Taiwania 68(3): 339–348, **2023**
DOI: 10.6165/tai.2023.68.339

Plant species and ecosystem diversity along national road in mountain sites: The case of Kennon Road in Cordillera Central Range, Philippines

Jones T. NAPALDET*

*Biology Department, Benguet State University, La Trinidad Benguet, Luzon Benguet 2601, Philippines. *Corresponding author's email: j.napaldet@bsu.edu.ph*

(Manuscript received 1 June 2023; Accepted 28 August 2023; Online published 1 September 2023)

ABSTRACT: Mountain roads are constructed to spur economic development and alleviate poverty but they are also major drivers of biodiversity loss in mountain areas. In the Philippines, road biodiversity is poorly understood. This study aims to contribute to this gap by presenting the plant diversity along Kennon Road, a national highway in Benguet, Philippines through population counts, biodiversity indices and floristic elements. A total of 338 species belonging to 280 genera and 99 families were inventoried in five sampling stations. Majority of the plant species were indigenous (186) with 35 endemic, 29 naturalized, 88 exotic species and with 18 threatened species (5.33% of the total species). Understory plants have the highest biodiversity indices, particularly Shannon index ranging from 3.49 to 3.93 (very high diversity). On the other hand, Shannon values for shrub ranges from 2.97 (moderate) to 3.51(very high) and least Shannon values were derived from tree diversity at 2.54 (moderate) to 3.31 (high). The floristic elements along Kennon Road are dominated by native (76.33%) but a significant part (23.675) of the vegetation are either naturalized or exotic with mostly Central American and Neotropical elements. Our results show the fragmentation of the secondary forest along the road with human built-up areas and the colonization by ruderal species including non-native species.The intermingling of these colonizers with resident species results in the formation of forest road ecosystems with high species richness in Kennon Road.

KEY WORDS: Conservation-important species, Kennon Road, Neotropical element, road biodiversity, Shannon diversity.

INTRODUCTION

Worldwide, roads are recognized as the major driver of biodiversity loss in mountain areas. Roads are constructed in mountainous regions to spur economic development and alleviate poverty. However, road infrastructures cause direct and indirect loss of biodiversity in mountain ecosystems. Direct loss refers to the reduction of forest area while indirect loss refers to the fragmentation and degradation of the ecosystem (Geneletti, 2003) and both compromise biodiversity and conservation values (Rashid *et al.*, 2021). Further, mountain roads provide corridors for the dispersal of colonizing species, including non-native species, and facilitating their spread into pristine environments (Dar *et al.*, 2015; Dar *et al.*, 2018). These non-native species are known to displace native species that depend on specialized undisturbed habitats (Lembrechts *et al.*, 2017). But on the positive side, the intermingling of these colonizers with resident species could result to the formation of a unique forest road ecosystems that is mixture of native and non-native species with their associated plants and animals (Lugo and Gucinski, 2000).

Although previous studies have shown the impacts of different land-uses on mountain species diversity (Balangen *et al.*, 2023), only few studies attempted to investigate the effects of roads on plant species and ecosystem diversity, rarely assessing more than one plant life form. As a result, few information are available concerning how road affects plant species and ecosystem in mountain landscapes (Lisboa *et al.*, 2022). This is concerning amidst the several benefits of measuring species richness of different plant life forms such as the increase efficiency and stability of some ecosystem functions (Tilman *et al.*, 1996; Peterson *et al.*, 1998); provide information on susceptibility to invasions and trophic structure necessary for ecosystem resilience (Ruiz-Jaen and Aide, 2005); benefits for agricultural production and livestock (Tilman *et al.*, 2001; Gaujour *et al.*, 2012); and as sources of food for animals and humans.

Mountains regions are topographically complex with highly diversified tectonic, erosional, and climatic processes over geologically short distance and time (Antonelli *et al.*, 2018; Rahbek *et al.*, 2019). These lead to huge differences in both physical environments and inter-species relationships along the elevation and the slope aspects. These environmental conditions influence natural biodiversity changes over mountain gradients. Previous studies had shown that the distributions of mountain biodiversity are shaped by topographic gradients (Buot and Okitsu, 1999; Warren *et al.,* 2010; Zhang *et al.,* 2016; Niu *et al.,* 2019). The steep terrain can also substantially restrict human influences and regulate the magnitude of road impacts. This phenomenon needs to be documented since such knowledge could contribute to mountain road planning that does not compromise biodiversity conservation.

In Cordillera Central Range (CCR), Northern Philippines, roads are the economic lifeblood in this mountainous region by serving as the only major transit of goods and services. However, it is also one of the major drivers of biodiversity loss in the area primarily by making

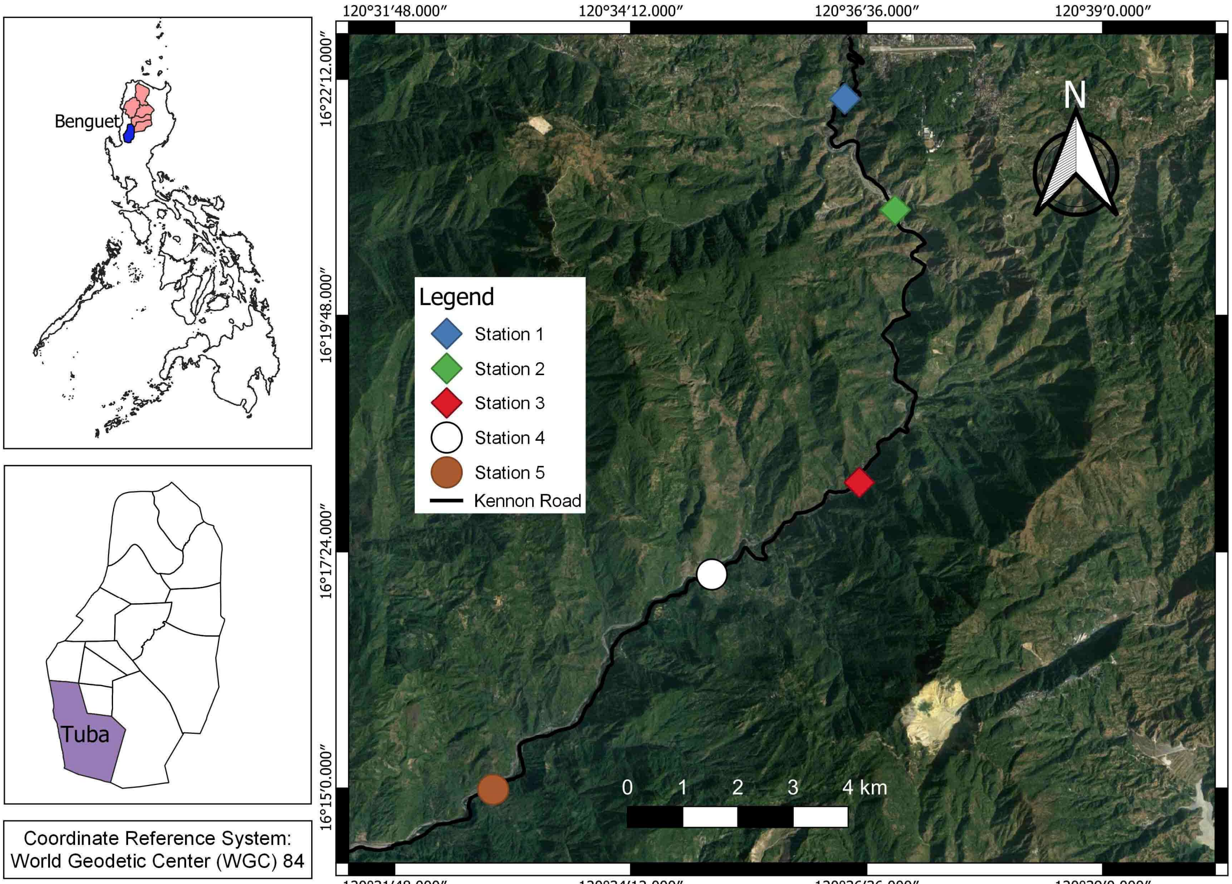

Fig. 1. Map of Tuba, Benguet showing Kennon Road and the sampling stations in the study

previously remote forest now accessible to farmers for conversion into agricultural farms. Kennon Road is one of major roads connecting CCR, particularly Baguio City and Benguet, to the lowland provinces and to the National Capital Region. It was constructed during the American colonization and is about 150 years old. The plant diversity that developed over time along with the human settlements could provide insight on understanding the dynamics of forest road ecosystems in the region and in the country.

The study documented the plant diversity, ecosystem diversity and floristic elements along Kennon Road. This study would be the first published plant diversity for the study site and would be the first for forest road ecosystems in the country. On the other hand, the floristic element component of the study would be the first for tropical road ecosystems. Floristic element studies had been conducted on islands (Morente-Lopez, 2022), desert biome (Manan *et al.,* 2022), submountain forests (Vahdati *et al.,* 2014), Europe continent (Finnie *et al.,* 2007) and country-wide studies (Ullah *et al.,* 2015) but none yet on tropical road ecosystem. It would be interesting to know how the plant diversity of forest road ecosystem compares with other forest ecosystems in the area and how the road and associated disturbances influence its floristic elements. Moreover, these knowledge could contribute to mountain road planning that minimize impacts on biodiversity.

MATERIALS AND METHODS

The study site

Kennon Road, also known as Rosario–Baguio Road, is one of the four major access roads that lead to the highland city of Baguio. It is a two lane 33.53 km (20.83 mi) roadway that connects the mountain city of Baguio and Benguet to the lowland town of Rosario in La Union province. It is the second oldest, after Quirino Highway, and the shortest route to the city for travelers from Manila and from provinces in central and southern Luzon. The entire road forms part of National Route 54 (N54) of the Philippine highway network.

Most of the stretch of Kennon Road encompasses the municipality of Tuba in the province of Benguet. The upward climb along the road reveals a picturesque view of the mountains, lush vegetation, and pine trees as one gets closer to the city. Moreover, the road was cut above and follows the course of Bued River. The original forest cover of the area is lowland evergreen forest but have been extensively modified by human activities creating a

Table 1. Diversity index and species evenness values and their interpretation.

VALUES	INTERPRETATION
Shannon (H')	
>3.5000	Very high
3.0000-3.4999	High
2.5000-2.9999	Moderate
2.0000-2.5999	Low
<1.9999	Very Low
Evenness Pielou index(E)	
0.96-1.0	Balanced
0.76-0.95	Almost Balanced
0.51-0.75	Semi-balanced
0.26-0.50	Less balanced
0.00-0.25	Unbalanced
Simpson's index (D)	
0.00	Absence of diversity
0.01-0.40	Low diversity
0.41-0.60	Moderate diversity
0.60-0.80	Moderately high diversity
0.81-0.99	High diversity
1.00	Absolute (perfect) diversity
Margalef's index (R)	
>5	>5
2.5-5	2.5-5
<2.5	<2.5
Margalef's index (R)	
>5	High species richness
2.5-5	Medium species richness

mosaic of secondary forest, residential areas, agricultural areas and denuded areas. The study site falls under tropical savanna climate based from Köppen climate classification. The climate is generally tropical with most months of the year marked by significant rainfall and short dry season. The mean yearly temperature is at 21.4°C/ 70.6 °F and precipitation is at 269.1 cm/ 105.9 inch.

Sampling stations. Five (5) sampling stations were determined along Kennon Road and were evenly spaced at approximately 6 km apart to get a random sample (Figure 1). Station 1 has an elevation of 973–1071 masl, Station 2 at 744–798 masl, Station 3 at 553–567 masl, Station 4 at 466–497 masl and Station 5 at 246–280 masl. A 2-km transect were established for each station. Placement of the transect route was within 50–100 m along the road side, and was marked every 50 m for the ecosystem level assessment. Nested plot measuring 20×20 m was established for vegetation analysis at 250 m interval of the transect. Two levels of assessment were performed at the transect lines, namely ecosystem and species. Ecosystem-level assessment refers to the types of vegetation and ecosystem structure based from the classification system by Fernando (2008) while species-level assessment include plant identification, diversity analysis, determination of importance values, and floristic element characterization.

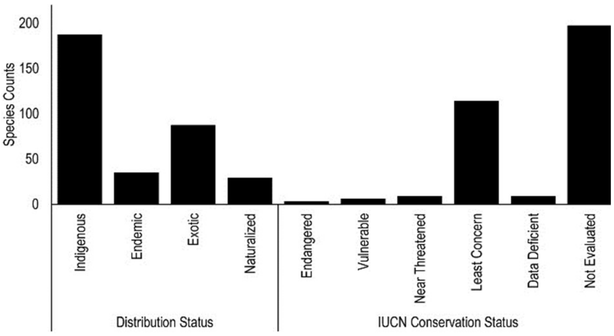

Fig. 2. Distribution and conservation status of the plant diversity along Kennon Road, Benguet.

Plant diversity assessment

Plot method was used to assess the plant diversity in the study. One 20m × 20m nested plot was established in each 250m interval of the 2 km-transect. Trees within these plots were identified and counted. Also, the diameter at breast height of the trees were measured from which the basal area was calculated. Within the 20m × 20m plot, two 5m × 5m quadrats were also established for shrubs and three 1m × 1m quadrats for vascular herbs. Each sampling station consists of nine 20 × 20 m plot for trees, 18 5 × 5 m plot for shrubs and 27 1 × 1 m plot for vascular herbs. Density, frequency, dominance and their relative values were the major parameters measured using standard formulae (Guron *et al.,* 2019).

Biodiversity indices

Plant species diversity were calculated using Shannon index (H'), Simpson's index (D) and Margalef's index (R) thru standard formulae (Guron *et al.,* 2019). The categories of the biodiversity indices are summarized in Table 1 and are based from the works of Fernando and Cereno (2020), Simpson (1949), Hussain *et al.* (2012) and Latumahina *et al.* (2020).

Floristic elements

To further understand the plant diversity along Kennon Road, the phytogeographic distributions or the floristic elements of the plants were identified using data from POWO (2023) and Co's Digital Flora (Pelser *et al.,* 2011-). The classification of floristic elements at the species level are based on the work of Armen Takhtajan (1986) while the conservation status of each species was assessed using IUCN conservation guideline (2019).

RESULTS

Species richness

A total of 338 species belonging to 280 genera and 99 families were inventoried in the five sampling stations along Kennon Road (See supplemental Table S1). Of these, 192 species were low lying plants (herbs, grasses including tree seedlings), 134 were shrubs (including tree saplings and tall grasses) and 84 were trees. Majority of the plant species were indigenous (186) with 35 endemic, 29

Table 2. The dominant herbs, shrubs and trees along Kennon Road.

Herbs	IV	Shrubs	IV	Trees	IV
Station 1					
Ageratina riparia	9.98	*Tithonia diversifolia*	20.05	*Pinus kesiya*	27.93
Mikania cordata	7.23	*Miscanthus floridulus*	14.46	*Leucaena leucocephala*	6.31
Alternanthera sessilis	4.40	*Acalypha amentacea*	6.53	*Gmelina arborea*	6.26
Bidens pilosa	4.09	*Dinochloa acutiflora*	4.45	*Hibiscus campylosiphon*	4.37
Centrosema molle	3.68	*Calliandra calothyrsus*	3.87	*Leptospermum amboinense*	3.65
Station 2					
Melinis repens	10.68	*Miscanthus floridulus*	14.06	*Pinus kesiya*	33.21
Cenchrus purpureus	5.39	*Tithonia diversifolia*	13.39	*Chrysophyllum cainito*	9.86
Xanthosoma sagittifolium	5.04	*Acalypha amentacea*	4.41	*Mangifera indica*	4.50
Mikania cordata	4.54	*Leucaena leucocephala*	4.03	*Ficus septica*	4.44
Synedrella nodiflora	4.31	*Macaranga tanarius*	3.52	*Persea americana*	4.26
Station 3					
Chromolaena odorata	6.82	*Acalypha amentacea*	10.12	*Pterocarpus indicus*	17.42
Ageratum conyzoides	6.06	*Miscanthus floridulus*	6.83	*Gliricidia sepium*	9.67
Alternanthera sessilis	5.30	*Breynia cernua*	5.99	*Spondias pinnata*	7.95
Drynaria quercifolia	3.79	*Tithonia diversifolia*	5.57	*Macaranga tanarius*	6.73
Synedrella nodiflora	3.79	*Leucaena leucocephala*	4.64	*Leucaena leucocephala*	5.28
Station 4					
Bauhinia monandra	12.61	*Bauhinia monandra*	22.27	*Bauhinia monandra*	33.81
Chromolaena odorata	7.40	*Dinochloa acutiflora*	6.65	*Leucaena leucocephala*	16.29
Begonia calcicola	4.47	*Miscanthus floridulus*	4.12	*Swietenia macrophylla*	12.60
Lantana camara	4.29	*Macaranga grandifolia*	4.12	*Pterospermum niveum*	3.83
Pogonatherum crinitum	4.28	*Leucaena leucocephala*	3.66	*Pterocarpus indicus*	2.87
Station 5					
Boehmeria heterophylla	6.12	*Dinochloa acutiflora*	16.47	*Pterocarpus indicus*	23.78
Alternanthera sessilis	6.01	*Acalypha amentacea*	9.32	*Bauhinia monandra*	13.86
Mikania cordata	5.29	*Bauhinia monandra*	8.60	*Mangifera indica*	6.82
Chromolaena odorata	4.01	*Leucaena leucocephala*	6.22	*Ficus minahassae*	5.74
Xanthosoma sagittifolium	4.00	*Chromolaena odorata*	4.30	*Lagerstroemia speciosa*	5.22

Note: IV – importance value

naturalized and 88 exotic species (Figure 2). Only few species fell in risk categories (12 or 3.5% of the total species under DAO 2017-11 but 18 or 5.33% under IUCN). Under DAO 2017-11, these included 2 endangered (*Sphaeropteris glauca*, *Sindora supa*), 4 vulnerable (*Pterocarpus indicus*¸ *Nephelium lappaceum, Alpinia elegans*, *Leptosolena haenkei*), 1 near threatened (*Boehmeria heterophylla*) and 5 other threatened species (*Rhaphidophora korthalsii*, *Canarium luzonicum*, *Aglaia cumingiana*, *Artocarpus rubrovenius*, *Carallia brachiata*). The species richness among stations ranged at 121-157 species with Station 1 having the highest while lowest at Station 4 (Figure 3). The species richness of herbs consistently outnumbered shrub and tree richness at rate of 140 – 150% higher than shrub and 230 – 240% higher than trees. Among the plant families, Poaceae and Fabaceae were the most represented with 31 and 30 species followed by Moraceae and Asteraceae with 18 species apiece, Rubiaceae with 15 species, Urticaceae with 11 species, Euphorbiaceae with 10 species, Phyllanthaceae with 9 species and Araceae with 8 species. Majority of the other families were represented by less than three species (Figure 4).

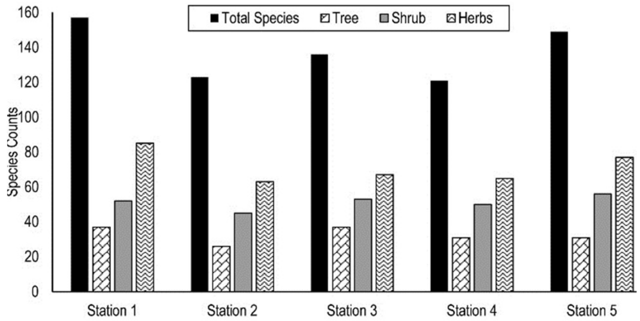

Fig. 3. Species richness in the different sampling stations along Kennon Road, Benguet

Dominant Species

The dominant species in the sampling stations along Kennon Road were presented in Table 2. In general, the dominant herbs were common weeds while the dominant shrubs were characteristics of secondary vegetation. The dominant trees differ by sampling station with *Pinus kesiya* being the most dominant species in Station 1 and 2, the most elevated among the stations. Other trees in these stations are planted fruits trees such as *Chrysophyllum cainito* and *Mangifera indica* and fast growing trees

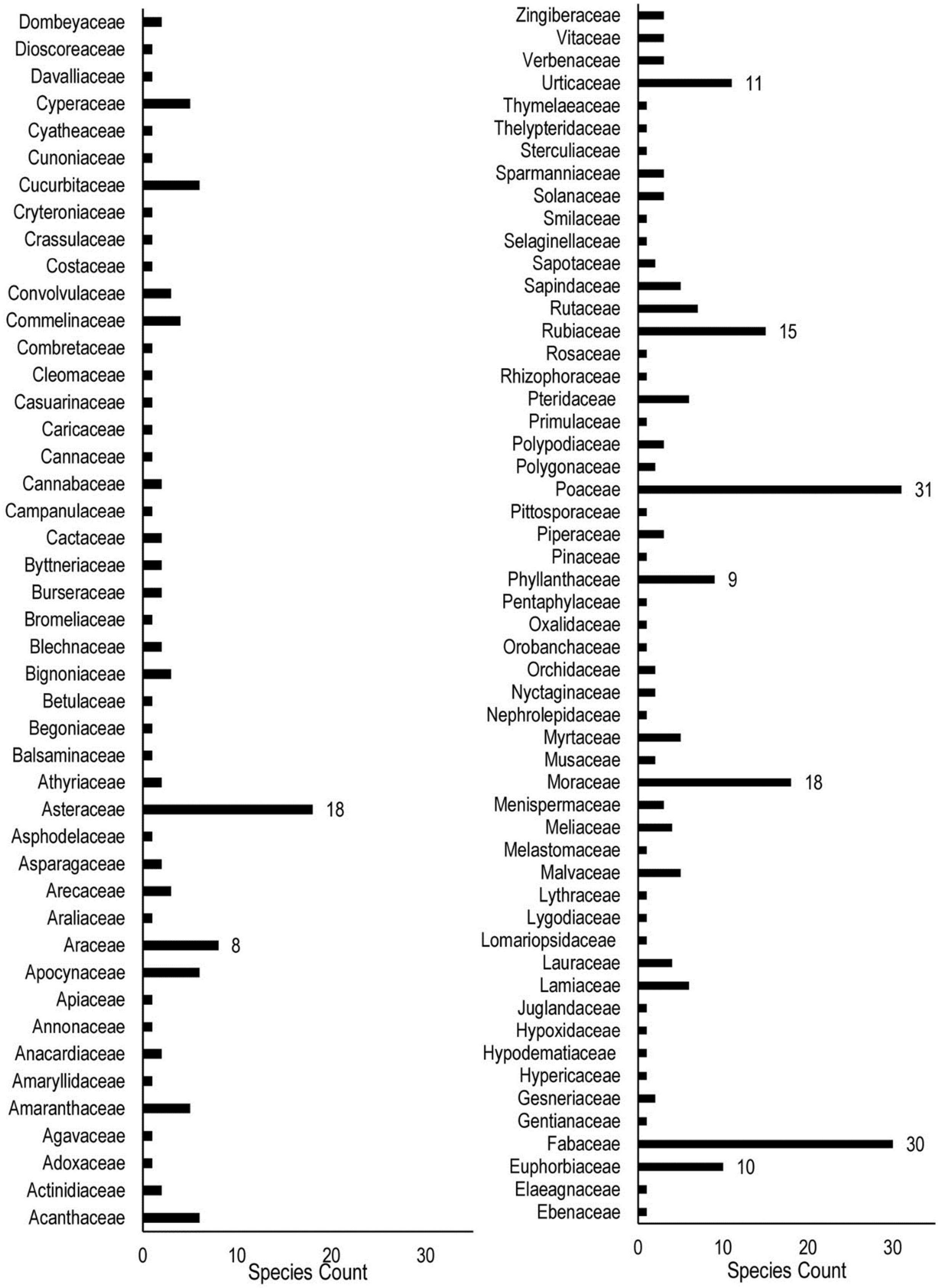

Fig. 4. Classification by family of plant species in Kennon Road.

Table 3. Biodiversity indices of the sampling stations along Kennon Road.

Sampling Stations	Biodiversity Indices			
	Shannon	Evenness	Simpson	Margalef
Station 1				
Herb	3.93 VH	0.69 SB	0.98 H	12.92 H
Shrub	3.10 H	0.58 SB	0.91 H	10.10 H
Trees	3.05 H	0.65 SB	0.95 H	6.43 H
Station 2				
Herb	3.49 H	0.63 SB	0.94 H	11.52 H
Shrub	3.02 H	0.56 SB	0.88 H	9.11 H
Trees	2.54 H	0.54 SB	0.85 H	6.41 H
Station 3				
Herb	3.68 VH	0.66 SB	0.96 H	11.83 H
Shrub	3.51 VH	0.66 SB	0.96 H	9.84 H
Trees	3.22 H	0.70 SB	0.95 H	7.82 H
Station 4				
Herb	3.60 VH	0.64 SB	0.96 H	10.96 H
Shrub	3.19 H	0.62 SB	8.58 H	0.93 H
Trees	2.71 H	0.60 SB	0.90 H	5.53 H
Station 5				
Herb	3.84 VH	0.68 SB	0.96 H	14.94 H
Shrub	2.97 H	0.54 SB	0.89 H	9.29 H
Trees	3.31 H	0.72 SB	0.96 H	7.83 H

Note: VH - very high diversity; H - high diversity; SB - semi-balanced

Table 4. Ecosystem type in the sampling stations along Kennon Road, Benguet

Ecosystem Type	Percent (%) Cover in the Sampling Stations				
	Station1	Station2	Station3	Station4	Station5
Secondary broad-leaf Forest	65.00	27.50	77.50	90.00	90.00
Pine Secondary Forest	2.50	20.00	_	_	_
Agroforestry with fruit trees	_	7.50	_	_	_
Reforestation site of DENR*	7.50	_	7.50	_	_
Stream/ Creek	2.50	5.00	2.50	2.50	_
Built-up/ Residential Areas	15.00	27.50	5.00	2.50	10.00
Eroded slope (no trees)	2.50	2.50	5.00	_	_
Eroded slope with few trees	5.00	10.00	_	_	_
Road	_	_	2.50	2.50	_
Rockwall	_	_	_	2.50	_

Note: * - Department of Environment and Natural Resources

characteristics of early secondary succession like *Ficus septica* and *Leucaena leucocephala*. *Pterocarpus indicus*, an endangered species, dominated in Stations 3 and 5 along with some indigenous trees, commonly found in lowland areas like *Macaranga tanarius* and *Ficus minahassae*. On the other hand, *Bauhinia monandra,* an exotic species, dominated in Station 4 as the tree canopy down to sapling and seedling. Other exotic trees such as *Gmelina arborea* and *Swietenia macrophylla* were also dominant. Across stations, several large (>50cm dbh) trees were documented which suggest that the tree canopy are being maintained but the understory are regularly being cleared. Thus, only fast growing weedy plants dominated and native herbs were often outcompeted.

Biodiversity indices

Understory plants had the highest biodiversity indices, particularly Shannon index ranging from 3.49 to 3.93 (Table 3). These values would fall under very high diversity classification. On the other hand, Shannon values for shrub ranges from 2.97 (moderate) to 3.51(very high). Lower Shannon values were derived from tree diversity at 2.54 (moderate) to 3.31 (high). The high diversity values for understory vegetation could be directly attributed to the high species richness of herbs, grasses and seedlings which in turn could be attributed to the disturbed state of the stations. The disturbance in the area created several stages of secondary succession that allows several understory species to arise. Areas recently disturbed had primarily exotic and weed species while less disturbed areas had more of the indigenous/ endemic species that adds to the high overall numbers.

Between stations, Station 1 and Station 5 had greater diversity values compared to other stations. Station 5 had more intact overstory vegetation and less human disturbance while Station 1 was located in a steep slope thus containing several plant species transitioning between the lower and upper elevation. Station 4 had also intact overstory vegetation but the area is dominated by *Bauhinia monandra*, an exotic species. On the other hand, Stations 3 and 2 have several denuded slopes and more humanly disturbed areas, hence the lower diversity values.

Ecosystem diversity

The ecosystem types along the sampling stations were presented in Table 4. Secondary broad-leaf forest was the most dominant ecosystem type particularly in Stations 1, 3, 4 and 5. In Station 2, pine forest and residential areas were co-dominant with secondary broad-leaf forest. There were few agroforestry and reforestation sites along with streams/ creeks and some denuded areas. The interspersing of residential or built-up areas along the road were found in all sampled stations. However, trees were often planted in between houses that provide shade for houses and passing vehicles. Denuded areas were often observed in eroded slopes where the soil was stripped and only the rocky substratum was exposed.

Floristic elements

The floristic elements of the plant species along Kennon Road were presented in Table 5. Majority of the flora were native species (76.33%) but a significant part (23.675) of the vegetation were either naturalized or exotic species. Of these native species, majority were Malesian type (43.49%) and Philippinean (13.02%). Significant elements also were the pantropical (13.61%) and paleotropical (6.52%) species that included widely distributed weeds and grasses. On the other hand, majority of the introduced species were predominantly weeds or ornamental plants. A large number of these species were of Central American (5.33%) and Neotropics (9.76%).

Table 5. Floristic elements of the native and exotic/naturalized species found along Kennon Road, Benguet.

Floristic Elements for Native Species	f	%	Floristic Elements for Exotic/ Naturalized Species	f	%
Cosmopolitan	2	0.59	African	5	1.48
Pantropical	46	13.61	Australian	2	0.59
Paleotropical	19	5.62	Brazilian	4	1.18
Indomalesia-Australian	28	8.28	Caribbean	1	0.30
Indomalesia-Eastern Asiatic	7	2.07	Central American	18	5.33
Indomalesia-Madagascan	1	0.30	Central Chinese	1	0.30
Indomalesian	33	9.76	Eastern Asiatic	2	0.59
Chino-Malesian	3	0.89	Indochinese	5	1.48
Malesian	54	15.98	Indian	2	0.59
Malesia-Australian	13	3.85	Madagascan	2	0.59
Malesia-Eastern Asiatic	4	1.18	Neotropical	33	9.76
Malesia-Papuan	4	1.18	North American	2	0.59
Philippinean	44	13.02	North Central American	1	0.30
			Papua-Northeast Australian	1	0.30
			Sudano-Zambezian	1	0.30
Over-all	**258**	**76.33**	**Over-all**	**80**	**23.67**

Note: f –frequency; % - percentage

Examples of these were fruit trees like *Persea americana*, *Chrysophyllum cainito*, *Pouteria campechiana*; ornamental plants such as *Malvaviscus arboreus, Triplaris cumingiana, Duranta erecta*; and weeds such as *Cenchrus echinatus, Triumfetta semitriloba* and *Paspalum conjugatum*.

DISCUSSION

The high (338) species richness of Kenno Road is comparable with recent plant inventory in the Cordillera Central Range (CCR) that involves intensive samplings. For example, Dulnuan and Napaldet (2023) documented 249 species belonging to 200 genera and 74 families in Amburayan River while Balangen *et al.* (2023) documented 267 species belonging to 222 genera and 78 families in the secondary forest of Tadiangan, Tuba. In another study, Salcedo (2001) documented 280 species under 180 genera and 84 families in the northern slope of Mt. Amuyao, Mountain Province. These are much higher compared to the 68 species under 63 genera and 40 families documented by Guron *et al.* (2019) in Talinguroy Research Station, La Trinidad; the 78 species under 43 families by Lumbres *et al.* (2012) in Alno Communal Forest, La Trinidad; the 61 species under 25 families in Palina River, Kibungan; and the 52 species under 40 genera and 31 families by Rabena *et al.* (2015) in a muyong forest in Ifugao. This could be directly attributed to the more extensive inventory or sampling conducted in the former studies compared to the later studies. Also, equal attention to the understory and overstory (tree) inventory was performed unlike the inventory of Lumbres *et al.* (2012) and Rabena *et al.* (2015) that focused primarily on trees. In this study, we found that the species richness in the understory (herb and shrub combined) is much higher than the tree species.

Comparing our result with other studies dealing with road biodiversity, the species richness of our study site is higher compared to the 224 vascular plant species documented by Vaneste *et al.* (2020) across European sites. Also, it is higher than the 100 species including 67% native species and 33% alien species documented by Zheng *et al.* (2011) along the road of Yellow River Delta of China. This shows the high plant diversity being affected in road construction and maintenance in tropical countries like our study site. On the other hand, the high species richness in this current inventory could also indicate the ability of tropical plant diversity to re-establish after disturbance.

Our findings show that tropical forest road ecosystem in mountain sites like our study site, Kennon Road, could harbor high plant species richness. This could be attributed to the habitat fragmentation wherein the road activities and its associated disturbances result to the formation of 10 major ecosystems type in Kennon Road with their associated plant composition. Less disturbed ecosystem like secondary forest are generally the most diverse and are dominated by native species. On the other hand, the plant diversity becomes progressively less diverse and non-native dominated in residential areas and denuded slopes. Additionally, the differences in elevation of the sampling stations that ranges from 246 to 1071 masl contribute to the differences in species composition between stations but result to the over-all high species richness of the study site. Station 1 and 2 were characterized by mid to high elevation plants while the other stations were characterized by low elevation plants.

These findings support the observation of Lugo and Gucinski (2000) that the intermingling of non-native species with native ones along road ecosystems results to the formation of a unique forest road ecosystem exhibiting these mixtures. In the case of Kennon Road, its plant diversity was shown to be a mixture of native (43.49% Malesian, 13.02% Philippinean, 13.61% pantropical, 6.52% paleotropical) and non-native species (23.68% with 5.33% Central American and 9.76% Neotropics) and also a mixture of low, mid and high elevation plants.

Another factor that could account for the high plant species diversity in the sampling stations along Kennon Road is the intermediate disturbance hypothesis (IDH). The hypothesis describes that biotic diversity is increased in communities subjected to intermediate levels of disturbance (Connell, 1978; Catford *et al.,* 2012). Overall, the sampling stations recorded high species diversity and can be interpreted based on this hypothesis because of the anthropogenic disturbances along Kennon Road such as the presence of built up areas, denuded/eroded slopes and road clearing or maintenance activities. The presence of some naturalized (29) and several exotic species (88) along the road would also support this observation. This result is consistent with the findings of Balangen *et al.,* (2023) where different human activities that cause different intensities of disturbances forming a mosaic of different land-uses in Tadiangan, Tuba contribute to the over-all high species richness of the area.

The high representation of families Poaceae, Fabaceae and Asteraceae in the sampling stations could be attributed to the presence of several weed species from these families. These species would represent the edge effect of the resulting disturbances from the road and associated activities. Disturbances that cause ground cover or canopy openings generally favor fast growing plants like the weed species from these families. On the other hand, the high representation of family Moraceae is attributed to the presence of several *Ficus* spp. that are common in riverine and secondary forest. Other more represented families are Rubiaceae, Urticaceae, Euphorbiaceae, Phyllanthaceae and Araceae which contain several species commonly found in lowland secondary forest which is the original forest type along Kennon Road. These families were also found most represented in a secondary forest of Tadiangan, Tuba (Balangen *et al.,* 2023) which is also originally a lowland evergreen forest. However, our result differs greatly compared to the nearby Metropolitan Ilocos Norte Watershed Forest Reserve, an intact limestone forest where Batuyong *et al.* (2020) documented a total of 173 species under 140 genera and 59 families. The most represented families in this forest are Rubiaceae, Fabaceae, Orchidaceae, and Malvaceae. This shows the diversity and complexity of tropical forests wherein even nearby forests could differ greatly in species and family composition.

The biodiversity indices of Kennon Road summarized in Table 3 is comparable with those recorded by Dulnuan and Napaldet (2023) in Amburayan River with Shannon index of 4.48, an evenness index of 0.57, Simpson's index at 0.97, and a Margalef's index of 31.32; and by Balangen *et al.* (2023) in Tadiangan, Tuba with 3.73 – 4.24 Shannon index. Our results are also comparable with the results of Guron *et al.* (2019) in Talinguroy Research Station and Lumbres *et al.,* (2012) in Alno Communal Forest. Consistently, the herb diversity values are much higher than the shrub and tree diversity in all sampling stations. This result affirms the claim of Langenberger (2004) that understory plants should be also be prioritized together with tree species in forest inventories. The high diversity indices of the study site together with the other secondary forest sites are growing evidences showing that amidst different human disturbances, road activities in the case of this study, these sites still harbor significant plant diversity worthy of scientific study geared towards conservation and protection. This echo the call of several authors (Hellmann *et al.,* 2008, Hulme *et al.,* 2009) that as threats to biodiversity intensify and rates of species invasion continue to rise, effective ecological management requires detailed understanding of relationships among disturbance and diversity.

The presence of several exotic species is an indicator of the disturbed or denuded state along Kennon Road as previous shown the studies of Balangen *et al.* (2023) in Tadiangan, Tuba and by Dulnuan and Napaldet (2023) in Amburayan River. Even among the indigenous and endemic species, majority of these are characteristics of a secondary successioning forest or a disturbed riverine forest. Amidst the high species richness, majority are the least concern or common type which negate the conservation importance of these study sites. These characteristics would make the area fall under young secondary forest according to the criteria proposed by Phillips *et al.* (2017). Nonetheless, the presence of few threatened species could signal the development of the study site towards a more mature and stable forest state. Hence, the current inventory could serve as baseline for future monitoring.

Among the naturalized and exotic species in the sampling stations, majority are of Central American and Neotropical elements. This could be attributed to the introduction of several fruit trees, ornamental and weed plants during the Spanish and American colonization of the Philippines (Pelser *et al.,* 2011-). The Neotropical trend of non-native species was also observed by Morente-López *et al.* (2023) in Canary Island. These information on floristic element are essential information on different plant species diversity and their distribution (Gul *et al.,* 2018). The distribution of plant species is a valuable source of information for environmental factors and ecosystem services in a particular habitat (Watts *et al.,* 2022). In the case of Kennon Road, the presence of non-native species of primarily Central American and Neotropical element mixed with native species (43.49% Malesian, 13.02% Philippinean, 13.61% pantropical, 6.52% paleotropical) would be the first floristic element survey for forest road ecosystem in the tropics. These knowledge could contribute to mountain road planning that minimize impacts or loss of biodiversity.

Lastly, our results show that the presence of traffic and built-up areas along Kennon Road affected the plant diversity. The fragmentation of the secondary forest with human built-up areas was observed which is consistent with the studies of Forman and Alexander (1998) and Vanneste *et al.* (2020). The colonization by ruderal species including non-native species was observed along Kennon Road as indicated by the presence of several exotic and naturalized species. About 23.67% of the total floristic elements are not from the local region. This is consistent with the conclusion of Lembrechts *et al.* (2017), Dar *et al.,* (2015) and Dar *et al.* (2018) that mountain roads provide corridors for the dispersal of colonizing species, including non-native species, and facilitating their distribution into pristine environments.

CONCLUSION

A total of 338 species belonging to 280 genera and 99 families were inventoried in the five sampling stations along Kennon Road, Benguet Province, Philippines. Majority of the plant species were indigenous (186) with 35 endemic, 29 naturalized, 88 exotic species and with 18 threatened species (5.33% of the total species). The species richness among stations ranged at 121–157 species with Station 1 having the highest number and lowest in Station 4. The species richness of herbs consistently outnumbered shrub and tree richness at rate of 140 – 150% higher than shrub and 230 – 240% higher than trees. Understory plants have the highest biodiversity indices, particularly Shannon index ranging from 3.49 to 3.93 (very high diversity). On the other hand, Shannon values for shrub ranges from 2.97 (moderate) to 3.51(very high) and least Shannon values were derived from tree diversity at 2.54 (moderate) to 3.31 (high). The floristic elements along Kennon Road is dominated by native species (76.33%) but a significant part (23.68%) of the vegetation are either naturalized or exotic with mostly Central American and Neotropical elements. Our results show that the presence of traffic and built-up areas along Kennon Road effected the plant diversity. The fragmentation of the secondary forest with human built-up areas was observed with the colonization by ruderal species including non-native species. On the other hand, the intermingling of these colonizers with resident species results in the formation of forest road ecosystems with high species richness in Kennon Road.

ACKNOWLEDGMENTS

The author is grateful for the research fund granted from the project of Phillip A. Alviola of UPLB that made this study possible.

LITERATURE CITED

Antonelli, A., Kissling, W.D., Flantua, S.G.A., Bermúdez, M.A., Mulch, A., Muellner-Riehl, A.N., Kreft, H., Linder, H.P., Badgley, C., Fjeldså, J., Fritz, S.A., Rahbek, C., Herman, F., Hooghiemstra, H., Hoorn, C. 2018 Geological and climatic influences on mountain biodiversity. Nature Geosci. **11(10)**: 718–725.

Balangen, D.A., Catones, M.S., Bayeng, J.M., Napaldet, J.T. 2023 Intensities of human disturbance dictate the floral diversity in tropical forest: the case of a secondary forest in Benguet, Philippines. J. Mt. Sci. **20**: 1575–1588.

Batuyong, M.R., Calaramo, M.A., Alejandro, G.J.D. 2020 A checklist and conservation status of vascular plants in the Limestone forest of Metropolitan Ilocos Norte Watershed Forest Reserve, Northwestern Luzon, Philippines. Biodiversitas **21(9)**: 3969–3981.

Buot, I.E. Jr, Okitsu, S. 1999 Leaf size zonation pattern of woody species along an altitudinal gradient on Mt. Pulog, Philippines. Plant Ecol. **145(2)**:197–208.

Catford, J.A., Daehler, C.C., Murphy, H.T., Sheppard, A.W., Hardesty, B.D., Westcott, D.A., Rejmánek, M., Bellingham, P.J., Pergl, J., Horvitz, C.C., Hulme, P.E. 2012 The intermediate disturbance hypothesis and plant invasions: Implications for species richness and management. Perspect. Plant Ecol. Evol. Syst. **14(3)**: 231–241.

Connell, J.H. 1978 Diversity in Tropical Rain Forests and Coral Reefs. Science **199(4335)**: 1302–1310.

DAO 2017-11 Updated National List of Threatened Philippine Plants and Their Categories

Dar, P.A., Reshi, Z.A., Shah, M.A 2015 Roads act as corridors for the spread of alien plant species in the mountainous regions: a case study of Kashmir Valley, India Trop. Ecol. **56(2)**: 183–190

Dar, P.A., Reshi, Z.A., Shah, A.B. 2018 Attitudinal distribution of native and alien plant species along roadsides in Kashmir Himalaya, India.Trop. Ecol. **59(1)**: 45–55

Dulnuan, M.M., Napaldet, J.T. 2023 Mosaic interplay of floral diversity, soil properties, disturbance intensity and elevation in the riparian ecosystem under semi-subsistence agriculture of Cordillera Central Range, Northern Philippines. Aquat. Ecol. **57(2)**: doi: 10.1007/s10452-023-10033-x.

Fernando, E.S 2008 Forest Formations of the Philippines. ASEAN-Korea Environmental Cooperation Unit. p232.

Fernando, E.S., Cereno, R.P. 2020 Biodiversity and natural resource management in the Mt. Pulag National Park. In: Lapitan, P.G., Fernando, E.S., Suh, M.H. *et al.,* (eds), Biodiversity and Natural Resource Conservation in Protected Areas of Korea and the Philippines. ASEAN-Korea Environmental Cooperation Unit, Seoul National University, Korea. pp 120–177.

Finnie, T.J.R., Preston, C.D., Hill, M.O., Uotila, P., Crawley, M.J. 2007 Floristic elements in European vascular plants: an analysis based on Atlas Florae Europaeae. J. Biogeogr. **34(11)**: 1848–1872.

Forman, R.T.T., Alexander, L.E. 1998 Roads and their major ecological effects. Annu. Rev. Ecol. Syst **29(1)**:207–231

Gaujour, E., Amiaud, B., Mignolet, C., Plantureux, S. 2012 Factors and processes affecting plant biodiversity inpermanent grasslands: a review. Agron. Sustain. Dev. **32(1)**: 133–160.

Geneletti, D. 2003 Biodiversity Impact Assessment of roads: an approach based on ecosystem rarity. Environ. Impact Assess. Rev. **23(3)**: 343–365

Guron, M.A., Lumpio, R.G., Napaldet, J.T. 2019 Comparison of Floral Diversity of Pine Forest, Agroforestry and Agricultural Land-Uses in Talinguroy Research Station, Benguet State University, Northern Philippines. MJSIR **79(2)**: 21–34.

Gul, B., Ahmad, I., Khan, H., Zeb, U., Ullah, H. 2018 Floristic inventory of wild plants of Peshawar university campus. Acta Ecol. Sin. **38(6)**: 375–380.

Hellmann, J.J., Byers, J.E., Bierwagen, B.G., Dukes, J.S. 2008 Five potential consequences of climate change for invasive species. Conserv. Biol. **22(3)**: 534–543.

Hulme, P.E., Pysek, P., Nentwig, W., Vilà, M. 2009 Will threat of biological invasions unite the European Union? Science **324(5923)**: 40–41.

Hussain, N.A., Ali, A.H., Lazem, L.F. 2012 Ecological indices of key biological groups in Southern Iraqi marshland during 2005-2007. Mesopot. J. Mar. Sci. **27(2)**: 112–125

Latumahina, F.S., Mardiatmoko, G., Sahusilawane, J. 2020 Richness, Diversity and Evenness of Birds in Small Island. J. Physics: Conf. Series **1463(1)**: 012023.

Lembrechts, J.J., Alexander, J.M., L.A. Cavieres, Haider, S., Lenoir, J., Kueffer, C., McDougall, K., Naylor, B.J., Nuñez, M.A., Pauchard, A., Rew, L.J., Nijs, I., Milbau, A. 2017 Mountain roads shift native and non-native plant species' ranges. Ecography **40(3)**: 353–364.

Lisboa, P.V., Fernandes, E.H., Sottolichio, A., Huybrechts, N., Bendô, A.R. 2022 Coastal plumes contribution to the suspended sediment transport in the Southwest Atlantic inner continental shel. J. Mar. Syst **236**: 103796.

Lugo, A.E., Gucinski, H. 2000 Function, effects, and management of forest roads. For. Ecol. Manag. **133(3)**: 249–262.

Lumbres, R.I.C., Palaganas, J.A., Micosa, S.C. 2012 Floral diversity assessment in Alno communal mixed forest in Benguet, Philippines. Landscape Ecol. Eng. **10(2)**: 361–368.

Manan, F., Khan, S.M., Muhammad, Z., Ahmad, Z., Abdullah, A., Rahman, A., Han, H., Ariza-Montes, A., Contreras-Barraza, N., Raposo, A. 2022 Floristic composition, biological spectrum, and phytogeographic distribution of the Bin Dara Dir, in the western boundary of Pakistan. Front. For. Glob. Change. **5**:1019139.

Morente-López, J., Arjona, Y., Salas-Pascual, M., Reyes-Betancort, J.A., del Arco-Aguilar, M.J., Emerson, B.C., García-Gallo, A., Jay-García, L.S., Naranjo-Cigala, A., Patiño, J. 2023 Biogeographic origins and drivers of alien plant invasions in the Canary Islands. J. Biogeogr. **50(3)**: 576–590.

Niu, Y., Yang, S., Zhou, J., Chu, B., Ma, S., Zhu, H., Hua, L. 2019 Vegetation distribution along mountain environmental gradient predicts shifts in plant community response to climate change in alpine meadow on the Tibetan Plateau. Sci. Total Environ. **650**: 505–514.

Pelser, P.B., Barcelona, J.F., Nickrent, D.L. (eds.) 2011 onwards. Co's Digital Flora of the Philippines. www.philippineplants.org.

Peterson, G., Allen, C., Holling, C. 1998 Ecological Resilience, Biodiversity, and Scale. Ecosystems **1(1)**: 6–18.

Phillips, H.R.P., Newbold, T., Purvis, A. 2017 Land-use effects on local biodiversity in tropical forests vary between continents. Biodivers Conserv **26(9)**: 2251–2270.

POWO (Plants of the World Online) 2023 Plants of the World Online. Facilitated by the Royal Botanic Gardens, Kew. http://www.plantsoftheworldonline.org/. Accessed June 2023.

Rabena, M.A.F., Macandog, D.M., Cuevas, V.C., Espaldon, M.V.O. 2015 A vegetation inventory of a traditional secondary forest (Muyong) in Kinakin, Banaue, Ifugao, Northern Luzon, Philippines. Philipp. J. Syst. Biol. **9**: 10–32.

Rahbek, C., M.K. Borregaard, A. Antonelli, Colwell, R.K., Holt, B.G., Nogues-Bravo, D., Rasmussen, C.M.Ø., Richardson, K., Rosing, M.T., Whittaker, R.J., Fjeldså, J. 2019 Building mountain biodiversity: Geological and evolutionary processes. Science **365(6458)**: 1114–1119.

Rashid, I., S.M. Haq, Lembrechts, J.J., Khuroo, A.A., Pauchard, A., Dukes, J.S. 2021 Railways redistribute plant species in mountain landscapes. J. Appl. Ecol. **58(9)**: 1967–1980.

Ruiz-Jaen, M.C., Aide, T.M. 2005 Restoration success: How is it being measured? Restor. Ecol. **13(3)**: 569–577.

Salcedo, P.V.G. 2001 Floral diversity and vegetation zones of the northern slope of Mt. Amuyao, Mountain Province, Luzon (Philippines). Asia Life Sci **10(2)**: 119–157.

Simpson, E.H. 1949 Measurement of diversity. Nature **163(4148)**: 688.

Takhtajan, A. 1986 Phytogeography: Floristic Regions of the World. University of California Press, Berkeley 522 pp.

Tilman, D., Wedin, D., Knops, J. 1996 Productivity and sustainability influenced by biodiversity in grassland ecosystems, Nature **379(6567)**: 718–720.

Tilman, D., Reich, P.B., Knops, J., Wedin, D., Mielke, T., Lehman, C. 2001. Diversity and Productivity in a Long-Term Grassland Experiment. Science **294(5543)**: 843–845.

Ullah, Z., Ahmad, M., Khan, S.M. 2015 Phytogeographic Analysis and Diversity of Grasses and Sedges (Poales) of Northern Pakistan. Pak. J. Bot. **47(SI)**: 93–104.

Vahdati, F.B., Mehrvarz, S.S., Naqinezhad, A.R., Shavvon, R.S. 2014 Floristic characteristics of the Hyrcanian submountain forests (case study: Ata-Kuh forest). Casp. J. Environ. Sci. **12(2)**: 169–183.

Vanneste, T., Govaert, S., Kesel, W., Berge, S.V.D., Vangansbeke, P., Meeussen, C., Brunet, J., Cousins, S.A.O., Decocq, G., Diekmann, M., Graae, B.J., Hedwall, P.-O., Heinken, T., Helsen, K., Kapás, R.E., Lenoir, J., Liira, J., Lindmo, S., Litza, K., Naaf, T., Orczewska, A., Plue, J., Wulf, M., Verheyen, K., De Frenne, P., Biswas, S. 2020 Plant diversity in hedgerows and road verges across Europe. J. Appl. Ecol. **57(7)**:1244–1257.

Warren, B.H., D. Strasberg, J.H. Bruggemann, Prys-Jones, R.P., Thébaud, C. 2010 Why does the biota of the Madagascar region have such a strong Asiatic flavour? Cladistics **26(5)**: 526–538.

Watts, M., Hutton, C., Guel, E.M., Suckall, N., K. Peh, S.-H. 2022 Impacts of climate change on tropical agroforestry systems: a systematic review for identifying future research priorities. Front. For. Global Change. **5**: 880621.

Zhang, W., Huang, D., Wang, R., Liu, J., Du, N. 2016 Altitudinal patterns of species diversity and phylogenetic diversity across temperate mountain forests of Northern China. PLoS ONE **11(7)**: e0159995.

Supplementary materials are available from Journal Website