RESEARCH PAPER:

Riparian vegetation analysis along Tungabhadra River

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SUMMARY

The present study examined the variation in riparian vegetation communities along the Tungabhadra River, Karnataka, India. Direct sampling of 0.3 ha, by quadrat method for the study of plant communities and quantification of vegetation, documented 26 species and 87 individuals. Quantitative analyses on species diversity in addition to phytosociological attributes were conducted. The plant communities were determined in percentage of frequency, abundance value, relative density and importance value. The phytosociological studies revealed that in most part of area, the vegetation was characteristically dominated by *Pongamia pinnata* species followed by *Acacia nelotica*, which were also recorded as the most abundant and frequent species of the study area. The study also emphatically revealed that increase in the anthropogenic pressures within the river basin and surrounding landscapes have persistently stressed the riparian ecosystem structure adversely, besides altering its composition. The results indicated that the mean density and basal area of trees per plot were higher in the upstream of river than downstream. In addition, species composition indicated a relatively low or poor similarity between upstream and downstream. The Shannon–Weiner diversity of upstream was found to be 3.6, which was higher than downstream. The results of the present study clearly brought out the need for preparing and implementing site-specific conservation plans for riparian ecosystem.

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The word "Riparian" itself means along the river margin. Plant communities seen along the river margins are commonly referred to as the riparian vegetation. From the beginning to the end of a river, the riparian zone is highly influenced by the quantum and flow of water in the river channel. Usually altitude, total rainfall, duration of rainy season, wind, and temperature along with soil characteristics, influenced by climatic factors determine the nature of plant communities (Nair, 1994). The riparian wetlands are those areas that are inundated or saturated by surface or ground water at a frequency and duration sufficient to support, and that under normal circumstance do support a prevalence of vegetation typically adapted for life in saturated soil conditions (James *et al.,* 1992). Variations in the environmental conditions provide a diversity of inhabitants, for both aquatic and terrestrial animal community (Cairns and Pratt, 1995).

The unit characteristics of riparian system result from the spatial allocation and configuration. The plant communities in these systems are likely to be affected by both longitudinal (*i.e.*, upstream-downstream) (Vannote *et al.,* 1980) and transversal (*i.e.,* stream- floodplain or floodplainbasin) (Newbold *et al.,* 1982) linkages for species recruitment and species diversity (Tabacchi, 1995). Riparian zones have been reported as some of the most species rich and most productive systems and they are also some of the most sensitive to human influence and potentially threatened ecosystems (Malanson, 1993). The riparian canopy regulates stream temperature through shadowing and provides organic matter via litter fall, while their root systems stabilize the bank and filter lateral sediment and nutrient inputs, thereby controlling stream sediment and nutrient dynamics.

The surfaces of submerged leaves are sites of primary and secondary production by micro algae and bacteria, which can be rival that of phytoplankton and bactereophils in water column. The community serve as food for grazing invertebrates and protozoa, contibuting to bio-purification of organically polluted watercourses, and can be a substantial source of planktonic microorganisms.

In the lower reaches the riparian forests act as a buffer between the upland and the river. Rainfall on the watershed is efficiently absorbed by the litter covered forest floor. Evaporation rates are high so that runoff through the forest is generally kept at minimum. Runoff from adjacent uplands flowing across the riparian forest is purified by removal of inorganic nutrients, eroded sediments, and other materials such as agricultural pesticides (James *et al.,* 1992). Riparian communities within semi-arid and subarctic regions, where floods are extremely important for watering, fertilizing, cleaning, and sowing the land, are generally most severely altered by impoundment because water is so scarce. Low-altitude areas are generally more sensitive to water regulation than high altitude areas because the terrain is flatter and small alterations in flow may affect vast areas (Petts, 1984).

This study made an attempt to assess the status of the species composition, structure, distribution and dynamics of the riparian vegetation in an altitudinal gradient along the river.

Materials and Methods

Quadrat method was employed for the analysis of riparian vegetation. 10m wide and 10m long quadrats were laid on the riparian areas along an altitudinal gradient. Minimum size of the quadrat was determined by species area curve method. The dominant communities' *i.e.*, the trees were given importance. Hence, the 10x10 m quadrats were found to be most suitable. The plant components were identified, counted and measured. Girths of all the living trees = 20cm were measured 1.3 m (breast height) from the ground. For multi-stemmed trees girths were measured separately and the sum was calculated. The phyto-sociological characters like frequency, density, abundance, dominance and important value index were analysed. These characters were analysed by following the methods of Curtis and Mc Intosh (1950) and Misra (1968). Plant components were identified during the field visit. Photographic documentation was also done. The Shannon-Wiener index was used to calculate species diversity (Shannon and Wiener, 1963; Magurran, 1998).

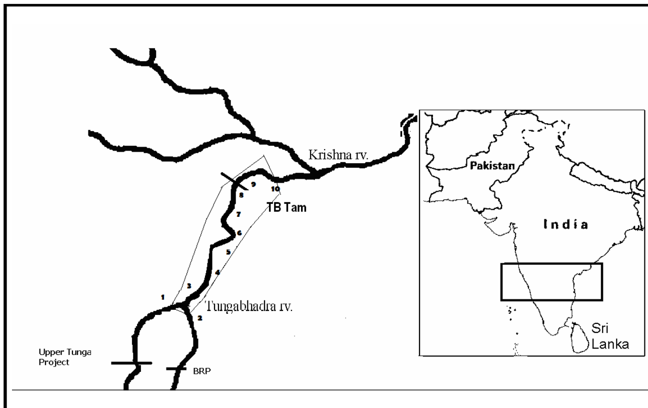

Fig. 1: Map of study area, Tungabhadra River Sub Basin

Study area:

River Tungabhadra is the largest tributary of the river Krishna, contributing an annual discharge of 14,700 million m^3 at its confluence point to the main river. The river is transboundary and flows about 531 kms from its origin in Karnataka state, before it joins river Krishna at Sanghameshwaram near Kurnool in the neighbouring state of Andhra Pradesh (Fig. 1). The TBSB stretches over an area of 48,827 Sq. km in both the riparian states of Karnataka (38,790 Sq. km) and Andhra Pradesh (9037 Sq. km) and finally joins Krishna that flows into Bay of Bengal.

Tungabhadra covers seven districts (Shimoga, Chikamaglur, Davanagere, Haveri, Bellary, Koppal and

Table 1 : Sampling locations in Tungabhadra sub basin

Sample No.	Sample Locations	Latitude E	Longitude N	Alt (MSL)
1.	Vaishnavahalli, Tunga River	75°38'40.37"E	13°58'26.46"N	564
2.	Bhadra River, Hole Honnur	75°40'32.61"E	13°59'43.75"N	566
3.	S. Kodamaggi, Tungabhadra River	75°41'39.25"E	14° 2'36.28"N	555
4.	DS, Honnali	75°38'35.45"E	14°15'58.28"N	541
5.	Sarathi	75°49'12.25"E	14°34'30.97"N	528
6.	Mylara	75°40'53.28"E	14°47'50.93"N	516
7.	Madalagatti	75°53'20.79"E	15° 6'39.42"N	502
8.	TB Dam	76°19'31.02"E	15°16'7.86"N	492
9.	Shanapur	76°38'49.54"E	15°26'33.96"N	395
10.	Honnarahalli	76°56'35.11"E	15°45'33.69"N	366

Raichur) and twenty-eight taluks (Chikamagalore, Tarikere, Koppa, Sringeri, N R Pura, Shimoga, Bhadravathi, Chennagiri, Harihar, Ranebennur) in Karnataka and four districts in Andhra Pradesh (Karnool, Cudappa, Ananthpur and Mahaboob nagar), the sub-basin is mostly rainfed, dominated by red soils with an average annual rainfall of 1200 mm. The upper basin of Tungabhadra is characterized by undulating terrain with high rainfall while the lower portion of the basin is characterized by much lower rainfall, drought conditions and mainly plain terrain. Agriculture is the major occupation across the basin. The major crops grown are paddy, jowar, sugarcane, cotton and ragi (finger millet). The river catchment includes a number of large and small-scale units supporting industrial activities. Fishing is next major activity that supports more than 10,000 families. Brick making, pottery etc., are other livelihood options practiced along the basin. For this study, sampling locations were selected from Vaishnavahalli with altitude of 564 mts (MSL) to Honnarahalli 366 mts altitude from MSL (Table 1).

Results and Discussion

Hydrological disturbances are a key factor for the riparian vegetation, which is a highly dynamic ecosystem prone to external forcing. Random fluctuations of water stages drive in fact the alternation of periods of floods and exposure of the vegetated plots. During flooding, the plots are submerged and vegetation is damaged by burial, uprooting and anoxia, while during exposure periods, vegetation grows according to the soil moisture content and the phreatic water table depth. The distribution of vegetation along the riparian transect is then directly connected to the stochasticity of river discharges.

River damming can have remarkable impacts on the hydrology of a river and, consequently, on the riparian vegetation. Several field studies show how the river regulation induced by artificial reservoirs can greatly modify the statistical moments and the autocorrelation of the discharge time series. The vegetation responds to these changes reducing its overall heterogeneity, declining - substituted by exotic species - and shifting its starting position nearer or far away from the channel centre. These latter processes are known as narrowing and widening, respectively (Camporeale and Ridolfi, 2006).

The structure and status of riparian vegetation was found to vary according to the topographical and demographical features of the area. Most of the riparian lands and vegetation in the lower elevations has been lost. The characteristics of a vegetation type is mainly dependent upon the dominant communities. The important value index is an analytical phyto-sociological index which represents the relative richness in terms of density, frequency and dominance of each species. The result shows that 10 sites have different species richness, evenness, or Shannon-Wiener index values. Plant communities were determined on the basis of Importance Value Index (IVI).

When the two zones (upstream and downstream) were compared, zone-I was found to possess the highest value for the basal area cover, species richness, and the number of individuals. A good percentage of the tree species present in the top 3 quadrats come under >100m girth class. Almost equal distribution of the middle girth classes and the some increase in the number in the lower girth class are noticeable and has provided a picture of the structure of the vegetation based on the different life forms found in the quadrats. The distribution of different girth classes and the height classes provide a clear picture of the structure of the vegetation. Here, the trees and lianas dominate and the medium sized trees dominate the emergent trees in the case of number and species. This explains one of the unique characteristics of the riparian ecology where the riverside always remain open and its influence determines abundance and presence of the medium sized evergreen and riparian tree species.

The altitudinal range of the entire study area is between 360-564 m MSL. The diagram indicates that the upper limit of the evergreen forest elements is 540 m. This distribution can continue into higher altitude but the study area is limited to above 360 m. To describe completely one has to study the distribution along the entire basin.

There were 26 species and 87 individuals in all quadrats. Highest numbers of species (16) were presented in first three sampling locations Tunga (L_1), Bhadra (L_2) and S. Kodamaggi (L_3) in the upstream and lowest 5 species were recorded from the downstream sampling locations L_9 and L_{10}. The highest numbers of individuals were presented in Tunga (L_1) had 18 Bhadra River (L_2), which had 17, while other locations namely Honnali (L_4) had 11, S.Kodamaggi (L_3), Mylara (L_6) had 9 individual numbers each (Table 2). Downstream locations TB dam (L_8) recorded 4 individual species and Honnarahalli (L_{10}) recorded number of individuals 5. It clearly indicates that downstream sampling stations recorded very lowest number of individuals than the upstream sampling stations.

The highest number of individual species were, *Pogemia pinneta* had 14, *Acacia nelotica* had 11, *Azadirachta indica* had 10, *Pongamia glabra* had 9, Thogase had 6, *Tamarindus indica* had 4, *Alangium salvifolium* and *Tectona grandis* had 3, *Abrus precatorius, Eucalyptus* spp., *Ficus glomerata,*

Table 2 : Plant species in the Tungabhadra river sub basin

Botanical name	Vernacular name	L_1	L_2	L_3	L_4	L_5	L_6	L_7	L_8	L_9	L_{10}	Total
Abrus precatorius	Goravanji						2					2
Acacia nelotica	Kari jali				9					2		11
Acacia sp.	Acacia	1										1
Agave sp.	Katthale		1									1
Alangium salvifolium	Ankali							3				3
Artocarpus integrifolia	Halasu											0
Azadirachta indica	Bevu	2	2	1					3	1	1	10
Bambusa arundinacea	Bamboo	1										1
Coleus spicatus	Patre					5						5
Dalbergia latifolia	Beete								1			1
Diospyros peregrina	Gabli			1								1
Eucalyptus sp.	Euacalyptus		2									2
Ficus benghalensis	Ala							1				1
Ficus glomerata	Atthi	1					1					2
Ficus religiosa	Arali										1	1
Mangifera indica	Mavu	1	1									2
Mellia dunia	Hebbevu						1					1
Pongamia glabra	Gobbara mara	4	3	2								9
Pongemia pinneta	Honge	8		3			3					14
Putranjiva roxburghii	Rudrakshi						1					1
Saraka indica	Ashoka		2									2
Tamarindus indica	Hunase							1			3	4
Tectona grandis	Tega		1		2							3
Xylia xylocarpa	Jambe									1		1
Grewia tiliaefolia	Thogase		5	1								6
Vateria indica	Hugada mara			1			1					2
Total		18	17	9	11	5	9	5	4	4	5	87

Mangifera indica, Saraka indica, Artocarpus integrifolia and *Hesarillada mara* had 2. *Acacia* spp., *Agave* spp., *Bambusa arundinacea, Dalbergia latifolia, Diospyros peregrine, Ficus benghalensis, Ficus religiosa, Mellia dunia, Putranjiva roxburghii, Xylia xylocarpa* had single individuals.

The species having highest IVI were considered as the leading dominants of the community. The plant communities in the study area were dominated by *Ficus religiosa, Ficus benghalensis, Tamarindus indica, Azadirachta indica, Pongemia pinneta* and *Acacia nelotica.* Phyto-sociological study showed that *Ficus religiosa* has the most huge IVI in the current study area. None of the species showed regular distribution pattern (Table 3).

Usually rivers and streams have a one-way downhill flow, and in these lotic environments flow rate is of prime importance in order to determine the nature of plant and animal community. The deterioration in the species composition and structure of riparian vegetation due to decrease in the flow of water can be observed in the riparian area just below Tungabhadra dam. The riparian zones are generally common lands. Overuse of this vegetation and the river is a major problem. Indiscriminate felling of riparian trees was located at many sites mainly for fire wood, timber use and agriculture use, destroyed the riparian habitat. Increased uptake of water for irrigation and related purposes along with sand mining has affected the water table, which indirectly has great influence on the riparian vegetation (L_9 and L_{10}).

Jacob in 1988 describes the importance of a profile diagram for analyzing the structure of a tropical rain forest and of other forest ecosystems. Here, in the two zones and within the zones, based on local geography, flow of river, altitude the nature and structure of the existing vegetation showed variations. This can only be analysed by constructing a clear profile picture of different zones. The riparian forest of upstream contains emergent as well as non-emergent evergeen tree species. Some true riparian species also occupies a particular position. The deciduous elements also appear in particular dimension. The profile of a riparian forest along the river margin

Table 3 : Analysis of vegetation in Tungabhadra river

Botanical name	Frequency	Density	Abundance	Basal area	RD	RF	RBA	IVI
Abrus precatorius	0.033	0.067	2.000	132.729	2.410	2.083	0.649	3.382
Acacia nelotica	0.133	0.367	2.750	546.736	13.253	8.333	2.675	13.684
Acacia sp.	0.033	0.033	1.000	19.634	1.205	2.083	0.096	2.275
Agave sp..	0.033	0.033	1.000	159.480	1.205	2.083	0.780	3.644
Alangium salvifolium	0.033	0.100	3.000	86.588	3.614	2.083	0.424	2.931
Artocarpus integrifolia	0.033	0.067	2.000	9.168	2.410	2.083	0.045	2.173
Azadirachta indica	0.167	0.333	2.000	950.955	12.048	10.417	4.653	19.722
Bambusa arundinacea	0.033	0.033	1.000	452.377	1.205	2.083	2.213	6.510
Coleus spicatus	0.100	0.167	1.667	219.889	6.024	6.250	1.076	8.402
Dalbergia latifolia	0.033	0.033	1.000	240.521	1.205	2.083	1.177	4.437
Diospyros peregrina	0.033	0.033	1.000	18.347	1.205	2.083	0.090	2.263
Eucalyptus sp.	0.067	0.067	1.000	27.886	2.410	4.167	0.136	4.440
Ficus benghalensis	0.033	0.033	1.000	5399.596	1.205	2.083	26.419	54.922
Ficus glomerata	0.067	0.067	1.000	637.338	2.410	4.167	3.118	10.403
Ficus religiosa	0.033	0.033	1.000	8318.577	1.205	2.083	40.702	83.487
Mangifera indica	0.067	0.067	1.000	42.029	2.410	4.167	0.206	4.578
Mellia dunia	0.033	0.033	1.000	134.436	1.205	2.083	0.658	3.399
Pongamia glabra	0.100	0.267	2.666	375.044	9.638	6.250	1.835	9.920
Pongemia pinneta	0.233	0.500	2.143	284.944	18.072	14.583	1.394	17.372
Putranjiva roxburghii	0.033	0.033	1.000	314.150	1.205	2.083	1.537	5.158
Saraka indica	0.067	0.067	1.000	8.121	2.410	4.167	0.040	4.246
Tamarindus indica	0.067	0.133	2.000	1673.445	4.819	4.167	8.188	20.543
Tectona grandis	0.067	0.100	1.500	35.713	3.614	4.167	0.175	4.516
Xylia xylocarpa	0.033	0.033	1.000	31.918	1.205	2.083	0.156	2.396
Tectona grandis	0.100	0.200	2.000	127.962	7.229	6.250	0.626	7.502
Xylia xylocarpa	0.067	0.067	1.000	190.350	2.410	4.167	0.931	6.029

varies from that of an islet or of a lower altitude, or of a disturbed zone. These variations, alignment and arrangement of different species are formed by the interaction of the system with the environment and other physical stress. This type of response of the system, structural dynamism in response to climate and physical forces gives the trends, direction and dimensions of ecosystem development.

The present vegetation in different zones and different samples gives a profile of the vegetation structure. Putting together these small pieces we get a clear picture of the structural organization of the riparian plant communities. The vegetation in the zone-I was structurally similar to evergreen forests (360- 400m). Good samples of riparian vegetation were not observed in the lower zones due to high disturbance caused by various activities like sand mining, encroachment etc. Only small patches were remaining.

Sand mining is the most destructive anthropogenic activity on the riverine habitat. Tungabhadra river is not an exception, sand mining takes place almost uniformly throughout the river. As a result, the riverbanks were seriously eroded, damaged and most of the riparian lands have disappeared. Older folks recollected presence of abundant riparian vegetation of bamboos and other wild trees.

Fregmentation of the riparian vegetation through clear felling and encroachment has seriously affected the entire riparian vegetation. Loss of continuity, deterioration in the species composition and structure are main effects of fragmentation. In the study area almost all-riparian vegetation were found to be cut down by local people for different purposes. Encroachment and reclamation of riparian area and vegetation for various purposes are another important anthropogenic impact on the riparian vegetation. This was noticed at many places. Local residents have invaded riparian areas at many places for various agricultural purposes.

The lower riparian areas are almost completely destroyed. Fragmentation and clearing of riparian forests, changes in the hydrological and physiochemical parameters of water and changes in the terrestrial and aquatic environment mainly due to human activities and are the major factors influencing riparian vegetation. The changes in the quantum and availability of water due to changes in the flow, irregular regulation and flushing out of water controlled by dams, uptake and diversion of water for various purposes, indiscriminate sand mining and subsequent lowering of water level etc has great influence. Many species located here have very important conservational values at national and international levels. Motor pumps operating directly from the river both legally and illegally were disrupting the continuity of the remaining vegetation at more than hundreds of location in the upstream and downstream.

Diversity indices:

Diversity is often represented in the form of statistical indices. These are referred to as heterogeneity indices. The Shannon (H= pi *log pi) and Simpson's (D = ∑n (n-1)/ N (N-1) diversity indices for this study indicate that the area is represented by few species (Simpson, 1949). The highest diversity (Shannon 0.98 and Simpson 0.99) was recorded from upstream of the river where as downstream showed lowest diversity (Table 4 and Fig. 2). These results were clearly supported by the IVI values of the species. It depicts the impact of factors like livestock grazing and other human intervention on the regeneration of different species.

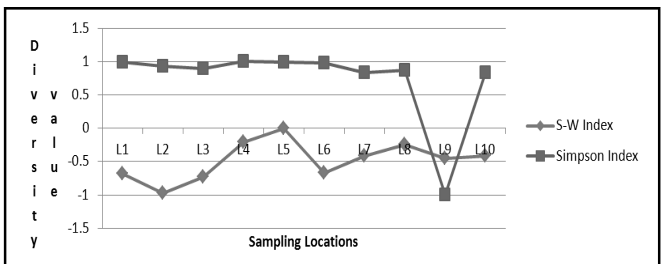

Fig. 2: Species diversity in Tungbhadra river

The seed dispersal pattern of the riparian plants have significant role in the development of the community. Most of the species are distributed through water. Another important character of riparian forests is that they support lot of epiphytic species. The riparian habitat provides microhabitat to a large extent by providing shade, trapping silt and sediments by anchoring roots which in turn supports a number of diverse organisms.

It is not easy to assess the biodiversity potential of the entire riparian habitat along the study area. Besides these forest areas, the lower areas also had very good biodiversity potential. Many species of fishes were located in the low lands. Many bird species were found in the wetlands. In the low altitude sampling stations like Madalagatti (L_7) and Honnarahalli (L_{10}), large number of migratory wetland birds were recorded. An attempt was made here to analyse the biodiversity richness of this riparian vegetation area. This richness in the biodiversity brings out the importance of the riparian forests.

Conclusion:

The riparian forest is a unique and rich natural ecosystem which has great influence on the adjacent aquatic as well as terrestrial systems. In addition to stabilizing and safeguarding the river bank from erosion, the riparian ecosystem increases the biotic productivity and the biodiversity potential of the river. They also have a major role in influencing the water quality of the river. In the highly degraded condition of forest ecosystems in our state, the remaining riparian forests have a significant role as they support human life especially of the majority of ordinary people including the marginalized indigenous communities

The emphasis of this study is on the status of the remaining riparian vegetation in the upstream and

Table 4 : Diversity indices in the study area

Sampling location	S-W index	Simpson index	Number of species	Numbers individual
L_1	-0.68666	0.996273292	7	18
L_2	-0.98161	0.929824561	11	17
L_3	-0.72831	0.888888889	6	9
L_4	-0.20592	0.997963717	2	11
L_5	0	0.986842105	1	5
L_6	-0.66895	0.976190476	6	9
L_7	-0.4127	0.833333333	3	5
L_8	-0.24422	0.866666667	2	4
L_9	-0.45154	-1	3	4
L_{10}	-0.4127	0.833333333	3	5
Mean	-0.47926	0.730932		

downstream of the Tungabhadra river. Some remaining riparian forests extremely fragmented and their conservation is an urgent need. Almost all riparian vegetation has been lost in the lower areas due to various anthropogenic activities. After studying the species composition and ecological importance of this ecosystem, the most prominent plant components and their peculiarities have been listed.

In view of the acute scarcity of all natural resources, especially of drinking water and the unchecked degradation of the river system, in depth and location specific studies are required for corrective action. Regeneration of forest areas, afforestation of the barren or dry hills, and conversion of dry forests and plantations to more wet and evergreen areas and stabilization of river banks, all require relevant information about the suitable plant components and their plant community composition for varying conditions. Only on the basis of detailed studies and field experiments on afforestation and eco-restoration, successful watershed management programmes can be planned and put into practice at the river basin level.

This study is a preliminary attempt and needs further scientific investigations, long-term observations and documentation. Extension of this study to the river basin level, detailed studies on the catchment areas and field experimentations on the regeneration process in some locations at least, are future prospective studies that need to be investigated.

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