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Comparison of Floral Diversity of Pine Forest, Agroforestry and Agricultural Land-Uses in Talinguroy Research Station, Benguet State University, Northern Philippines

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Abstract

The Secretariat of the Convention on Biological Diversity identified insufficient knowledge base as one of main barrier for biodiversity conservation. Additionally, tropical coniferous forest was identified as the least represented biome in terms of local-scale species richness amidst being susceptible to land-use change. This makes the study opportune and much needed as it documented and compared the floral diversity in three land-uses, namely agriculture, agroforestry and tropical pine forest, of Talinguroy Research Station, Benguet State University in Cordillera Central Range, Northern Philippines using plot method. A total of 68 species belonging to 63 genera and 40 families was documented, Family Poaceae and Asteraceae being the most represented with 11 and 10 species. Greater Asteraceae and herb species were documented in agricultural plots>agroforesty>forest but indigenous/endemic species, over-all species diversity, shrub and tree diversity was highest in forest>agroforestry>agricultural plots. Lowest species similarity was observed between agricultural plots and pine forest while highest between agroforestry and pine forest. These results illustrated a direct effect of human disturbance brought by land-use change on species diversity of the area. Greater disturbance resulted to a lower diversity of indigenous and endemic species, lower over-all species diversity, lower shrub and tree diversity but higher herb diversity. Moreover, the study found agriculture to cause more change in species composition than agroforestry. Interestingly, higher Asteraceae species were correlated positively with higher degree of human disturbance. These information are important baseline information in crafting conservation measures particularly for several endangered indigenous and endemic species in the region.

KEYWORDS

endemic
indigenous species
biodiversity indices
human disturbance

Introduction

Biodiversity, the variability among living organisms from genetic to species to ecosystems, is stressed by the Secretariat of the Convention on Biological Diversity (2018) to be at the heart of sustainable development. This is due to the fact that biodiversity underpins the provision of food, fibre and water; it mitigates and provides resilience to climate change; it supports human health and provides jobs in agriculture, fisheries, forestry and many other sectors (OECD, 2014). Thus, practically, biodiversity supports the achievement of all Sustainable Development Goals (SDGs). The role of biodiversity and healthy ecosystems is reflected not only in SDG 14 (life below water), and SDG 15 (life on land), but also in many other goals and targets. For example, there are critical dependencies for biodiversity in SDG 2 on zero hungers; SDG 6 on the ecosystem providing reliable source of freshwater; SDG 7 on bio-energy from renewable biomass as clean and affordable energy; and SDG 11 where ecosystems provide clean water, air and resilience to climate change and natural calamities (Biodiversity and the 2030 Agenda for Sustainable Development).

The Philippines, being a signatory in the United Nation SDGs, has a strong interest in biodiversity and its conservation. The country is one of the top biodiverse countries but is also a biodiversity hotspot due to the fast rate of biodiversity loss (Philippine Biodiversity Conservation Priorities, 2002). The Secretariat of the Convention on Biological Diversity (2018) identified insufficient knowledge base as one of main barriers for biodiversity conservation together with insufficient mainstreaming of biodiversity considerations in the economic sectors, and in cross-sectoral policies such as development plans and budgets. These two factors are evident in the ineffective biodiversity conservation in the country. A review paper by Langenberger (2004) showed the poor representation of Philippine vegetation in international research compared to other tropical rainforest areas. There is a recent spike of biodiversity researches in the country but still not enough to account for its rich biodiversity (Napaldet & Buot, 2019); thus, the need for more biodiversity studies.

Another major and compounding factor that threatens biodiversity is land-use change. It is well recognized that the Earth's biodiversity is undergoing significant changes resulting from land-use change (Butchart et al. 2010; Barnosky et al. 2011). A review paper by Murphy and Rumanok (2016) showed that, among the world's biomes, tropical coniferous forest was one of the least represented biomes in terms of local-scale species richness and distribution studies. This lack of studies in tropical coniferous forests is particularly concerning because it is one of least represented biome in terms of local-scale species richness and at the same time, one of most susceptible biome to land-use changes. This case is particularly true in the tropical coniferous forests of Cordillera Central Range (CCR), Northern Philippines. Studies that explore changes in species richness resulting from land-use changes are essential to understand how human activities affect biodiversity and have important implications for ecosystem management and policy formation.

These scenarios make the study timely and much needed. We inventoried and compared the floral diversity between the different land uses at Talinguroy Research Station, Benguet State University (BSU), Northern Philippines. Talinguroy Research Station is one of the remaining forest cover in La Trinidad, Benguet being managed by BSU. Certain patches were transformed for agriculture (semi-temperate vegetables) and agroforestry (coffee under alnus) purposes. This study hope to contribute in elucidating how land-use change affects floral diversity in a tropical coniferous forest, the dominant forest type in the locality. Moreover, the results of the study is an important instructional material and guide for plant identification which could help mainstream biodiversity information to the general public. This could foster appreciation for biodiversity from the public, make them more concern, which in turn, could help greatly in biodiversity conservation.

Materials and Methods

Documentation and Identification

Inventory of vascular plants diversity was conducted in different land uses at Talinguroy Research Station. Three (3) land-uses were identified in the area namely, agricultural plots, agroforestry plots and pine forest that served as sampling stations. This was done by photo documenting and identifying all vascular plants in the sampled plots. Several taxonomy references were consulted for proper identification of the vascular plants such as Vascular Plants of Mt. Makiling and Vicinity Volumes 1-4 (Pancho & Gruezo, 1983, 2006, 2009, 2012), Manual of Ricefield Weeds (Pancho & Obien 1995), and Co's Digital Flora (Pelser et al., 2011 onwards). Identification is considered a primary process for the researchers to have an easier way of describing, classifying and incorporating information related to a certain floral species. Scientific names and classification were checked and verified in the Kew website: www.theplantlist.org.

Plot Method

Plot method was employed in data gathering. This method is simple to use, and the materials needed are readily available. Aside from its convenience, the uniform shapes of the plots together with the randomized distribution throughout the sampling area makes it straight forward. Although physically demanding, this method is not destructive to the plants. In agricultural areas, six (6) 1m x 1m quadrats were established for herbs/grass. On the other hand, agroforestry and forest sites were sampled with six (6) 1m x 1m quadrats for understory herbs/grass, four (4) 2m x 10m plots for understory shrub, and two (2) 20m x 50m plots for trees. Plants in the plots were identified and documented. Under the agroforestry and forest sites, tree seedlings were counted as understory herbs while saplings (=<5 cm in diameter) as shrubs. Additionally, diversity indices such as Shannon-Wiener, Simpson's, Margalef's and Jaccard index of similarity were computed. Shannon-Wiener diversity index takes into account species richness and the proportion of each species within the local community. It also takes into account the evenness or the distribution of individuals among the species. It was calculated as follows:

$$H = \sum_{i=l}^{S} pi(lnpi)$$

where: H = Shannon-Wiener diversity index
pi = Number of individuals of species i/ total number of samples
S = Number of species or species richness

Evenness quantitatively depicts the distribution of species within the area. It is interpreted as 0 with no evenness or complete dominance and 1 with complete evenness or equal distribution. It was calculated as follows:

$$E = \frac{H}{Hmax}$$

where: E = evenness
H*max* (maximum diversity possible) = ln (N)

Simpson's diversity index is the complementary of evenness. It is the common measure of dominance with values ranging from 0 to 1, with 1 representing infinite diversity and 0, no diversity (Barcelona Field Studies Centre, 2018). It was computed as follows:

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

where: ni = total individual of species i
N = total number of individual of all species

On the other hand, Margalef's index is simpler. It was computed as:

$$R = \frac{(S-1)}{\ln\ (N)}$$

where: R = richness
S = no. of species
N = no. of individuals (of all species)

To compare the diversity between sampling stations, Jaccard index of similarity was used. It was computed as:

$$J = \frac{Sc}{Sa + Sb + Sc}\ x\ 100$$

where:
Sc - number of species common to the two samples
Sa - number of species unique to station a
Sb - number of species unique to station b

Aside from measuring the population counts and diversity indices, the study also look into the indigenous and endemic species. These were compared between the three sampling stations (land-uses) and these information could serve as an additional way of looking on how land-use change affect species richness. Indigenous and endemic species were counted in the sampling stations, and these served for computation of its percentage and index. Indigenous/endemic species index was pattered with minor revision from the formula for biodiversity index proposed by American Museum Natural History (2001). It was computed as follows:

$$Endemic\ species\ index = \frac{No.\ of\ indigenous\ or\ endemic\ species}{Total\ number\ of\ all\ individuals\ of\ all\ species}\ x\ 100$$

Results and Discussion

Species Richness

A total of 68 species belonging to 63 genera and 40 families were documented in Talinguroy Research Station. These include 41 herbs or grass species (including tree seedlings), 24 shrubs (including tree saplings) and 16 tree species. In terms of species richness, family Poaceae and Asteraceae were the most represented with 11 and 10 species, respectively (Figure 1A). These were followed by Cyperaceae, Fabaceae and Rosaceae

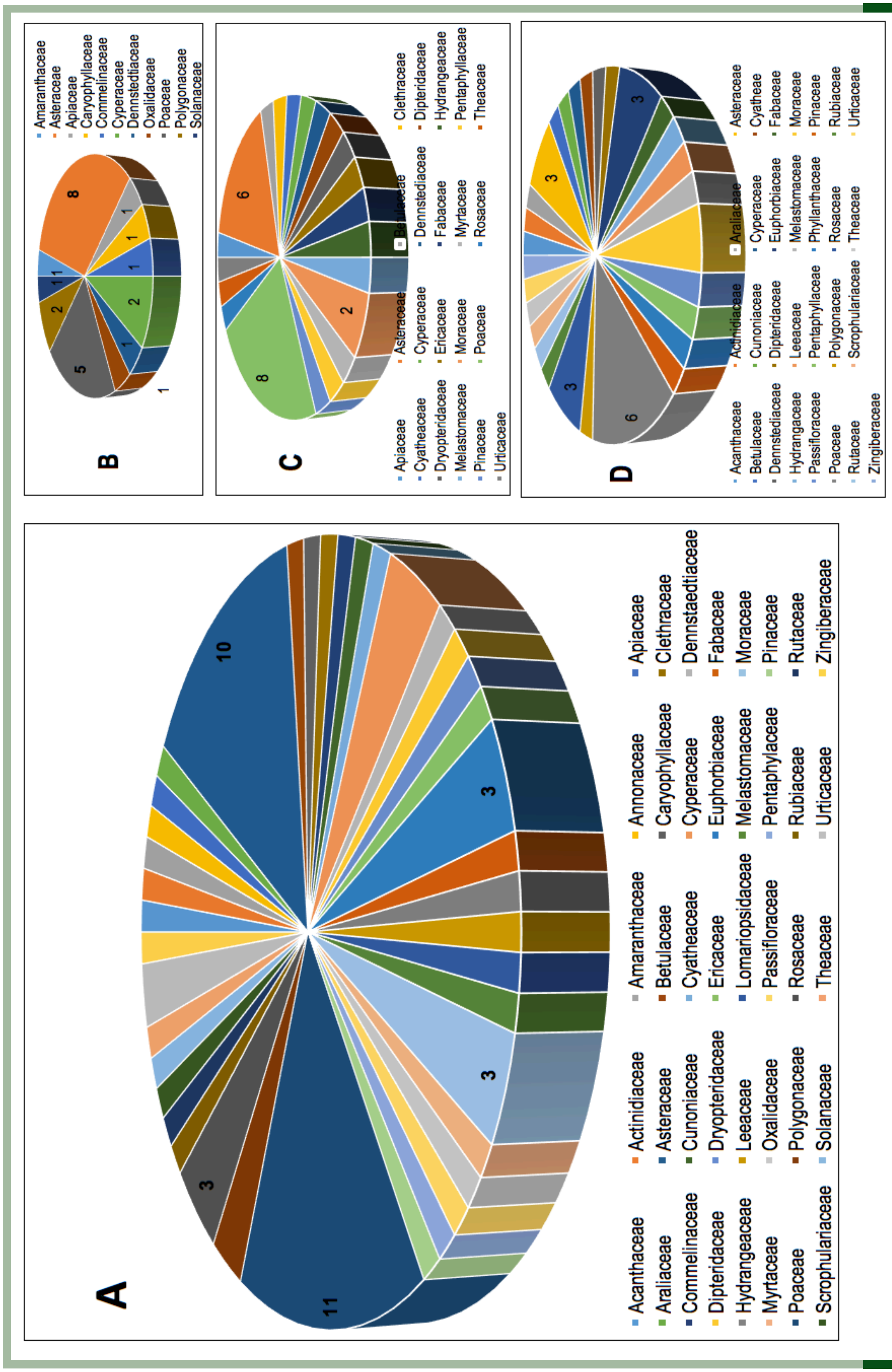

Figure 1. Family distribution of vascular floral species of Talinguroy Research Station (A – overall; B – agricultural plots; C – agroforestry plots; D- pine forest)

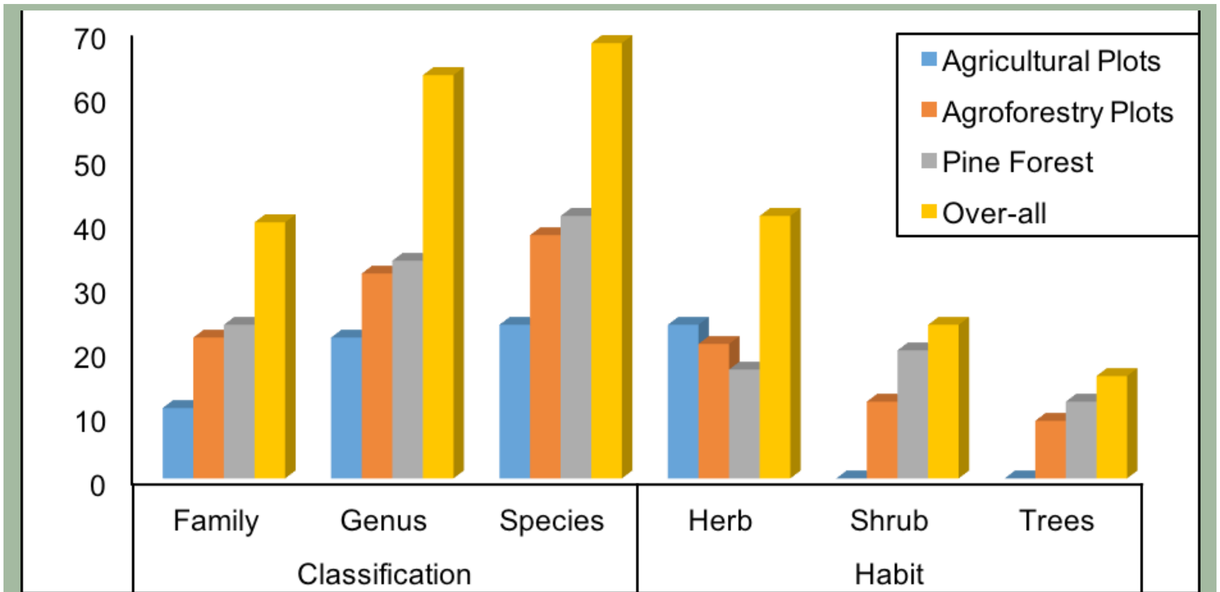

Figure 2. Classification and plant habit of floral species in Talinguroy Research Station

with three (3) species each while the rest were represented by a single species. These over-all trend was also observed in the sampling stations. Family Poaceae and Asteraceae had five (5) and eight (8) species in agricultural plots; eight (8) and six (6) in agroforestry plots; and, six (6) and three (3) in the forest (Figure 1B-D).

The species richness in the area is comparable with those documented in nearby Alno Communal Forest by Lumbres et al. (2014) at 78 species belonging to 43 families and in Palina River, Kibungan by Batani et al. (on press) at 61 species under 25 families. On the other hand, the species richness of families Asteraceae and Poaceae in the area is expected since these are two of the largest plant families (Pancho & Gruezo, 2012). These families harbors species of several importance and have wide distribution. Asteraceae or sunflower family consists of 1,911 genera and 32,205 species worldwide (Royal Botanic Gardens Kew and Missouri Botanic Garden, n.d.) while Poaceae has 759 genera and 11, 554 species.

In the study area, the trend in Asteraceae species richness is interesting wherein it was highest in agricultural plots then lessen in agroforestry and least in forest plots. This reflects one possible direct effect of land-use change or human disturbance to species richness. In the most disturbed plots namely agricultural, it harbors the highest species of Asteraceae and this could be readily attributed to the removal of original vegetation resulted to opening of new areas that weedy Asteraceae can readily colonize. This family is equiped with fast dispersal of their cypsela and fast growth rate (Napaldet & Buot, 2019). Fewer Asteraceae species were observed in the agroforestry plots and fewest in the forest which is less disturbed. The same trend was observed by Guron and Napaldet (on press) in nearby Mt. Jambo, La Trinidad where 16 Asteraceae species were inventoried in highly disturbed residential and agricultural plots but only five (5) in the less disturbed summit. These observations are leading to the generalization that the diversity of Asteraceae species corresponds to the degree of human disturbance, at least in Cordillera Central Range, Philippines. However, we are not proposing this to be true in low elevation areas since family Asteraceae is predominantly of temperate affinity (Pancho & Gruezo, 2012).

Between stations, 24 species belonging to 22 genera and 11 families were inventoried in the agricultural plots; 34 species under 32 genera and 22 families in the agroforestry plots; and 41 species under 38 genera and 24 families in the pine forest (Figure 2). In terms of habit, 24 weedy herb/grass species are found in the agricultural plots; 21 herbs, 12 shrubs and 9 trees in the agroforestry plots; and 17 herbs, 20 shrubs and 12 trees in the forest plots. A clear trend is immerging from these numbers and also could be deduced in the figure. There is an increasing total species diversity, shrub and tree diversity from agricultural to agroforestry to forest plots but opposite for herb diversity. This could be attributed to the level of human disturbance in the different land-use stations. All shrubs and trees were removed in the agricultural plots thus only weedy herbs and grasses grew. The agroforestry plots, on the other hand, were intended for coffee production under alnus tree thereupon other competing shrubs and trees are being cleared. Lastly, the forest plots were relatively less disturbed allowing indigenous or endemic shrubs and trees to grow. These results support the findings of Butchart et al. (2010) and Barnosky et al. (2011) that land-use change have a direct effect on species richness. Moreover, the study demonstrated that land-use change in the area did not just have a direct effect on species richness but also specifically on diversity based on plant habit and on Asteraceae species diversity. Greater degree of human disturbance resulted to greater diversity of Asteraceae species and herb species but lower diversity of shrub and tree species.

Indigenous and Endemic Species. Indigenous species refer to native organisms of a particular area that are also naturally occurring in other areas while endemic species are those confined only in a particularly area and nowhere else (Pelser et al,. 2001 onwards). These species are the most susceptible to land-use change and other human disturbances (Pancho and Gruezo 2009, 2012). Results of the study confirmed this. As shown in Table 1, very few indigenous/ endemic species occur in agricultural plots, more in agroforestry and most in the forest. Consequently, indigenous/ endemic species index was lowest in agricultural plots, higher in agroforestry and highest in the forest. This trend showed a direct effect of land-use change on the diversity of indigenous and endemic species. Greater disturbance brought by land-use change resulted to lower diversity of indigenous and endemic species.

Population Counts and Dominance. Table 2 presents the species composition of the agricultural plots in Talinguroy Research Station. The most dominant species were primarily Poaceae and Asteraceae species including *Eleusine indica, Galinsoga parviflora, Paspalum conjugatum, Ageratum conyzoides* and *Crassocephalum crepidioides*. The inventory was conducted during the farrow period thus weeds were allowed to grow but eventually will be cleared for cropping. Almost all the plants identified in the agricultural plots were weeds. In fact, *E. indica, G. parviflora, P. conjugatum, A. conyzoides, Imperata cylindrica, Murdannia nudiflora, Axonopus compressus, Bidens pilosa* and *Oxalis corniculata* were included in the world's worst weeds (Holm et al., 1977).

On the other hand, Tables 3a–c present the species composition in the agroforestry plots from understory herbs (3a) to understory shrubs (3b) to overstory trees (3c). *Ageratina riparia* was the most dominant understory herbs, *Coffea arabica* and *Alnus japonica* saplings were the dominant understory shrubs and *Alnus japonica* was the dominant tree cover. *Ageratina riparia*, a native of South America (Turner, 1997), is now becoming a dominant understory weed in different parts of Cordillera Central Range. This was also observed to be dominant by Batani et al. (on press) in Palina River, Kibungan. In the agroforestry plots, few understory herbs were indigenous and endemic species including *Rubus luzoniensis, Themeda triandra, Miscanthus floridulus* and *Pteridium aqualinum*. More indigenous and endemic species were shrubs including *Camellia sinensis, Clethra canescens* var. *luzonica, Cyathea contaminans, Deutzia pulchra, Eurya coriacea, Ficus benguetensis, Melastoma malabathricum* and *Vaccinium barandanum*. However, these are regularly being trimmed or cut to remove possible competition to the coffee plants. Nonetheless, these results showed that agroforestry has a lesser impact to indigenous/ endemic species than pure agriculture.

Table 1

Indigenous/Endemic Species Index of the Different Land-Uses in Talinguroy Research Station

Sampling Stations	Number of Indigenous/ Endemic Species	% Indigenous/ Endemic Species	Indigenous/ Endemic Species Index
Agricultural Plots	2	8.33	0.387
Agroforestry Plots	19	55.88	3.237
Forest	28	68.29	9.929
Over-all	32	47.06	2.314

Table 2

Population counts of herbs in agricultural plots (under farrow) at Talinguroy Research Station, Benguet State University, Philippines

Species name	ni	Ji	Di	Fi	RDi	RFi	IV	Rank
Ageratina riparia (Regel) R.M.King & H.Rob.	14	3	2.33	50.00	2.71	5.08	3.90	10
Ageratum conyzoides (L.) L.	57	4	9.50	66.67	11.03	6.78	8.90	4
Amaranthus spinosus L.	9	1	1.50	16.67	1.74	1.69	1.72	
Axonopus compressus (Swartz) P. Beauv	2	1	0.33	16.67	0.39	1.69	1.04	
Bidens pilosa L.	24	4	4.00	66.67	4.64	6.78	5.71	7
Centella asiatica (L.) Urban	31	5	5.17	83.33	6.00	8.47	7.24	5
Crassocephalum crepidioides (Benth.) S.Moore	34	4	5.67	66.67	6.58	6.78	6.68	6
Cyperus distans L.f.	7	1	1.17	16.67	1.35	1.69	1.52	
Cyperus pygmaeus Rottboll	17	1	2.83	16.67	3.29	1.69	2.49	
Dicrocephala auriculata	2	1	0.33	16.67	0.39	1.69	1.04	
Digitaria violascens Link	20	4	3.33	66.67	3.87	6.78	5.32	8
Drymaria cordata (L.) Willd. ex Schult.	28	2	4.67	33.33	5.42	3.39	4.40	9
Eleusine indica (L.) Gaertn	94	5	15.67	83.33	18.18	8.47	13.33	1
Erigeron sumatrensis Retz	7	1	1.17	16.67	1.35	1.69	1.52	
Galinsoga parviflora Cav.	60	4	10.00	66.67	11.61	6.78	9.19	2
Imperata cylindrica (L.) Raeusch.	3	1	0.50	16.67	0.58	1.69	1.14	
Murdannia nudiflora (L.) Brenan	1	1	0.17	16.67	0.19	1.69	0.94	
Oxalis corniculata L.	16	2	2.67	33.33	3.09	3.39	3.24	
Paspalum conjugatum P. J. Bergius	50	5	8.33	83.33	9.67	8.47	9.07	3
Persicaria capitata (Buchanan-Hamilton ex D. Don) H. Gross	6	2	1.00	33.33	1.16	3.39	2.28	
Persicaria chinensis (L.) H. Gross	1	1	0.17	16.67	0.19	1.69	0.94	
Pseudognaphalium hypoleucum (DC.) Hilliard and B.L. Burtt	5	3	0.83	50.00	0.97	5.08	3.03	
Pteridium aqualinum (L.) Kuhn.	8	2	1.33	33.33	1.55	3.39	2.47	
Solanum americanum Mill.	21	1	3.50	16.67	4.06	1.69	2.88	
	517		86.17	983.33	100.00	100.00	100.00	

Table 3a

Population counts of understory herbs in the agroforestry plots at Talinguroy Research Station, Benguet State University, Philippines

Species name	ni	Ji	Di	Fi	RDi	RFi	IV	Rank
Ageratina adenophora (Spreng.) R.M. King and H. Rob.	3	1	0.50	16.67	1.08	2.86	1.97	
Ageratina riparia (Regel) R.M. King and H. Rob.	123	5	20.50	83.33	44.24	14.29	29.27	1
Ageratum conyzoides (L.) L.	1	1	0.17	16.67	0.36	2.86	1.61	
Axonopus compressus (Swartz) P. Beauv	1	1	0.17	16.67	0.36	2.86	1.61	
Bidens pilosa L.	15	1	2.50	16.67	5.40	2.86	4.13	5
Bolbitis crenata (C.Presl) C.Chr.	1	1	0.17	16.67	0.36	2.86	1.61	
Centella asiatica (L.) Urban	1	1	0.17	16.67	0.36	2.86	1.61	
Crassocephalum crepidioides (Benth.) S.Moore	3	1	0.50	16.67	1.08	2.86	1.97	
Dipteris conjugata Reinw.	1	1	0.17	16.67	0.36	2.86	1.61	
Elephantopus tomentosus L.	5	1	0.83	16.67	1.80	2.86	2.33	10
Gonostegia hirta (Blume ex Hassk.) Miq.	24	1	4.00	16.67	8.63	2.86	5.75	4
Imperata cylindrica (L.) Raeusch.	3	2	0.50	33.33	1.08	5.71	3.40	6.5
Miscanthus floridulus (Labill.) Warb.	1	1	0.17	16.67	0.36	2.86	1.61	
Oplismenus hirtellus (L.) P. Beauv	7	1	1.17	16.67	2.52	2.86	2.69	8
Paspalum conjugatum P.J. Bergius	54	5	9.00	83.33	19.42	14.29	16.86	2
Pogonatherum crinitum (Thunb.) Kunth	3	1	0.50	16.67	1.08	2.86	1.97	
Pteridium aqualinum (L.) Kuhn.	19	5	3.17	83.33	6.83	14.29	10.56	3
Rubus luzoniensis Merr.	6	1	1.00	16.67	2.16	2.86	2.51	9
Scleria laevis Willd.	3	1	0.50	16.67	1.08	2.86	1.97	
Sporobolus indicus (L.) R.Br.	3	2	0.50	33.33	1.08	5.71	3.40	6.5
Themeda triandra Forssk.	1	1	0.17	16.67	0.36	2.86	1.61	
Total			46.33	583.33	100.00	100.00	100.00	

Lastly, species composition of the pine forest are shown in Tables 4a (understory herbs), b (understory shrubs) and c (trees). *Ageratina riparia* and *Oplismenus hirtellus* were the dominant herbs, *Melastoma malabatricum* was the most dominant shrub and *Pinus kesiya* was the most dominant tree. Shrub species were more diverse in pine forest and the distribution of individuals is more even compared to agroforestry plots. No shrub species was distinctively dominant under

Table 3b

Population counts of understory shrubs in the agroforestry plots at Talinguroy Research Station, Benguet State University, Philippines

Species name	ni	Ji	Di	Fi	RDi	RFi	IV	Rank
Alnus japonica (Thunb.) Steud.	92	4	4.60	100.00	38.02	16.00	27.01	2
Callindra calothyrsus Meisn.	8	3	0.40	75.00	3.31	12.00	7.65	3
Camellia sinensis (L.) Kuntze	2	1	0.10	25.00	0.83	4.00	2.41	10.5
Clethra canescens var. *luzonica* (Merr.) Sleumer	4	2	0.20	50.00	1.65	8.00	4.83	7
Coffea arabica L.	106	4	5.30	100.00	43.80	16.00	29.90	1
Cyathea contaminans (Wall. ex Hook.) Copel.	4	1	0.20	25.00	1.65	4.00	2.83	8.5
Deutzia pulchra S.Vidal	4	2	0.20	50.00	1.65	8.00	4.83	7
Eurya coriacea Merr.	4	2	0.20	50.00	1.65	8.00	4.83	7
Ficus benguetensis Merr.	6	2	0.30	50.00	2.48	8.00	5.24	4.5
Ficus variegata Blume	2	1	0.10	25.00	0.83	4.00	2.41	10.5
Melastoma malabathricum (L.) Smith	6	2	0.30	50.00	2.48	8.00	5.24	4.5
Vaccinium barandanum S.Vidal	4	1	0.20	25.00	1.65	4.00	2.83	8.5
Total			12.10	625.00	100.00	100.00	100.00	

Table 3c

Population counts of trees in the agroforestry plots at Talinguroy Research Station, Benguet State University, Philippines

Species name	ni	BA	Ji	Di	Fi	RDi	RFi	RBA	IV	Rank
Alnus japonica (Thunb.) Steud.	48	58.38	2	0.24	100.00	71.64	20.00	75.00	55.55	1
Clethra canescens var. *luzonica* (Merr.) Sleumer	3	0.94	1	0.02	50.00	4.48	10.00	1.21	5.23	6
Cyathea contaminans (Wall. ex Hook.) Copel.	2	2.99	1	0.01	50.00	2.99	10.00	3.84	5.61	5
Eucalyptus deglupta Blume	1	1.61	1	0.01	50.00	1.49	10.00	2.07	4.52	7
Eurya coriacea Merr.	1	0.35	1	0.01	50.00	1.49	10.00	0.44	3.98	9
Ficus benguetensis Merr.	1	0.40	1	0.01	50.00	1.49	10.00	0.52	4.00	8
Ficus variegata Blume	3	2.43	1	0.02	50.00	4.48	10.00	3.13	5.87	3
Pinus kesiya Royle ex Gordon	4	9.93	1	0.02	50.00	5.97	10.00	12.76	9.58	2
Vaccinium barandanum S.Vidal	4	0.81	1	0.02	50.00	5.97	10.00	1.03	5.67	4
Total		77.85		0.34	500.00	100.00	100.00	100.00	100.00	

pine forest as compared to agroforestry plots where coffee and alnus saplings were evidently dominant. Moreover, the pine forest sampling stations harbored the highest number of indigenous/endemic species. The presence of indigenous/ endemic species in the agroforest and pine forest were encouraging as these were similar with those documented by Norman Edward Kowal way back 1966. This supports the findings of Batani et al. (on press) that pristine areas in the Cordillera Central Range still harbors significant amount of indigenous/endemic species; thus, should be maintained.

Biodiversity Indices. Diversity indices in the three land-use sampling stations are presented in Figure 3. Pine forest plots had the highest number of species and consequently had the highest diversity indices of Shannon-Wiener, evenness, Simpson's and Margalef's at 2.96, 0.53, 0.91 and 8.20, respectively. Lower indices were recorded in the agroforestry and agricultural plots which could be attributed to their lower species richness. Agroforestry plots had the lowest indices even if it has higher species richness than agricultural plots. This could be attributed to high dominance (=less evenness) of *Ageratina riparia* as understory herbs, *Coffea arabica* as understory shrub and *Alnus japonica* as overstory cover. In most ecological studies, Shannon-Wiener's index was

Table 4a

Population counts of understory herbs in the forest at Talinguroy Research Station, Benguet State University, Philippines

Species name	ni	Ji	Di	Fi	RDi	RFi	IV	Rank
Ageratina adenophora (Spreng.) R.M.King & H.Rob.	3	1	0.50	16.67	2.07	2.94	2.51	8
Ageratina riparia (Regel) R.M.King & H.Rob.	65	5	10.83	83.33	44.83	14.71	29.77	1
Aralia bipinnata Blanco	1	1	0.17	16.67	0.69	2.94	1.82	
Buddleja asiatica Lour.	1	1	0.17	16.67	0.69	2.94	1.82	
Dipteris conjugata Reinw.	1	1	0.17	16.67	0.69	2.94	1.82	
Elephantopus tomentosus L.	7	2	1.17	33.33	4.83	5.88	5.35	7
Imperata cylindrica (L.) Raeusch.	12	2	2.00	33.33	8.28	5.88	7.08	5
Miscanthus floridulus (Labill.) Ward	1	1	0.17	16.67	0.69	2.94	1.82	
Oplismenus hirtellus (L.) P.Beauv.	27	4	4.50	66.67	18.62	11.76	15.19	2
Paspalum conjugatum P.J.Bergius	1	1	0.17	16.67	0.69	2.94	1.82	
Passiflora edulis Sims	1	1	0.17	16.67	0.69	2.94	1.82	
Persicaria chinensis (L.) Nakai	7	3	1.17	50.00	4.83	8.82	6.83	6
Pteridium aqualinum (L.) Kuhn.	8	4	1.33	66.67	5.52	11.76	8.64	3
Rubus fraxinifolius Poir.	1	1	0.17	16.67	0.69	2.94	1.82	
Rubus luzoniensis Merr.	5	4	0.83	66.67	3.45	11.76	7.61	4
Scleria laevis Willd.	2	1	0.33	16.67	1.38	2.94	2.16	9.5
Strobilanthes cincinnalis C.B.Clarke	2	1	0.33	16.67	1.38	2.94	2.16	9.5
Total			24.17	566.67	100.00	100.00	100.00	

Table 4b

Population counts of understory shrubs in the forest at Talinguroy Research Station, Benguet State University, Philippines

Species name	ni	Ji	Di	Fi	RDi	RFi	IV	Rank
Aralia bipinnata Blanco	12	1	0.3	25.00	8.22	2.27	5.25	9
Callindra calothyrsus Meisn.	8	2	0.2	50.00	5.48	4.55	5.01	10.5
Clethra canescens var. *luzonica* (Merr.) Sleumer	4	2	0.1	50.00	2.74	4.55	3.64	
Coelorachis rottboellioides (R.Br.) A. Camus	2	2	0.05	50.00	1.37	4.55	2.96	
Coffea arabica L.	6	2	0.15	50.00	4.11	4.55	4.33	
Cyathea contaminans (Wall. ex Hook.) Copel.	8	3	0.2	75.00	5.48	6.82	6.15	5.5
Eurya coriacea Merr.	8	2	0.2	50.00	5.48	4.55	5.01	10.5
Ficus benguetensis Merr.	6	4	0.15	100.00	4.11	9.09	6.60	4
Ficus septica Burm. f. Auili	2	3	0.05	75.00	1.37	6.82	4.09	
Leea philippinensis Merr.	2	1	0.05	25.00	1.37	2.27	1.82	
Leucosyke benguetensis Unruh	8	3	0.2	75.00	5.48	6.82	6.15	5.5
Macaranga cumingii (Baill.) Müll.Arg.	2	2	0.05	50.00	1.37	4.55	2.96	
Melastoma malabatricum	28	4	0.7	100.00	19.18	9.09	14.13	1
Melicope triphylla (Lam.) Merr.	2	1	0.05	25.00	1.37	2.27	1.82	
Miscanthus floridulus (Labill.) Warb.	16	3	0.4	75.00	10.96	6.82	8.89	2
Rosa transmorrisonensis	2	1	0.05	25.00	1.37	2.27	1.82	
Rubus fraxinifolius Poir.	10	4	0.25	100.00	6.85	9.09	7.97	3
Strobilanthes cincinnalis C.B.Clarke	10	2	0.25	50.00	6.85	4.55	5.70	7.5
Vanoverberghia sepulchrei Merr.	10	2	0.25	50.00	6.85	4.55	5.70	7.5
Total			3.65	1100.00	100.00	100.00	100.00	

generally between 1.5 and 3.5 with higher number indicating greater species richness and evenness (Fernando, 1988). The three land-use stations in Talinguroy had Shannon-Wiener index ranging from 2.41 to 2.96 with agroforestry plot falling under low diversity while agriculture and pine forest would fall under medium diversity. Overall, Talinguroy Research Station had a Shannon-Wiener's, evenness, Simpson's and Margalef's index of 3.33, 0.46, 0.94 and 9.26, respectively. These values were much higher than those recorded by Napaldet and Buot (2019) in Balili River but lower than those derived by Batani et al. (on press) in Palina River, Kibungan.

The index of similarity between land-use stations was low, ranging from 8 to 27% only (Table 5). Lowest species similarity (8.33%) was observed between agricultural plots and pine forest while highest (27.12%) between agroforestry and pine forest. These results indicate that land use change brought heterogeneity of species composition in the area. Agriculture caused the most change in species composition.

Table 4c

Population counts of trees in the forest at Talinguroy Research Station, Benguet State University, Philippines

Species name	ni	BA	Ji	Di	Fi	RDi	RBA	Rfi	IV	Rank
Alnus japonica (Thunb.) Steud.	3	5.50	1	0.02	50.00	4.69	3.34	6.25	4.76	5
Pseuduvaria luzoniensis (Merr.) Y.C.F.Su & R.M.K.Saunders	1	0.18	1	0.01	50.00	1.56	0.11	6.25	2.64	
Clethra canescens var. luzonica (Merr.) Sleumer	1	0.50	1	0.01	50.00	1.56	0.30	6.25	2.70	10
Deutzia pulchra S.Vidal	2	0.97	1	0.01	50.00	3.13	0.59	6.25	3.32	6
Eurya coriacea Merr.	1	0.32	1	0.01	50.00	1.56	0.19	6.25	2.67	
Ficus benguetensis Merr.	6	5.11	2	0.03	100.00	9.38	3.11	12.50	8.33	3
Ficus septica Burm. f. Auili	9	5.14	2	0.05	100.00	14.06	3.12	12.50	9.90	2
Mallotus mollissimus (Geiseler) Airy Shaw	2	0.47	1	0.01	50.00	3.13	0.29	6.25	3.22	7
Omalanthus macradenius Pax & Hoffm.	2	1.10	2	0.01	100.00	3.13	0.67	12.50	5.43	4
Pinus kesiya Royle ex Gordon	35	143.72	2	0.18	100.00	54.69	87.36	12.50	51.52	1
Saurauia elegans (Choisy) F.-Villar	1	0.53	1	0.01	50.00	1.56	0.32	6.25	2.71	9
Weinmannia luzoniensis S.Vidal	1	0.97	1	0.01	50.00	1.56	0.59	6.25	2.80	8
Total		164.52		0.32	800.00	100.00	100.00	100.00	100.00	

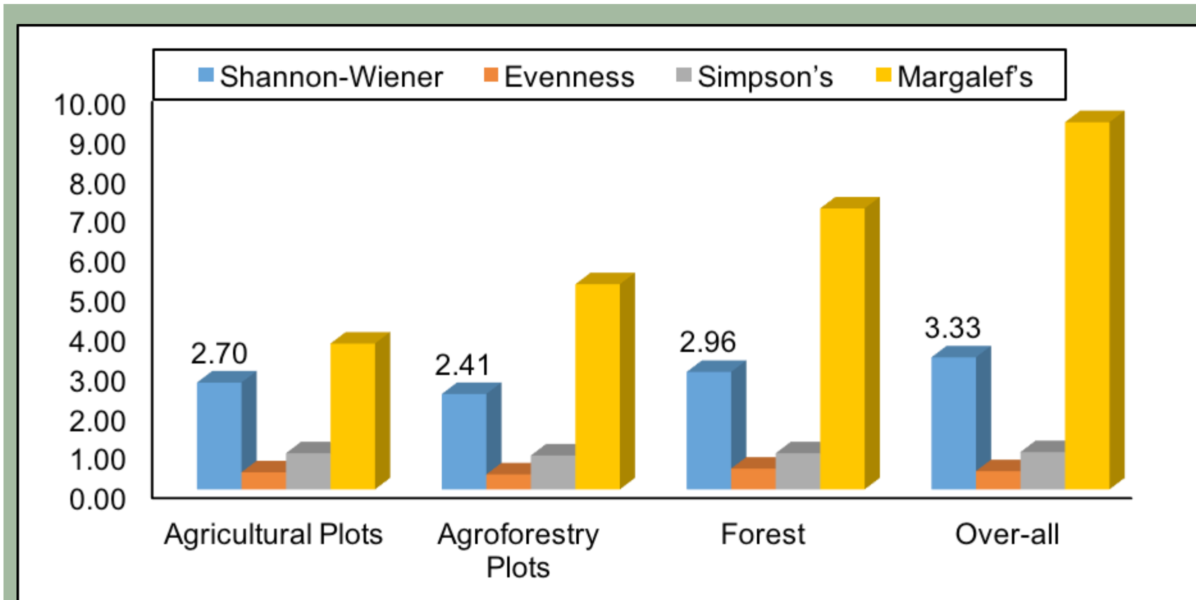

Figure 3. Biodiversity indices of Talinguroy Research Station

Table 5

Jaccard's index of similarity (%) among stations

Plots	Agroforestry Plots	Pine Forest
Agricultural Plots	18.37	8.33
Agroforestry Plots		27.12

Conclusions

A total of 68 species belonging to 63 genera and 40 families was documented in Talinguroy Research Station. Family Poaceae and Asteraceae were the most represented with 11 and 10 species followed by Cyperaceae, Fabaceae and Rosaceae with three (3) species each. Between land-use stations, 24 species belonging to 22 genera and 11 families were inventoried in the agricultural plots; 34 species under 32 genera and 22 families in the agroforestry plots; and 41 species under 38 genus and 24 families in the pine forest. In terms of habit, all are weedy herb/grass species in the agricultural plots; 21 herbs, 12 shrubs and nine (9) trees in the agroforestry plots; and 17 herbs, 20 shrubs and 12 trees in the forest plots. Indigenous/endemic species index was lowest in the agricultural plots, higher in agroforestry and highest in the forest. The three land-use stations had 2.41 to 2.96 Shannon-Wiener index with agroforestry plot falling under low diversity while agriculture and pine forest would fall under medium diversity. Lastly, the index of similarity between the stations was low, ranging from 8 to 27% only. Lowest species similarity was observed between agricultural plots and pine forest while highest between agroforestry and pine forest. These results showed a direct effect of human disturbance brought by land-use change on the species diversity in the area. Greater disturbance resulted to lower diversity of indigenous and endemic species, lower over-all species richness and lower shrub and tree diversity but higher herb and Asteraceae diversity. Moreover, these results indicate that land use change brought heterogeneity of species composition in the area. Agriculture caused the most change in species composition.

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