderately-shaded area and is best adapted to moist, and warm environments, although it grows well in full sunlight. Moreover, it also occurs at high altitudes in tropical areas (Randall, 2017). On the other hand, *Elephantopus mollis* and *Ageratum conyzoides,* both of the Asteraceae family, have high invasion success due to its capability to existing in areas with high rainfall, evident in the months of October-December (Pysek *et al.,* 2017). Also, these vigorous plants have broad-leafed seedlings that allow them to glide and prolifically reproduce in humid and nutrient-rich soil (Madulid *et al.,* 2009). All the environmental requirements suitable for alien plants to become invasive in Mt. Manunggal. Moreover, the fresh seeds of these species can germinate rapidly at any time of the year, suggesting no significant dormancy, thus increasing success in establishment, growth, and proliferation in any environment (Pysek *et al.,* 2017). They have a persistent root system and have fruits with numerous seeds which simply disperse and germinate even in poor, acidic, soils (Pergl *et al.,* 2018). Control has become difficult because these plants are prolific seeder and seed banks develop tremendously in the soil (Vicente *et al.,* 2019).

High species richness with low species abundance in Site 1 (Fig. 2) against the low species richness but high species abundance in Site 2 can be explained through the stages of invasion by alien plant species: 1) transport, 2) establishment, 3) spread/invasion (Pysek *et al.,* 2016; Vicente *et al.,* 2019). In the first stage of invasion, anthropogenic activities such as land tillage, trade, and tourism are the key drivers in determining the fate of species after their first introduction in lower altitudes (Pysek *et al.,* 2017). Recently, it has been emphasized that the stochastic effects brought by anthropogenic activities are dependent on the residence time (the time since the introduction of the alien plants in the new area) and propagule pressure (the number of introduction events) (Vicente *et al.,* 2019). Emerging generalizations of invasion biology accentuates on the probability of invasion success because of these two factors: 1) residence time and propagule pressure (Pysek *et al.,* 2017), and 2) suitable environmental conditions (Vicente *et al.,* 2019). First, residence time and propagule pressure are the factors to be considered in the introduction and establishment of alien plant species in its newest environment. Residence time represents another dimension of propagule pressure wherein, the longer the species is present in the region, the more propagules are gradually established in an area. Moreover, residence time and propagule pressure increase the probability of founding a new population in the site (Pysek *et al.,* 2011; Pysek *et al.,* 2017). Resident time and propagule pressure are factors which provides a better chance to achieve early introduction and establishment but not to become more abundant in the area yet (Pysek *et al.,* 2011). The abundance of alien plants can be attributed to suitable environmental factors which are present at higher altitudes. Most of these alien plant species were herbs and shrubs which can thrive in wet and humid places, and even in areas as high as 500-2000 masl (Heida *et al.,* 2009; Pysek *et al.,* 2010). The study by Ahmad *et al.* (2018) states that the areas of low plant species richness may be invaded easily than the areas of high plant species richness. This could be the case of S1. As a highly-disturbed site, it has more anthropogenic activities which assist the introduction of aliens and eventually allow the establishment and spread/invasion of alien plants, through suitable environmental conditions. Shannon diversity index (H’) measures the degree of uncertainty in a sample area. If the diversity is low, the certainty of picking a particular species at random is high. If it is high, it is then difficult to predict the identity of a randomly picked individual. This implies that the higher the resulting value, the more diverse the site is; high diversity means high uncertainty. H’ includes both species richness and species evenness (Studeny *et al.,* 2010). Therefore, it allows knowing not only the number of species but how the abundance of the species is distributed among all the species in the community. Table 2 shows that S1 (H’= 2.76) had higher diversity than S2 (H’= 2.41). However, it seems that the invasive alien plant species were the ones contributing much to the high diversity in S1, and a

Table 2. List of native and alien plant species abundance and diversity in S1 and S2 of Mt. Manunggal, Cebu Island, Philippines.

		S1				S2					
Taxa family	Plant species	N	H'	D	PE	N	H'	D	PE	Total	Status
Asteraceae	*Mikania micrantha*	701	0.18	0.004435151	0.043733341	1420	0.136101665	0.00187998	0.041295025	2121	Alien
	Ageratum conyzoides	391	0.122374966	0.001378268	0.03	5203	0.292313221	0.02525263	0.088691653	5594	Alien
	Elephantopus mollis	1667	0.291936175	0.025101691	0.070735805	4226	0.264270037	0.016658606	0.08	5893	Alien
	Erechtites valerianifolius	67	0.032205387	4.00E-05	0.007803329	0	0	0	0	67	Alien
Araceae	*Colocasia esculenta*	100	0.044260559	8.95E-05	0.010724284	102	0.017980929	9.61E-06	0.005455649	202	Alien
Casuarinaceae	*Casuarina equisetifolia*	35	0.018984282	1.08E-05	0.00459987	14	0.003317197	1.70E-07	0.001006481	49	Native
Convulvulaceae	*Ipomoea purpurea*	0	0	0	0	44	0.008886461	1.77E-06	0.002696268	44	Alien
Combretaceae	*Quisqualis indica*	18	0.010901245	2.77E-06	0.002641359	10	0.0024722	8.40E-08	0.000750098	28	Native
	Terminalia nitens	17	0.01	2.46E-06	0.002517	7	0.001806802	3.92E-08	0.000548207	24	Native
Cyatheaceae	*Cyathea contaminans*	95	0.042510775	8.07E-05	0.01	963	0.103723295	0.000864338	0.031471004	1058	Alien
Dilleniaceae	*Dillenia philippinensis*	23	0.013393404	4.57E-06	0.003245207	12	0.002899813	1.23E-07	0.000879841	35	Native
Dipterocarpaceae	*Dipterocarpus grandiflorus*	30	0.016711877	7.86E-06	0.004049269	13	0.003109681	1.46E-07	0.000943518	43	Native
	Parashorea malaanonan	10	0.006615033	8.13E-07	0.001602815	5	0.00134196	1.87E-08	0.000407168	15	Native
	Pentacme contorta	5	0.00363699	1.81E-07	0.000881239	8	0.002032287	5.22E-08	0.000616622	13	Native

Table 2. (Continued)-1

		S1				S2					
Taxa family	Plant species	N	H'	D	PE	N	H'	D	PE	Total	Status
	Cinnamomum mercadoi	2	0.001629013	1.81E-08	0.000394708	0	0	0	0	2	Native
Leguminosae	*Acacia aurei*	33	0.018084059	9.54E-06	0.004381747	0	0	0	0	33	Alien
Lythraceae	*Langerstroemia speciosa*	12	0.007730049	1.19E-06	0.001872982	3	0.000851985	5.60E-09	0.000258503	15	Native
Malvaceae	*Theobroma cacao*	36	0.019430279	1.14E-05	0.004707935	0	0	0	0	36	Alien
	Bombycidendron vidalianum	2	0.001629013	1.81E-08	0.000394708	1	0.000317552	0	9.63E-05	3	Native
Melastomataceae	*Miconia calvescens*	123	0.052019845	0.00013563	0.01260435	1060	0.111063747	0.001047332	0.033698193	1183	Alien
Meliaceae	*Swietenia macrophylla*	108	0.047011235	0.000104448	0.011390769	332	0.046558361	0.000102529	0.014126416	440	Alien
	Aglaia rimosa	5	0.00363699	1.81E-07	0.000881239	7	0.001806802	3.92E-08	0.000548207	12	Native
Moraceae	*Broussonetia papyrifera*	0	0	0	0	27	0.005855802	6.55E-07	0.001776727	27	Alien
	Artocarpus heterophylla	5	0.00363699	1.81E-07	0.000881239	0	0	0	0	5	Alien
	Ficus balete	12	0.007730049	1.19E-06	0.001872982	17	0.003927208	2.54E-07	0.001191566	29	Native
	Ficus minahassae	10	0.006615033	8.13E-07	0.001602815	5	0.00134196	1.87E-08	0.000407168	15	Native
Myrtaceae	*Syzigium cumini*	0	0	0	0	41	0.008369002	1.53E-06	0.002539265	41	Alien
	Psidium guajava	390	0.122156931	0.001371218	0.03	0	0	0	0	390	Alien
	Eucalyptus globulus	9	0.006043676	6.51E-07	0.001464376	0	0	0	0	9	Alien
Muntingiaceae	*Muntingia calabura*	12	0.007730049	1.19E-06	0.001872982	0	0	0	0	12	Alien
Oxalidaceae	*Oxalis corniculata*	112	0.048365171	0.000112366	0.011718826	0	0	0	0	112	Alien

Table 2. (Continued)-2

		S1				S2					
Taxa family	Plant species	N	H'	D	PE	N	H'	D	PE	Total	Status
Passifloraceae	*Passiflora incarnata*	0	0	0	0	68	0.012829451	4.25E-06	0.003892623	68	Alien
Poaceae	*Axonopus compressus*	442	0.133185266	0.001761786	0.03227064	5571	0.301359204	0.028951482	0.091436323	6013	Alien
	Pennisetum purpureum	331	0.108838239	0.000987266	0.026371382	1709	0.154130963	0.002723406	0.046765349	2040	Alien
	Imperata cylindrica	1901	0.309177361	0.032645859	0.074913325	3611	0.243157904	0.01216234	0.073777288	5512	Alien
	Paspalum conjugatum	1500	0.277742852	0.020322881	0.067296779	3330	0.232475959	0.010342856	0.070536246	4830	Alien
	Bambusa sp.	39	0.020752704	1.34E-05	0.005028357	39	0.008020333	1.38E-06	0.002433474	78	Alien
	Cynodon dactylon	121	0.051362572	0.000131238	0.012445093	0	0	0	0	121	Alien
	Dendrocalamus giganteus	17	0.01	2.46E-06	0.002517	0	0	0	0	17	Alien
Rubiaceae	*Coffea arabica*	41	0.021622019	1.48E-05	0.005238991	0	0	0	0	41	Alien
	Mussaenda philippica	11	0.007176868	9.94E-07	0.001738947	12	0.002899813	1.23E-07	0.000879841	23	Native
Rutaceae	*Citrus microcarpa*	19	0.011409211	3.09E-06	0.002764439	0	0	0	0	19	Alien
	Citrus grandis	16	0.01	2.17E-06	0.002391284	0	0	0	0	16	Alien
Simaroubaceae	*Quassia indica*	18	0.010901245	2.77E-06	0.002641359	12	0.002899813	1.23E-07	0.000879841	30	Native
Urticaceae	*Leucosyke capitellata*	5	0.00363699	1.81E-07	0.000881239	0	0	0	0	5	Native
Verbenaceae	*Stachytarpheta jamaicensis*	1133	0.24	0.011592276	0.058154492	802	0.090863783	0.000599362	0.02756926	1935	Alien
	Lantana camara	301	0.101692392	0.000816169	0.024639952	741	0.085743192	0.000511602	0.026015606	1042	Alien
	Duranta plumerii	10	0.006615033	8.13E-07	0.001602815	0	0	0	0	10	Alien
	TOTAL	10519	2.76	0.1017263	0.67	32739	2.41	0.11	0.73	43258	
	Site 1					37 Alien 25 Native					
	Site 2					30 Alien 25 Native					

egend: (N- Species abundance; H'-Shannon-Weiner diversity index; D-Simpson diversity index; PE- Pielou's evenness) similar trend can be seen in S2. Since there were more disturbances in S1 brought about by anthropogenic activities, it is not surprising to have a higher alien plant species richness in this site. The chance of having more vectors (i.e., humans, animals, etc.) in S1 that intentionally or unintentionally introduced these species of plants to establish and proliferate is higher. Anthropogenic activities, which has brought social and economic benefits to many people, can contribute to an increased abundance of introduced plants, thus facilitating 'invasional meltdown' (Pysek *et al.,* 2011). The globalization of trade, travel and transport is greatly increasing the number of IAS that are being moved around the world, as well as the rate at which they are moving (Bai and Cheng, 2019).

Simpson's diversity index (D) is employed to identify the probability of randomly sampled individuals belong to the same species or any categories other than species (Magrussan and Boyle, 1995). The resulting value shows that the number nearest to 0 is infinitely diverse and the value nearest to 1 is less diverse (Magrussan and Boyle, 1995). In this case, without taking into account the species richness, Site 1 (D=0.10) is more diverse compared to S2 (D=0.11) (Table 3), i.e., alien plants were concentrated and dominant in S1, composed of 37 alien plants compared to 30 alien plants of S2 (Table 3). On the other hand, Pielou's evenness index showed that S2= 0.73 showed more even distribution compared to S1= 0.67 (Table 3). In this index, the values nearest to 1 mean even distribution of species. These values showed the inverse proportionality of species dominance to species evenness--the higher the dominance, the lower the evenness or vice versa. According to Studeny *et al.* (2010), the natural community is never perfectly even. However, the degree of unevenness provides important insights into the mechanisms that structure a community and the extent to which it is disturbed. Pielou's evenness index showed how evenly and equally the individuals of the species are distributed and the value constraints between 0 and 1. Species richness and species evenness are often correlated. However, in some instances, they show higher diversity, but the individuals per species may not be evenly distributed. Results of the floral survey in all study sites in Mt. Manunggal showed a dominance of alien plant species against native plant species. This could mean that the rate of growth of alien plant species is faster than that of native plant species. Since Mt. Manunggal is a secondary forest (DENR, 2007), and most of the plants were part of reforestation programs endorsed by the government and locals, the invasion of alien plant species was facilitated (NRCBD, 2009). Anthropogenic activities (i.e., farming, tilling of land, livestock and poultry for livelihood) hastened the establishment, growth and proliferation of alien plant species in the study sites. Farmers have been tilling parts of the area since birth to secure livelihood and according to Ali *et al.* (2018), forests ecosystems with agricultural lands are more prone to alien plant species because during clearing and cutting, the farmers may leave a vacant, clear habitat where alien plant species can proliferate. Animal domestication is associated with alien plant invasion due to the presence of granivores (grain-eating animals) and frugivores (fruit-consuming organisms) which assist in the dispersal of seeds in the different forests. Continuous increase in the number of alien plant species may potentially alter forest community structure and function, thereby threatening ecological and environmental

Table 3. Summary of species richness, evenness, and diversity of native and alien plants in Site 1 and Site 2, Mt. Manunggal, Cebu Island, Philippines.

Sampling site	R	H'	D	PE
S1	62	2.76	0.10	0.67
S2	55	2.41	0.11	0.73

Legend: (R-Taxa (species) richness; H'-Shannon-Weiner diversity index; D-Simpson diversity index; PE-Pielou's evenness

Table 4. Top 13 alien species of plants in Site 1 and Site 2, Mt. Manungal, Cebu Island, Philippines.

No.	Top 13 IAS	Abundance (%)
1	*Axonopus compressus*	13.90
2	*Elephantopus mollis*	13.62
3	*Ageratum conyzoides*	12.93
4	*Imperata cylindrica*	12.74
5	*Paspalum conjugatum*	11.16
6	*Hyptis capitata*	7.68
7	*Mikania micrantha*	4.90
8	*Pennisetum purpureum*	4.71
9	*Stachytarpheta jamaicensis*	4.47
10	*Miconia calvescens*	2.73
11	*Cyathea contaminans*	2.45
12	*Lantana camara*	2.41
13	*Swietenia macrophylla*	1.02

significance of Mt. Manunggal and could eventually lead to stochastic extinction of native species of plants in the area.

The listed alien plant species in Table 4 occur as major weeds in moist areas at elevations as high as 500-2000 masl. These plants require high light intensity from the sun and thrive at different moisture conditions (MacLaren *et al.,* 2019). They grow best where soil fertility, organic matter, and air humidity are all high. Most of these species were found in S2 (Table 4). As observed, both the study sites were located at the peak of Mt. Manunggal where the air is very humid. Also, in the search to identify factors that make alien plant troublesome invaders, many studies have compared various measures of alien invasive plant performance against the natives. This includes higher growth rates, competitive ability or fecundity, higher leaf area, lower tissue construction costs which are advantageous under high light and nutrient conditions. Alien plants also have greater phenotypic plasticity, which is particularly beneficial in disturbed areas where conditions are in frequent flux; and the increase resource availability and altered disturbed regimes associated with human-mediated activities often differentially increase the performance of alien invaders over that of natives (Pysek *et al.,* 2011).

Anthropogenic Activities and Economic Importance and Function of Alien and Native Plants

There were 77 responses from the local villagers when asked about the activities they usually do in Mt. Manunggal, especially at the study sites (Table 5). Higher anthropogenic activities were recorded in S1 than in S2. In S1, a total of 45 local villagers were into farming, and 32 were into animal grazing. Twenty-nine (29) local villagers utilized plants for medicinal purposes, while 26 use plants as a source of wood for charcoal. Other anthropogenic activities that were also rampant in S1 were hunting/poaching (25), livestock (25), carpentry (22), and abaca processing (21). On the other hand, in S2, only 11 local villagers were into farming, while 9 were into abaca processing, utilization of medicinal plants, and mountain climbing. Only five local villagers were into hunting/poaching, while 4 were into animal grazing, slashing, cutting and burning. Other anthropogenic activities that were practiced in Site 2 by the local villagers were carpentry (3) and utilization of wood for charcoal (3). For the months of October 2016 to February 2017, there were ten activities of mountain climbing and camping in Site 1, while a total of nine cases of mountain climbing and 7 cases for camping in S2. The number of activities were the bases in the identification of the site as highly-disturbed site (S1) and less disturbed site (S2). From the inventory presented in Table 1, there were 68 species of alien and native plants belonging to various families that had different economic uses to the local villagers in both sites of Mt. Manunggal, Cebu Island, Philippines. Of the most economically important plant species identified by the locals (Table 5), 11 are alien plant species such as *Cyathea contaminans*, *Acacia mangium*, *Gmelina arborea*, *Theobroma cacao*, *Swietenia marcophylla*, *Artocarpus heterophylla*, *Psidium guajava*, *Bambusa* sp., *Coffea arabica*, *Citrus microcarpa* and *Citrus maxima*. There were some natives, and these were: *Casuarina equisitifolia*, *Terminalia nitens*, *Cinnamomum mercadoi* and *Langerstroemia speciosa* (Table 2). The alien plants were either natural recruits or planted intentionally for utility. This is in congruence to the study of Garces and Genterolizo (2018), where other uses of alien plant species include feed to livestock, human induced farming, medicinal utilization and prevention of erosion.

For instance, *Cyathea contaminans* is native of Australia and is a known spore-bearing tree alien in the Philippines forests. Its spores were most likely dispersed through wind resulting in its widespread distribution in Mt. Manunggal. It grows in wastelands or pioneer-stage secondary forests. It is a hardy plant and can be grown in sunny areas. Aside from being used as food, the majority of the villagers also use this as ornament and source of wood. However, the

Table 5. Anthropogenic activities recorded in S1 and S2, Mt. Manunggal, Cebu Island, Philippines

Anthropogenic activities	S1	S2
Animal grazing	32	4
Hunting/poaching/consumption	25	5
Livestock	25	8
Farming	45	11
Medicinal plants	29	9
Abaca processing	21	9
Carpentry	22	3
Wood charcoal	26	3
Slashing, cutting and burning	21	4
Mountain climbing	10	9
Camping	10	7

Department of Environment and Natural Resources-VII (DENR-VII) has strictly prohibited its utilization to avoid further erosion in the site. G. *arborea* was used several years ago by the government as one of the planting materials for reforestation. The same history goes to A. *mangium* and S. *macrophylla*. On the other hand, T. *cacao* was intensely endorsed by the government to be planted in the different areas of Mt. Manunggal as a major source of chocolate for income generation by the local villagers, as well as a source of wood for fuel and carpentry (Garces and Genterolizo, 2018). All of these were consistently mentioned during the interviews of the locals conducted in S1 and S2. Seed-bearing trees of A. *heterophylla*, P. *guajava*, C. *arabica*, C. *microcarpa*, and C. *maxima* served as source of food, wood, and medicine. The selection by the local villagers is mostly due to convenience as individual alien plant species of C. *contaminans*, A. *mangium*, G. *arborea*, T. *cacao*, S. *marcophylla*, A. *heterophylla*, P. *guajava*, *Bambusa sp.,* C. *arabica*, C. *macrocarpa*, and C. *maxima* were found everywhere in the forest. Several of these alien plant species have similar economic uses in other parts of the world. Species of *Miconia calvescens* and *Eucalyptus globulus* have been recorded as excellent insect-repellent. The selection of these plants may be due to its mint-smelling leaves which have bioactive compounds of p-methane-3, 8-diol present in both plants and are said to be comparable to the active ingredients present in commercial products (Nerio *et al.,* 2010). Interestingly, four of the most invasive alien plant species identified in the site have been reported in published papers to have medicinal properties, namely: *Lantana camara*, *Ageratum conyzoides*, *Paspalum conjugatum*, and *Elephantopus mollis*. L. *camara* and E. *mollis* are found useful in fold remedies for cancers and tumors. A tea is prepared from the leaves and flowers and taken orally against fever, influenza and stomachache. These medicinal uses have been confirmed by some local villagers in Mt. Manunggal. Local villagers in the site also used P. *conjugatum* and A. *conyzoides* to treat fever through decoction. Its leaves are also useful in the treatment of boils, skin diseases and wound healing, as confirmed in the study of Egunyomi *et al.* (2005). On the other hand, native trees of *Casuarina equisitifolia, Terminalia nitens, Shorea stylosa, Shorea negrosensis, Dillenia philippinensis* and *Langerstroemia speciosa,* were utilized before by the local villagers as their source of wood for fuel and for carpentry. A few individuals of *Cinnamomum mercadoi* and *Quassia indica* were recorded in the site, but because of the threats of habitat fragmentation, the introduction of alien plant species and overexploitation, these remaining native trees have been protected and conserved by the DENR. In the recent years, the Philippine government has appreciated the importance of the involvement of the local people in the management and protection of our forests, most especially for native tree species. The DENR has designed resource management programs, together with local villagers in the community in the protection and conservation of the remaining native trees in our forests. One of its programs includes the Integrated Social Forestry Program and Community Forestry Program. The most recent umbrella program is the Community-Based Forest Management. Although these programs have enabled the local community to work hand-in-hand with the government, it is still needful to consider efforts in determining suitable tree species that would fit into the people's needs and practices in the short, medium and long-term period. The use of alien trees such as G. *arborea* and S. *macrophylla* had been commonly practiced in the reforestation sites in the Philippines. Although they can be propagated easily and are proven to grow in all types of soils, farmers still prefer native trees since these are well-adapted to Philippine conditions and utilized for high-quality wood and products. For example, C. *mercadoi* has leaves and barks which are valued for its aromatic oil which is useful as a condiment and flavoring material (Ravindran *et al.,* 2004). C. *equisetifolia*, L. *capitalla*, F. *balete*, and F. *minhassae* have high-quality timber which were converted to lumber, wood pulp, charcoal, and construction materials. The knowledge of local villagers about trees is necessary for the development of workers and policy-makers. Full awareness of farmers concerning to suitable tree species for smallholder forests are valuable inputs to community-based forest management. In particular, this will be important as a reference in the choice of species to be planted for community-based reforestation. It is more likely that farmers desire for native trees in forest reforestations.

CONCLUSION

The vegetation survey revealed domination of alien plant species in terms of species richness (S1;

R=37 and S2; R=30) and abundance (S1; N=10519; S2; N=32,739) in both sites. However, there was higher species richness (S1; R=62 and S2; R=30) and diversity (S1; H'=2.76, D=0.10 and S1; H'=2.41, D=0.11) but lower abundance (S1; N=10519 and S2; N=32739) and evenness (S1; PE=0.67 and S2; PE=0.73) in S1 than in S2. High richness and diversity in S1 could be attributed to a higher species richness of alien plants in this highly disturbed site than in the less disturbed site. The high abundance (both for native and alien plants) and evenness in S2 could be due to favorable environmental conditions, anthropogenic activities and economic uses for both native and alien plants. It is recommended that future studies of alien plant species effects on native plant species and native pollination success at larger spatial and temporal scale since most studies on native-alien interactions are focused on small spatial scale and few seasons. Assessment on the negative impacts by alien plant invasion to native floral diversity, enhanced by anthropogenic activities and economic uses, must therefore serve as bases in future directions and implication for restoration and conservation of the remaining forests of Mt. Manunggal, Cebu Island, Philippines. Work is essential with the research focusing on the early detection, introduction pathway, degree of establishment and impact mechanism of alien plant species in order to establish a robust rapid response program in some of the remaining protected forests of the Philippines. Additionally, the need for steadfast dissemination of information on the differences between alien and native plant species, must be emphasized.

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CONFLICT OF INTEREST

The author declares that there is no conflict of interests regarding the publication of this manuscript. In addition, the ethical issues, including plagiarism, informed consent, misconduct, data fabrication and/or falsification, double publication and/or submission, and redundancy have been completely observed by the authors.

ABBREVIATIONS

Brgy.	Barangay
CHED	Commission of Higher Education
CCPL	Central Cebu protected landscape
D	Simpson diversity index
Dr.	Doctor
DENR	Department of Environment and Natural Resources
Eq.	Equation
Fig.	Figure
Has.	Hectares
H'	Shannon-weiner index
IAS	Invasive alien species
Ln	Natural logarithm
m	Meters
masl	Meters above sea level
Mt.	Mount
ni	Number of individuals
NGP	National greening program
N	Species abundance
NIPAS	National Integrated Protected Areas System
NRCBD	National Report to the Convention on Biological Diversity
PE	Pielou's evenness
PCARRDD	Council for Agriculture, Forestry and Natural Resources Research and Development
PAMB	Protected Area and Management Bureau
PIC	Prior Informed Consent
R	Taxa (species richness)
S1	Site 1
S2	Site 2
UNEP	United Nations Environment Program

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