Research Journal of Agriculture and Forestry Sciences ISSN 2320 – 6063
Vol. **9(2),** 32-43, April **(2021)** *Res. J. Agriculture and Forestry Sci.*

Species richness in community forestry and exploration of relationship among area, flora and fauna

Parbat Raj Thani[1]* and Prashid Kandel[2]
[1]United for Sustainable Development, Kathmandu, 44600, Nepal
[2]Kathmandu Forestry College, Kathmandu, 1276, Nepal
parbatkawa123@gmail.com

Available online at: www.isca.in, www.isca.me
Received 4th December 2020, revised 27th February 2021, accepted 16th March 2021

Abstract

Forest biodiversity is increasingly threatened as a result of human being, and to discourage its loss, urgent need to apply all the possible measures has been realized. Study of species richness has great importance to support in the conservation, resource management and sustainable development planning. However, its data deficiency and resulting unclear relationship among area, flora and fauna are major concerns. The purpose of this study was to study incorporation status of species richness into operational plans, and to identify relationships among area, flora and fauna through assessing species richness in the community forests of different geographical regions of Nepal. We observed trivial number of species mentioning in operational plans than they really existed. Furthermore, there was weak positive correlation between size of the area and species richness and we found comparatively good species richness even in the community forests with smaller areas. Similarly, the correlation between flora and fauna was moderately positive and we observed the number of flora greater than the number of fauna in most of the community forests of terai/siwalik and hill but fauna was higher in mid-mountain. Besides this, overall species richness was found to be highest in terai/siwalik and the least in mid-mountain.

Keywords: Community forests, participatory method, flora-fauna relationship, species-richness assessment.

Introduction

Significance and value of biodiversity for human being is always higher[1–3]. The reason is due to its direct and indirect connection with human well-being, including the access to water and basic raw materials for a satisfactory life, and security in the face of environmental change, through its effects on the ecosystem processes that lie at the core of the Earth's most vital life support systems[4]. Despite this fact, currently, forest biodiversity is increasingly threatened globally because of activities linked to human beings and as a result, many species are endangered and many are in the verge of extinction[5–9]. Therefore, measures to discourage its losses are urgently needed[10–12].

The need of biodiversity assessment has thus been realized to support in the conservation and management of biodiversity[13–15]. So that, its importance has been stressed in many international conventions and agreements[16]. It addresses the inquiries concerning three overarching characteristics of biodiversity which describe structure, composition and function and provide short of information to decision makers that facilitate more effective land use planning and management of biodiversity and associated resources[17-19]. Several methods have been developed with specific purpose and applied for the assessment of biodiversity[20]. Furthermore, study on species richness is one which is very important part of biodiversity assessment.

The term, “species richness” which was first coined by McIntosh refers to the number of different species present in a given ecosystem, region or particular area[21]. It is related to species diversity, but they are not the same thing; richness does not take the proportional abundances into account, while species diversity does[22,23]. Knowledge about species richness in particular ecosystem or area is essential because it is an important index when thinking about conservation of a given habitat. An accurate species richness index can help determine what conservation measures need to be taken to provide a habitat where species can survive and thrive[24–26]. Therefore, this fact clearly indicates that the study of species richness in community forestry of Nepal is crucial since it covers remarkable percentage of the land area and links to the millions of households ensuring their active participation in conservation, management and utilization of forest resources to support in their subsistence. But unfortunately, the study made by many authors indicates that assessment of species richness in community forestry is lacking; and due to this data deficiency, the relationship among area, flora and fauna is unclear which is imperative to know for the better conservation, management and utilization of the resources[27–30]. The main purpose of this study was to assess floral (herb/shrub, tree, climber) and faunal (mammal, reptile, bird, insect and water animal) species richness in the community forests of different geographical regions (terai/siwalik, hill and mid mountain) and find the connection between the size of the area and species richness, flora and fauna, and the feature of species richness in different geographical regions.

Methodology

Study sites: Nepal is situated on the southern slopes of the central Himalayas occupying a total area of 147,516km^2. The country is roughly a rectangular piece of land and located between latitudes 26^{o}22' and 30^{o}27' N and longitudes 80^{o}40' and 88^{o}12' E. Its average length from east to west is 885 km and the width varies from 145km to 241km, with a mean of 193km north to south. Hills and high mountains represent about 86% of the total land area and the remaining 14% are the flatlands of the Terai, which are less than 300m in elevation. Altitudinal range is from some 60m above sea level in the Terai to Mount Everest (Sagarmatha) at 8,848m, the highest peak of the world.

Total of 18 community forests were selected randomly for the study taking into consideration the three geographical regions namely, terai/siwalik, hilly region and middle mountain, and seven provinces of Nepal. From the physiographical aspect, six community forests were selected from those each geographical region. Terai occurs at an elevation ranging from 60 to 200m with tropical climate while Siwalik occurs at an altitudinal range from 200 to 1,500m with tropical and subtropical climate[31]. However, the altitudinal range of selected community forests in terai/siwalik were between 100m and 1000m therefore, it represented tropical climate forest type[32]. Similarly, the community forests of hilly region were situated at an altitude from 1000m to 2000m and represented forest of subtropical-lower temperate climate. The community forests of middle-mountain were between the altitudinal range of 2000m to 3000 m and represented lower temperate-upper temperate climate[32]. Besides this, out of total selected community forests, 5 were from province 1. Province 6 (Karnali province) and province 7 (Sudur paschim province) represented 2 community forests each. Similarly, province 2 and province 4 (Gandaki province) had one community forest each. Furthermore, province 3 (Bagmati province) and province 5, represented 3 and 4 community forests respectively. The detail of the selected community forests is illustrated in Table-1 and Figure-1.

We selected those community forests as a sample sites to represent the range of variation in forest environment.

Primary data collection: Users group meeting: Rural indigenous people bear great knowledge about flora and fauna, including their identification and ecology[33,34]. Furthermore, declining funding for taxonomy, enormity of the extinction crisis, limited time, and good knowledge of biodiversity resources to forest users has forced to apply participatory method for the biodiversity inventory and assessment[7,35]. Therefore, rapid species richness assessment was carried out through participatory approach since it was verified and suggested by Arances et al.[36] and Jinxiu et al[37]. The study was carried out in 2019. Approximately, 35-40 forest users of the respective community forest were invited taking into consideration the economic status, religion, gender, age, education, culture and cast to ensure the equal representation of all groups including elderly people, women, excluded groups or other disadvantaged groups in discussion. They were the fully or partially forest dependent for their subsistence and had different level of knowledge about their forest biodiversity. In addition, we also invited forest executive committee members of respective community forest along with forest technicians from the nearby range forest office to secure all needed information and their verification. We presumed most of the forest users unfamiliar with the terms, “species richness”. Therefore, they were sensitized before the assessment.

Assessment of species richness: We developed simple format for the biodiversity assessment (Table-2). Following the format, we asked participants to mention the name of each species which they had seen into their community forest within past 5 years. For this, first, they remembered and expressed the species of one category only, for example, mammal. Once all the participants didn’t able to remember any further name of mammal, we shifted to next category such as reptile and so on. From this way, we collected all the mentioned name of herb/shrub, tree, climber under flora and mammal, reptile, bird, insect and water animal under fauna which were existed in selected community forests.

Table-1: Selected community forests for the study.

Tarai/Siwalik Region	Hilly Region	Middle- mountain Region
Radha Krishna buffer zone community forest, Bara	Dumri Thumka community forest, Udayapur	Ramite community forest, Okhaldhunga
Namuna buffer zone community forest, Nawalpur	Naudhara community forest, Godawari, Lalitpur	Andheri community forest, Okhaldhunga
Bandevi community forest, Kailali	Maranga jhakrebhir community forest, Gulmi	Jhyari Buffer Zone community forest, Mugu
Lathuwa community forest, Kailali	Godawari kunda community forest, Lalitpur	Ratamata Choti Khada buffer zone community forest, Mugu
Bhotedaha community forest, Dang	Kafalgaira community forest, Gulmi	Mahabir community forest, Dolakha
Himali community forest, Dharan, Sunsari	Andheri Chharchhare community forest, Palpa	Thumki Baisakhe community forest, Sankhuwashava

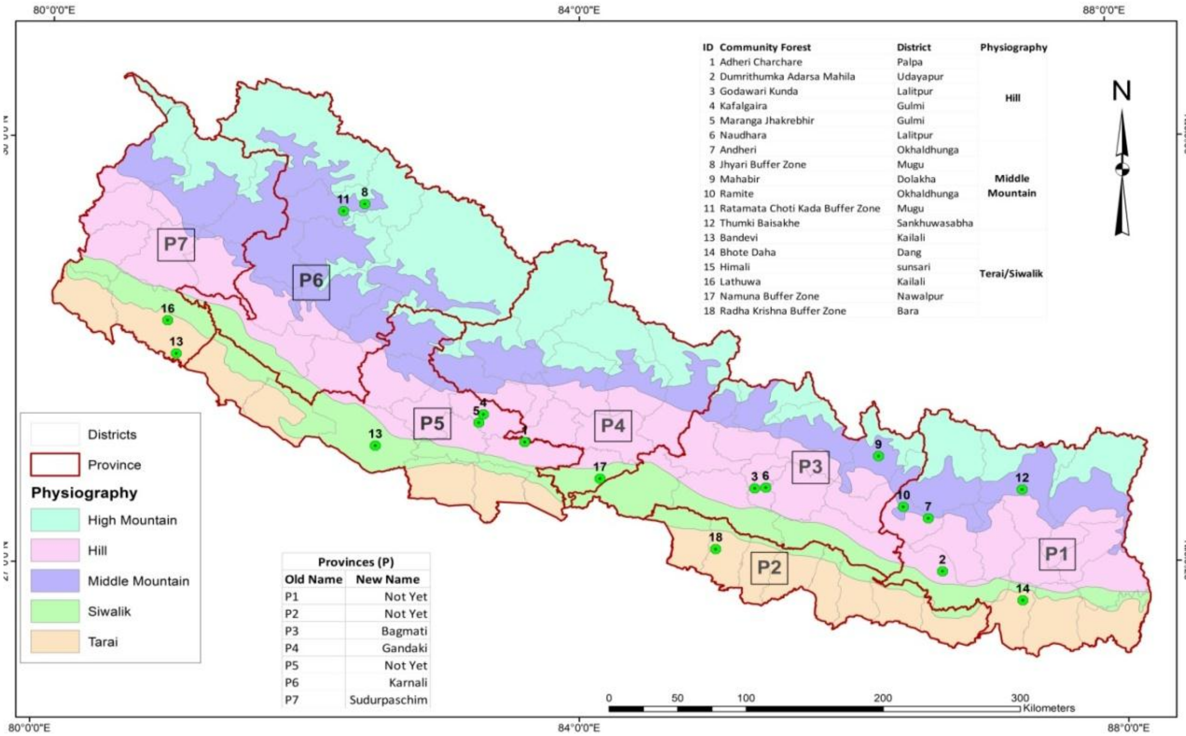

Figure-1: Selected community forests for the study.

Field Observation; Field observations were carried out with forest technicians/experts and community forest executive committee members to identify and collect the sample of any confused flora regarding their existence. The samples of all the confused floral species were further conformed and verified from the online data base (https://plantdatabase.kath.gov.np/ and http://www.floraofnepal.org/onlineflora) of national herbarium and plant laboratories, Phulchoki.

Secondary data collection: We collected 500 community forest operational plans randomly from the different geographic regions to study the incorporation status of species richness into those documents. Similarly, general idea about species richness of selected 18 community forests was also obtained from their operational plan, published and unpublished documents. For those documents, we consulted with respective community forest and related range forest offices. We also collected desired data from those organizations who worked in respective community forests currently or previously. In addition, different publications and journal articles related to the assessment of species richness from nearby areas and other regions were consulted as secondary information. Those secondary data were taken into account to verify assessed species richness.

Data analysis: We employed quantitative data for the study. We used Pearson product-moment correlation coefficient to study relationship among forest area, flora and fauna[38,39]. All the quantitative data analysis was carried out with the use of Microsoft Excel.

Results and discussion

Rapid species richness assessment through participatory method: The number of total species (flora and fauna) that we recorded from the 18 different community forests using participatory method (Table-3) ranged between 76 and 291 where, minimum number of species was recorded in Ratamata chotikhada buffer zone community forest, Mugu and maximum number of species in Lathuwa community forest, Kailali.

On the other hand, the operational plan of 500 community forests, which included the operational plans of 18 selected community forests, were studied very carefully and found that no community forest operational plan recorded more than 30 species of flora and fauna both in combine (Table-2). In addition, all the operational plans had mentioned herb/shrub and tree species however; the climber species was mentioned in almost negligible operational plans. Similarly, no operational plan contained more than 10 herb/shrub species and more than 15 tree species. Furthermore, mammal and bird were mentioned in all the operational plans whereas, reptile, insect and water animal were mentioned by 471, 52 and 13 operational plans respectively. Besides this, no operational plan contained more than 5 species of reptile, insect and water animal, 10 species of mammal and 15 species of birds.

Table-2: Number of community forests those included different categories of species into their operational plans.

Biodiversity	Number of community forests those included different categories of species into their operational plans			
	1- 5	6-10	11-15	Total
Flora				
Herb/Shrub	372	128	0	500
Tree	46	313	141	500
Climber	17	0	0	17
Fauna				
Mammal	344	156	0	500
Bird	197	299	4	500
Reptile	471	0	0	471
Insects	52	0	0	52
Water animal	13	0	0	13

This result clearly indicates that operational plan of community forests mention the very few or almost negligible names of flora and fauna. This claim is strongly supported by Thani[30] who observed worse incorporation status of biodiversity and ecosystem services into community forest operational plan while studying 100 operational plans of community forests from the different regions of Nepal. Since, the proper assessment of species richness can make forest users aware about their natural capital for the further planning, conservation and management, it becomes necessary to include it into operational plan. Nepal National Biodiversity Strategy and Action Plan (NBSAP) 2014-2020 also supports this view. It has identified 6 thematic areas and 15 cross cutting themes (MoFSC, 2014) and under which, one point has been strongly mentioned about community forestry that by 2020, all community managed forests to incorporate a biodiversity chapter into their operational plan. However, no progress has been made on it yet and no clear methodology has been developed[30]. Therefore, including species richness into biodiversity chapter of operational plan might be meaningful.

Does area matters in species diversity richness?: The magnitude of correlation coefficient for two variables, area of different community forests and their plant species richness was calculated as 0.476967, and the correlation coefficient of area and faunal species richness was calculated as 0.319001. It means little bit stronger correlation between area and flora in comparison with area and fauna however; the overall indication of these values is weak positive correlation between area and species richness (both flora and fauna). Similar findings was obtained by group of Oertli as well while studying different ponds and their species diversity[40]. The result we obtained explains that the size of the area plays weak role in increase or decrease of species richness. If this is fact, then how was there significant difference in species richness among different community forests (Table-3)? For example, we observed remarkably good species richness even in the community forests with smaller areas. Some examples are Lathuwa CF and Bhotedaha CF in terai/siwalik, Maranga jhakrebhir CF and Godawari Kunda CF in Hill. The area of which were remarkably less than the area of many other CFs such as Radhakrishna CF and Namuna Bufferzone CF in terai/Siwalik and the Ramite CF in mid mountain but the species richness were more or less equal to them (Figure-2 and Table-3). So, there might be certainly many other factors which determine the increase or decrease of species richness. Many authors have pointed habitat diversity/heterogeneity as a responsible factor in increasing or decreasing plant species richness[41–44]. According to them, habitat diversity/heterogeneity within the area is important rather than uniform habitat and they believe that the more the habitat diversity the more the plant species richness is. This point is found to be applicable in the case of fauna too. For example, positive effects were found for insects[45–50], birds[51–53], mammals[54,55], amphibians[56] and reptiles[57].

However, some studies prove evidence that increase in habitat heterogeneity may also decrease species richness. This was shown, e.g. for small forest bottom-dwelling mammals[58], birds[59] or butterflies[60]. Such inconsistency might be as a result of many different covarying factors in which habitat biodiversity/ heterogenity is dependent. Those factors are environmental factors and identified as climatic such as temperature, solar radiation, humidity, wind[61–65]; topographic such as altitude, aspect[41]; edaphic such as physical, chemical and organic properties of soil[66–68] and the biotic such as structure and composition of flora and fauna, human action/anthropogenic disturbances[69,70]. Besides this, Tews et al.[71] has stressed that the relationship between habitat heterogeneity of the vegetation and animal species diversity generally depend on how habitat heterogeneity is perceived by the animal guild studied, the measurement of species diversity, the definition and measurement of vegetation structure and the temporal and spatial scale of the study are crucial.

Table-3: Assessment of species richness through participatory method in community forests of different geographical regions.

Name of community forest	Place	Total area (Ha)	Species diversity										
			Flora (A)				Fauna (B)				Total A	Total B	Total A+B
			Herb/ Shrub	Tree	Climber	Mammal	Bird	Reptile	Insect	Water animal			
Community forests of Terai/Siwalik region													
Radha Krishna	Bara	621	55	59	27	24	37	7	40	5	141	113	254
Namuna	Nawalparasi	405	59	64	11	29	37	6	13	9	134	94	228
Bandevi	Kailali	312.51	32	70	29	23	40	7	17	4	131	91	222
Lathuwa	Kailali	140.83	61	79	15	31	46	8	23	28	155	136	291
Bhotedaha	Dang	136.17	44	63	25	15	51	10	16	3	132	95	227
Himali	Dharan	53.48	24	40	14	20	35	6	31	10	78	102	180
Community forests of Hilly region													
Dumri thumka	Udayapur	183.9	18	67	6	14	13	1	6	3	91	37	128
Naudhara	Lalitpur	174	28	66	3	23	23	3	12	4	97	65	162
Maranga Jhankrebhir	Gulmi	173.08	23	82	5	29	31	7	19	9	110	95	205
Godawari Kund	Lalitpur	147	53	85	19	17	31	3	26	7	157	84	241
Kafalgaira	Gulmi	23.07	18	69	5	28	29	7	20	8	92	92	184
Andheri Chharchhare	Palpa	18	26	60	25	14	28	7	14	6	111	69	180
Community forest of middle-mountain region													
Ramite	Okhaldhunga	279.67	15	42	10	15	37	11	17	19	67	99	166
Andheri	Okhaldhunga	109.09	11	40	9	16	26	11	15	13	60	81	141
Jhyari	Mugu	79.21	22	34	1	20	18	2	7	2	57	49	106
Ratamata chotiKhada	Mugu	40.27	18	22	1	5	20	2	6	2	41	35	76
Thumki Baisakhe	Sankhuwashava	28.39	16	42	10	13	37	15	18	20	68	103	171
Mahabir	Dolakha	29	7	31	10	11	16	15	17	8	48	67	115

Relationship between flora and fauna: The correlation coefficient was calculated as 0.555468 for flora and fauna of different community forests. This indicates moderately positive correlation between them. Similar result was obtained by

Vanbergen et al.[68]. The flora and fauna are interrelated in different ways so the extent of floral diversity is responsible in increasing or decreasing faunal diversity and vice versa. But much of the overall diversity depends on plant diversity, because plants provide both food and habitat for other organisms[72]. Many factors related to habitat diversity/ heterogeneity have been identified that determine whether floral or faunal diversity is higher in the particular area[71]. Because of this reason, we observed the number of floral species higher or less than faunal species in some areas and sometimes even equal to faunal species diversity. While studying floral and faunal diversity in different community forests, we found the number of flora greater than the number of fauna in many community forests. Those community forests were all the community forests of terai/siwalik except Himali CFs where fauna was higher than the number of floral species; all the CFs of hill except kafalgaira where flora and fauna were in equal number; Jhyari and ratamata CFs of mid-mountain. In mid mountain remaining CFs, had higher faunal diversity rather than flora. In others words, floral diversity was higher than faunal diversity in most of the community forests of terai/siwalik and hill, while it was lower in mid-mountain (Figure-3).

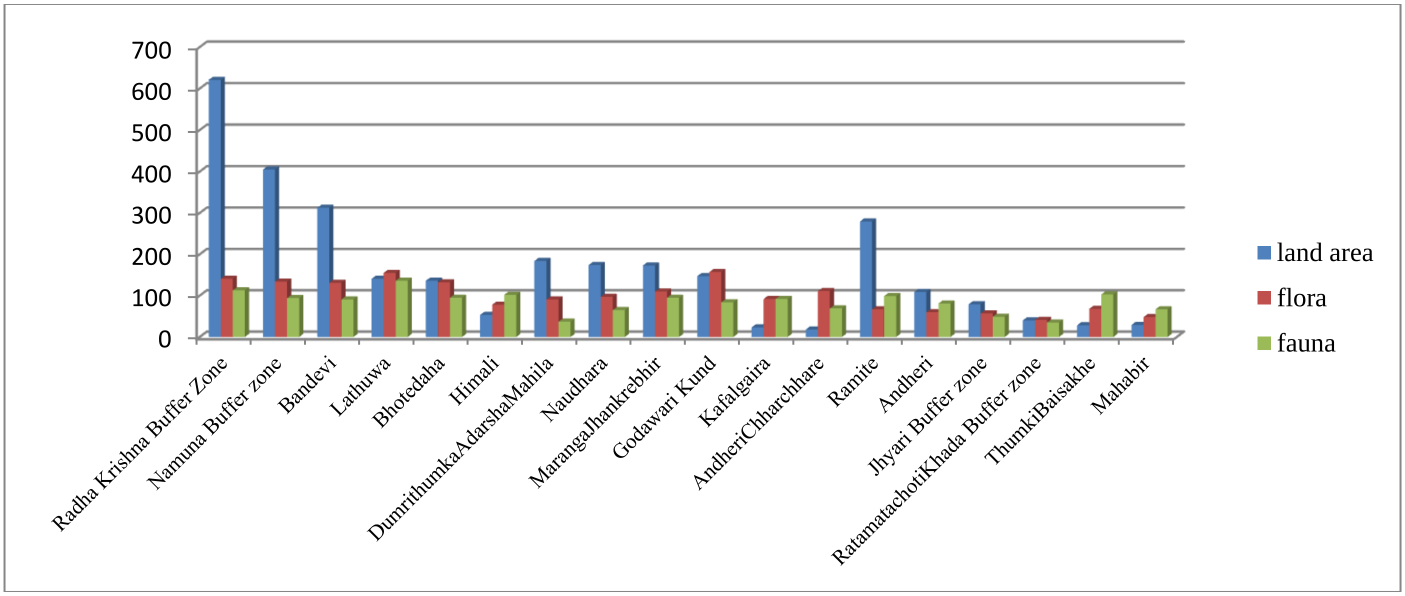

Figure-2: Species richness in different community forests.

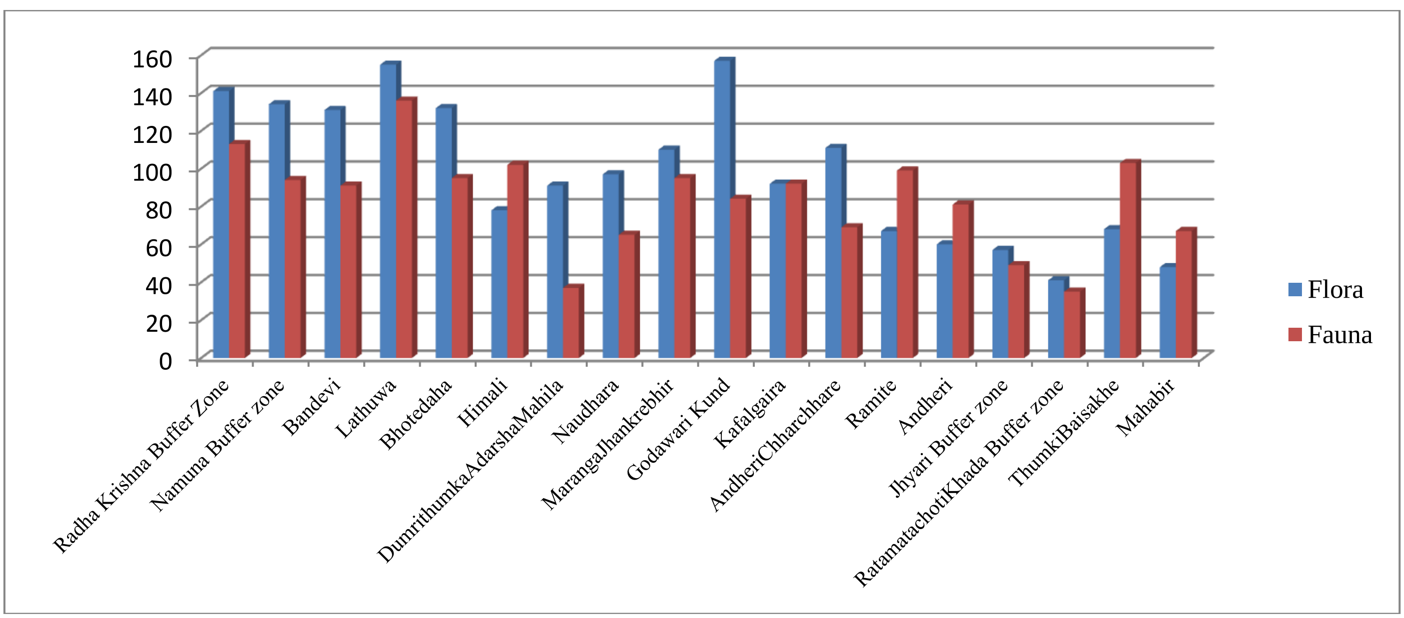

Figure-3: Flora and fauna relationship in different community forests.

Species richness in different geographical regions: While comparing species richness in different geographical regions, Terai/Siwalik, Hill and Mid-mountain, we noticed the higher diversity of herb/shrub and climber species in terai/siwalik in comparison with the hill and mid-mountain. However, the hill was the one which had highest diversity of tree species than other regions. In addition, all the herb/shrub, tree and climber species diversity were lowest in mid-mountain. We also found that the overall floral species richness (herb/shrub, tree, and climber) was highest in terai/siwalik and the least in mid-mountain. With regards to fauna, the number of mammals, birds, and insects were highest in terai/siwalik and the lowest in mid- mountain except bird which was equal in both hill and mid-mountain. The numbers of reptiles and water animals were highest in mid-mountain and lowest in hill. Besides this, the overall faunal species richness (mammal, bird, reptile, insect and water animal) was highest in terai/siwalik and lowest in mid mountain (Table-4).

The data on Table-4 also clearly illustrates that the value of total average species richness in terai/siwalik, hill and mid-mountain was 233, 182 and 129 respectively which means the total of average species richness (flora and fauna) in terai/siwalik was comparatively higher than in hill, while it was least in middle-mountain.

Decreasing trend in species richness with increasing elevation have been observed by many authors[73–79]. However, others have observed a hump shaped relationship between species richness and elevation[80–82]. The mechanistic reasons for these patterns are a matter of ongoing debate[83–85] and it is not yet known whether a universal explanation exists[86–88]. While studying species richness in three different geographical regions at different altitudes, 100-1000m, 1000-2000m and 2000-3000m, this study clearly showed the decreasing pattern of overall biodiversity both flora and fauna along the altitudinal gradients (Table-3 and 4). The work of different researchers[75,77,89,90] also supports our overall result about pattern of species richness, but the result made on reptiles by Stevens, G. C.[89] and Chettri, B.[91] does not matches and opposite to this result.

Many factors play role in enhancing species richness. Firstly, availability of higher water and optimum energy, because they increase photosynthesis, which leads to higher biological activities and ultimately an increase in species richness[65,92]. Other different mechanisms avoiding competition, such as spatiotemporal heterogeneity (weaker competitors may find a more favorable place or time) or environmental stress (competition is assumed to be less intensive under difficult conditions)[93]. Besides this, the species pool is regarded as an important factor in determining community richness[93,94].

Table-4*:* Average number of species richness in different geographical regions.

Biodiversity	Average number of recorded species in different geographical regions		
	Terai/siwalik	Hill	Mid-mountain
Flora			
Herb/Shrub	46	28	15
Tree	62	71	35
Climber	20	10	7
Total average of flora	128	109	57
Fauna			
Mammal	24	21	13
Birds	41	26	26
Reptiles	7	4	9
Insects	23	16	13
Water animal	10	6	11
Total average of fauna	105	73	72
Total average of flora and fauna	233	182	129

Conclusion

The community forest operational plans do not include the list of overall existed species richness although the assessment of species richness can make forest users aware about their forest resources for the further better planning, conservation and management. Since NBSAP has planned to include a biodiversity chapter in Operational Plan of all the community forests, including species richness into biodiversity chapter of operational plan might be meaningful.

The correlation between size of the area and species richness is positive but weak. However, there is remarkably good species richness even in the community forests with smaller areas. In other words, the community forest with smaller size might have higher species richness than the community forests with bigger size. Similarly, the correlation between flora and fauna is moderately positive. Besides this, most of the community forests in Terai/Siwalik and hill have higher number of flora than fauna, while the number of flora is less than the number of fauna in mid-hill.

The higher species richness of herb/shrub and climber was noticed in terai/siwalik in comparison with the hill and mid-mountain. However, the hill was the one which had highest number of tree species than in other regions. In addition, all the herb/shrub, tree and climber species richness were lowest in mid-mountain. We also found that the overall floral species richness was highest in terai/siwalik and the least in mid-mountain. With regards to fauna, the number of mammals, birds, and insects were highest in terai/siwalik and the lowest in mid- mountain except bird which was equal in both hill and mid-mountain. The numbers of reptiles and water animals were highest in mid-mountain and lowest in hill. Besides this, the overall faunal species richness was highest in terai/siwalik and lowest in mid mountain. Furthermore, the total of average species richness (flora and fauna) in terai/siwalik was comparatively higher than in hill, while it was least in middle-mountain.

References

1. Butler, C. D., & Oluoch-Kosura, W. (2006). Linking Future Ecosystem Services and Future Human Well-being. *Ecology and Society*, 11(1). https://www.jstor.org/stable/ 26267788.
2. Harrison, P. A., Vandewalle, M., Sykes, M. T., Berry, P. M., Bugter, R., de Bello, F., Feld, C. K., Grandin, U., Harrington, R., Haslett, J. R., Jongman, R. H. G., Luck, G. W., da Silva, P. M., Moora, M., Settele, J., Sousa, J. P., & Zobel, M. (2010). Identifying and prioritising services in European terrestrial and freshwater ecosystems. *Biodiversity and Conservation*, 19(10), 2791–2821. https://doi.org/10.1007/s10531-010-9789-x.
3. Costanza, R., de Groot, R., Sutton, P., van der Ploeg, S., Anderson, S. J., Kubiszewski, I., Farber, S., & Turner, R. K. (2014). Changes in the global value of ecosystem services. *Global Environmental Change*, 26, 152–158. https://doi.org/10.1016/j.gloenvcha.2014.04.002
4. Díaz, S., Fargione, J., Iii, F. S. C., & Tilman, D. (2006). Biodiversity Loss Threatens Human Well-Being. *PLOS Biology*, 4(8), e277. https://doi.org/10.1371/journal.pbio. 0040277
5. Cardinale, B. J., Duffy, J. E., Gonzalez, A., Hooper, D. U., Perrings, C., Venail, P., Narwani, A., Mace, G. M., Tilman, D., Wardle, D. A., Kinzig, A. P., Daily, G. C., Loreau, M., Grace, J. B., Larigauderie, A., Srivastava, D. S., & Naeem, S. (2012). Biodiversity loss and its impact on humanity. *Nature*, 486(7401), 59–67. https://doi.org/10.1038/nature 11148
6. Chapin, F. S., Zavaleta, E. S., Eviner, V. T., Naylor, R. L., Vitousek, P. M., Reynolds, H. L., Hooper, D. U., Lavorel, S., Sala, O. E., Hobbie, S. E., Mack, M. C., & Díaz, S. (2000). Consequences of changing biodiversity. *Nature*, 405(6783), 234–242. https://doi.org/10.1038/35012241
7. McNeely, J. A., Miller, K. R., Reid, W. V., Mittermeier, R. A., & Werner, T. B. (1990). Conserving the world's biological diversity. *Conserving the World's Biological Diversity*. https://www.cabdirect.org/cabdirect/abstract /199 11620843
8. Sayer, J. A., & Whitmore, T. C. (1991). Tropical moist forests: Destruction and species extinction. *Biological Conservation*, *55*(2), 199–213. https://doi.org/10.1016/0006 -3207(91)90056-F
9. Turner, I. M. (1996). Species Loss in Fragments of Tropical Rain Forest: A Review of the Evidence. *Journal of Applied Ecology*, 33(2), 200–209. https://doi.org/10. 2307/2404743
10. Assessment (MEA), M. E. (2005). Ecosystems and Human Well-Being: Wetlands and Water Synthesis. Washington, D.C.: World Resources Institute. https://vtechworks.lib.vt.edu/handle/10919/65899
11. Drake, J. A. (1989). Restoration Ecology: A Synthetic Approach to Ecological Research. William R. Jordan III , Michael E. Gilpin , John D. Aber. *The Quarterly Review of Biology*, 64(4), 517–518. https://doi.org/10.1086/416533
12. UNEP/CBD/COP/8/29. (2014). Report of the twelfth meeting of the conference of the parties to the convention on biological diversity. 293.
13. Heywood, V. H., & Watson, R. T. (1995). Global biodiversity assessment. Vol. 1140. Cambridge University press Cambridge.
14. Kremen, C., Colwell, R. K., Erwin, T. L., Murphy, D. D., Noss, R. F., & Sanjayan, M. A. (1993). Terrestrial Arthropod Assemblages: Their Use in Conservation Planning. *Conservation Biology*, 7(4), 796–808.
15. Lorimer, G. S. (2006). Inventory and Assessment of Indigenous Flora and Fauna in Boroondara 491.
16. Innes, J. L., & Koch, B. (1998). Forest biodiversity and its assessment by remote sensing. *Global Ecology &*

Biogeography Letters, 7(6), 397–419. https://doi.org/10.1046/j.1466-822X.1998.00314.x

17. Franklin, J. F., Cromack, K. J., Denison, W., McKee, A., Maser, C., Sedell, J., Swanson, F., & Juday, G. (1981). Ecological characteristics of old-growth Douglas-fir forests. Gen. Tech. Rep. PNW-GTR-118. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station. 48 p, 118. https://doi.org/10.2737/PNW-GTR-118

18. Noss, R. F. (1990). Indicators for Monitoring Biodiversity: A Hierarchical Approach. *Conservation Biology*, 4(4), 355–364.

19. Vermeulen, S., & Koziell, I. (2002). Integrating Global and Local Values: A Review of Biodiversity Assessment. IIED.

20. Gabel, V., Home, R., Stöckli, S., Meier, M., Stolze, M., & Köpke, U. (2018). Evaluating On-Farm Biodiversity: A Comparison of Assessment Methods. *Sustainability*, 10(12), 4812. https://doi.org/10.3390/su10124812

21. McIntosh, R. P. (1967). An Index of Diversity and the Relation of Certain Concepts to Diversity. *Ecology*, 48(3), 392–404. https://doi.org/10.2307/1932674

22. Tuomisto, H. (2010). A consistent terminology for quantifying species diversity? Yes, it does exist. *Oecologia*, *164*(4), 853–860. https://doi.org/10.1007/s00 442-010-1812-0

23. Sanjit, L., & Bhatt, D. (2005). How relevant are the concepts of species diversity and species richness?. *Journal of Biosciences*, 30(5), 557–560. https://doi.org/10.1007/BF02703552

24. McKinney, M. L. (2008). Effects of urbanization on species richness: A review of plants and animals. *Urban Ecosystems*, 11(2), 161–176. https://doi.org/10.1007/s11252-007-0045-4

25. Tilman, D., & Pacala, S. (1993). The maintenance of species richness in plant communities. *Unknown Journal*, 13–25.

26. Waide, R. B., Willig, M. R., Steiner, C. F., Mittelbach, G., Gough, L., Dodson, S. I., Juday, G. P., & Parmenter, R. (1999). The Relationship Between Productivity and Species Richness. *Annual Review of Ecology and Systematics*, 30(1), 257–300. https://doi.org/10.1146/annurev.ecolsys.30.1.257

27. Acharya, K. P. (2003). Conserving biodiversity and improving livelihoods: The case of community forestry in Nepal. 22.

28. Lawbuary, J. (1999). Reclaiming the Forests? People’s Participation in Forest Management, East India. https://www.ganesha.co.uk/JoPubWeb/Frontdiss.htm

29. Padma, T. V. (2007). Community forestry: The regreening of the Himalayas. SciDev.Net. http://www.scidev.net/index.cfm?originalUrl=/global/livestock/feature/community-forestry-the-regreening-of-the-himalaya.html&

30. Thani, P. R., Kc, R., Sharma, B. K., Kandel, P., & Nepal, K. (2019). Integrating biodiversity conservation and ecosystem services into operational plan of community forest in Nepal: Status and gaps. *Banko Janakari*, 29(1), 3–11.

31. NHMRCC. (2015). Draft Report: Study of Climate and Climatic Variation over Nepal. 41.

32. Stainton, J. D. A. (1972). Forests of Nepal. First Edition. J. Murray.

33. Redford, K. H., & Padoch, C. (Eds.) (1992). Conservation of Neotropical Forests: Working from Traditional Resource Use. p. 475 Pages. Columbia University Press.

34. Johnson-Gottesfeld, L. M., & Hargus, S. (1998). Classification and nomenclature in witsuwit’en ethnobotany: a preliminary examination. 33. Johnson-Gottesfeld, L. M., & Hargus, S. (1998). Classification and nomenclature in Witsuwit'en ethnobotany: a preliminary examination. Journal of Ethnobiology, 18, 69-101.

35. Gaston, K. J., & May, R. M. (1992). Taxonomy of taxonomists. *Nature*, 356(6367), 281–282. https://doi.org/10.1038/356281a0

36. Arances, J. B., Amoroso, V. B., Gruezo, W. S., Ridsdale, C., Visser, L., Tan, B. C., Rufila, L. V., Galvezo, J. B., Opiso, G. S., Comilap, R., Lumaray, C., Comilap, C., Pacut, N., Montimar, B., & Sacal, S. (2004). Development of a participatory methodology for inventory and assessment of floral resources and their characterization in the Montane Forests of Mt. Malindang [Philippines]. https://agris.fao.org/agris-search/search.do?record ID=PH2004001437

37. Jinxiu, W., Hongmao, L., Huabin, H., & Lei, G. (2004). Participatory Approach for Rapid Assessment of Plant Diversity through a Folk Classification System in a Tropical Rainforest: Case Study in Xishuangbanna, China. *Conservation Biology*, 18(4), 1139–1142. https://doi.org/10.1111/j.1523-1739.2004.00075.x

38. Puth, M.-T., Neuhäuser, M., & Ruxton, G. D. (2014). Effective use of Pearson’s product–moment correlation coefficient. *Animal Behaviour*, 93, 183–189. https://doi.org/10.1016/j.anbehav.2014.05.003

39. Benesty, J., Chen, J., Huang, Y., & Cohen, I. (2009). Pearson Correlation Coefficient. In I. Cohen, Y. Huang, J. Chen, & J. Benesty (Eds.), *Noise Reduction in Speech Processing* (pp. 1–4). Springer. https://doi.org/10.1007/978-3-642-00296-0_5

40. Oertli, B., Joye, D. A., Castella, E., Juge, R., Cambin, D., & Lachavanne, J.B. (2002). Does size matter? The relationship between pond area and biodiversity. *Biological*

Conservation, 104(1), 59–70. https://doi.org/10.1016/S0006-3207(01)00154-9

41. Panitsa, M., Trigas, P., Iatrou, G., & Sfenthourakis, S. (2010). Factors affecting plant species richness and endemism on land-bridge islands – An example from the East Aegean archipelago. *Acta Oecologica*, 36(4), 431–437. https://doi.org/10.1016/j.actao.2010.04.004

42. Kagiampaki, A., Triantis, K., Vardinoyannis, K., & Mylonas, M. (2011). Factors affecting plant species richness and endemism in the South Aegean (Greece). *Journal of Biological Research*, 16, 282–295.

43. Deshaye, J., & Morisset, P. (1988). Floristic Richness, Area, and Habitat Diversity in a Hemiarctic Archipelago. *Journal of Biogeography*, 15(5/6), 747–757. https://doi.org/10.2307/2845337.

44. MacArthur, R. H., & Wilson, E. O. (2016). The theory of island biogeography. Princeton university press.

45. Haslett, J. R. (1997). Insect Communities and the Spatial Complexity of Mountain Habitats. *Global Ecology and Biogeography Letters*, *6*(1), 49–56. https://doi.org/10.2307/2997526

46. Brose, U. (2003). Regional diversity of temporary wetland carabid beetle communities: A matter of landscape features or cultivation intensity?. *Agriculture, Ecosystems & Environment*, 98(1), 163–167. https://doi.org/10.1016/S0167-8809(03)00078-1

47. Halaj, J., Ross, D. W., & Moldenke, A. R. (2000). Importance of habitat structure to the arthropod food-web in Douglas-fir canopies. *Oikos*, 90(1), 139–152. https://doi.org/10.1034/j.1600-0706.2000.900114.x

48. Greenstone, M. H. (1984). Determinants of web spider species diversity: Vegetation structural diversity vs. prey availability. *Oecologia*, 62(3), 299–304. https://doi.org/10.1007/BF00384260

49. Romero-Alcaraz, E., & Ávila, J. M. (2000). Landscape heterogeneity in relation to variations in epigaeic beetle diversity of a Mediterranean ecosystem. Implications for conservation. *Biodiversity & Conservation*, 9(7), 985–1005. https://doi.org/10.1023/A:1008958720008

50. Tanabe, S.-I., Toda, M. J., & Vinokurova, A. V. (2001). Tree shape, forest structure and diversity of drosophilid community: Comparison between boreal and temperate birch forests. *Ecological Research*, 16(3), 369–385. https://doi.org/10.1046/j.1440-1703.2001.00402.x

51. Wiens, J. A., & Rotenberry, J. T. (1981). Habitat Associations and Community Structure of Birds in Shrubsteppe Environments. *Ecological Monographs*, 51(1), 21–42. https://doi.org/10.2307/2937305

52. Thiollay, J. M. (1990). Comparative diversity of temperate and tropical forest bird communities: the influence of habitat heterogeneity. *Acta Oecologica*, 11(6), 887–911.

53. Poulsen, B. O. (2002). Avian richness and abundance in temperate Danish forests: Tree variables important to birds and their conservation. *Biodiversity & Conservation*, *11*(9), 1551–1566. https://doi.org/10.1023/A:10168395181 72.

54. Southwell, C. J., Cairns, S. C., Pople, A. R., & Delaney, R. (1999). Gradient analysis of macropod distribution in open forest and woodland of eastern Australia. *Australian Journal of Ecology*, 24(2), 132–143. https://doi.org/10.1046/j.1442-9993.1999.241954.x

55. Williams, S. E., Marsh, H., & Winter, J. (2002). Spatial Scale, Species Diversity, and Habitat Structure: Small Mammals in Australian Tropical Rain Forest. *Ecology*, *83*(5), 1317–1329. https://doi.org/10.1890/0012-9658(2002)083[1317:SSSDAH]2.0.CO;2

56. Atauri, J. A., & de Lucio, J. V. (2001). The role of landscape structure in species richness distribution of birds, amphibians, reptiles and lepidopterans in Mediterranean landscapes. *Landscape Ecology*, 16(2), 147–159. https://doi.org/10.1023/A:1011115921050

57. Pianka, E. R. (1967). On Lizard Species Diversity: North American Flatland Deserts. *Ecology*, *48*(3), 333–351. https://doi.org/10.2307/1932670

58. Sullivan, T. P., & Sullivan, D. S. (2001). Influence of variable retention harvests on forest ecosystems. II. Diversity and population dynamics of small mammals. *Journal of Applied Ecology*, 38(6), 1234–1252. https://doi.org/10.1046/j.0021-8901.2001.00674.x

59. Ralph, C. J. (1985). Habitat Association Patterns of Forest and Steppe Birds of Northern Patagonia, Argentina. *The Condor*, 87(4), 471–483. https://doi.org/10.2307/1367943

60. Hill, J. K., Hamer, K. C., Lace, L. A., & Banham, W. M. T. (1995). Effects of Selective Logging on Tropical Forest Butterflies on Buru, Indonesia. *Journal of Applied Ecology*, 32(4), 754–760. https://doi.org/10.2307/2404815

61. Rohde, K. (1992). Latitudinal Gradients in Species Diversity: The Search for the Primary Cause. *Oikos*, 65(3), 514–527. https://doi.org/10.2307/3545569

62. Bhattarai, K. R., & Vetaas, O. R. (2003). Variation in plant species richness of different life forms along a subtropical elevation gradient in the Himalayas, east Nepal. *Global Ecology and Biogeography*, 12(4), 327–340. https://doi.org/10.1046/j.1466-822X.2003.00044.x

63. Turner, J. R. G., Gatehouse, C. M., & Corey, C. A. (1987). Does Solar Energy Control Organic Diversity? Butterflies, Moths and the British Climate. *Oikos*, 48(2), 195–205. https://doi.org/10.2307/3565855

64. Grytnes, J. A., Birks, H. J. B., & Peglar, S. M. (1999). Plant species richness in Fennoscandia: Evaluating the relative importance of climate and history. *Nordic Journal of Botany*, 19(4), 489–503. https://doi.org/10.1111/j.1756-1051.1999.tb01233.x

65. O'Brien, Eileen M. (1993). Climatic Gradients in Woody Plant Species Richness: Towards an Explanation Based on an Analysis of Southern Africa's Woody Flora. *Journal of Biogeography*, 20(2), 181–198. https://doi.org/10.2307/2845670

66. Maraun, M., Salamon, J.-A., Schneider, K., Schaefer, M., & Scheu, S. (2003). Oribatid mite and collembolan diversity, density and community structure in a moder beech forest (Fagus sylvatica): Effects of mechanical perturbations. *Soil Biology and Biochemistry*, 35(10), 1387–1394. https://doi.org/10.1016/S0038-0717(03)00218-9

67. Padhan, D., Kundu, R., Sen, A., Yadav, V., & Adhikary, S. (2019). Current Research in Soil Fertility. pp. 37–59. AkiNik Publications. https://doi.org/10.22271/ed.book.437

68. Vanbergen, A. J., Watt, A. D., Mitchell, R., Truscott, A.-M., Palmer, S. C. F., Ivits, E., Eggleton, P., Jones, T. H., & Sousa, J. P. (2007). Scale-specific correlations between habitat heterogeneity and soil fauna diversity along a landscape structure gradient. *Oecologia*, 153(3), 713–725. https://doi.org/10.1007/s00442-007-0766-3

69. Peak, R. G., & Thompson, F. R. (2006). Factors Affecting Avian Species Richness and Density in Riparian Areas. *The Journal of Wildlife Management*, 70(1), 173–179. https://doi.org/10.2193/0022-541X(2006)70[173:FAASRA]2.0.CO;2

70. Wardlaw, T. J., Grove, S. J., Hingston, A. B., Balmer, J. M., Forster, L. G., Musk, R. A., & Read, S. M. (2018). Responses of flora and fauna in wet eucalypt production forest to the intensity of disturbance in the surrounding landscape. *Forest Ecology and Management*, 409, 694–706. https://doi.org/10.1016/j.foreco.2017.11.060

71. Tews, J., Brose, U., Grimm, V., Tielbörger, K., Wichmann, M. C., Schwager, M., & Jeltsch, F. (2004). Animal species diversity driven by habitat heterogeneity/diversity: The importance of keystone structures. *Journal of Biogeography*, 31(1), 79–92. https://doi.org/10.1046/j.0305-0270.2003.00994.x

72. Hunter, M. D. (1990). Differential susceptibility to variable plant phenology and its role in competition between two insect herbivores on oak. *Ecological Entomology*, 15(4), 401–408. https://doi.org/10.1111/j. 1365-2311.1990.tb00823.x

73. Alexander, G., & Hilliard, J. R. (1969). Altitudinal and Seasonal Distribution of Orthoptera in the Rocky Mountains of Northern Colorado. *Ecological Monographs*, 39(4), 385–432. https://doi.org/10.2307/ 1942354.

74. Hamilton, A. C. (1975). A quantitative analysis of altitudinal zonation in Uganda forests. *Vegetatio*, 30(2), 99–106. https://doi.org/10.1007/BF02389611

75. Wolda, H. (1987). Altitude, habitat and tropical insect diversity. *Biological Journal of the Linnean Society*, 30(4), 313–323. https://doi.org/10.1111/j.1095-8312.1987. tb00305.x

76. Gentry, A. H. (1988). Changes in Plant Community Diversity and Floristic Composition on Environmental and Geographical Gradients. *Annals of the Missouri Botanical Garden*, 75(1), 1–34. https://doi.org/10.2307/2399464

77. Navarro S, A. G. (1992). Altitudinal distribution of birds in the Sierra Madre del Sur, Guerrero, Mexico. *The Condor*, 94(1), 29-39. https://doi.org/10.2307/1368793

78. Austrheim, G. (2002). Plant diversity patterns in semi-natural grasslands along an elevational gradient in southern Norway. *Plant Ecology*, 161(2), 193–205. https://doi.org/10.1023/A:1020315718720

79. G., J. A. V., & Givnish, T. J. (1998). Altitudinal Gradients in Tropical Forest Composition, Structure, and Diversity in the Sierra de Manantlan. *Journal of Ecology*, 86(6), 999–1020.

80. Fleishman, E., Austin, G. T., & Weiss, A. D. (1998). An Empirical Test of Rapoport's Rule: Elevational Gradients in Montane Butterfly Communities. *Ecology*, 79(7), 2482–2493. https://doi.org/10.1890/0012-9658(1998)079[2482:AETORS]2.0.CO;2

81. Grytnes, J. A., & Vetaas, O. R. (2002). Species Richness and Altitude: A Comparison between Null Models and Interpolated Plant Species Richness along the Himalayan Altitudinal Gradient, Nepal. *The American Naturalist*, 159(3), 294–304. https://doi.org/10.1086/338542

82. Odland, A., & Birks, H. J. B. (1999). The altitudinal gradient of vascular plant richness in Aurland, western Norway. *Ecography*, 22(5), 548–566. https://doi.org/10.1111/j.1600-0587.1999.tb01285.x

83. Lomolino, M. V. (2001). Elevation gradients of species-density: Historical and prospective views. *Global Ecology and Biogeography*, 10(1), 3–13. https://doi.org/10.1046/j.1466-822x.2001.00229.x

84. Whittaker, R. J., Willis, K. J., & Field, R. (2001). Scale and species richness: Towards a general, hierarchical theory of species diversity. *Journal of Biogeography*, 28(4), 453–470. https://doi.org/10.1046/j.1365-2699.2001.00563.x

85. Brown, J. H. (2001). Mammals on mountainsides: Elevational patterns of diversity. *Global Ecology and Biogeography*, 10(1), 101–109. https://doi.org/10.1046/j.1466-822x.2001.00228.x

86. Colwell, R. K., & Hurtt, G. C. (1994). Nonbiological Gradients in Species Richness and a Spurious Rapoport Effect. *The American Naturalist*, 144(4), 570–595. https://doi.org/10.1086/285695

87. Rahbek, C. (1997). The Relationship among Area, Elevation, and Regional Species Richness in Neotropical

Birds. *The American Naturalist*, 149(5), 875–902. https://doi.org/10.1086/286028

88. Rahbek, C. (1995). The elevational gradient of species richness: A uniform pattern?. *Ecography*, 18(2), 200–205. https://doi.org/10.1111/j.1600-0587.1995.tb00341.x

89. Stevens, G. C. (1992). The Elevational Gradient in Altitudinal Range: An Extension of Rapoport's Latitudinal Rule to Altitude. *The American Naturalist*, 140(6), 893–911. https://doi.org/10.1086/285447

90. Patterson, B. D., Stotz, D. F., Solari, S., Fitzpatrick, J. W., & Pacheco, V. (1998). Contrasting patterns of elevational zonation for birds and mammals in the Andes of southeastern Peru. *Journal of Biogeography*, 25(3), 593–607. https://doi.org/10.1046/j.1365-2699.1998.2530593.x

91. Chettri, B., Bhupathy, S., & Acharya, B. K. (2010). Distribution pattern of reptiles along an eastern Himalayan elevation gradient, India. *Acta Oecologica*, 36(1), 16–22. https://doi.org/10.1016/j.actao.2009.09.004

92. O'Brien, E. M., Whittaker, R. J., & Field, R. (1998). Climate and woody plant diversity in southern Africa: Relationships at species, genus and family levels. *Ecography*, 21(5), 495–509. https://doi.org/10.1111/j.1600-0587.1998.tb00441.x

93. Zobel, M. (1997). The relative of species pools in determining plant species richness: An alternative explanation of species coexistence?. *Trends in Ecology & Evolution*, 12(7), 266–269. https://doi.org/10.1016/S0169-5347(97)01096-3

94. Eriksson, O. (1993). The Species-Pool Hypothesis and Plant Community Diversity. *Oikos*, 68(2), 371–374. https://doi.org/10.2307/3544854