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Research Article

HERB LAYER BIOMASS OF THE RIVERINE FOREST ALONG SONG RIVER IN FOOTHILLS OF WESTERN HIMALAYA, UTTARAKHAND, INDIA

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ABSTRACT

Riverine ecosystems are transitional zone between the aquatic and terrestrial habitats and they have their own unique characteristics like soil, floral and faunal composition, community structure, relationships and biomass production. Variations in the environmental conditions provide a diverse nature which creates and supports a unique ecosystem. Herbaceous biomass assessment study was carried out along the Song River in Doon Valley. Harvest method was employed to collect the data on the monthly basis from the riverine ecosystem along the Song River. It was found that there was considerable variation in monthly production of herbaceous biomass.

INTRODUCTION

Riverine ecosystems are complex features of the landscape displaying structures and processes that reflect the influence of many variables at a range of scales. Thus, the physical, chemical and ecological character of riverine ecosystems differs between them and may change over time, often at different rates and in different ways (Thoms, 2006). In addition, the structure and function of riverine ecosystems also varies downstream. From the beginning to the end of a river, the riverine 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). Due to this availability of watered condition, humidity, and open areas provided by the river, vegetation present in this area will have some unique characteristics. The availability of water, seasonal flooding and sedimentation influences the vegetation and also its development. The dynamic but stable environment also provides a unique ecosystem essential for the normal health of the river system.

Constantly changing mosaics of habitats are present along the riverine landscapes (Ward *et al*, 2002). The environmental gradients and natural disturbance regimes that characterize these open systems make them complex and diverse systems that are very sensitive to human activities (Bornette *et al,* 1998; Ward, 1998). The fertile and flat soils of the river floodplains tend to be highly modified by agricultural land use, urbanization and industrialization (Smits *et al*, 2000).

Riverine ecosystems have been described as changing ecosystems far from equilibrium, alternating between periods of relative stasis and dramatic change (Ward *et al,* 1999). Plant communities in a riverine zone may include some common elements or may be true riverine plant which can only be seen within this environment, many processes of their lifecycle are supported by this riverine environment, for example they need more water for their growth and seed dispersal, etc. or may need a seasonal availability of water. These plants, their establishment and development depend on the riverine environment. The riverine 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 (Naiman and Decamps, 1997).

Riverine forests play an important role in river ecosystem structure and function, Stabilizing riverbanks (Cordes *et al,* 1997; Kubicek *et al,* 2008). Their frequent flooding and linear structure leads to a species-rich ecosystem (Ward *et al*, 2002) but also makes them highly susceptible to invasion by exotics (Brown and Peet, 2003; Renofalt *et al,* 2005; Francisca *et al,*

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2006). The relationship between species richness and productivity in the herb layer was studied in European deciduous forests (Axmanova *et al,* 2011). Phytocoenological characteristics and production analysis of herbaceous layer biomass of the softwood floodplain forests was analysed (Vojtkova *et al,* 2014).

The structure and relationships of riverine forests in different altitudes of Khoh river of Garhwal Himalayas were studied (Joshi, 1984). Impact of *lantana camara* L. invasion on four major woody shrubs along Nayer river of Pauri Garhwal, in Uttarakhand Himalaya was studied (Dobhal *et al,* 2010). Preliminary investigations on various ecological parameters of the tributaries of the Ganga and Yamuna were studied by various workers (Ray *et al,* 1966; Shah and Abbas, 1979; Sharma and Singh, 1980; Badola and Singh, 1981; Singh and Dobriyal, 1981; Nautiyal, 1986; Singh *et al*, 1994 and Mahar, 2002). Present study was conducted on the herbaceous biomass of the riverine ecosystem along the Song River in Doon Valley.

MATERIALS AND METHODS

Study Site: The study site riverine ecosystem of Song River under investigation is present in Eastern part of Doon Valley, Western Himalaya, Uttarakhand. Song River rises in Tehri district and unites with the Bandal River near Maldevta, Dehradun and finally joins the river Ganga in Haridwar. Song River is one of the largest river systems draining the major part of Doon valley forest which extend up to the length of 24 km with the total catchment area of about 1115 sq. km.

The main concentration is on the part of the river from the Maldevta which we consider as the origin of Song River in Dehradun to Gullarghati which itself is a swampy due to the river. Song River is dry for nine months in the year, but during the rains they carry a considerable volume of water. Availability and non-availability of water in Song River greatly affects the vegetation of the surrounding. East and West banks of the river show the very much variation in the vegetation and there will be a variation in the production of biomass.

Three representative sites viz Maldevta, Raipur and Gullarghati along the Song River are selected for the study during the years 2012-2013. In all three sites, the study was conducted on either side of the river represented as East and West bank of Song River. Maldevta is having an elevation ranging from 650 m to about 1,050 m asl and lies between $30^{\circ}21$'N Latitude and $78^{\circ}7.5$'E Longitude whereas Raipur lies between $30^{\circ}20$'N Latitude and $78^{\circ}06$'E Longitude. Song River is surrounded by mountain in northern limit at Maldevta. Gullarghati lies between $30^{\circ}13'$ N Latitude and $78^{\circ}12'$ E Longitude. The river is flat and width of river is approximately 1 km and one side of the river bank is covered by dense forest and other side by degraded wetland area (Fig 1).

Herbaceous Biomass Estimation

Biomass studies were done for herbaceous layer at monthly intervals by harvest method at three sites. Each study site is further sub-divided into two sub-sites viz, East bank of the Song River and West bank of the Song River.

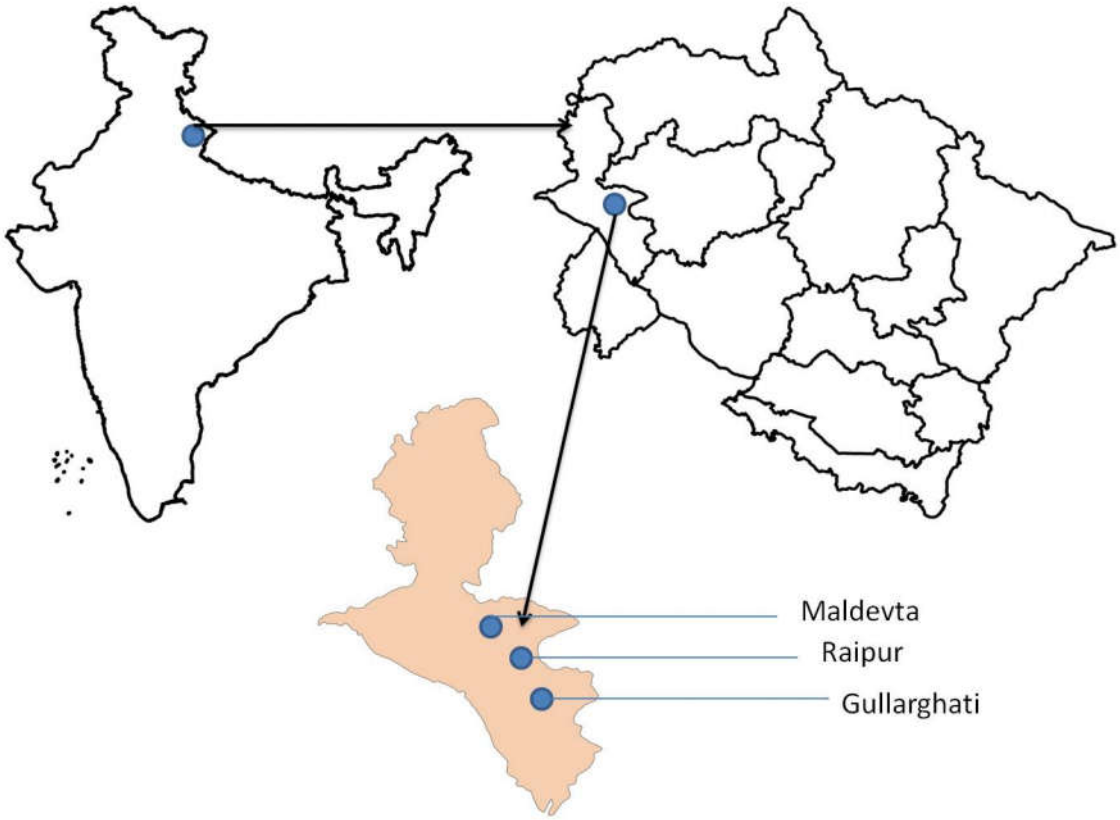

Fig 1 Location of study sites

At each sub-site, ten samples are collected from 1m × 1 m quadrat. Thus at one study site, total number of samples collected are twenty. Similarly, samples are collected from all the three sites. A total of 30 samples are collected from all the sites in a month. Samples are collected in the first week of the month. The collected samples are divided into two main components: above ground sample and below ground sample. The Above ground sample is sub-divided into three components viz. Green (live), Standing Dead and Litter while the below ground sample is represented by the roots. Clipping was done by hand with the help of sharp scissors. In order to obtain a valid estimation of herbage, the vegetation was harvested very close at the ground level. The cut vegetation from each harvested plot was packed in polythene bags and brought to the laboratory, where the material was then separated into green (live) and non-green (standing dead) categories. The live material was separated species wise. The sorted species were bagged separately. The litter present on the ground surface was gathered after plot harvesting. The litter samples from each harvested plot were washed in the laboratory and dried. For estimation of belowground biomass, five 15×15×15cms monoliths from each harvested plot were dug out. The belowground plant parts were removed from the soil core by washing thoroughly with running water.

All the plant components i.e. green (live), non-green (standing dead), litter and belowground, so collected were dried in a hot air oven at 80˚C for 48 hrs and weighed. Live material was weighed separately according to species. Monthly data so obtained were arranged and biomass values for different components were expressed in terms of tones per hectare (t/ha).

RESULTS

Variation in aboveground live biomass

Maldevta: The maximum aboveground live biomass on the East-Maldevta (0.56 t/ha) was recorded in the month of January while the minimum (0.22 t/ha) was recorded in April. At the West-Maldevta, maximum aboveground live biomass (0.39 t/ha) was recorded in the month of December and minimum (0.20 t/ha) was recorded in the month of May (Table 1).

Raipur: The maximum value (0.34 t/ha) of aboveground live biomass was found in February followed by December (0.33 t/ha), November (0.32 t/ha) while the minimum (0.22 t/ha) was recorded in the month of March in the East Raipur. Maximum aboveground live biomass was found to be 0.45 t/ha in the month of December while the minimum (0.21 t/ha) was recorded in the month of March from the West Raipur (Table 1).

Table 1 Variation in Aboveground live biomass at various study sites

Months	Aboveground live biomass (t/ha)					
	East Maldevta	West Maldevta	East Raipur	West Raipur	East Gullarghati	West Gullarghati
November	0.33	0.32	0.32	0.29	0.48	0.45
December	0.38	0.39	0.33	0.45	0.25	0.25
January	0.56	0.35	0.26	0.43	0.57	0.15
February	0.35	0.34	0.34	0.44	0.43	0.30
March	0.35	0.38	0.22	0.21	0.19	0.22
April	0.22	0.31	0.23	0.24	0.11	0.15
May	0.24	0.20	0.26	0.25	0.25	0.22

Gullarghati: Maximum value (0.57 t/ha) of aboveground live biomass was recorded in the month of January and minimum (0.11 t/ha) was in April month from East Gullarghati while the maximum (0.45 t/ha) aboveground live biomass was recorded in the month of November from West Gullarghati while the minimum was found in the month of January and April (Table 1).

Variation in Aboveground Standing Dead Biomass

Maldevta: Maximum aboveground standing dead biomass (0.98 t/ha) was recorded during the month of December and then it decreases to a 0.26 t/ha in the month of January after this it gradually increases in February and March and further decreases in April in the East Maldevta. Maximum (3.69 t/ha) aboveground standing dead biomass was recorded in the month of December while the minimum (0.25 t/ha) was recorded in the month of February (Table 2).

Raipur: In East Raipur, the maximum value of (1.01 t/ha) of aboveground standing dead biomass was found in the month of December while minimum value (0.20 t/ha) was recorded in January. In West Raipur, the maximum (1.25 t/ha) aboveground standing dead biomass was recorded in the month of November while the minimum (0.24 t/ha) was recorded in the month of April (Table 2).

Gullarghati: In the East Gullarghati, standing dead biomass was ranged from 0.27 t/ha to 0.65 t/ha in the month of May and December respectively while the maximum aboveground standing dead biomass (1.17 t/ha) was recorded in the month of December and minimum (0.29) in the month of May from the West Gullarghati (Table 2).

Table 2 Variation in Aboveground standing dead biomass at various study sites.

Months	Aboveground standing dead biomass (t/ha)					
	East Maldevta	West Maldevta	East Raipur	West Raipur	East Gullarghati	West Gullarghati
November	0.30	0.26	0.57	1.25	0.62	0.68
December	0.98	3.69	1.01	0.30	0.65	1.17
January	0.26	0.32	0.20	0.56	0.46	0.69
February	0.33	0.25	0.23	0.52	0.29	0.59
March	0.46	0.54	0.50	0.60	0.49	0.72
April	0.18	0.60	0.49	0.24	0.61	0.36
May	0.39	0.50	0.34	0.79	0.27	0.29

Variation in Aboveground Litter Biomass

Maldevta: The maximum aboveground litter biomass at the East-Maldevta (3.80 t/ha) was recorded in the month of November while the minimum (0.52 t/ha) was recorded in February. Maximum aboveground litter biomass (4.51 t/ha) was recorded in the month of November and minimum (0.67 t/ha) was recorded in the month of February at the East Maldevta (Table 3).

Raipur: The maximum value (3.31 t/ha) of aboveground litter biomass was found in December while the minimum (1.04 t/ha) was recorded in the month of May in the East Raipur. Maximum aboveground litter biomass was found to be 3.09 t/ha in the month of March while the minimum (1.16 t/ha) was recorded in the month of May from the West Raipur (Table 3).

Gullarghati: Maximum value (2.73 t/ha) of aboveground litter biomass was recorded in the month of March and minimum (0.87 t/ha) was recorded in May month from the East Gullarghati while the maximum (2.01 t/ha) aboveground litter biomass was recorded in the month of March and minimum (0.82 t/ha) in the month of May (Table 3).

Table 3 Variation in Aboveground litter biomass at various study sites.

Months	Aboveground litter biomass (t/ha)					
	East Maldevta	West Maldevta	East Raipur	West Raipur	East Gullarghati	West Gullarghati
November	3.80	4.51	1.92	1.62	2.28	2.01
December	3.20	2.90	3.31	2.82	1.61	1.69
January	1.50	1.48	2.54	1.64	1.30	1.39
February	0.52	0.67	1.63	1.20	1.33	1.90
March	1.12	1.08	2.49	3.09	2.73	1.78
April	2.12	1.89	1.45	1.41	1.30	1.38
May	2.39	2.65	1.04	1.16	0.87	0.82

Variation in belowground biomass

Maldevta: The maximum belowground biomass from the East-Maldevta (0.44 t/ha) was recorded in the month of November while the minimum (0.11 t/ha) was recorded in April. Maximum belowground biomass (0.25 t/ha) was recorded in the month of November and minimum (0.13 t/ha) was recorded in the month of February from East Maldevta.

Raipur: The maximum value (0.40 t/ha) of belowground biomass was found in November while the minimum (0.09 t/ha) was recorded in the month of April from East Raipur. Maximum belowground biomass was found to be 0.30 t/ha in the month of November while the minimum (0.11 t/ha) was recorded in the month of January from the West Raipur.

Gullarghati: Maximum value (0.26 t/ha) of belowground biomass was recorded

Table 4 Variation in belowground biomass at various study sites.

Month	Belowground biomass (t/ha)					
	Maldevta		Raipur		Gullarghati	
	East	West	East	West	East	West
November	0.44	0.25	0.40	0.30	0.26	0.26
December	0.21	0.17	0.18	0.27	0.21	0.13
January	0.15	0.18	0.14	0.11	0.17	0.23
February	0.14	0.13	0.22	0.19	0.13	0.21
March	0.14	0.18	0.14	0.23	0.13	0.18
April	0.11	0.20	0.09	0.12	0.17	0.19
May	0.13	0.20	0.15	0.18	0.12	0.12

Variation in Total Biomass

Maldevta: Maximum total biomass (4.87 t/ha) was recorded in the month of November while minimum (1.34 t/ha) was recorded in the month of February from East Maldevta. Similarly, maximum total biomass (7.15 t/ha) was recorded in the month of December and minimum (1.39 t/ha) in the month of February.

Raipur*:* Maximum total biomass (4.83 t/ha) was recorded in the month of December and minimum (1.79 t/ha) in the month of May from East Raipur while maximum total biomass (4.13 t/ha) was recorded in the month of March while the minimum total biomass (2.01 t/ha) was recorded in the month of April from West Raipur.

Gullarghati: November was the month of maximum (3.63 t/ha) total biomass production while minimum total biomass (1.50 t/ha) was produced in the month of May from East Gullarghati. Maximum (3.39 t/ha) total biomass is produced in the month of November and minimum (1.44 t/ha) in the month of May from West Gullarghati (Table 5, Fig 2).

Table 5 Variation in total biomass from various study sites.

Month	Total biomass (t/ha)					
	Maldevta		Raipur		Gullarghati	
	East	West	East	West	East	West
November	4.87	5.34	3.21	3.46	3.63	3.39
December	4.77	7.15	4.83	3.84	2.71	2.24
January	2.47	2.33	3.14	2.74	2.49	2.45
February	1.34	1.39	2.42	2.31	2.17	2.99
March	2.07	2.18	3.35	4.13	3.54	2.60
April	2.63	3.00	2.26	2.01	2.19	2.08
May	3.15	3.55	1.79	2.38	1.50	1.44

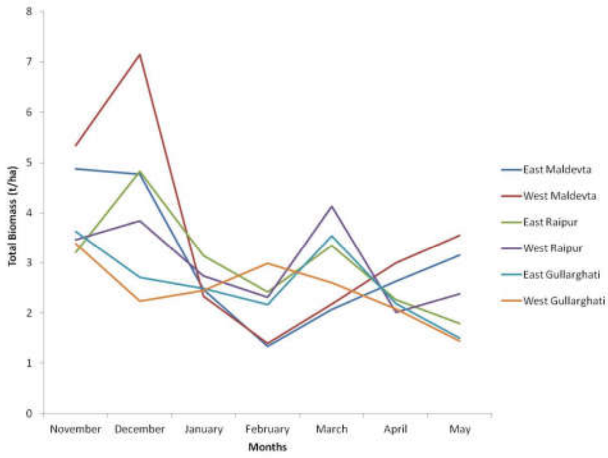

Fig 2: Variation in Herbaceous Total Biomass at different study sites along the Song River.

t/ha) wa

DISCUSSION

The growth and development of vegetation of an ecosystem is mainly controlled by climatic and edaphic factors. The major climatic factors that govern the structure and function of the vegetation are temperature, atmospheric humidity, solar insulation and wind velocity. Soil has great role in development of aboveground and belowground biomass. Limitation of soil resources results in high biomass allocation to belowground parts to increase nutrient uptake (Tilman, 1988). On the contrary, high soil nutrients favour high allocation to aboveground parts. At a global scale soil conditions change widely along the gradients of altitude and latitude and the relative biomass allocation between aboveground and belowground parts varies widely among ecosystem (Cairns *et al,* 1997). In riverine ecosystem soil nutrients, soil moisture and water level has great role in development of vegetation as well as biomass of the ecosystem.

In the present study all sites are different in their edaphic condition and water availability which may result in diverse habitat and these diverse habitat favour different types of vegetation growth and development in each study site. In East Maldevta, total biomass was maximum in November and starts decreasing continuously upto February and then increases till May. Same trend of total biomass was observed in West Maldevta. Total biomass production was maximum in the month of December at Raipur also while in Gullarghati, total biomass production decreases in the month of December. This may be due to the availability of water as Maldevta and Raipur receives more rainfall as compared to Gullarghati. In all sites of the study area, total biomass increases or decreases at different rate because different habitats or sites favour diverse vegetation, growth and development which have different phenology characteristic pattern. The pattern of aboveground standing crop, belowground biomass and above: belowground ratios are controlled by water availability, length of growing season, exposure and soil stability. Biomass production is positively correlated with phenological development of plant species (May and Webber, 1982). The total biomass showed variation throughout the study period. The peak biomass showed considerable differences which is due to the differences in phenological behaviour, growth pattern and time of major activities of individual species (Misra, 1968). Peak values were observed in December at Maldevta and Raipur for total biomass. The maximum biomass in December is due to the maximum growth in vegetation due to the first flush of herbs that started growing in October-November reached their maturity in December and added the maximum biomass. However, total biomass increased in May at Maldevta is due to enough rainfall and maximum flowering period of the second flush (Gupta, 1973; Chaudhary, 1976). April and May shows less production in the biomass which is due to the rise in the temperature. Due to increase in the temperature, the moisture content of the soil water availability from soil becomes less decreases thus affecting the normal life cycle of the plants.

In present investigation, most of the total biomass in Maldevta and Raipur was contributed by a large number of species, while in Gullarghati few species contributed in biomass in different months. Blaisdell (1958), Singh (1968), Singh and Yadav (1974) have also reported that bulk of biomass is made up of few dominant species. Results of herbaceous biomass along the Song River are new information dealing with herb layer biomass of riverine forest ecosystems in Doon Valley.

CONCLUSION

The riverine forests a unique natural ecosystem which impacts the adjacent aquatic and terrestrial systems. Herbaceous diversity along the riverine forests stabilizes and safeguards the river bank erosion. Herb biomass play a significant role in carbon sequestration and the conservation of these forests will support the river as well as helps in climate change mitigation. Riverine forests support the flow of ecosystem services that caters the need of the local community. Riverine forest has special role to play in maintaining the health of the river. It also has special roles within the overall body of forests on either side of the river. The high diversity in the riverine areas is associated with the physical and chemical substratum variability and the interaction between the topography and hydrological regime of the watershed. The amount of their biomass gives an idea about primary productivity and biomass storage capacity of forest ecosystem

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