

Floristic Diversity of Vascular Plants in Annapurna Conservation Area (ACA), Gandaki Province, Nepal

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Abstract

The Annapurna Conservation Area (ACA) is the first and largest conservation area in Nepal and one of the richest protected areas of Nepal in terms of biodiversity. But the richness of the floristic diversity in ACA is not well documented. The present study was done through a review of the published and authentic works of literatures such as journals, books, reports to explore the diversity of vascular plants in the entire ACA. This study documented a total of 1,739 species of vascular plants belonging to 771 genera and 154 families, comprising 118 species of fern and fern allies, 16 species of Gymnosperms and 1,605 species of Angiosperms respectively. Asteraceae with 56 genera and 149 species was found to be the largest family, followed by Poaceae (61 genera, 91 species), Fabaceae (42 genera, 83 species), Rosaceae (23 genera, 82 species), Orchidaceae (43 genera, 81 species), Ranunculaceae (11 genera, 73 species) and Lamiceae (29 genera, 58 species) respectively. Similarly, *Saxifraga* was found to be the largest genera with 28 species followed by *Primula* (26 species), *Potentilla* (19 species), *Pedicularis* (18 species), *Saussurea* and *Gentiana* (17 species each) and *Berberis* (16 species) respectively. In terms of growth form (habits) of the species found in ACA, trees (11% species), shrubs (14% species), herbs (69% species) and climbers (6% species) respectively. Total 102 species of Angiosperms were found to be the Endemic to Nepal from ACA. The rich diversity of vascular plants reflects that ACA is the central point for wide range of compositions of eastern and western Himalayan floristic components.

Keywords: Conservation, Diversity, Endemic plant, Protected area, Vascular plant

Introduction

Biodiversity is the variety of different forms of life on earth, including the different plants, animals, micro-organisms (Rawat & Agarwal, 2015). More broadly, biological diversity is the diversity of life at three levels, i.e. variability in genes (within species), diversity of different taxa among living organisms (within genera and so on) and the variety of ecosystems including communities and ecological complexes of which they are part of biome (Chaudhary et al., 2016). The Himalayan regions are supposed to be the hotspot of biodiversity in terms of diverse vegetation community and floral diversity (Chalise et al., 2019; Khakurel et al., 2020). The biodiversity is very significant for survival of all kinds of living beings. However, it conveys us the various ecosystem services and goods. Thus, it is compulsory to conserve the biodiversity in all level. Conservation and sustainability of biodiversity can be obtained only with proper documentation of scientific knowledge of vegetation of the area.

Extensive scientific excursion and exploration are the major tools to document the biodiversity. Nepal has an extensively diverse ecology, flora and fauna with respect to its unique geographic position and variation in altitude and climate. It is home to 5,820 species of angiosperms (Shrestha et al., 2022). It ranks 10th in terms of the richest flowering plant diversity in Asia, and 31st in the world (Bhujju et al., 2007).

The floristic study refers to the documentation of all plant species in a given geographical region (Simpson, 2006). Such studies are empirical to update existing plant species of the particular locality through field exploration, adding herbarium specimens and their nomenclature in the database. Particularly, floristic studies comprises the list of species, their life form, their geographical distribution and identification of threatened species for assessing ecological components such as biodiversity, growth capacity, conservation and regulation (Ali et al., 2018). The floristic study results in the form of floras, which

may be at local, regional or national level. The previous floristic studies of ACA have reflected total 1,345 species of vascular plants. Among them 1,258 species were Angiosperms (1,057 spp. Dicots & 201 spp. Monocots), 15 spp. were Gymnosperms and 72 species were Pteridophytes (KMTNC-ACAP, 1994; NTNC-CODEFUND, 2016).

Due to impact of various factors such as habitat degradation, natural and human induced diseases, and biological invasion, climatic factors, natural disaster and illegal poaching many species are vanishing and many have already been disappeared from the earth. IUCN keep records of the status of species that needs conservation attention in IUCN's Red list threatened species and it becomes global comprehensive information centre for threatened species (IUCN Red List, 2022). However, the trade in wild animals and plants crosses borders between countries; the effort to regulate it requires international cooperation to safeguard certain species from over-exploitation. Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES) was conceived in the spirit of such cooperation. CITES has been categorized such over exploited species into 3 groups viz: Appendix I, Appendix II and Appendix III (CITES, 2022). Based on global treaties, national requirement and conservation of threatened species, government of Nepal has promulgated many policy documents, such as different acts, regulations and directives, which have been implementing to conserve such species in national and regional level.

The endemic flowering plants of ACA are those plants whose distributions are confined to ACA and are said to be endemic species of Nepal too. If the distribution of such species is found outside of that particular region of the nation, they are not recognized as endemic species for the region or nation. The typical geographical and climatic factors, such as high mountains and islands play the vital role to develop endemic plants (Tiwari et al., 2019). Endemic plants are very significant and highly prioritized because of their limited distribution. If they are lost from that particular area, they will be

lost for forever from the world (Rajbhandari et al., 2021). Therefore, paramount importance has to be given to the conservation of these plants. The recent updated list of endemic flowering plants of Nepal revealed 293 species belonging to 129 genera and 45 families (Rajbhandari et al., 2021).

The aim of this study was to explore the updated floristic diversity of the vascular plant in ACA and to identify the endemic species in ACA too. However, these findings will further support to conserve the floral diversity in ACA.

Materials and Methods

Study area

The study was conducted in entire Annapurna Conservation Area (ACA), the first conservation area of Nepal. ACA is the largest protected areas of Nepal, covering 7,629 km (Baral, 2018). It lies between 83°34' to 84°25' E longitude and 28°15' to 28°50' N latitude in Gandaki Province, in central Nepal (Figure 1). It is bordered to the east by Marsyangdi Valley, to the west by Kali Gandaki River, to the north by dry alpine desert of Dolpa district and Tibet (China) and to the south by the valley and foothills of Pokhara. ACA extends over five administrative districts of Nepal, namely Kaski, Myagdi, Lamjung, Manang and Mustang. Kaski, Myagdi, Lamjung are partly covered, Manang is mostly and Mustang is completely covered by ACA. Within the altitudinal range between 790 m asl (Madi Valley) to 8,091 m asl (Annapurna I) (KMTNC-ACAP, 1994), ACA has an entire habitat gradient from sub-tropical Sal forest to nival (perennial snow). The annual mean temperature of ACA is 14°C with maximum and minimum temperature 35°C & -30°C respectively. Southern Annapurna region has the highest precipitation rate in the country while northern Annapurna receives 25 mm to 500 mm of precipitation annually. Microclimate vary with altitude and its various aspect. Annual rainfall ranges between 193 mm to 2,987 mm from the Trans-Himalayan region of Mustang to the Cis-Himalayan region of Ghandruk, Kaski (National Trust for Nature Conservation [NTNC], 2017).

Physiographic, climatic and cultural phenomenon of ACA makes it a wonderful tourism destination for global communities. It is featured with some of the world's highest peaks such as Annapurna-I (8,091 m, 10th highest peak in the world), Annapurna-II (7,993 m), Annapurna-III (7,555 m), Annapurna-IV (7,525 m) and Fish Tail (6,993 m) etc. The world's deepest gorge the Kali Gandaki River Valley, the pristine glacial lake located at the world's highest elevation the Tilicho (4,919 m) and Damodar Kunda located at an elevation of 4,890 m are positioned in the ACA. Both Tilicho and Damodar Kunda are the major high altitude lakes in ACA and are much popular among pilgrims and researchers. Kali Gandaki, Marsyangdi and Modi are the foremost rivers that drain the ACA. 10 ethnic groups belonging to Tibeto-Burmese and Indo-Aryan dwell in the area. The cave architecture of Muktinath valley in Mustang and medieval earthen walled city of Lomanthang are most magnificent and spectacular components of ACA. There are many

antique monasteries (Thupchen and Chhyoede Gumba at Lomanthang, Tare Gumba at Khangshar and Tashi Lakang Gumba at Phoo in Manang) and holy temple Muktinath in Mustang, which also are the most significant religious and cultural heritage site of ACA. The world's largest *Rhododendron* forest lies in the Ghorepani (Baral, 2018; Gewali, 2013). ACA has 29 ecosystems and 22 forest types, which are the habitats for 128 Mammals, 519 birds, 41 Reptiles, 23 Amphibians, 20 Pisces and 358 butterflies. Annually more than 150,000 visitors visit the ACA (NTNC-ACAP, 2021).

Sources of data

This study was accomplished with the help of secondary information collected from the various validly published literatures. Books (Baral, 2018; Chapagain & Chetri, 2006; Chhetri et al., 2006; Press et al., 2000), reports (Chapagain & Chetri, 2006; KMTNC-ACAP, 1994; Maden et al., 2019; NTNC, 2017; NTNC-ACAP, 2021; NTNC-CODEFUND, 2016), scientific publications (Chalise et al., 2019; Chapagain & Chhetri, 2006; Khakurel et al., 2020; Rajbhandari et al., 2016, 2021; Shrestha & Rajbhandary, 2019; Tiwari et al., 2019) and online database: <http://www.plantdatabase.gov.np> (KATH, 2022) were used to gather floristic information. The valid and updated botanical names were confirmed from online sources Plants of World Online (<https://powo.science.kew.org>) and World Flora Online (<https://www.worldfloraonline.org>).

Results and Discussion

Floristic diversity of vascular plants in ACA

This study revealed that 1,739 species of vascular plant species belonging to 771 genera and 154 families. Among them, Dicotyledons were the biggest taxonomic group that comprised 1,306 species belonging to 556 genera and 111 families while Gymnosperms were the smallest taxonomic group that encompassed only 16 species belonging to 9 genera and 5 families. The detail has shown in Figure 2.

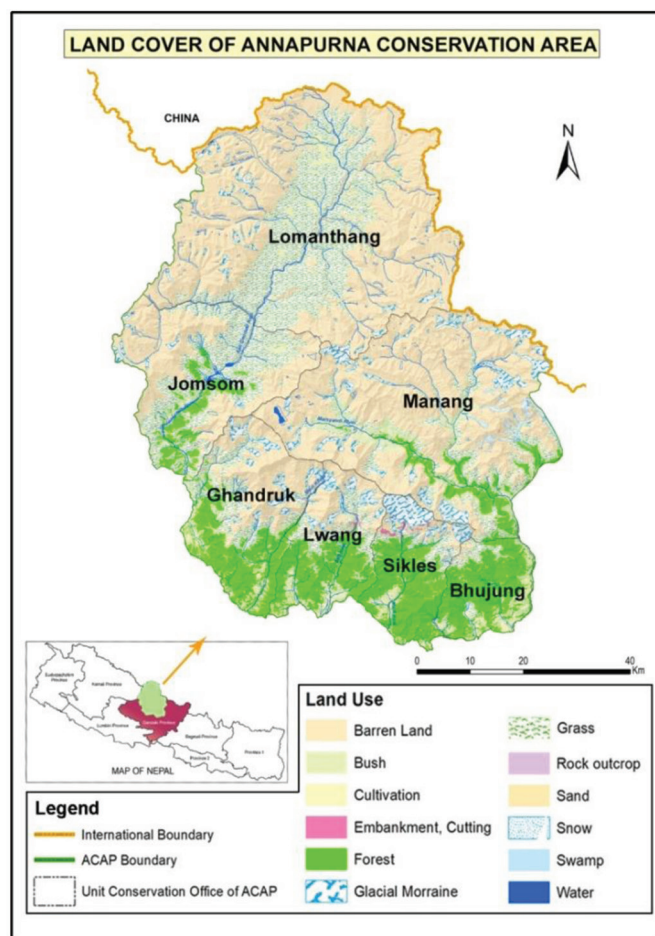


Figure 1: Map of study area

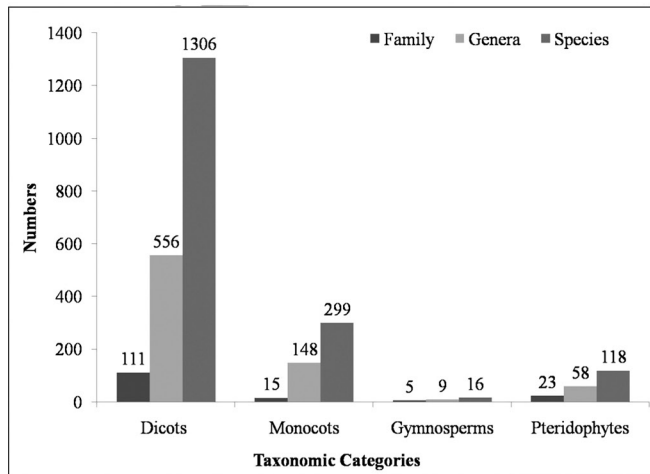


Figure 2: Numbers of species, genera and family based on taxa

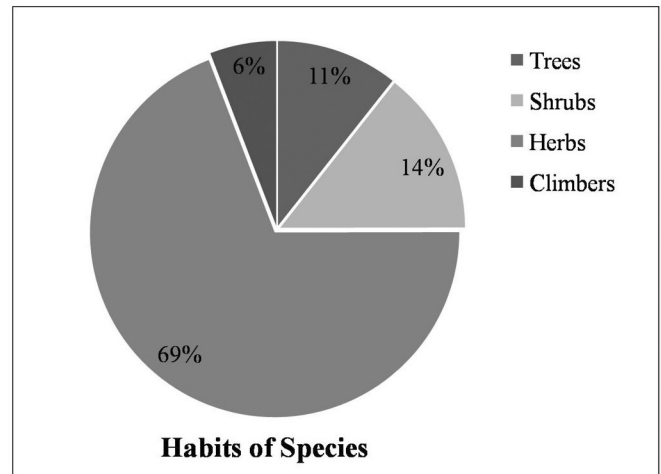


Figure 3: Habit of species in percentage

Habits of vascular plants of ACA

Based on plant’s growth and its development, four major life forms (habits) were considered in this study. Among these four forms, 11% species were trees, 14% species were shrubs, 69% species were herbs and 6% were climbers. The details are shown in Figure 3.

Dominant families of the vascular plants in the ACA

Among the 154 families, 15 families were observed dominant; Asteraceae was found to be the most

dominant family with 56 genera and 149 species, followed by Poaceae with 61 genera and 91 species, and rest of the families with genera and species number as shown in Figure 4.

Dominant families in different taxonomic group

The comparative study of dominant families among four taxonomic groups was also carried out. Asteraceae with 56 genera and 149 species was found to be the most dominant families in Dicots, whereas by Poaceae with 61 genera, and 91 species

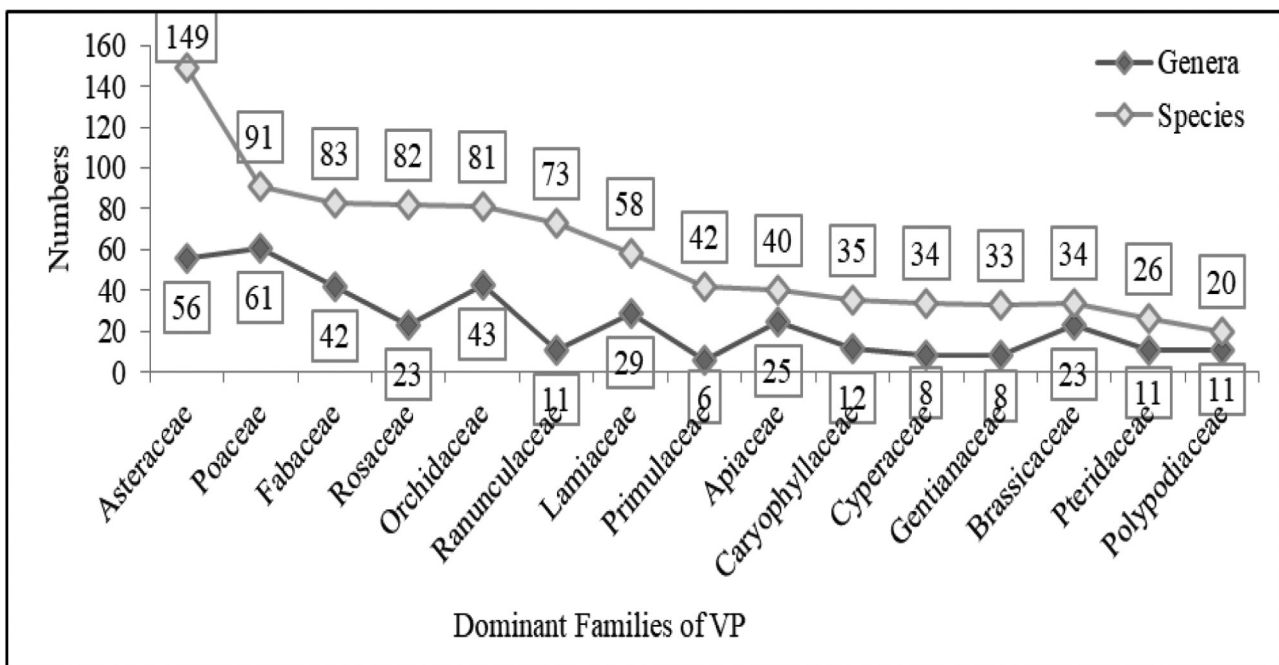


Figure 4: Dominant families of the vascular plant in the study area

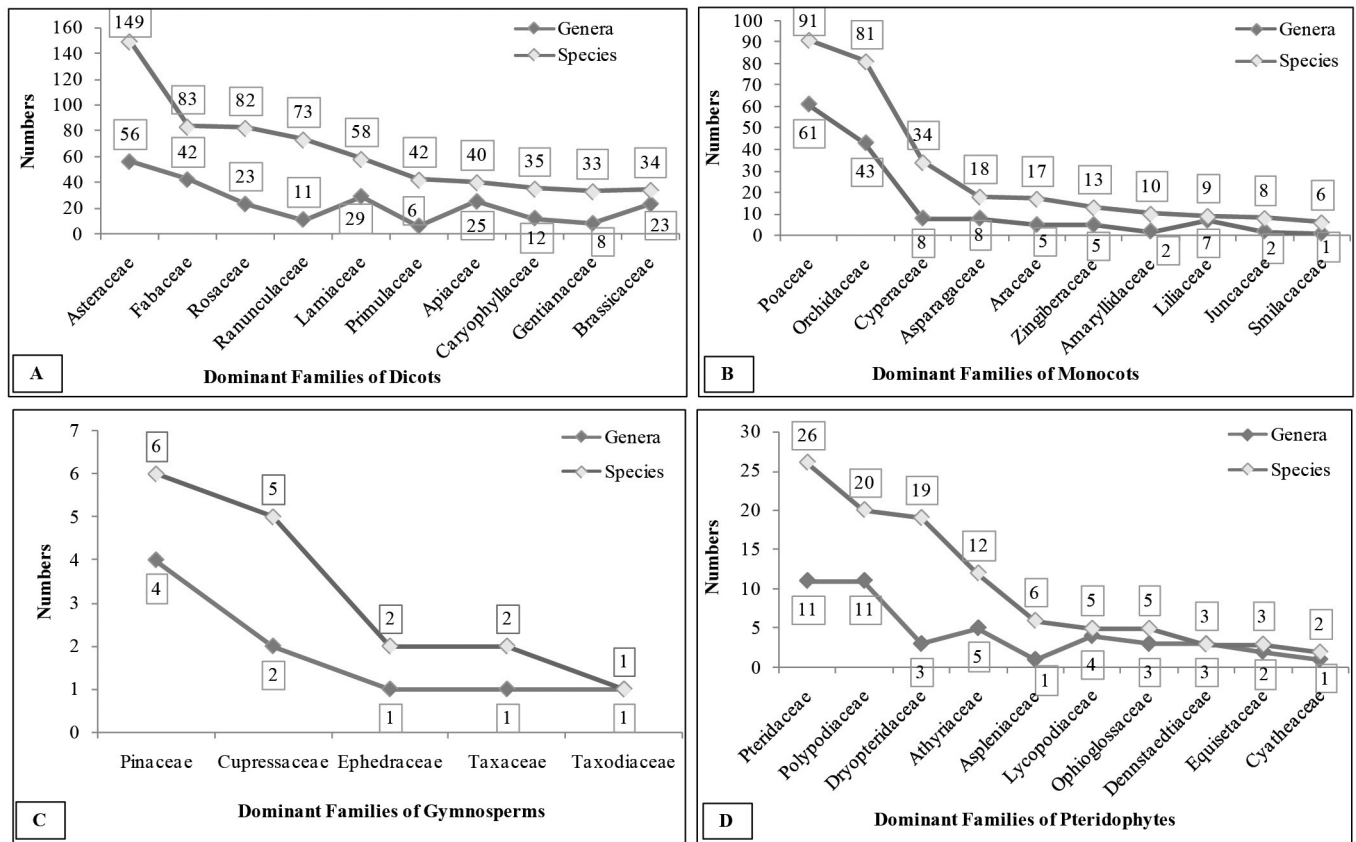


Figure 5: Comparative study of families in, A. dicots, B. monocots, C. gymnosperms, D. pteridophytes

in Monocots, Pinaceae with 4 genera and 6 species was the most dominant in Gymnosperms, and Pteridaceae with 11 genera and 26 species was the most dominant families in Pteridophytes (Figure 5).

Dominant genera of vascular plants of ACA

Regarding the dominant genera among 771 genera of vascular plants of ACA, *Saxifraga* with 28 species was found to be the largest genera, followed by *Primula* with 26 species. Figure 6

shows the summary of species rich genera from the study area.

Comparative study of dominant genera in four taxonomic group

Comparison of dominant genera in each taxonomic group showed *Saxifraga*, *Carex*, *Juniperus* and *Polystichum* as the dominant genera in dicots, monocots, gymnosperms and pteridophytes respectively (Figure 7).

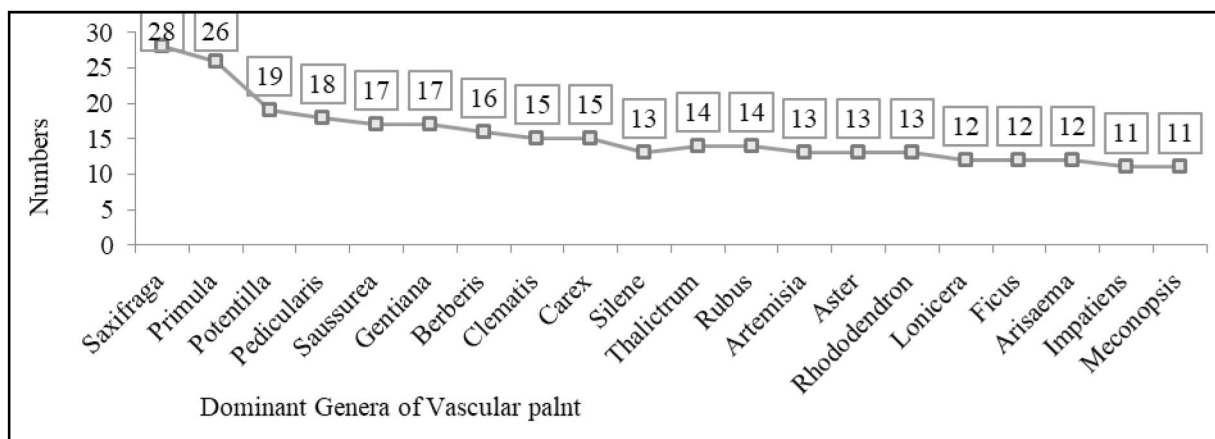


Figure 6: Dominant genera of vascular plants in ACA

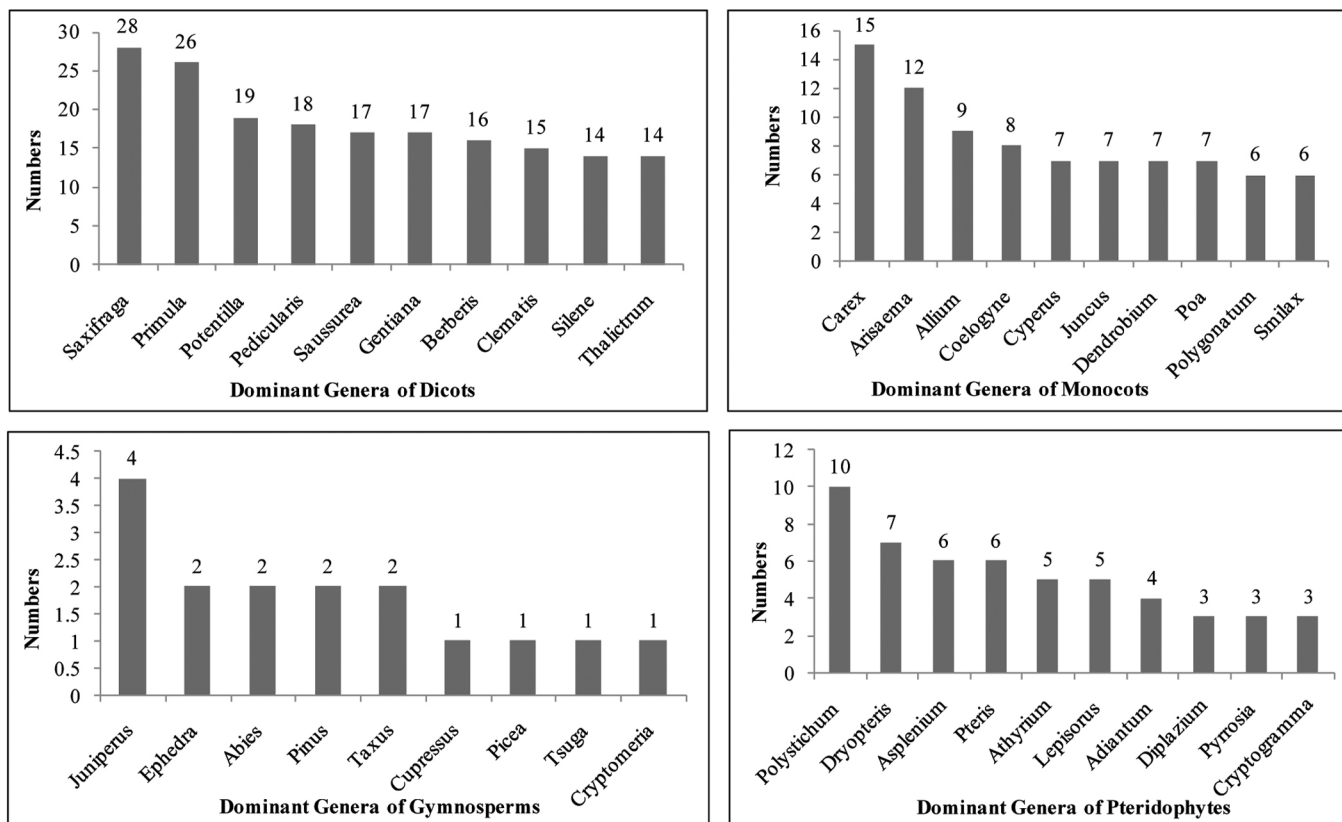


Figure 7: Comparative study of dominant genera of four taxonomic group

Conservation significance

Conservation significance determines the presence, absence and disappearance condition of the species in the nature, which was influenced by various natural and anthropogenic factors. Here, conservation significance of the species has been assessed in two states, i.e. global and national level. IUCN Red List of Threatened Species and CITES were considered as global, while the Government of Nepal’s protection categories of species was considered as national level. Conservation significance of the present study was assessed as follows:

Numbers and habits of protected species:

Altogether 152 species of vascular plants belonging to 97 genera and 32 families were marked in list of conservation significance. Among them, 33 species belonging to 27 genera and 19 families were recognized as dicots, while 100 species belonging to 58 genera and 6 families were assessed as monocots. Similarly, 14 species belonging to 8 genera and 4 families were assessed as gymnosperms and 5

species belonging to 4 genera and 3 families were assessed as pteridophytes. Of the 152 species on the protected list, 76 % were herbs, 19 % were trees, 4 % were shrubs and 1 % was climbers (Figure 8).

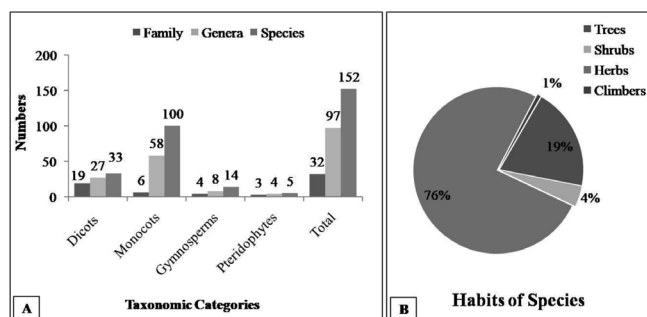


Figure 8: Numbers and habits of protected species in A & B

Significance of protected species in ACA:

This study unveiled that a total 66 species belonging to 53 genera and 33 families were found to be on the global threatened category i.e., IUCN Red List Threatened Species. Among them, 2 species (*Gentiana Kurroo* and *Nardostachys jatamansi*) were critically endangered (CR), 5 species (*Aconitum*

heterophyllum, *Cypripedium elegans*, *Cypripedium himalaicum*, *Taxus contorta* and *Taxus wallichiana*) were endangered (EN), 3 species (*Aconitum violaceum*, *Cypripedium cordigerum* and *Saraca asoca*) were vulnerable (VU), 2 species (*Abies spectabilis* and *Cryptomeria japonica*) were near threatened (NT), 51 species were list concern (LC) and 2 species (*Magnolia doltsopa* and *Magnolia kisopa*) were data deficient (DD). Similarly, 11 species belonging to 9 genera and 9 families were found to be the nationally protected species by Government of Nepal and 93 species belonging to 52 genera and 10 families were found to be globally protected under CITES. Among them 91 species were found in Appendix-II and another single species i.e., *Meconopsis regia* was found in Appendix-III. The details are shown in Figure 9.

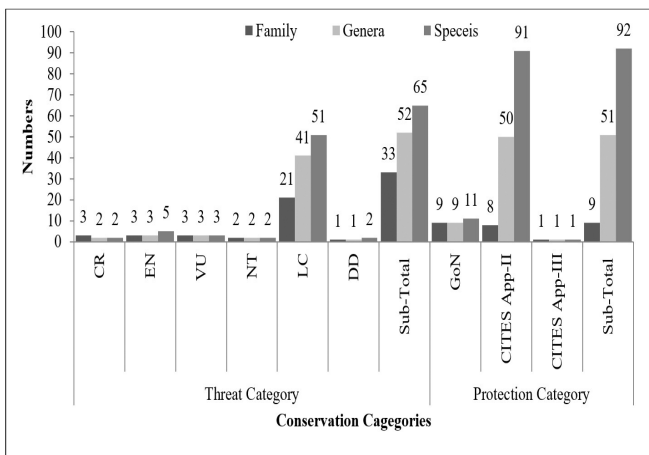


Figure 9: Significance of protected species in ACA

Diversity of endemic flowering plants in ACA

This study showed that there are 102 endemic flowering plant species in ACA belonging to 59 genera and 33 families. Among them, 88 are dicots and 14 are monocots. Out of 102 species, 68 are restricted to ACA while the other 34 species are endemic to Nepal (Figure 10).

Habits of endemic flowering plants in ACA:

Total 87% of species of endemic flowering plants were found to be the herbs, 7% were shrubs, 4% were climbers and 2% were trees respectively (Figure 11).

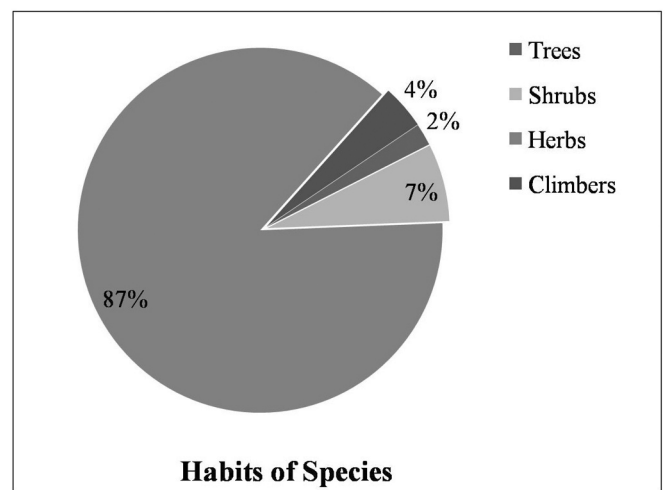


Figure 11: Habit of endemic flowering plants of ACA

Family and genera having more than two species of endemic flowering plants of ACA:

Total 22 dominant families were found to have more than 2 species (Figure 12). Fabaceae was found as the

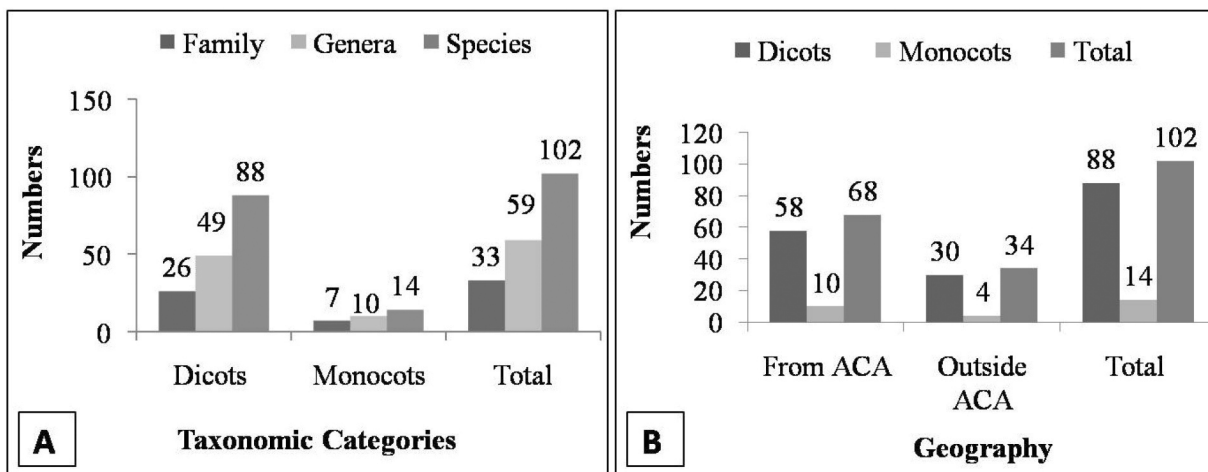


Figure 10: A & B. Diversity of endemic flowering plant in ACA

most dominant family with 3 genera and 10 species, followed by Saxifragaceae with single genus and 10 species and Asteraceae and Apiaceae each with 6 genera and 9 species.

Similarly, there were 22 dominant genera each with more than 2 species (Figure 13). Among them, *Saxifraga* with 10 species was the most dominant genera, followed by *Astragalus* with 5 species, *Silene*, *Oxytropis*, *Primula* each with 4 species, *Sinocarum*, *Saussurea*, *Pedicularis* and *Meconopsis* each with 3 species and so on.

Sinocarum, *Saussurea*, *Pedicularis* and *Meconopsis* each with 3 species and so on.

Comparative study of endemic flowering plants - Nepal vs. ACA: This comparative study showed that ACA comprised 34.81% of endemic species of flowering plant of Nepal; similarly, it encompassed 55.75% of total genera of endemic flowering plants of Nepal and 73.33% of the total family of endemic flowering plants of Nepal (Figure 14).

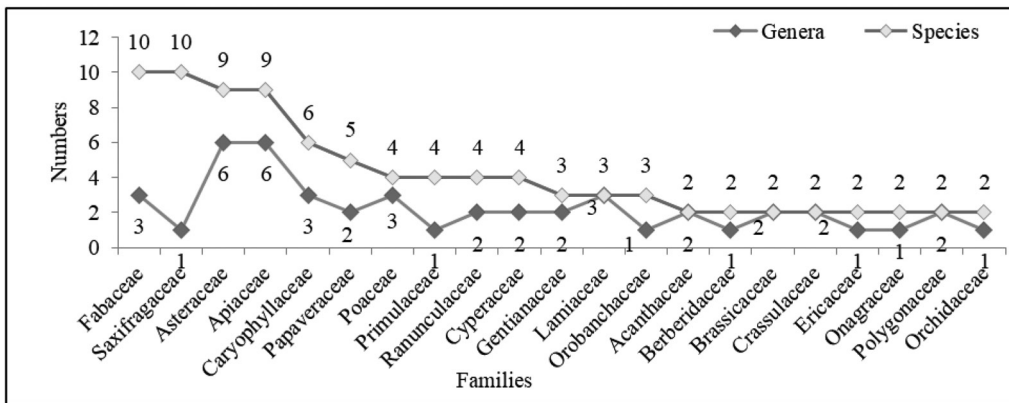


Figure 12: Family having more than two species of endemic flowering plants of ACA

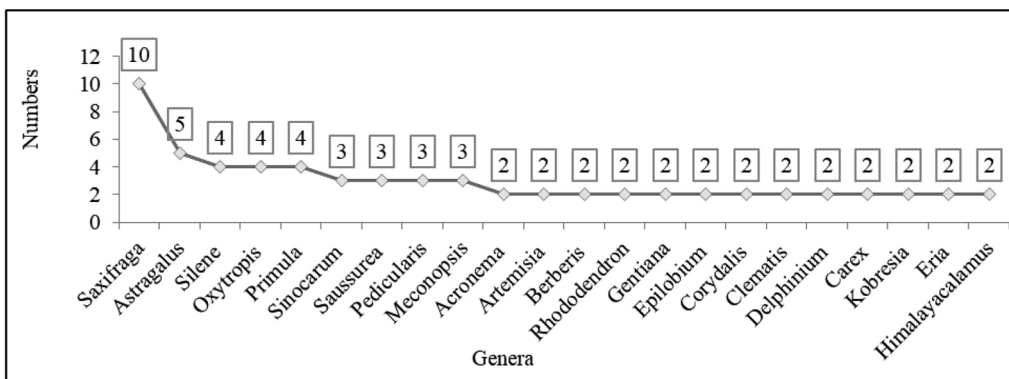


Figure 13: Genera having more than two species of endemic flowering plants of ACA

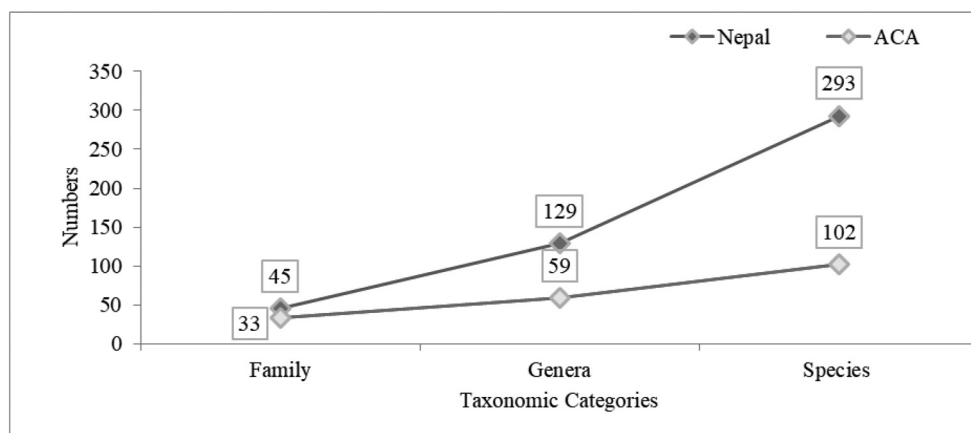


Figure 14: Comparative study of endemic flowering plants in ACA

Conclusion

This study has provided the updated floristic information of the entire Annapurna Conservation Area which is based on three key headings i.e., floristic diversity, conservation significance and endemism. From this study, we could conclude that ACA is the home for 1,739 species belonging to 771 genera and 154 families, similarly in terms of life forms 185 species are trees, 250 species are shrubs, 1,203 species are herbs, and 101 species are climbers. However, the comparative data reflects that ACA abodes 20% of Angiosperms, 62% of Gymnosperms and 22% of Pteridophytes of total species of Nepal (Ministry of Forests and Soil Conservation [MoFSC], 2014).

This study has added 394 species (Dicots: 249, Monocots: 98, Gymnosperms: 1 and Pteridophytes: 46 species respectively) belonging to 246 genera (Dicots: 160, Monocots: 59, Gymnosperms: 1 and Pteridophytes: 26 genera) and 79 families (Dicots: 57, Monocots: 11, Gymnosperms: 1 and Pteridophytes: 10 families). Total 152 species are in conservation significant, out of them 66 are in IUCN threatened red list species categories, similarly 11 species are in nationally protected categories and 104 species are in CITES Appendix II and III. Total 102 endemic flowering plant species are reported from ACA out them 68 are endemic to ACA, which is about 35% of total number of endemic species of Nepal.

These findings are noteworthy and could be the valuable documents for further research work to update the data of flora of ACA. Moreover, it will guide to conduct research work especially in field of proper conservation and management of the endemic flowering plants of ACA. There is need for more comprehensive research task to further document the floral diversity in ACA. Due to altitudinal variation and climatic pattern, research should be done in multiple time frames throughout the year to get proper data of the plant species in the ACA.

Author Contributions

All the authors were involved in concept development, research designing, defining of intellectual content

and literature search. B. L. Tiruwa collected and analyzed data, and prepared manuscript. A. Subedi and R. K. Gurung edited and reviewed the manuscript. B. L. Tiruwa, as a corresponding author, is the guarantor for this article.

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