ISSN (Online): 2349-1183; ISSN (Print): 2349-9265
TROPICAL PLANT RESEARCH
The Journal of the Society for Tropical Plant Research
9(2): 69–86, 2022
DOI: 10.22271/tpr.2022.v9.i2.012

Research article

Plant community patterns and edge effect study in the ecotone region of River Pabber and Tons in Western Himalaya

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Abstract: The present study was carried out in riverine ecotone of Tons and Pabber rivers which are tributary of river Yamuna in Garhwal Himalaya to understand the edge effect on distribution and structure of plant community patterns. The study was done at an altitude of 900 m to 1300 m to identify the plant diversity and community structure of riverine ecotone areas within a stretch of 64 km. In total Seventeen (N=17) tree species twenty one (N=21) shrub species, thirty-eight (N=38) species of herbs and three (N=3) species grasses were identified. *Mallotus philippensis*, *Alnus nepelensis*, and *Pinus roxburghii* were found to be dominant threes having 35.7%, 14.9% and 13.6% representation in total tree population. Out of nine (N=9), sample sites *Mallotus philippensis* and *Pinus roxburghii* were having the highest densities and relative densities in five (N=5) sites. *Rubus elipticus* was dominating shrub species with 16% representation followed by *Zanthoxylum armatum* 12.2%, *Adhatoda vasica* 10.3% and *Agave cantula* 9.3%. *Rubus elipticus* and *Zanthoxylum armatum.*were having the highest numbers in sites where the slope was gentle and soil conditions were not sandy. Whereas *Adhatoda vasica* was more uniformly distributed and was found growing uniformly in riverine sandy soil areas *Agave cantula* preferred the southern and western aspects with rocky slopes and poor soil conditions. In grasses, *Carex infuscata* was having highest dominance (43.64), in herbs *Trifolium repens* was having the highest dominance (21) followed by *Cannabis sativa* (20.92), *Cynodon dactylon* (17.8) and *Verbascum thapsus* (10.71). Species diversity indices used in the study was the Shannon Index, the value of diversity indicated by H' was 2.44 which indicates that the herb diversity in the ecosystem is uniformly distributed, no single herb species is dominant, whereas the dominance value which is 0.11 corroborate the diversity of the ecosystem. The value of Shannon wiener (H') index for shrub species was 1.58 which indicates that the majority of shrub (66.6%) species are distributed uniformly except *Berberis lycium*, *Clerodendrum phlomidis*, *Euphorbia royleana*, *Indigofera heterantha*, *Lantana camara*, *Woodfordia fruticosa* and *Viburnum cotinifolium*.

Keywords: Riverine ecotone - Tributary - Community structure - Dominance - Relative densities - Diversity.

[Cite as: Joshi V & Arunachalam K (2022) Plant community patterns and edge effect study in the ecotone region of River Pabber and Tons in Western Himalaya. *Tropical Plant Research* 9(2): 69–86]

INTRODUCTION

The Himalayas are one of the richest and most unusual ecosystems on earth with a variety of forest types due to great altitudinal and climatic variations from foothills to alpine peaks; vegetation types have a direct relationship with altitude (Mani 1978). This influences the temperature gradient, a factor shaping vegetation types and determining their diversity and distribution (Heaney & Proctor 1989, Tanner *et al*. 1998, Vazquez & Givnish 1998). The quantitative analysis of community composition and structure is a prerequisite for the precise evaluation of biodiversity (Oosting 1956, Singh *et al*. 2014). However, assessment of tree communities is usually sited specific and provides a reliable data on various ecological attributes such as composition, abundance, distribution and dominance which ultimately help in understanding the natural regeneration processes and dynamics (Logman & Jenik 1987, Puhlick *et al*. 2012, Sarkar & Devi 2014). *Pinus roxburghii* Sarg. has been identified as an early succession species for the region (Champion & Seth 1968) and in many

Received: 10 November 2021 Published: 31 August 2022
https://doi.org/10.22271/tpr.2022.v9.i2.012

areas along the riverine ecotone *Pinus roxburghii* forms dominating forest species. Since pine needles in general are acidic they will tend to acidify soil character which will in turn may affect the distribution of herbs and shrubs in the riverine ecotone too. But other species have also occupied the areas in riverine ecotone this study is aimed at the identification of plant diversity and community structure of riverine ecotone along the river Pabber and Tons in Uttarakhand (Fig. 1). Within one altitude, the cofactors like topography, aspect, and inclination of slope and soil type affect the forest composition (Shank & Noorie 1950). With the change in environmental conditions, the vegetation cover reflects several changes in its structure, density and composition (Gaur 1982) same is also true for riverine ecotone where the structure, density, and composition of trees, shrubs, grasses, and herbs depends on environmental conditions because of cyclic pattern of flooding in the ecotone.

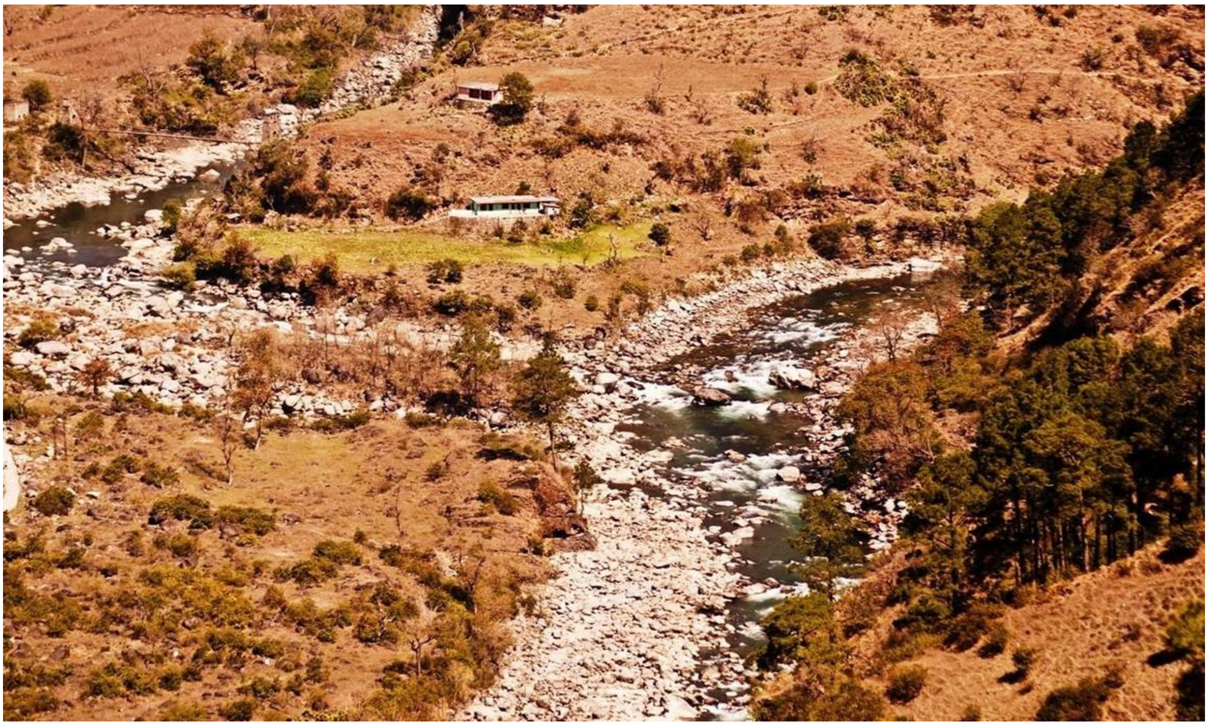

Figure 1. Riverine ecotone at confluence of river Pabber and Tons at Tyuni, Uttarakhand.

The river Tons is the largest tributary of the river Yamuna and flows through Garhwal region in Uttarakhand, also touching border villages of Himachal Pradesh Its source lies in the 20,722 feet high (6,316 m) at *Bandarpunch* and is one of major perennial Indian Himalayan rivers. Tons river cuts a gorge and flows with almost no major habitations for almost the first 50 to 60 km within the state of Uttarakhand. In this short span, river Tons descend almost 5100 m. and only after reaching *Netwar* and *Mori* villages situated at about 1150 m in north-west Garhwal this river enters in a stretch of about 35 km with gentler slopes and wide valley. This is the area which was having the highest concentration villages on the banks of river Tons and similarly, river Pabber also has villages in wider valley areas. We investigated the plant community structure on the riverine ecotone and resource utilization pattern in these areas for this study. This river meets river Yamuna at *Kalsi* near Dehradun, Uttarakhand.

The *Pabber* river is a glacier-fed river that originates from lake *Chandra Nahan* in *Rohru tehsil* of Himachal Pradesh. This glacier-fed lake is considered the point of origin of the Pabbar River and is located 3970 m at on the south-eastern slopes of the main Himalayas which lies to the northwest of *Rohru* in Shimla district of Himachal Pradesh. The present study was done near the confluence areas in two open wide valleys in the riverine ecotone stretches of both rivers where the riverine ecotone areas are inhabited and are being used by locals inhabited for grazing and other purposes.

To document the edge effect of two ecosystems on community distribution patterns and study of different factors such as anthropogenic, geographical and micro-climatic on plants along the riverine ecotone this study was designed.

Changes in species abundance and community structure in the ecotone between two contrasting habitats are often termed 'edge effects' (Murica 1995, Ewers & Didham 2006). Floristic inventory and diversity studies help us to understand the species composition and diversity status of forests (Phillips *et al*. 2003, Bargali *et al*. 2014, 2015). Our study focused on floristic inventory, diversity of habitat and the changes in plant communities and their niche preferences due to edge effects within ecotone of river Pabber and Tons. As a general rule edge effects result from alterations in environmental conditions, vegetation structure, and composition (Ries & Sisk 2004, Santos *et al*. 2008, Bajpai *et al*. 2015, Malik & Nautiyal 2016). Human settlements on riverside locations where conditions are habitable village settlements and hamlets are a common features in the Himalayas. These riverside landscapes have unique ecotone and human interaction with nature has altered and influenced the distribution, growth, and structure of plant communities in the riverine ecotone areas (Fig. 2).

Figure 2. An panorama of river Pabbar to show the villages situated along the riverine ecotone near site 1.

The capacity of native species to use anthropogenic habitats or to move through them is one of the main determinants of landscape functional connectivity (Tischendorf & Fahrig 2000, Antongiovanni & Metger 2005, Hansbauer *et al*. 2010, Watling *et al*. 2010, Zurita & Bellocq 2010) and this provides an opportunity to study the edge effects in the ecotone. The native plant species also many times undergo the problem of the chronic form of forest disturbance in which the plant's communities or ecosystems often do not get time to recover adequately because the human onslaught never stops (Singh 1998). In Uttarakhand, forests are rich sources of wood, grass, medicinal plants, wild edible fruits, etc., and thus they sustain all life forms (Singh & Singh 1987, Agarwal 1990, Mehra *et al*. 2014).

As the riverine forests are comparable with the `habitat pioneer' communities Ohsawa (1991). Few studies have been done in the Himalayan region to investigate the vegetation composition in the riverine ecotone. There is exceptionally low data available how the riverine ecotone species are distributed along the Himalayan Rivers. This research was designed to understand the plant community patterns and edge effect of adjoining riverine and forest ecosystems on development, spread of plant species along the river Pabber and Tons in Western Himalaya. The study was designed to evaluate the natural dispersal pattern of individual plant species *i.e.*, herbs, shrubs, and trees along the riverine ecotone and effect of anthropogenic disturbances on distribution of shrubs and herbs. As both the Himalayan rivers traverse through diverse habitat such as deep gorges, with rock faces, valley bottom with gentle slopes which are generally used by local village communities for fodder collocation, grazing grounds etc., and wide open valley floor where within 100–200 meter distance villages are located along the confluence of river Pabber and Tons. We focused our study to investigate the diversity plant in different micro-habitat along the riverine ecotone. Our objective was to investigate the effects of different soil conditions, canopy cover, shade, aspect, etc on species distribution pattern in riverine ecotone. We also investigated the formation of clusters pattern, of herb and shrub species, and impact of anthropogenic activates on distribution pattern and population size of shrub and herb species.

MATERIAL AND METHODS

The study area is covered under two forest divisions; *viz*., Tons Forest Division, Purola (Area between River Tons and River *Pabber*) and Chakrata Forest Division. The diversified forests of the majestic Himalaya, based on ecology as per classification of forest type were identified following Champion & Seth (1968) in the riverine ecotone areas of river Pabber and Tons. The forest present in the study area belongs to Tropical Dry Deciduous Forests (Group 5), Subtropical Pine Forests (Group 9), Himalayan Moist Temperate Forests (Group 12), and Degraded Forest as per the classification of Champion & Seth (1964).

For enumeration of trees fifty (N=50) (sample plots) quadrates (10×10 m) were laid and trees (> 31.5 cbh, circumference at breast height, *i.e.* 1.37 m from the ground) and saplings (between 10.5–31.4 cm) were measured. Within each (10×10 m) quadrats (5×5 m) quadrats were laid for shrub and seedling of trees and also within each 10×10 m quadrats 10, 1×1 m random quadrats were laid for ground flora (herbs).

A line transect of 1250 m was laid from the area near the starting point of sample plot 1 and finished near sample plot 5 in each site for the collection of data on lopping cutting and grass collection (Mishra 1968). In each sampled plot, trees (> 30 cm CBH), their CBH (the circumference at breast height *i.e.*, 1.34 m above ground level), and percentage canopy cover were measured.

The number of saplings (>10 to 29.99 cm CBH) and seedlings (<9.99 cm CBH) were also recorded for each tree species following Knight (1963). Shrubs were counted inside a 5 m plot, nested within the 10 m plot. Grass/herb species were recorded in one 1 m × 1 m plots nested within the same plot.

Habitat parameters: Parameters such as altitude, aspect, slope and vegetation cover were measured as follows:

Altitude was measured using a GARMIN global position system; Aspect was measured on an eight-point scale (North: 337º–22º, Northeast: 23º–67º, East: 68º–112º, Southeast: 113º–157º, South: 158º–203º, Northeast: 204º–247º, West 258º–292º, and Northwest: 293º–336º) using a Sunnto compass.

Cover categories for canopy, tree, shrub, grass and rock & soil were measured on an eight-point scale (1–10, 11–20, 21–0, 31–40, 41–50, 51–60, 60–80 and >80 %) based on visual observations. (Dombois & Ellenberg 1974).

For getting approximation of the humus cover on forest floor humus depth was categorised in five-point scale (Cat 1 0.5 cm, Cat 2 0.5–1.0 cm, Cat 3 1.0–1.5 cm, Cat 4 1.5–2.0 cm, Cat 5 >2 cm). For estimation of the area of humus inside the sample plots, line point intercept method was applied (Herrick *et al*. 2009). A rope of 1 meter was taken and at each 10 cm in the rope, a knot was tied. The rope was thrown in a random manner inside the sampling plot 5 times and at the point where the rope landed readings were taken at each knot for measuring humus depth categorized, small stones, bare soil, sandy soil, etc.

$$\text{Density/Quadrat} = \frac{\text{Total number of individuals in all the quadrats}}{\text{Total number of quadrats studies}}$$

$$\text{Frequency} = \frac{\text{Total number of the quadrat in which species occurred}}{\text{Total number of quadrats studies}} \times 100$$

$$\text{Mean basal area} = \frac{C^2}{4\pi}$$

$$\text{Relative Density} = \frac{\text{Total number of individual of a species}}{\text{Total number of individuals of all species}} \times 100$$

$$\text{Relative Frequency} = \frac{\text{Total number of occurrence of a species}}{\text{Total number of occurrence of all species}} \times 100$$

$$\text{Relative Dominance} = \frac{\text{Total basal cover of a species}}{\text{Total basal cover of all species}} \times 100$$

Importance Value Index (IVI) = Relative Density + Relative Frequency + Relative Dominance

Diversity was calculated using the following formula (Mueller *et al*. 1974, Brown & Curtis 1952), Misra (1968), Shannon & Weaver (1949).

$$H' = -\Sigma\,(ni/N) \times \ln\,(ni/N)$$

Where, H′ = Shannon's information index of species diversity; ni = Total number of individuals of one species; N = Total number of individuals of all the species in one stand

Richness was calculated by counting the total number of species observed in each habitat. Evenness (Equability) was calculated using Pielou's (1966) equation, Margalef, 1968

$$\text{Evenness (E)} = H'/ H' \text{ max.} = H' \log S \text{ or } H'/\ln S$$

Where, S = Number of species; H′ = Diversity

Evenness ranges between 0 and 1. If the evenness value is higher the variation in communities between the species would be less.

To determine to determine if a distribution of shrub species is clumped, uniform, or random along the riverine ecotone Clark–Evans nearest neighbor method (Clark & Evans 1954) was used.

$$R = (\text{Mean Distance}) \times 2 \sqrt{\text{Density}}$$

Principal Component Analysis was done for reducing the dimensionality of dataset, and increase the interpretability of the dataset. Large datasets are increasingly widespread in many disciplines. In order to interpret such datasets, methods are required to drastically reduce their dimensionality in an interpretable way, such that most of the information in the data is preserved (Jolliffe & Cadima 2016)

RESULTS

In the study area along the riverine ecotone of Pabber and Tons we laid fifty (N=50) quadrates in ten (N=10) different sites (Fig. 3; Table 1). The plant specimens were photographed properly at sites and were identified with the help of literature (Hooker 1872–97; Polunin & Stainton 1984). *Mallotus philippensis* (Lam.) Müll.Arg. was having the highest numbers (N=55) in fifty (N=50) quadrates followed by *Alnus nepelensis* D.Don (N=23) and *Pinus roxburghii* (N=21). The relative (N=115) trees were recorded, trees were represented by sixteen different families (N=16). It was observed *Mallotus philippensis* despite having the highest numbers, was having low ranking in relative dominance 17.1 because of the low mean circumference of trees 41.39 cm, whereas *Ficus palmata* Forssk., having lower densities was having relatively high relative dominance because of higher girth class trees; mean circumference of *Ficus palmata* was 163 cm. Similar was true for *Pinus roxburghii* and *Dalbergia latifolia* Roxb. trees was 136.19 cm.

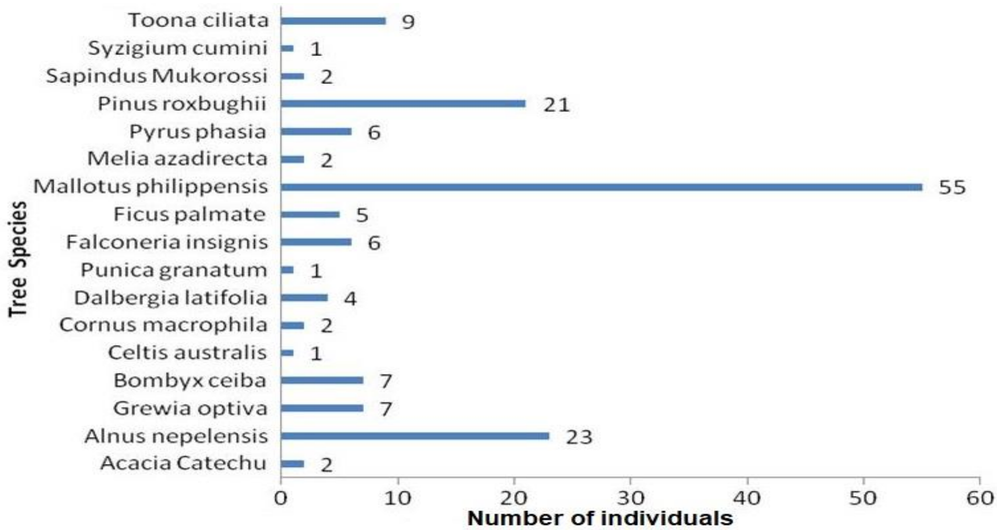

Figure 3. Total number of tree species individuals observed in ecotone.

Table 1. Family of Tree Species in Ecotone.

S.N.	Species	Family
1	*Acacia catechu* (L.f.) Willd.	Mimosaceae
2	*Alnus nepelensis* D.Don	Betulaceae
3	*Ficus palmata* Forssk	Moraceae
4	*Bombax ceiba* Burm.f.	Bombacaceae
5	*Cornus macrophylla* Wall.	Cornaceae
6	*Dalbergia latifolia* Roxb.	Fabaceae
7	*Punica granatum* L.	Punicaceae
8	*Falconeria insignis* Royle.	Euphorbiaceae
9	*Grewia optiva* J.R. Drumm. ex Burret	Tiliaceae
10	*Mallotus philippensis* (Lam.) Müll.Arg.	Euphorbiaceae
11	*Melia azadirachta* L.	Meliaceae
12	*Pyrus pashia* Buch.-Ham. ex D.Don	Rosaceae

13	*Pinus roxburghii* Sarg.	Pinaceae
14	*Sapindus trifoliatus* L.	Sapindaceae
15	*Syzygium cumini* L.	Myrtaceae
16	*Toona ciliata* M. Roem.	Meliaceae
17	*Celtis australis* L.	Cannabaceae

It was observed that in some tree species relative density was higher than relative dominance *i.e.*, *Celtis australis* L., 35.3; *Mallotus philippensis* 32.2; *Alnus nepelensis* 34.2 and *Grewia optiva* J. R. Drumm. ex Burret 15.8 these trees were having the majority of the population in lower girth classes (Fig. 4).

Relative density of *Alnus nepelensis* was found to be the highest RD=34.2 followed by *Mallotus philippensis* RD=32 and *Pinus roxburghii* RD=20.1. Whereas relative dominance values were highest for *Pinus roxburghii* RDoM=35, followed by *Ficus palmata* RDoM=29.7; *Dalbergia latifolia* RDoM=26.6; *Alnus nepelensis* RDoM=26.1; *Toona ciliata* M. Roem. RDoM=18.2; *Mallotus philippensis* RDoM=17.1; and *Bombax ceiba* Burm.f. RDoM=15.6 (Fig. 4).

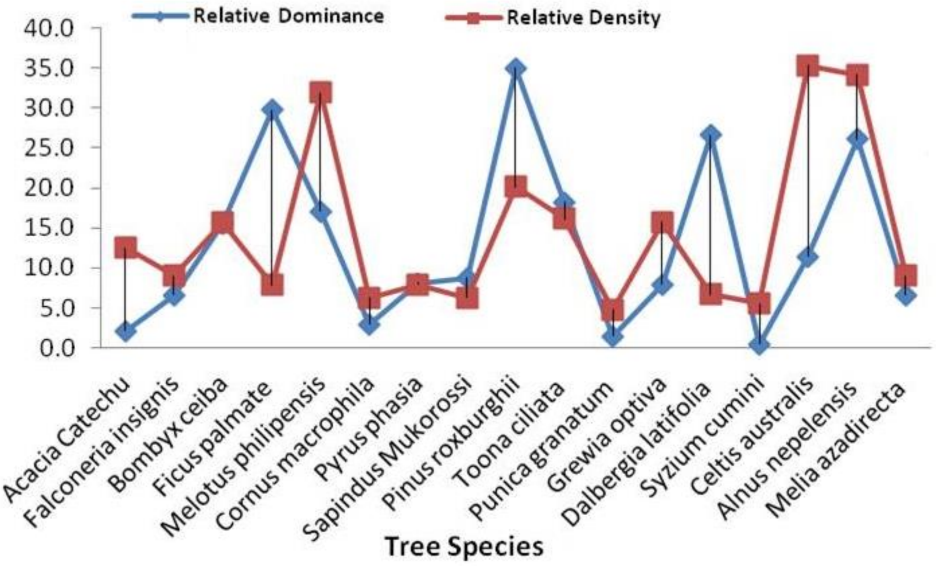

Figure 4. Difference between relative density and dominance of tree species in ecotone.

It was observed that the highest representation in the total population of shrub species was of *Rubus elipticus* Sm., 16%; followed by *Zanthoxylum armatum* DC., 12.2%; *Adhatoda vasica* Nees., 10.3%; *Agave cantula* (Haw.) Roxb., 9.3%; and *Debregeasia longifolia* (Burm. f.) Wedd., 8.2%. As the soil of riverine ecotone in wide valleys retain soil moisture in many pockets, *Rubus elipticus* grows well in mesic and wet conditions, it was observed that the shrub was forming impenetrable thickets in many areas where the conditions were favorable.

Zanthoxylum armatum belonging to Rutaceae also grows well in warmer valleys, although it tends to grow in well-protected areas with low population size, it was observed that *Zanthoxylum armatum* was growing in marginal and unproductive lands among the riverside ecotone but not at the banks of the river.

Table 2. Distribution pattern of shrub species along the riverine ecotone.

Species Name	Intra Distance of Shrub Species in quadrat (m)	Density	R=(Mean Distance) x 2 √ Density	Distribution Pattern of Shrub Species
Adhatoda Vasica Nees.	0.2	0.5	0.28	Clumped
Agave cantula (Haw.) Roxb.	0.7	0.6	1.08	Random
Barberis asiatica Roxb. ex DC.	0.5	0.6	0.77	Clumped
Berberis lycium Royle.	1.7	0.1	1.08	Random
Clerodendrum phlomidis L.f.	0.4	0.1	0.25	Clumped
Colebrookea oppositifolia Sm.	0.2	0.2	0.18	Clumped
Debregeasia longifolia (Burm. f.) Wedd.	1.2	0.6	1.86	Uniform
Eupatorium adenophorum Spreng.	0.9	0.3	0.99	Random
Euphorbia sp.	1.1	0.2	0.98	Random
Indigofera heterantha Wall. ex Brandis	1.1	0.3	1.20	Random
Lantana camara L.	1.2	0.2	1.07	Random

Murraya koenigii (L.) Spreng.	1.8	0.5	2.55	Uniform
Prinsepia utilis Royle.	0.6	0.7	1.00	Random
Rabdosia rubescens (Hemsl.) H.Hara	0.9	0.3	0.99	Random
Rhus parviflora Roxb.	1.6	0.6	2.48	Uniform
Rosa macrophylla Lindl.	1.5	0.4	1.90	Uniform
Rubus elipticus Sm.	0.6	0.8	1.07	Random
Solanum surattense Burm.f.	0.8	0.4	1.01	Random
Viburnum prunifolium L.	1.8	0.1	1.14	Random
Woodfordia fruticosa (L.) Kurz	2	0.1	1.26	Random
Zanthoxylum sp.	1.4	0.9	2.66	Uniform

Adhatoda vasica was found to be growing in all soil types mesic, sandy and dry gravel type. *Agave cantula,* preferred dryer sites and *Debregeasia longifolia* was found to be growing in all areas in uniform pattern but seem to prefer deep and mesic sites in such areas the numbers of this shrub were high growing in clumped but irragular distribution pattern. Other herbs that were found to grow in clumped distribution form were *Barberis asiatica* Roxb. ex DC. having 6.9% representation, *Rhus parviflora* Roxb., 6.9%, *Colebrookea oppositifolia* Sm., 5.6% and *Euphorbia* spp. with a 5.4% representation. Herb diversity was more uniformly distributed throughout the riverine ecotone (Table 2).

Shannon's diversity index value was 3.124 on the scale of 0 to 5 whereas the evenness value was 0.062. Similarly, for the shrub Shannon's diversity index value was 2.86 and evenness value was 0.064.

Species diversity indices used in the study was the Shannon Index, the value of diversity indicated by H' was 2.44 which indicates that the herb diversity in the ecosystem is uniformly distributed.

None of the herb species was found to be dominant at landscape level, the dominance value was also 0.11 corroborating the diversity of the ecosystem. This also indicates that the grass and herbs are stable in the sampled ecosystem. The interpretation of the results of Shannon wiener (H') index reveals that the value of H' in herbaceous flora was found to be 2.44 which indicates that no particular species in the herb community is dominant and all the species observed under the herbaceous community are uniformly distributed in the ecosystem. Similarly, the value of Shannon wiener (H') index for shrub species was 1.58 which indicates that the majority of shrub (66.6 %) species are distributed uniformly except *Berberis lycium* Royle., *Clerodendrum phlomidis* L.f., *Euphorbia royleana* Boiss., *Indigofera heterantha* Wall. ex Brandis, *Lantana camara* L., *Woodfordia fruticosa* (L.) Kurz, and *Viburnum cotinifolium* D.Don. These species have a random at landscape level and clumped distribution pattern inside quadrate in general. The dominance (D) value was 0.31 which was slightly higher when compared with herbs because of the lower number of species that occurred in our sampled plots. Overall none of our sites was dominated by single herb or shrub species.

It was observed that the Asteraceae family was having highest representation with 22% share in herb population with nine (N=9) members and total number two hundred forty-one (N=241) individuals which is 15.06 % of total herb population .

Poaceae was having a second-largest representation of 7.3% of representation and three (N=3) members and a total number of two hundred one (N=201) individuals which is 12.56% of total herb population. Polygonaceae, was represented by 4.9% of the total herb population with two (N=2) members and 44 individuals which is 2.75% of the total herb population. Similarly, Scrophulariaceae, Solanaceae, Urticaceae were also represented by having 4.9% of the total herb population with two (N=2) members each. The total number of individuals of Scrophulariaceae was 79 which is 4.9 %, Solanaceae as 21 which is 1.3% and Urticaceae were 30 individuals which are 1.8% of total herb population rest of the families were represented by one member each.

The regression analysis was done to analyze the independent factor of anthropogenic pressure and its effect on the dependent factor such as the population size of shrub species in different stages of disturbances in different sampled sites along riverine ecotone (Fig. 5). We have also analyzed the impact of fodder collection, grass cutting and grazing of herbs and shrub by livestock and the synergetic effects of all these factors on the distribution pattern and population size of all 21 shrubs species. We found that the anthropogenic factor taken as independent factor does not seem to affect the dependent factor of the shrub population adversely. In different types of habitats where sampling was done for shrub species along the riverine ecotone, the negative r-value of regression ($r2= -0.057$) indicates that the shrub population is negatively affected by anthropogenic activates in the specific habitat types in a riverine ecotone. We observed that the growth of shrub species in our sampled sites was not negatively or positively related to fodder, grass collection and Fuel-wood collection from the riverine ecotone (Figs. 6 & 7).

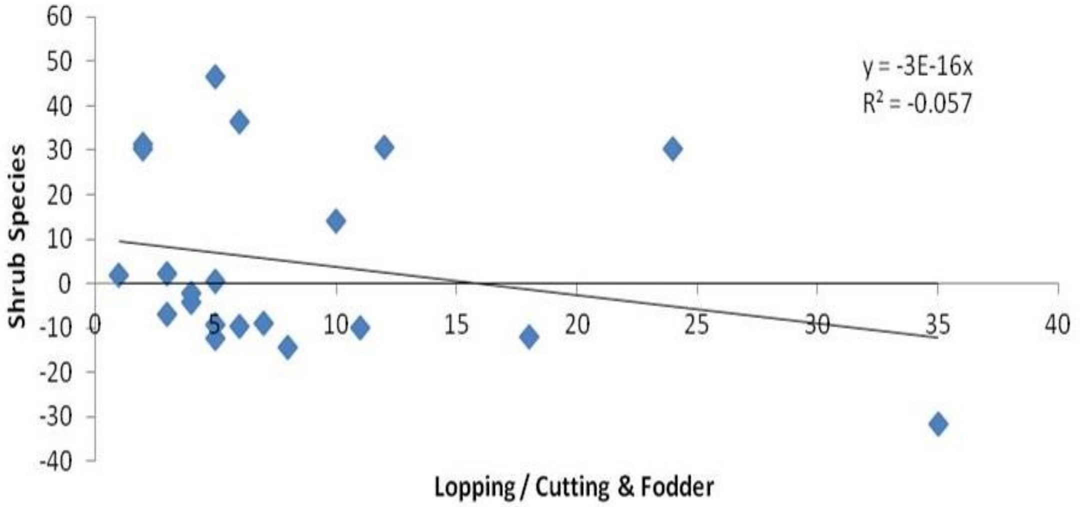

Figure 5. Regression analysis of shrub population and disturbance factors in ecotone.

Figure 6. Pine forest site being used for grazing and fodder collection, site no 4.

Figure 7. Fuel wood collection from riverine ecotone in river Tons site no 3.

Individual species may be affected more by site parameters such as favorable soil conditions, canopy cover, shade, aspect, etc. but may not have a direct impact of anthropogenic activates on distribution pattern and population size of shrub species.

Principal Component Analysis (PCA) was also done to study the association of shrub species with different abiotic and biotic factors such as anthropogenic pressure, habitat type, soil condition, aspect, and slope angle etc., (Fig. 8). In total 21 shrub species were found growing along the riverine ecotone of river Pabber and Tons between 900–1200 m. As river Pabber and Tons flow through both the wider valley areas and narrow and deep gauges. The distribution of vegetation was deeply affected by these topographical factors. The principal component analysis (PCA) shows clearly the site preferences and association of shrub species to particular sites. As shown in figure 8.

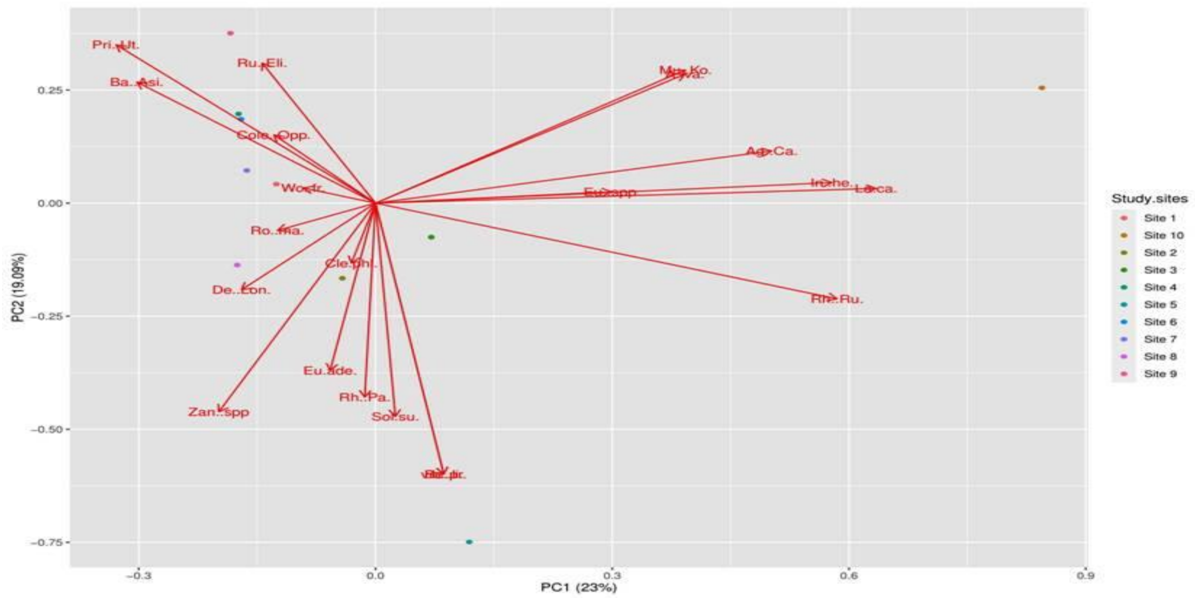

Figure 8. Principal component analysis (PCA) of shrub species showing association with sites in ecotone.

The correlation matrix was also developed for trees, shrubs and herbs species to check the association of plant species to specific site conditions such as canopy cover, rock faces, grazing sites, slope direction, etc. the result of this analysis reveled whether the plant species were positively or negatively correlated with site conditions, as shown in figure 9.

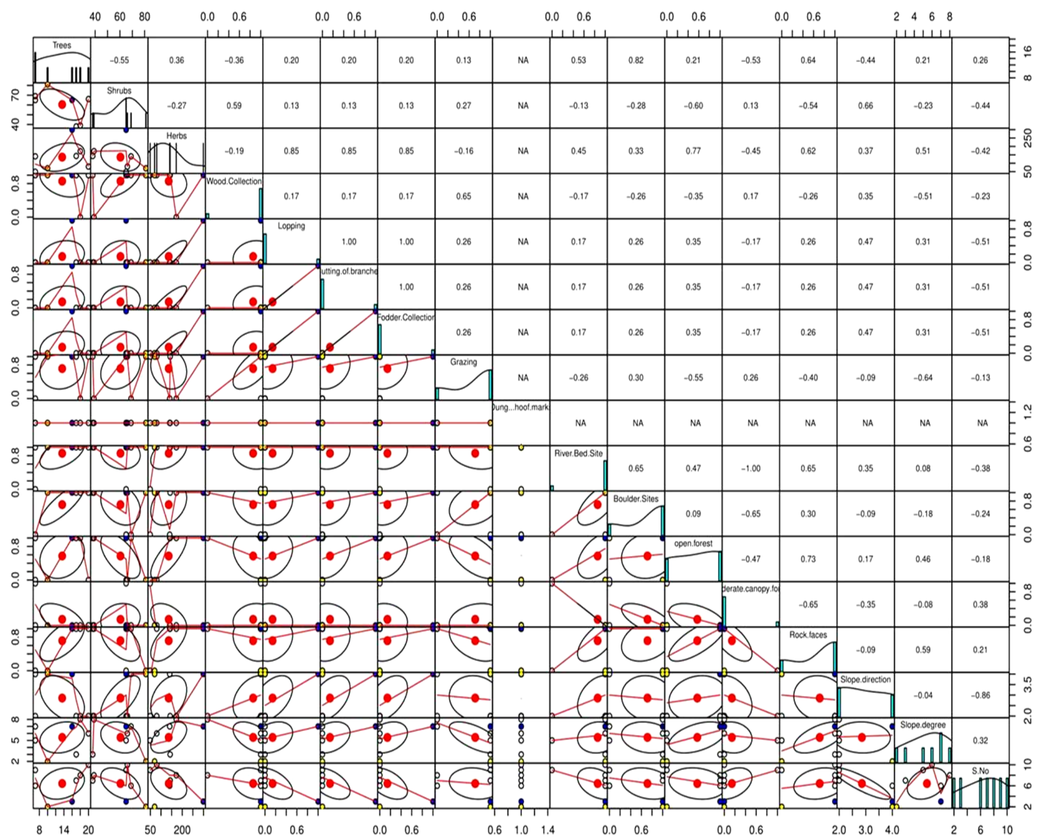

Figure 9. Correlation matrix showing relationship among species in ecotone.

Principal Component Analysis (PCA) was done to study the association of herb species with different abiotic and biotic factors such as anthropogenic pressure, habitat type, soil condition, aspect, and slope angle, etc. (Fig. 10). The results of PCA shows that out of forty one (N=41) herb species only 10 species have association with specific site characters. About 24% herb species were found growing in similar habitat types; this confirms that these herbs species have somewhat wider niche hence they do not have specific niche requirements.

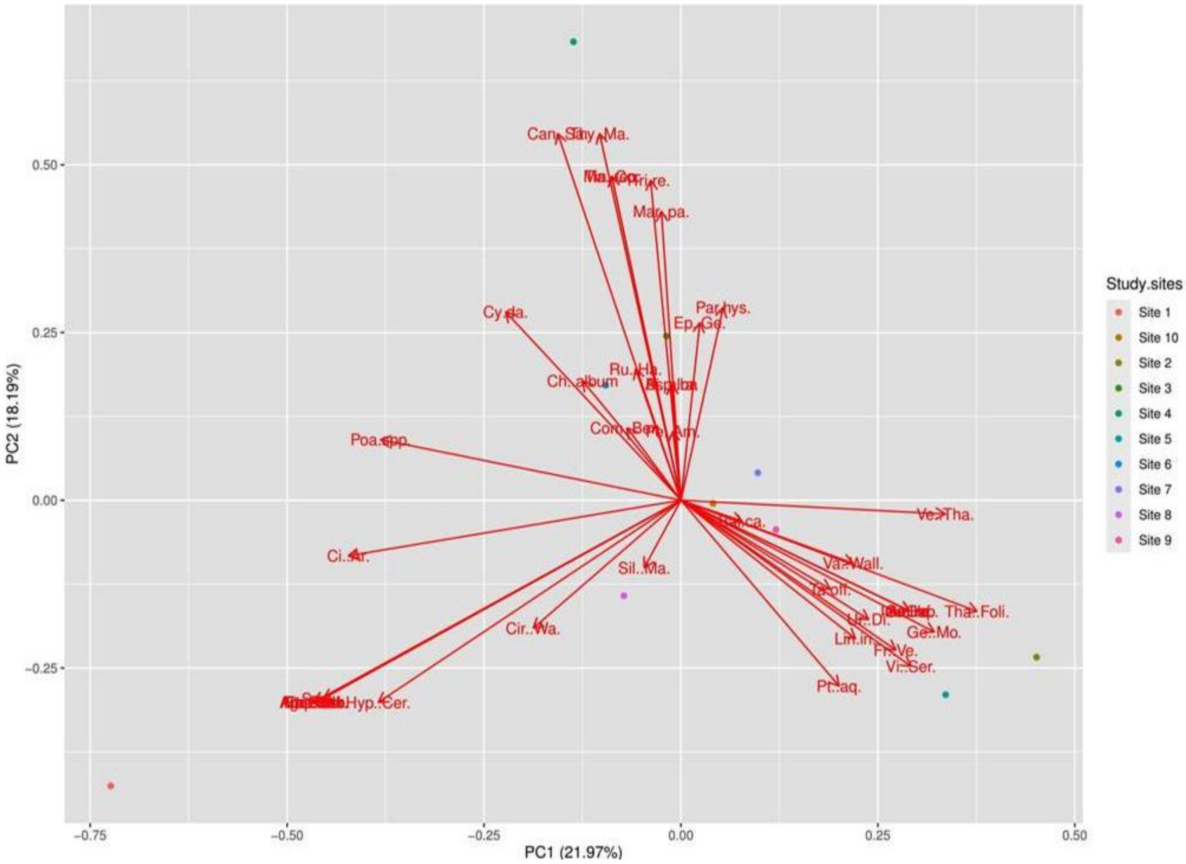

Figure 10. Principal component analysis (PCA) of herb species showing association with sites in Ecotone.

Cannabis sativa L., *Cirsium arvense* (L.) Scop., *Cynodon dactylon* (L.) Pers., *Geranium molle* L., *Parthenium hysterophorus* L., *Poa annua* L., *Thalictrum foliolosum* DC., *Trifolium repens* L., *Verbascum thapsus* L., and *Pteridium aquilinum* L. showed association with site characters hence growing together, as shown in figure 13, but the total number of these herbs in entire sampled herb population was only 55.5%. The remaining herb species were not growing together in all sampled sites and were site-specific in nature with the narrow ecological niche. *Caryx infuscate* L., *Dactyloctenium aegyptium* (L.) Willd. and *Poa annua* where being used as fodder. The herb species which shared similar niche characteristics. *Trifolium repens* was having highest representation of 20.1% closely followed by *Cannabis sativa* 19.8%, *Cynodon dactylon* 16.1% and *Parthenium hysterophorus* 10.9% (Fig. 11).

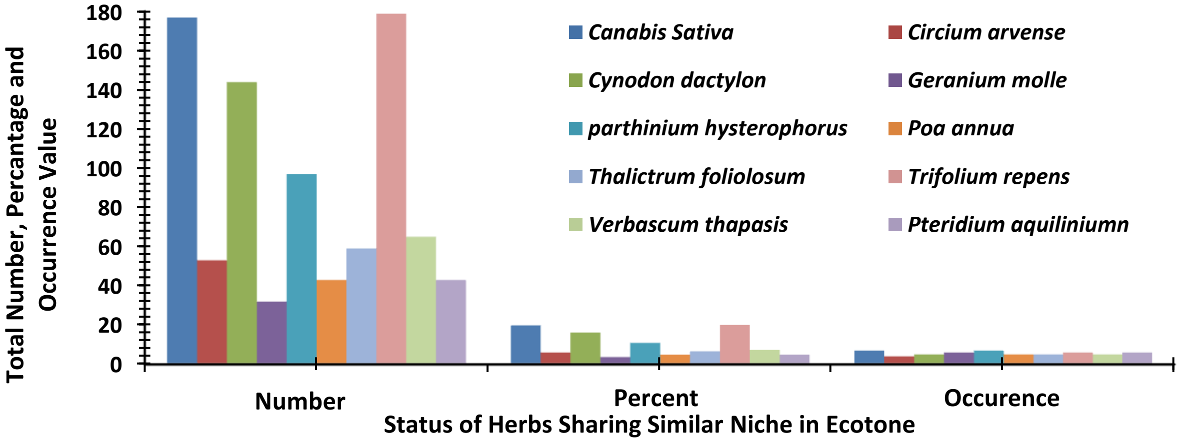

Figure 11. Total number of herb species having similar niche requirement, their percent representation (N=10 Species) and occurrence in quadrate.

At landscape level in the ecotone only three herb species *Caryx infuscate* (11.6 %), *Trifolium repens* (11.15%) and *Cannabis sativa* (11.02 %) was having highest representation in herb community in the ecotone areas. These three species were found to have the highest cover; other herb species which were site-specific have low cover and low numbers in herb population in the ecotone.

DISCUSSION

Fodder and fuel wood collection, canopy cover, geographical factors such as slope direction, slope angle etc., have a great influence on plant community distribution pattern. We have also investigated the influences of geographical, physical factors and edaphic factors of soil, edge effect, anthropogenic activities along riverine ecotone of river Pabbar and Tons in Uttarakhand Himalaya. We find that the combination of anthropogenic activities and factors named above have influenced the plant community structure and shrub, herb diversity in riverine ecotone.

Plant community undergoes different stages of succession over a long time period due to inter species competition, the resilience of plant species within an ecosystem and gradually moving towards stability. Similarly, the riverine ecotone areas also provide valuable natural resources to human settlements. The dependency of humans on diverse natural resources of riverine ecotone and adjacent forest areas have shaped the plant communities in the ecotone areas. Several authors have documented the resource utilization from forest. In Uttarakhand, forests have been rich sources of wood, grass, medicinal plants, wild edible fruits, etc., and thus they sustain all life forms (Singh & Singh 1987, Agarwal 1990). But not much data is available to describe the affects of geographical, physical factors and edaphic factors of soil, edge effect, anthropogenic activities in unique ecotone such as riverine ecotone. We have investigated the riverine ecotone of Pabber and Tons to study the plant community patterns and edge effect in the ecotone region of both rivers.

In total one hundred fifty-seven trees (N=157) trees were recorded in ten sites within fifty (N=50) quadrates. In all ten sites in total seventeen (N=17) tree species were present in the riverine ecotone area as well as areas between about a hundred (100) meters above uphill and river bed. The identified trees were as following: *Acacia catechu* (L.f.) Willd., *Alnus nepelensis*, *Bombax ceiba*, *Cornus macrophylla* Wall., *Dalbergia latifolia*, *Punica granatum* L., *Falconeria insignis* Royle., *Ficus palmata*, *Grewia optiva*, *Mallotus philippensis*, *Pyrus pashia* Buch.-Ham. ex D.Don, *Melia azadirachta* L., *Cornus macrophylla*, *Punica granatum*, *Pinus roxburghii*, *Sapindus trifoliatus* L., *Syzygium cumini* L., *Toona ciliata*, and *Celtis australis.* These trees were represented by fifteen different families Mimosaceae, Betulaceae, Bombacaceae, Cannabaceae, Cornaceae, Euphorbiaceae, Fabaceae, Ficideae, Meliaceae, Moraceae, Myrtaceae, Pinaceae, Punicaceae, Rosaceae, Sapindaceae, and Tiliaceae.

In site one *Bombax ceiba*, *Ficus palmata*, *Pyrus pashia* and *Falconeria insignis* were dominant tree species. In site two *Pinus roxburghii* was dominant tree species this site was being used by villagers for collection of fodder, fuel wood and grazing ground.

We observed in our study that tree species such as *Pinus roxburghii*, *Ficus palmata* and *Dalbergia latifolia* were having higher relative dominance, despite lower number of trees occurred in quadrats along the riverine ecotone. This was due to the old growth larger girth trees. Trees such as *Alnus nepelensis* which are commonly found growing in abundance in the early succession ecotone. We observed that this abundant growth of *Alnus nepelensis* was restricted to areas where landslide have occurred in near past. Both relative density and dominance of *Alnus nepelensis* was higher in such areas where the hillside in riverine ecotone have landslide in past decades. Contrary to this *Mallotus philippensis* a tropical tree species, which is commonly dominant as the undergrowth was having lower dominance but higher relative density. The main reason behind this may be the drought tolerant and slow-growing nature of this tree species. *Mallotus philippensis* is commonly found in secondary succession stage forest and it also indicates that the studied riverine ecotone, the ecosystem is slowly moving towards stability, despite disturbances. *Mallotus philippensis* was forming dense thicket in most of the sites and the majority were pole stage trees. We also observed that the representations of trees which are commonly used by villagers for the collection of fodder such as *Celtis australis*, *Grewia optiva*, *Cornus macrophylla* and *Ficus palmata*, etc., occurred in low numbers in the quadrats laid along the riverine ecotone. This was due to over-exploitation of fodder trees and disruption of seed production. Other trees whose numbers are mentioned in figure 3 have small representation in ecotone and this may be due to the geographical and edaphic factors, of riverine ecotone such as sandy soil, slope angle, rock faces, drier exposed sites on both side of ecotone which have restricted the spread of these climax stage forest species in the riverine ecotone. Another factor restricting the spread of these tee species was less availability of deep soil areas and agriculture along the ecotone, as majority of areas where the valley widened ecotone strips are being used for agriculture.

It was observed that in the riverine ecotone areas the shrub density was higher in comparison to tree density. Even within the shrub community only five (N=5) shrub species *Adhatoda vasica*, *Rubus elipticus*, *Zanthoxylum armatum*, *Agave cantula* and *Debregeasia longifolia* out of twenty one (N=21) were dominating the riverine ecotone. This was primarily due to frequent availability of ecological niche of these shrub species along the riverine ecotone, such as sandy soil, low humus content *i.e.*, Cat1 0.5 cm, Cat 2 0.5–1.0 cm, drier and exposed steep slopes and utilization of wider valley area for agriculture etc. Out of these five shrub species *Zanthoxylum armatum*, and *Debregeasia longifolia* were found growing in areas which were extensively used for livestock grazing. It was also observed that these shrub species are not preferred by the livestock for browsing. We observed that *Zanthoxylum armatum*, and *Debregeasia longifolia* were found growing in a uniform distribution pattern as shown in table 2.

Agave cantula, and *Adhatoda vasica*, though have a narrow ecological niche in comparison of other shrub species, but in case of riverine ecotone areas favoring niche of these shrub species were quite frequent, such as drier exposed sites and sandy river side. These species were found growing in both clumped and random distribution pattern. Shrub species such as *Debregeasia longifolia*, and *Rubus elipticus* preferred growing in sites with higher humus content in soil Cat 4 1.5–2 cm , Cat 5 >2 cm. these sites were having comparatively mesic soil then other dryer sites. We observed that these two shrub species have clumped distribution as there were fewer sites with such soil conditions, but where ever the soil condition were suitable these species were growing in abundance.

It was also observed that *Zanthoxylum armatum* was growing in marginal and unproductive lands among the riverside ecotone but not at the banks of the river. *Adhatoda vasica* was found to be growing in all soil types mesic, sandy and dry gravel type. *Agave cantula,* preferred dryer sites and *Debregeasia longifolia* was found to be growing in all areas in uniform pattern but seem to prefer deep and mesic sites in such areas the numbers of this shrub were high growing in clumped but irregular distribution pattern.

The diversity index value of shrubs in the riverine ecotone was 3.12 which indicates that the shrub community is stable in the ecotone. We found that the anthropogenic factor taken as independent factors does not seem to affect the dependent factor of the shrub population adversely. In different types of habitat where sampling was done for shrub species along the riverine ecotone, the negative r-value of regression ($r2= -0.057$) indicates that the shrub population is negatively affected by anthropogenic activates in the specific habitat types in a riverine ecotone. This also indicates that shrub community once established is relatively less affected by grazing and natural flood cycles.

It was observed that *Agave cantula*, as expected preferred the xerophytic sites but due to the topographical factors, the distribution pattern of *Agave cantula* was random. Species such as *Agave cantula*, and *Adhatoda vasica* preferred sites with canopy cover in category one.

The distribution of *Indigofera heterantha* was clumped. Similarly, other shrubs species *Viburnum cotinifolium* and *Clerodendrum phlomidis*. with lower frequency were also observed growing in association with *Indigofera heterantha* was having 6% frequency whereas *Viburnum cotinifolium* and *Clerodendrum phlomidis* were having only 2% frequency each. The distribution of *Viburnum cotinifolium* and *Clerodendrum phlomidis* was random at landscape level but within the site where this species was present the distribution was uniform. All these species were having narrow ecological niche along with riverine ecotone areas.

Lantana camara was growing in small numbers in more or less all habitat types, where the forest canopy cover was open to moderate. The species was found in anthropogenic disturbed areas, burnt forest sites, and riverine areas too, suggesting a somewhat wider ecological niche when compared to species such as *Indigofera heterantha*, *Viburnum cotinifolium*, *Clerodendrum phlomidis* and *Colebrookea oppositifolia*. However, the frequency of the *Lantana camara* was only 6%.

Barberis asiatica, *Debregeasia longifolia*, *Prinsepia utilis* Royle., and *Woodfordia fruticosa* were also found to grow in different habitat types such as xerophytic sites, meisic sites where conditions occurred with high humus depth (Cat 4–5) and high soil moisture. The distribution of *Woodfordia fruticosa* and *Barberis asiatica, Debregeasia longifolia*, *Prinsepia utilis* was random at landscape level but within the site where this species was present the distribution was uniform. The frequency of all other species excluding *Barberis asiatica* was only 6%, whereas *Barberis asiatica* was having a higher frequency of 38% along riverine ecotone. This suggests that all these species have a wide ecological niche and uniformly distribution pattern. Among these species, *Barberis asiatica,* has the widest ecological niche, and was having clumped distribution pattern with a frequency of 14%. Similarly, *Solanum virginianum* L. was also *Euphorbia royleana* was found to be growing in the dryer and open forest (low canopy cover) slopes and where humus depth was low (Cat: 1–2), but site conditions were less xerophytic when compared to sites where *Agave cantula* was growing. The distribution of *Euphorbia royleana* was random at landscape level but within the site where this species was present the distribution was uniform. This species was having clumped found growing with *Euphorbia royleana* with 8% frequency in the riverine ecotone. The PCA analysis indicates that the distribution of these species was random at landscape level but within the site where this species was present the distribution was uniform, having a narrow ecological niche when compared to *Agave cantula, Lantana camara, Berberis lycium*, etc. *Rubus elipticus* was found growing in different habitat types, boundaries of agriculture fields, and also on the riverbed sites where the sand portion in soil was comparatively higher than other studied sites, this indicates that the ecological niche of this species is wide allowing the species to grow in various soil conditions. The distribution of *Rubus elipticus* was random at landscape level but within the site where this species was present the distribution was clumped, with a high frequency of 32% in the riverine ecotone.

Adhatoda vasica was uniformly distributed at landscape level but within the site where this species was present the distribution was clumped the shrub species also have strongly correlated with *Eupatorium adenophorum* Spreng. and *Lantana camara* because ecological niche of *Adhatoda vasica* and *Eupatorium adenophorum* are narrow but due to topography of riverine ecotone, are overlapping dryer sites can still exist in between the rock faces and boulder sites adjacent to river bed sites where humus layer was in the category of 1–2, hence both species preferring different soil condition site. We found that the local village communities were highly dependent on fodder and fuel wood along the riverine ecotone. Due to heavy anthropogenic disturbances, *Lantana camara* was also found invading these pockets hence showing a positive correlation with *Adhatoda vasica*. It was observed that sharing the similar ecological niche *Barberis asiatica* was having a positive correlation with *Rubus elipticus* (0.6) and *Prinsepia utilis* (0.41). In these shrub species, Prinsepea utalis was having fewer individuals along the ecotone.

Berberis lycium was having a positive correlation with *Solanum virginianum* (0.47), *Rabdosia rugosa* (Wall. ex Benth.) H.Hara (0.46), and *Zanthoxylum armatum* (0.45). *Solanum virginianum* and *Zanthoxylum armatum* have a narrow ecological niche but their niche overlaps with the niche of *Berberis lycium.* In the sites where the micro-climatic and topographic conditions were favorable for *Solanum virginianum* and *Zanthoxylum armatum* they occurred frequently with *Berberis lycium*.

Clerodendrum phlomidis was having a strong positive correlation with *Rhus parviflora* (0.74) although both species have different requirements of soil conditions where humus depth was high in the category between 4–5 for growth. *Clerodendrum phlomidis* prefers soil with higher organic content and higher soil moisture, but in river bed sites where there were an open canopy and exposed dryer sites with boulders, *Rhus parviflora* was found growing in clumped distribution.

Euphorbia royleana was having a positive correlation with *Solanum virginianum* (0.58) both species have a similar and narrow ecological niche. But the population of *Solanum virginianum* was low when compared to *Euphorbia royleana* this indicated that the soil conditions which may promote the growth of *Solanum virginianum* were not frequent along the bank of river Pabber and Tons.

Indigofera heterantha had a strong positive correlation with *Rabdosia rugosa* (0.8) and *Murraya koenigii* (L.) Spreng. (0.60). *Indigofera heterantha* prefers shady sites but in some places where canopy cover was not very dense and soil was comparatively having less humus depth under cat 1–2 and floor was dryer and full of gravels within the depressions and valleys *Rabdosia rugosa* was growing with *Indigofera heterantha* in clumped form.

Prinsepia utilis was having a strong positive correlation with *Woodfordia fruticosa* (0.62) and *Rubus elipticus* (0.57). Two shrub species and *Prinsepia utilis, Rubus elipticus* have wide niche hence wherever the conditions were favorable these two species were found together in clumped distribution. Whereas *Woodfordia fruticosa* had a narrow ecological niche and wherever the niche conditions overlapped with and *Prinsepia utilis, Rubus elipticus*, *Woodfordia fruticosa* was found growing together.

It was observed that *Agave cantula* as expected preferred the xerophytic sites but due to the topographical factors, the distribution pattern of *Agave cantula* was random growing in a microclimatic condition where species were favored by soil condition. It was also observed that in general all the microclimatic sites dominated by *Agave cantula*, were resource scares sites in terms of fodder availability. The canopy cover was in category one. This species was found to be having a wider ecological niche.

Adhatoda vasica was growing in mesic sites along the riverine ecotone, preferring the area with open canopy cover and where soil conditions were highly sandy. These species have a narrow ecological niche but wider and uniformly distribution patterns along with the river bed sites of both rivers. This species was very commonly growing on both river bed sites with 38% frequency.

Colebrookea oppositifolia was growing in mesic sites along the riverine ecotone, preferring the area with moderate canopy cover and where condition due to natural depression has increased the soil moisture content and where dense growth of sapling and pole stage trees of *Mallotus philippensis*, *Albizia lebbeck* (L.) Benth., and *Pinus roxburghii* was observed. The humus depth in the sites where these shrub species were found was in categories 4 and 5. We also observed that where ever *Colebrookea oppositifolia* was growing normally in those sites were not having high anthropogenic disturbances was. The frequency of this species along the riverine ecotone was 6%, which indicates a narrow niche of the species. Similar conditions were observed for *Rabdosia rugosa* and *Zanthoxylum armatum*, as these shrub species also have a narrow ecological niche. The distribution pattern was highly clumped. The frequency of *Rabdosia rugosa* was 6% whereas the frequency of *Zanthoxylum armatum* was 32%.

Berberis lycium was found growing in different habitat types such as grassy slopes in pine forest, boundaries of agriculture fields. It also occurred on the riverbed sites where the soil texture was more on the sandy side, in comparison to other studied sites. The humus depth in the sites where these shrub species were found was in category 2. This indicates that the ecological niche of this species is wide allowing the species to grow in various soil conditions. The distribution pattern was uniform with a high frequency of 38% in the riverine ecotone.

Indigofera heterantha was growing in the sites where soil moisture and humus depth were almost similar as the sites where *Colebrookea oppositifolia* was growing. This species also preferred growing in moderate canopy cover area and shady areas. The humus depth in the sites where these shrub species were found was in categories 4 and 5. It was also observed that these sites were having the highest diversity of shrubs compared to the other open canopy sites. We also observed that the sites having such topographical characters explained above were not very common in the riverine ecotone.

The main tree species found were *Pinus roxburghii*, *Bombax ceiba*, *Dalbergia sisso*, there was a random clumped distribution of *Barberis asiatica*. Signs of heavy anthropogenic pressure such as wood collection, grazing, and lopping signs were present everywhere inside the sample plots and outside transact. The most dominant shrub species in sites one and two were *Agave cantala* Roxb., *Woodfordia fruticosa*, *Prinsepia utilis* Royle, *Eupatorium* spp., *Zanthoxylum armatum*, *Rhus parviflora*. In grasses, *Caryx infuscate* was dominant whereas *Anaphalis royleana* DC., *Verbascum thapsus* and *Thalictrum foliolosum* were dominant herbs.

In site three *Ficus palmata* and *Dalbergia latifolia* were dominant tree species, as the site was xerophytic *Euphorbia* shrub was dominating the site followed by *Woodfordia fruticosa*, *Prinsepia utilis*, and *Eupatorium adenophorum*. *Bidens alba* (L.) DC. and *Trifolium repens* were dominating herb species. The majority of the area was rocky and the riverine area was having some abandoned agriculture fields. This site was highly degraded due to overgrazing and the collection of fuel wood, as more than 70% of the area was rocky with very little grass cover. The rock faces were covering several km of the area along the riverside with a very little gentle slope, immediately about 20–30 meters along the river bed. Shrub and herb density was less than 20% and the majority of the area was sandy. It was observed that shrub *Adhatoda vasica* was also growing in abundance, in areas near river sites were ever the soil conditions are creating favorable conditions. On the uphill side, the steep slope was full of *Euphorbia* spp. and *Bauhinia variegata* L. and *Agave cantala*.

In site four *Ficus palmata* and *Pyrus pashia* were the dominant trees. Along the riverine ecotone, in some areas soil conditions allowed growing shrubs in a dense clumped distribution pattern (Odum 1971). *Colebrookea oppositifolia* and *Rubus elipticus* were the dominant shrub species, with some random distribution of *Adhatoda vasica*, *Cannabis sativa*, *Cynodon dactylon*, *Trifolium repens*, *Mazus reptans* N.E. Br., *Marchantia palmata* L., and *Parthenium hysterophorus* were main herb species. This site was also having abandoned agriculture fields which have gradually turned into grazing areas for livestocks. Evidence of Lopping, cutting of trees for fuel wood were present inside as well as out-side transact and sample plots. Site number six was dominated by *Alnus nepelensis* trees, *Celtis australis*, *Dalbergia latifolia*, and *Mallotus philippensis*. Many saplings, pole stage trees of *Alnus nepelensis* were observed outside the sample plots during the survey work. *Debregeasia longifolia*, *Barberis asiatica*, *Rubus ellipticus* Sm. and *Adhatoda vasica*, were dominant shrubs species with regular distribution. In herbs *Ephedra gerardiana* Wall. ex Stapf., *Trifolium repens* were dominant species. In general outside the sample plot areas and adjoining to transact the riverine area was having abandoned farming sites which have turned gradually into a grazing land area for livestock with moderate shrub cover.

In site number seven majority of our sample plots and transect area fall in the riverside boulder areas, few larger girth trees of *Pinus roxburghii* and small girth trees of *Mallotus philippensis* were found in sample plots. Only two shrub species *Barberis asiatica* and *Zanthoxylum armatum*, were having dominant growth in clumped distribution patterns (Odum 1971) where the soil conditions allow growing. The vegetation was xerophytic. At this site, the river Tons was covered with steep slopes and rock faces but in some areas where slopes were less steep, there was moderate grass cover. In areas where the river was broad and not going through rocks, there was dense growth of *Alnus nepelensis* trees. Only *Cannabis sativa*, *Cirsium wallichii* DC. and *Parthenium hysterophorus* were dominant in herbs where ever the soil conditions are favorable.

Site number eight which was tributary rivulet to river Tons was dominated by young growth of *Alnus nepelensis* trees and *Pinus roxburghii* trees on both sides of the narrow valley. Four out of five of our sample plots and one transact was laid on the narrow stream. The majority of *Alnus nepelensis* trees were old grown but many trees outside our transact and sample plots were in the sapling and pole stage indicating that this area is in the early succession stage.

As mentioned this is a narrow valley shrub diversity was low and only *Debregeasia longifolia* was dominating shrub. *Cannabis sativa* and *Parthenium hysterophorus* were whereas the dominating herb covers which less than 50% were in general. This site was situated in a natural depression at one of the furrow sides of the mountain. Due to this special condition of natural depression, soil moisture content was higher and there was dense growth of sapling and pole stage trees of *Mallotus philippensis*, *Albizia lebbeck* and *Pinus roxburghii* throughout this site. *Alnus nepelensis* seedling and sapling was having very regular distribution along the rivulet.

On site nine the dominant tree species of were *Mallotus philippensis* and *Pinus roxburghii*, whereas the density of both the trees was on the lower side as compared to other sites in the riverine ecotone. In riverine areas outside transact and our sample plots *Alnus nepelensis* was having dense growth in patchy and scattered distribution. Only two shrubs *Rubus ellipticus* and *Berberis asiatica* Roxb. ex DC. were dominant. *Cynodon dactylon*, *Thalictrum foliolosum* and *Trifolium repens* were dominant herb species.

At this site, river Tons enters into a wide valley and the river banks are extended 150–200 meters on both sides which regularly get flooded cyclically. Hence there was no presence of any shrub cover but in this riverine ecotone area where there were conditions for grass to develop properly. In dryer sites, *Agave cantula* was also growing but it commonly found to be grown in boundaries of agriculture fields. The evidence of lopping cutting were also present.

At the site ten main tree species were *Mallotus philippensis*, *Alnus nepelensis* and *Toona ciliata*. Among these *Mallotus philippensis* was the dominating tress. This side was situated on south-western slope which is considered the warmest aspects, and this was also reflecting in the vegetation inside and outside of our transact and sample plots. The site was having xerophytic conditions with *Agave cantula* and *Adhatoda vasica* dominating the shrub layers. The slope of the mountain was too steep in majority of riverine area, filled with loose scree and stones with almost negligible grass cover. This site was not being used by local villagers for any agriculture or fuel wood collection. This was the driest site among all with south western slope there were good distribution of Xerophytic species, in shrub *Agave cantula* and *Euphorbia royleana* and in tress *Pinus roxburghii* and *Toona ciliata*, trees were present but the distribution was random and only isolated individuals were standing here and there. The slope angle category 6 and grass cover was very less. The entire site has loosely blinded soil with gravels and small stones. *Mallotus philippensis* and *Albizia lebbeck* were occupying ridges and furrows, growth of *Indigofera heterantha.* shrub was also good in such areas which serve as food source to monkeys. The riverside area was not being utilized by local villagers for grazing ground or any agricultural practice.

CONCLUSION

The riverine ecotone of Pabber and Tons is also influenced by anthropogenic effects, this was evident from our survey that eight (N=8) out of total ten (N=10) sites surveyed have signs of collection of fodder and fuel wood, and grazing ground for livestock. The majority of riverine areas are a narrow valley and the wider valley area along the length of these rivers is extensively being used for grazing of livestock and fodder and fuel wood collection regeneration of all tree species except *Alnus nepelensis* and *Mallotus philippensis*. We found that the grass, shrub species being used as fodder for livestock were in acute shortage. And wherever these species are available are under enormous pressure. As the studies on the dynamics of forest ecosystems are primarily concerned with changes in the structure and composition of forests over time, which includes the response of forests to various natural and anthropogenic disturbances (Pretzsch 2009, Taylor *et al*. 2009, Kneitel 2012). We also studied the response of forests to various natural and anthropogenic disturbances. We found that the ecosystem in ecotone areas is more or less stable even after the cyclic disturbances of flooding, fire, and other anthropogenic causes. The species diversity indices "Shannon Index" indicates that herb communities have adapted and evolved according to these cycles of disturbances because the herb diversity in the ecotone is uniformly distributed and no single herb species is dominant, throughout the ecotone. Vegetation communities around the world have been affected by anthropogenic disturbances for millennia (Bond *et al*. 2005, Perry & Millington 2008) causing changes in vegetation structure and composition and leading to different successional trajectories. We found that herb species with a wider niche have evolved in such a way that these occur in various soil conditions in the ecotone. The resilience of herb species such as *Cannabis sativa*, *Cirsium arvense*, *Cynodon dactylon*, *Geranium molle*, *Parthenium hysterophorus*, *Poa annua*, *Thalictrum foliolosum*, *Trifolium repens*, *Verbascum thapsus* and *Pteridium aquilinum* was higher to various natural and anthropogenic disturbances and the herb species were found growing in various soil types and site conditions.

Our hypothesis that all plant communities in ecotone have adapted and evolved according to these cycles of disturbances was occurring to be true because the results of regression analysis shows the evidence that individual species of shrubs and herbs may be affected more by site parameters such as favorable soil conditions, canopy cover, shade, aspect, etc. rather than direct impact of anthropogenic disturbances on population size. Species with wider ecological niche were more common and higher in numbers, for example, *Adhatoda vasica* and *Agave cantula* were found to be growing in all soil types mesic, sandy and dry gravel type with good population representation. *Rubus elipticus* was also a dominating shrub, In the mesic sites *Rubus elipticus*, *Zanthoxylum armatum*, *Rhus parviflora* and *Barberis asiatica*, were growing in random clumped distribution pattern whereas *Agave cantula, Barberis asiatica* and *Colebrookea oppositifolia* were growing in random distribution patterns. In herbs *Cannabis sativa*, *Cynodon dactylon*, *Trifolium repens*, *Verbascum thapsus*, *Thalictrum foliolosum*, *Pteridium aquilinum*, *Parthenium hysterophorus*, *Cirsium arvense* and *Geranium molle* were found to grow in more than six (N=6) out of nine (N=9) sites. *Ephedra gerardiana*, *Persicaria amplexiculis* D. Don. and *Urtica dioica* L., were found to be growing in the clumped form in river bed areas.

When we focus on tree species normally fifteen species except for *Syzygium cumini, Ficus palmata* and *Bombax ceiba,* were extensively being used for the collection of fuel wood and fodder requirements. Only *Alnus nepelensis*, *Acacia catechu*, *Dalbergia latifolia* and *Mallotus philippensis* were having seedlings. Other tree species with old growth were not forming dense forests and were scattered in random distribution patterns. Livestock grazing, frost, and fire seem to affect healthy regeneration in general. Chronic disturbances play a strong role in shaping the vegetation structure and composition of these forests (Kumar *et al*. 2009, Khali & Bhatt 2014, Wangchuk *et al.* 2014). Similar patterns have been observed by other authors too in Himalayan ecosystems. Forest degradation in the Himalaya occurs primarily due to small-scale chronic disturbances (Singh 1998). Natural and human disturbances both are considered as major drivers of species diversity in plant communities. In general, frequency and magnitude of disturbance are key factors for changes in species diversity (Shrestha *et al*. 2013, Baboo *et al.* 2017).

Overall *Mallotus philippensis*, *Alnus nepelensis* and *Pinus roxburghii* were dominating tree species, at landscape scale along the ecotone. Even out of four species *Alnus nepelensis*, *Acacia catechu*, *Dalbergia latifolia* and *Mallotus philippensis* only *Alnus nepelensis* trees were having saplings in good number (N=76) other species were combined having less than twenty-six (N=26) seedlings in total which is clearly because of edge effect in ecotone because of overlapping of contrasting habitats and capacity of these species to use anthropogenic habitats. We found good evidence in our study that plant community patterns in the ecotone of river Pabber and Tons have a strong influence on synergetic disturbances anthropogenic and natural on plant regeneration distribution pattern is determined. Also due to overlapping of habitat and edge effects the plant species have adapted and evolve in such a way that wider ecological niche species were having higher numbers, and over the entire ecosystem is stable.

ACKNOWLEDGEMENTS

This research was funded by a grant from Ministery of Environment forest and Cimate Change. We are grateful to Govind Ballabh Pant Institute of Himalayan Environment & Development Almora funding. We are also grateful to Doon University School of Environment and Natural resources for providing necessary logistic support to conduct this study.

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