Assessing the status of *pinuchu* as indicator of socio-ecological resilience of Chaya Socio-Ecological Production Landscape, Ifugao, Philippines

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Abstract. Santiago JO, Buot Jr IE. 2018. Assessing the status of *pinuchu* as indicator of socio-ecological resilience of Chaya Socio-Ecological Production Landscape, Ifugao, Philippines. *Biodiversitas* 19: 2010-2019. Safeguarding biodiversity should be one of the priorities of the community to attain resilience. This study was aimed to determine the conditions of the woodlot (*pinuchu*) along the altitudinal zones of the mountain ranges in Chaya and correlated this to resilience. Specifically, it aimed to (i) determine the species composition, structure, and diversity of the tree species in selected *pinuchu* and (ii) determine the environmental variables associated with the vegetation composition. Vegetation data were subject to classification and ordination analyses. Species diversity was also calculated using Shannon-Wiener index. The tree diversity showed an overall diversity of ($H'=3.83$) corresponding to relatively high diversity. According to canonical correspondence analysis (CCA), elevation, temperature, and human disturbances influenced the vegetation composition. It is recommended that to sustain resilience of the CSEPL, *pinuchu* should be biodiversity-rich at all times. Policymakers should use native species as planting material in the reforestation program instead of using fast-growing exotic species.

Keywords: Biodiversity, resilience, socio-ecological production landscape, *pinuchu*

INTRODUCTION

Biodiversity plays a vital role in ecosystem resilience and in sustaining desirable ecosystem attributes (Peterson et al. 1998). In the context of socio-ecological production landscape, biodiversity is considered significant for it contributes to resilience by providing ecosystem services and acts as buffer against perturbations (Bergamini et al. 2014; Jacobi et al. 2013).

Indeed, biodiversity is really an integral part of resilience (Jacobi et al. 2013). Hence, in this study, the storehouse of biodiversity in a socio-ecological production landscape (SEPL), the *pinuchu*, was investigated. *Pinuchu* or *muyong* in other dialect (Banaue) is a private woodlot with clearly demarcated boundaries owned and maintained by Ifugao families or clans (Soriano and Herath 2018). Diverse tree species have unique ecological values contributing to landscape functioning. The *pinuchu* serves as a watershed ensuring an all-year-round supply of water for the rice field (Camacho et al. 2016) and in fact unknowingly to lowland rivers as well. The *pinuchu* protects the lower farmlands from runoff and erosion (Serrano and Cadaweng 2005). In addition, the *pinuchu* provides firewood, fruits, lumber and medicinal plants (Castonguay et al. 2016). It is also the major source of wood for wood carving industry in Ifugao (DENR, 2008). The *pinuchu* helps regulate hydrology and microclimate thereby providing buffer against extreme weather events (Bergamini et al. 2014). This demonstrates the importance of biodiversity of *pinuchu* in sustaining the integrity of the

whole landscape.

This means that safeguarding biodiversity should be one of the priorities of the community to attain resilience. However, information on the status of the biodiversity in the forest of Chaya has not been studied and thus a baseline information is required to serve as guide in measuring ecological indicators of socio-ecological resilience. This will lead to the formulation of management and conservation strategies. Hence, this study aims to (i) determine the species composition, structure, and diversity of the tree species in selected *pinuchu* and (ii) determine the environmental variables associated with the vegetation composition.

MATERIALS AND METHODS

Study area

The study was conducted in Barangay Chaya, Mayoyao, Ifugao, Philippines (Figure 1). The study sites were the mountain slopes of Bfu-lak, Nagchayan and Munchipfichib. These three mountains surrounded the Chaya Rice Terraces, one of the eight rice terraces of Central Mayoyao Rice Terraces inscribed as UNESCO World Heritage Site in Mayoyao, Ifugao. Barangay Chaya's climate is classified as Type III. Rainfall is significant in most months of the year, and the short dry season has negligible effect (Figure 2). The northeast monsoon locally known as "amihan" and the Pacific trade winds influence the climate of the village. Heaviest rains occur during the months of July to November with an average annual rainfall of 1,651.4 mm. Precipitation is lowest in February with an average of 23 mm.

Figure 2. Climograph for Baguio City, the nearest weather station to Chaya, Mayoyao, Ifugao, Philippines (Data source: PAGASA, 1985-2016 climate data)

Generally, the climate is cool with temperature ranging from 16°C to 20°C. It is relatively dry from March to May and generally wet for the rest of the year. The coolest

months are November, December, and January, while the hottest month is April. Barangay Chaya has a very steep and mountainous terrain with high ridges, deep valleys and with waterfalls from rivers, creeks, and brooks coming from barangay Liwo River flowing down to Peñanga and Magat River. The forested mountains in the uppermost part of the barangay is regarded as important for it is the watershed area which serves as water source of the barangays.

Methods

Biodiversity was identified as important ecological indicator of resilience in Chaya Socio-ecological production landscape in the study by Santiago and Buot (2018). Vegetation analysis was used to describe the conditions of *pinuchu* of Chaya. Vegetation sampling was done in the selected *pinuchu* in the mountains of Bfu-lak, Nagchayan and Munchipfichib. In determining the plots, random sampling was done per elevation starting from 1000 m to 2000 m altitude. Every plot was set up at 100 m interval from the foot slope up to the peak of the three mountains. A total of fifteen (15) plots of 10 x 10 m² size were established in the entire sites (Figure 1). All woody tree species with a height of about 1 m were identified. The scientific names and local names were recorded. Diameter at breast height (DBH) and total height of each species were recorded (Figure 3).

Figure 1. The study area showing the sampling plots (green dots). Lower left inset map shows the location of Mayoyao, Ifugao in the Philippines and the location of Barangay Chaya in Mayoyao (Generated using QGIS)

Figure 3. Two residents of Chaya, Mayoyao, Ifugao, Philippines helping in the collection of vegetation data

Basal area was computed from DBH data using the equation;

$$\text{Basal area (BA)} = 0.7857 \times D^2 \text{ (cm}^2\text{)}$$

Where, D = diameter at breast height (Cintron and Novelii 1984).

The dominant species were identified and calculated based on the relative basal area (RBA) derived from DBH values and the dominant species was determined using the equation by Ohsawa (1984):

$$d = \frac{1}{N} \{ \sum_{i \in T} (x_i - \bar{x})^2 + \sum_{i \in U} x_i^2 \}$$

Where, d= the deviation, x_i = the actual percent share [in this case, the RBA] of the top species (T), i.e., the top dominant in the one-dominant model, or the two top dominants in the two-dominant model and so on, $\bar{x}$ = the ideal percent share based on the remaining species (U) and N= the total number of species.

RBA was further subjected to classification and ordination analyses using Paleontological Statistics (PAST) version 3.13. Cluster analysis was done using Bray-Curtis similarity index. A dendrogram was then constructed using the Unweighted Pair Group Method with Arithmetic mean (UPGMA) algorithm (Sneath and Sokal 1973).

Physical and environmental data such as elevation, coordinates, and disturbances in each site were noted. In each plot, composite random soil samples were taken from the topsoil (up to 30 cm below ground). Each soil sample was analyzed for pH, Nitrogen (N) and Phosphorous (P) content using the UPLB Soil Test Kit. Temperature at different altitude was extracted from the climatic data from Philippine Atmospheric and Geophysical Astronomical Services Administration (PAGASA) using the assumption of Sarmiento (1986) that for every 100 m elevation rise, there is a corresponding decrease of 0.6° C of temperature.

The Canonical Correspondence Analysis (CCA) of Ter Braak (1987) was used to pinpoint which environmental data are influencing species RBA.

Tree diversity was measured using the Shannon-Wiener index of diversity computed as follows:

$$H' = - \sum_{i=1}^s p_i \ln p_i$$

Where, S = the number of species

p_i = the relative abundance of each species, calculated as the proportion of individuals of a given species to the total number of individual in the community: $\frac{n_i}{N}$

n_i = the number of individuals in species i

N = the total number of all individuals

Sample specimens of unknown species were identified by an expert of College of Forestry and Natural resources, University of the Philippines Los Baños (UPLB) using the lexicon of Philippine Trees (Rojo, 1999). Nomenclature follows that of the International Plant Name Index (IPNI) website (<https://www.ipni.org>), Co's Digital Flora of the Philippines (<http://www.philippineplants.org/>), Fernando et al (2004), Backer and Bakhuizen v.d. Brink (1965) and Merrill (1923). Voucher specimens of the unidentified plants were deposited at the Herbarium of the Plant Biology Division, Institute of Biological Sciences (PBDH), University of the Philippines Los Baños, Laguna, Philippines. Photographs of these specimens were also deposited at the herbarium.

RESULTS AND DISCUSSION

Species composition, structure, and diversity

Table 1 showed the structural characteristics of the species composition of each zone. The number of species, species diversity, maximum DBH and the RBA per plot were also indicated for comparison. A total of 88 species were found in the entire woodlot, 67 of which belong to 35 families such as Pinaceae, Lauraceae, Moraceae, Rubiaceae, and Fagaceae and others. On the other hand, 16 species were identified only at their local name level and the remaining five were not identified.

Using the RBA, the species were subjected to cluster analysis forming two big zones with each two sub-zones (Figure 4). Each zone was named according to the dominant species.

Zone I (Pinus-Gmelina-Swietenia) or the Near Residence Zone: This zone was in the lower elevation (1050 m to 1200 m) of Mount Nagchayan. This zone was dominated by *Pinus kesiya* Royle ex Gordon, *Gmelina arborea* Roxb. and *Swietenia macrophylla* King. The highest RBA was 100 found in plot 7 while the lowest RBA was 0.01 found in plot 14 (Table 1). The maximum DBH value was 54 cm found in sampling plot 8. The species diversity (H') in Zone 1 was 2.98 dit. This is considerably lower than Zone 2 mainly because this zone was near the residential area and most of the plots were

reforestation sites. The soil in Zone I had pH ranging from 6-6.4. Nitrogen content was found to be high in plots 14 and 15 while Phosphorus content was high in plots 6,7 and 8.

Subzone Ia (*Gmelina-Bischofia-Palaquim*). At similarity level of 0.05, Zone I was further divided into two zones. The first zone was composed of plots 5, 14 and 6 and was dominated by *Gmelina arborea* Roxb., *Bischofia javanica* Blume and *Palaquium luzoniense* S.Vidal. The species diversity (H') was 2.941 dit.

Subzone Ib (*Pinus-Swietenia-Citrus*). This zone was composed of plots 7 and 8 and was dominated by *Pinus kesiya* Royle ex Gordon, *Swietenia macrophylla* King and *Citrus maxima* (Burm.) Merr. The species diversity (H') was 1.745 dit.

Zone II (*Lithocarpus-pfoloblo-Toona-Elaeocarpus-Cleistocalyx-unknown*) or Forest Zone. This zone was composed of plots 1,2,3,4,9,10,11,12 and 13 located in Mount Bfu-lak and Mount Munchipfichib from 1300 m to 2000 m asl. This was dominated by *Lithocarpus submonticola* (Elmer) Rehder, *pfoloblo* (local name), *Toona calantas* Merr. & Rolfe, *Elaeocarpus* sp., *Cleistocalyx operculatus* (Roxb.) and another unknown species. The highest RBA was 80.92 found in plot 12 while the lowest was 0.01 found in plot 9. This site had a species diversity of 3.49 dit. The maximum DBH value was 54 cm found in sampling plot 12. The soil in Zone II had pH of 6. Nitrogen content was found to be low to medium while Phosphorus content varied from low to high.

Subzone IIa (*Toona-unknown 3-Radermachera-Elaeocarpus-Luecosyke*). At similarity level of 0.08, the Zone II was divided into two sub-zones. Sub-zone IIa was dominated by *Toona calantas* Merr. & Rolfe, unknown 3, *Radermachera acuminata* Merr., *Elaeocarpus* sp. and *Leucosyke capitellata* Wedd. The species diversity (H') was 3.331 dit.

Subzone IIb (*Lithocarpus-pfoloblo-Litsea*). This was composed of plots 1, 2, 12 and 13 and dominated by *Lithocarpus submonticola* (Elmer) Rehder, *pfoloblo* and *Litsea perrottets* (Blume) Fern.-Vill. The species diversity (H') was 3.058 dit.

The species diversity (H') for the entire Chaya was 3.83 dit.

Discussion

The floristic characters of pinuchu along different elevation of chaya mountain ranges

The floristic composition of the *pinuchu* in Chaya Socio-Ecological Production Landscape (CSEPL) is comparable to the results of Magcale-Macandog et al (2013), Taguiling (2014) and Rabena (2015) in various woodlots in the municipalities of Ifugao. The species were of northern character except *Gmelina arborea* Roxb. and *Swietenia macrophylla* which were introduced species.

The *pinuchu* forest structural features along altitudinal gradient were illustrated in Figure 5.A to 5.F. The number of species per sampling site increased with increasing elevation as with species diversity (Figure 5.A-5.B). Ideally, these two parameters should decrease towards higher altitudes because of the low temperature in higher elevation based on the observation of Buot and Okitsu (1998) and Banaticla and Buot (2005). The inverse relationship could be attributed to the proximity of *pinuchu* to the residential area. Since these were located at the lower elevation, humans could easily access the woodlot for their timber needs. The anthropogenic disturbance could jeopardize the structural characteristics of the forest as observed in the study of Buot and Osumi (2011) in Mount Makiling. Meanwhile, the dbh and height were decreasing at increasing elevation.

Figure 4. The dendrogram constructed using Unweighted Arithmetic Average Clustering (UPGMA) showing the two zones and their respective dominant species and land use types. Bootstrapping was done at $n=100$, cophenetic correlation is 0.9719

The structure of the biodiversity of Chaya's *pinuchu* was illustrated in a dendrogram (Figure 4) with a simple zonation pattern of two zones, each composed of two subzones, with Zone I (pine forest) and Zone II (mossy forest). This type of zonation is similar to Mount Akiki and Mount Pulag landscape having a pure and mixed *Pinus* zone and an extensive montane forest dominated by *Lithocarpus* (Buot 2007; Buot and Okitsu 1999). The only difference for this study is the presence of

Gmelina arborea Roxb and *Swietenia macrophylla* King indicating that there were already anthropogenic disturbances. In Ifugao, *pinuchu* owners preferred hardwood species for their wood carving and house construction. *Gmelina arborea* Roxb and *Swietenia macrophylla* King are the most common reforestation species being planted nowadays considering their short rotation period and widespread availability (Camacho et al. 2016).

Figure 5. The forest structural features along altitudinal gradients of Chaya, Mayoyao, Ifugao, Philippines. A. Number of species, B. Species diversity, C. Maximum dbh, D. Minimum dbh, E. Maximum height, F. Minimum height

Figure 6. Ordination diagram showing the distribution of plots as influenced by environmental factors using Canonical Correspondence Analysis

Table 1. Species composition along altitudinal gradients of Chaya mountain ranges, Mayoyao, Ifugao, Philippines showing Relative Basal Area (RBA). Dominant species are indicated with asterisk (*). Arrangement of taxa is according to elevation (from lowest to highest)

Site number	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	
Plot name	14	5	15	6	7	1	8	2	9	3	10	4	11	12	13	
Elevation	1047	1100	1101	1197	1300	1380	1406	1480	1510	1580	1608	1642	1714	1817	1916	
Number of species	45	34	17	33	12	19	23	21	29	55	32	51	29	51	38	
Shannon_H (per plot)	2.06	2.22	1.95	2.58	0	1.72	1.06	2.65	2.29	2.73	2.56	2.50	2.43	2.60	2.11	
Maximum DBH (in cm)	49	22	41	14	30	40	54	54	29	50	25	34	28	60	42	
Minimum DBH (in cm)	0.63	0.63	1.27	0.4	10.82	1.27	1.27	0.95	1.27	0.63	0.95	0.63	6.37	0.95	0.95	
Maximum height (in m)	26	15	22	18	10	16	14	20	15	20	16	18	8	16	16	
Minimum height (in m)	1.1	1.1	2.2	1.4	7	1.7	1	1.6	1.51	1.1	1.4	1.2	1.24	1.5	1.64	
Name of species	Family	Local name	RBA	RBA	RBA	RBA	RBA	RBA	RBA	RBA	RBA	RBA	RBA	RBA	RBA	RBA
<i>Gmelina arborea</i> Roxb. ex Sm.	Lamiaceae	<i>melina</i>	93.09*	87.19*		59.50*										
<i>Bischofia javanica</i> Blume	Phyllanthaceae	<i>tuwor</i>	0.66	4.90*												
<i>Palaquium luzoniense</i> (Fern.-Vill.) Vidal	Sapotaceae	<i>chalaan</i>	2.36*													
<i>Astronia candolleana</i> Cogn.	Melastomataceae	<i>talana'</i> (big leaves)				13.39*	0.86	0.20		2.45	0.96	0.76	3.22	0.86	9.74*	
<i>Toona calantas</i> Merr. & Rolfe	Meliaceae	<i>pfangtinon</i>				7.06*				53.59*						
<i>Neonauclea reticulata</i> (Havil.) Merr.	Rubiaceae	<i>alantap</i>				5.34*										
<i>Pinus kesiya</i> Royle ex Gordon	Pinaceae	<i>benguet pine</i>			3.85	1.52	100*	94.60*								
<i>Swietenia macrophylla</i> G. King	Meliaceae	<i>mahogany</i>			43.98*											
<i>Pterocarpus indicus</i> Herb. Madr. ex Wall.	Fabaceae	<i>narra</i>		6.12*		11.86*										
<i>Garcinia venulosa</i> Choisy	Clusiaceae	<i>pfunog</i>				10.26*										
<i>Radermachera acuminata</i> Merr.	Bignoniaceae	<i>pfaghapfajon</i>					4.76*	33.45*								
<i>Weinmannia luzoniensis</i> S. Vidal	Cunoniaceae	<i>tabangawon</i>	0.05	0.23			0.45*			0.11						
Pfoloblo	-											76.05*	20.79*			
<i>Lithocarpus submonticola</i> (Elmer) Rehder	Fagaceae	<i>palajun</i>			0.24			0.06					51.36*	80.92*	50.92*	
<i>Litsea perrottetii</i> (Blume) Fern.-Vill.	Lauraceae	<i>baan</i>										12.46*				
Unknown 1	-											9.65*				
<i>Knema</i> sp.	Myristicaceae											1.01*				
<i>Semecarpus cuneiformis</i> Blanco	Anacardiaceae												14.40*			
Apfala	-											4.99*				
<i>Clerodendrum</i> sp.	Lamiaceae	<i>mananor</i>												10.10*		
Archachanum	-							0.01					1.30	3.62*	0.75	
<i>Elaeocarpus</i> sp.	Elaeocarpaceae	<i>taudchachay</i>							33.46*						12.17*	
<i>Cleistocalyx operculatus</i> (Roxb.) Merr. & L.M.Peri	Myrtaceae						0.10	0.84	6.59	2.97*	28.95*			0.09	16.97*	
<i>Gomphandra</i> sp.	Icanicaceae	<i>lopot</i>						5.33	3.52	1.58	27.24*					
<i>Clethra tomentella</i> Rolfe ex Dunn	Clethraceae	<i>umog</i>						9.23*		1.32	4.80*	6.64	0.23		1.60*	2.49

<i>Leucosyke capitellata</i> (Poir.) Wedd.	Urticaceae	<i>pfahog</i>					27.46*												
Pfa'an	-				0.12		17.16*												
Unknown 3	-									48.70*									
Talana' small leaves	-							16.47*											
Ameleng	-							10.26*											
<i>Cryptocarya paucinervia</i> Gamble	Lauraceae	<i>tempo</i>						0.01	17.95*	0.30					0.18	0.44	0.90		
Palubphan	-						7.59		8.58*		12.87*								
<i>Symplocos</i> sp.	Symplocaceae	<i>olatton</i>						0.32	7.60*	0.18	0.36				0.09	0.16	0.16		
<i>Syzygium polycephaloides</i> (C.B.Rob.) Merr.	Myrtaceae	<i>ato ang-ang</i>			2.30														
<i>Prunus pubescens</i> Pursh	Rosaceae	<i>alacheng</i>	0.01					1.08		20.98*					0.94	0.02			
<i>Calophyllum soulattri</i> "Burm." ex F.Mull.	Clusiaceae	<i>bitaor</i>						2.28		16.79*						0.38			
<i>Engelhardtia</i> sp.	Juglandaceae	<i>attapfong</i>									13.74*				1.20		5.06		
<i>Cryptocarya lanceolata</i> Merr.	Lauraceae	<i>tuyphu</i>						4.81	3.67	1.22						0.75	0.79		
<i>Chloranthus elatior</i> R.Br.	Chloranthaceae	<i>loblopfong</i>						0.03			0.06	0.42		0.45	0.05				
<i>Eurya japonica</i> Thunb.	Theaceae	<i>penalenghendon</i>		0.08	2.69		0.17	0.08	2.01		0.80						0.06		
<i>Evodia benguetensis</i> Elmer	Rutaceae															1.30			
<i>Mangifera indica</i> L.	Anacardiaceae	<i>mangka</i>	1.29																
<i>Coffea</i> sp.	Rubiaceae	<i>coffee</i>	0.28			0.09													
<i>Glochidion</i> sp.	Euphorbiaceae	<i>amamokug</i>	0.16																
<i>Ficus nota</i> Merr.	Moraceae	<i>lapfoy</i>	0.01	0.11											0.18				
Pfalo	-		0.01	0.11	1.34	0.02													
<i>Villebrunea trinervis</i> Wedd.	Urticaceae	<i>loppeng</i>		0.81	3.90														
<i>Fraxinus griffithii</i> C.B.Clarke	Oleaceae	<i>onop</i>		0.28															
<i>Ficus annulata</i> Blume	Moraceae	<i>peggwe</i>		0.07					0.05										
<i>Callicarpa subintegra</i> Merr.	Lamiaceae	<i>atorpfo</i>		0.04			0.03												
<i>Deutzia pulchra</i> S.Vidal	Hydrangeaceae	<i>hana'te</i>		0.02					0.08										
<i>Melastoma malabathricum</i> L.	Melastomataceae	<i>pfugtayun</i>		0.02	0.69		0.17	1.10		0.36						0.02			
<i>Grewia laevigata</i> Vahl	Tiliaceae	<i>alanchong</i>			3.27														
Alinaw	-				0.48														
<i>Saurauia bontocensis</i> Merr.	Actinidiaceae	<i>choggoy</i>			0.21														
<i>Saurania elegans</i> Fern.-Vill.	Actinidiaceae	<i>pfenor</i>			0.21														
Lanipaw	-				0.02														
<i>Artocarpus heterophyllus</i> Lam.	Moraceae					7.59													
<i>Ficus odorata</i> Merr.	Moraceae	<i>apla</i>				0.03													
<i>Macaranga dipterocarpifolia</i> Merr.	Euphorbiaceae	<i>anablon</i>						0.07											
Lachao								3.50		5.56		1.07							
<i>Leea aculeata</i> Blume	Leeaceae	<i>ang-ang</i>						0.03					0.07						
<i>Canthium ellipticum</i> Hochst. ex Delile	Rubiaceae								1.07										
<i>Helicia paucinervia</i> Merr.	Proteaceae	<i>lakot</i>							0.68		0.23								
<i>Antherostele callophylla</i> Bremek.	Rubiaceae	<i>lanuhi (kahoy)</i>							0.24										
<i>Eurya japonica</i> Thunb. var. <i>nitida</i> (Korth.) Dyer	Theaceae								0.21										
<i>Praravinia viridescens</i> (Elmer) Bremek.	Rubiaceae	<i>lungtian</i>							0.10										
Unknown 2	-								0.08										
Unknown 4	-										6.34								
<i>Archidendron clypearia</i> (Jack) I.C.Nielsen	Fabaceae	<i>haguchachit</i>								1.99	0.06								

Chulangon	-		0.08		
<i>Ardisia</i> sp.	Primulaceae		0.90		
<i>Evodia</i> sp.	Lauraceae		0.28		
Chulagon	-		0.23		
<i>Calophyllum buxifolium</i> Vesque	Clusiaceae		0.11		
<i>Cryptocarya merrillii</i> C.T.White	Lauraceae		0.01		
<i>Neolitsea villosa</i> (Blume) Merr.	Lauraceae			1.33	
Hangachon	-			1.03	
Lohong	-			0.51	0.17
Lapponte	-			0.18	
Afingor	-				1.71
<i>Ficus septica</i> var. <i>salicifolia</i> Corner	Moraceae				1.29
<i>Ficus</i> sp.	Moraceae				0.26
<i>Ficus septica</i> Burm.f.	Moraceae	liwliw		1.79	0.02
<i>Neolitsea vidalii</i> Merr.	Lauraceae				0.10
<i>Evodia melicefolia</i>	Rutaceae				0.05
Unknown 5	-				0.02

The presence of *Pinus kesiya* Royle ex Gordon, *Gmelina arborea* Roxb. and *Swietenia macrophylla* King could have a profound influence in the future of landscape's ecosystem services. Pine trees were reported to have allelopathic effect in plants and this can inhibit the growth of other trees (Kimura et al. 2015). In the same way, *Swietenia macrophylla* King is also allelopathic in nature (Mukaromah et al. 2017). *Gmelina arborea* Roxb. and *Swietenia macrophylla* King is a potential be bio-invasive species in the area as emphasized by Baguinon and Miel (2013).

In the study of Soriano et al. (2017), farmers in Kiangnan, Ifugao perceived that the introduction of non-native species in their forest led to the degradation of forest quality which in turn reduced the effective provision of ecosystem services of the forest. However, *pinuchu* is a privately managed forest and people use the above-mentioned species for construction materials, so bio-invasion is less likely to occur. The high diversity index of the entire *pinuchu* in Chaya ($H' = 3.83$) is an evidence that bio-invasion is not yet happening. However, this should not be the reason to plant more introduced species in the locality, especially as reforestation planting material.

Environmental variables influencing floristic diversity

Environmental variables including elevation, temperature, soil characteristics, and anthropogenic disturbances were tested if they influence the floristic structure and zonation of the Chaya *pinuchu*. It was found out that elevation, temperature, and disturbance were positively influencing the structure of the *pinuchu* but soil nutrients and pH had minimal impact (Figure 6). This observation is similar to that of Sopsop and Buot (2013) where human disturbance (e.g. kaingin farming) impacted species composition. It is observable that as the elevation gets higher, native species belonging to the families of Fagaceae such as *Lithocarpus submonticola* (Elmer) Rehder dominated the area. This is because of the higher and steep slopes which make it difficult for humans to access the *pinuchu*, hence only lower elevation species were altered and planted with some introduced species. This was also observed by Buot and Osumi (2011) in their study in Mount Makiling.

Meanwhile, with higher elevation and hence, lower temperature, the species composition was dominated by Fagaceae and Lauraceae families. Fagaceae and Lauraceae were the dominant vegetation type in the mountains of tropical Asia (Sri-Ngernyuan et al. 2003) particularly, in higher elevation of Cordillera Mountain ranges (Buot 2014; Buot 2007; Buot and Okitsu 1998). Nitrogen also played a vital role in the distribution of species in plots 14 and 15 which were all in the lower elevation. This could be explained by possible accumulation of Nitrogen that has been leached from the upper slopes.

The Chaya Pinuchu Biodiversity and its implication to resilience

The species diversity (H') for the entire Chaya's *pinuchu* was 3.83 dit. Based on Fernando (1998) scale of

diversity values, this is considered very high. Interestingly, Chaya's *pinuchu* is more diverse as compared to the diversity of Namnama, Alfonso Lista ($H' = 3.59$), Nagacadan, Kiangnan ($H' = 3.7$) and Bato, Mayoyao, Ifugao ($H' = 3.6$) as observed in the study of Taguiling (2014). This may be attributed to the fact that *pinuchu* in Chaya was located at a much higher elevation and hence, not highly disturbed as compared with the *pinuchu* in Alfonso Lista and Bato, Mayoyao which were being used for slash and burn farming (Taguiling 2014). Associated with its rich biodiversity is the availability of water resources which provided irrigation for the rice terraces.

The high diversity in Chaya's *pinuchu* is critical to resilience. In the face of environmental fluctuations, "biodiversity insures ecosystem health as many species provide greater support and some maintains functioning even if others fail" (Yachi and Loreau 1999). This insurance effect can help maintain a desirable ecosystem state for the CSEPL to continue provide ecosystem services for the entire socio-ecological system.

In conclusion, this study measured the ecological indicators of socio-ecological resilience by vegetation assessment and household survey. This was the first attempt to document the vegetation status of the biodiversity in the forest of Chaya. The study revealed that *pinuchu* of Chaya has now been planted with introduced species found in the lower slopes. Two of these species were the exotic fast-growing, *Gmelina arborea* Roxb and *Swietenia macrophylla* King. Elevation, pH, temperature and human disturbances were influencing the vegetation structure. The species diversity was high ($H' = 3.83$). The *pinuchu* must be biodiversity-rich if the entire Chaya Socio-Ecological Production Landscape has to be resilient through the years. The presence of exotic species in the *pinuchu* of CSEPL requires certain steps to protect and conserve native biodiversity should these exotics naturally spread and harm the natural biota. Protection of biodiversity is indeed important to sustain its ecological function in the whole landscape. Policy makers and implementers need to patronize the use of pioneer native tree species as planting material in the reforestation program instead of using exotic fast-growing species.

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