Riparian Plant Diversity in the Watershed of Nachiketa Tal, Garhwal Himalaya

Vijayta Tiwari[1]* • Ramesh Chandra Sharma[1]

[1]*Department of Environmental Sciences, H.N.B. Garhwal University (A Central University), Srinagar-Garhwal, Uttarakhand, India*

*Corresponding Author Email: drrameshcsharma@gmail.com

Abstract: Riparian zone is an important ecotone between terrestrial and aquatic ecosystems, as all the rainwater runoff, contaminants along with litter passes through this zone before moving into the aquatic ecosystem. Therefore the riparian zone determines the health of the aquatic ecosystem. Riparian plant diversity restricts erosion of soil. The riparian plant diversity of Nachiketa Tal comprises of 10 species of trees, 14 species of shrubs and 14 species of herbs. Rosaceae was the dominating family (7 species) in the Nachiketa Tal followed by Asteraceae (3 species) and Fagaceae (3 species). Frequency, density, abundance, total basal area and important value index (IVI) were calculated for all the plant species. A significant degradation of riparian vegetation of Nachiketa Tal has been recorded with the help of satellite imagery of 2005, 2010 and 2017. Therefore, conservation and management of riparian zone have been suggested for maintaining the health of the Nachiketa Tal.

Introduction

The plants are the best indicators for assessing the health of any ecosystem. Any environmental effect is reflected by the vegetation of that area (Billings, 1952). The vegetation and diversity of plant species of riparian zone were first studied by Hombolt (Basiri, 2011). The riparian zone is the place where aquatic and terrestrial ecosystem meets. Riparian zone is an important zone, as the entire rainwater runoff passes through the zone before moving into adjacent aquatic ecosystem. The contaminants along with litter also enter into aquatic ecosystem through this zone. Therefore, the riparian zone determines the health of the aquatic ecosystem. The riparian zone also reduces the non-point source of pollution in the watershed (Lawrence et al, 1984). Aquatic and riparian vegetation in aquatic ecosystem have important ecological and regulatory functions (Strayer, 2010). Broadmeadow and Nisbet, (2004) studied that the canopy of trees and shrubs affects the microclimatic condition and primary productivity of the aquatic ecosystem and the leaf litter provides shelter to the wildlife of the riparian zone. The riparian zone is the smallest landscape but in most parts of world, this zone faces alteration due to the human activities and through the invasion of alien species (Richardson et al. 2007). A considerable work has been done on the different aspects of riparian vegetation of rivers and streams of the world. Robertson and Rowling (2000) studied the effect of livestock on riparian vegetation in

Australian dryland river; Johnson (2002) studied the riparian vegetation of Missouri River; while Renoflat and Nilsson (2008) studied the effect of landscape on riparian vegetation.

In spite of the paramount importance of the riparian plant diversity for all the aquatic ecosystems-stream, lakes and rivers. No sincere attempt has been made so far on the study of the riparian biodiversity of Himalayan lakes. Therefore, a sincere attempt has been made to study the riparian plant diversity in the watershed of Nachiketa Tal, Garhwal Himalaya.

Materials and Methods

Nachiketa Tal is one of the important and beautiful lakes of the Garhwal Himalaya. The lake is surrounded by dense forest of *Querecus* and *Rhododendron*. The lake is located between latitude N 30^0 38.666' N and longitude E 078^0 28.362' E at an altitude of 2,453 m above mean sea level to northeast of Uttarkashi town at Chaurangikhal, Uttarakhand. At the time of maximum water level, the area of Nachiketa Tal is about 0.49 ha. It is elliptical in shape, measuring about 132 m length, and 58 m width with a periphery of 413 m. Nachiketa Tal receives water contaminants and litter from its watershed. This water adds nutrients and alters the physico-chemical variables of Nachiketa Tal. Plant samples were collected and photographed in several field visits made in different seasons. Plants were identified with the help of the village people and consultation of plant taxonomist. The scientific validation of plants was made by the Himalayan Herbarium, Department of Botany and Microbiology, H.N.B. Garhwal University (A Central University) Srinagar-Garhwal, Uttarakhand. Analysis of riparian plant diversity was carried out from May 2014 to April 2015 at four sampling sites covering the entire riparian zone around the lake were identified for assessing the riparian plant diversity. In every study site, 10 transects of 10 m X 10 m (100 m^2) size were randomly laid to study tree species and 10 quadrats of 5m X 5m (25 m^2) size were randomly laid to study shrub species. The herbaceous species were studied by laying 10 quadrats of 1m X 1m (1 m^2) size randomly in each study site. The data for all the sites were clubbed and the mean was taken. The dominance of the plant species was determined using the Importance Value Index (IVI) of the species. The composition of vegetation was calculated by analyzing the frequency, density, abundance and IVI using the formula given by Curtis and McIntosh (1951). The Shannon-Wiener diversity index was also calculated using PAleontological STatistica (PAST) Software Version 2.16. For detecting degradation of riparian vegetation, satellite images were taken from the Goggle Earth and developed by using CorelDraw.
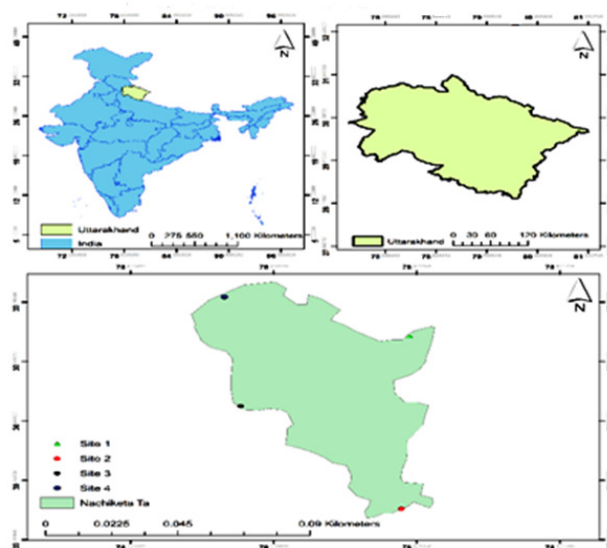
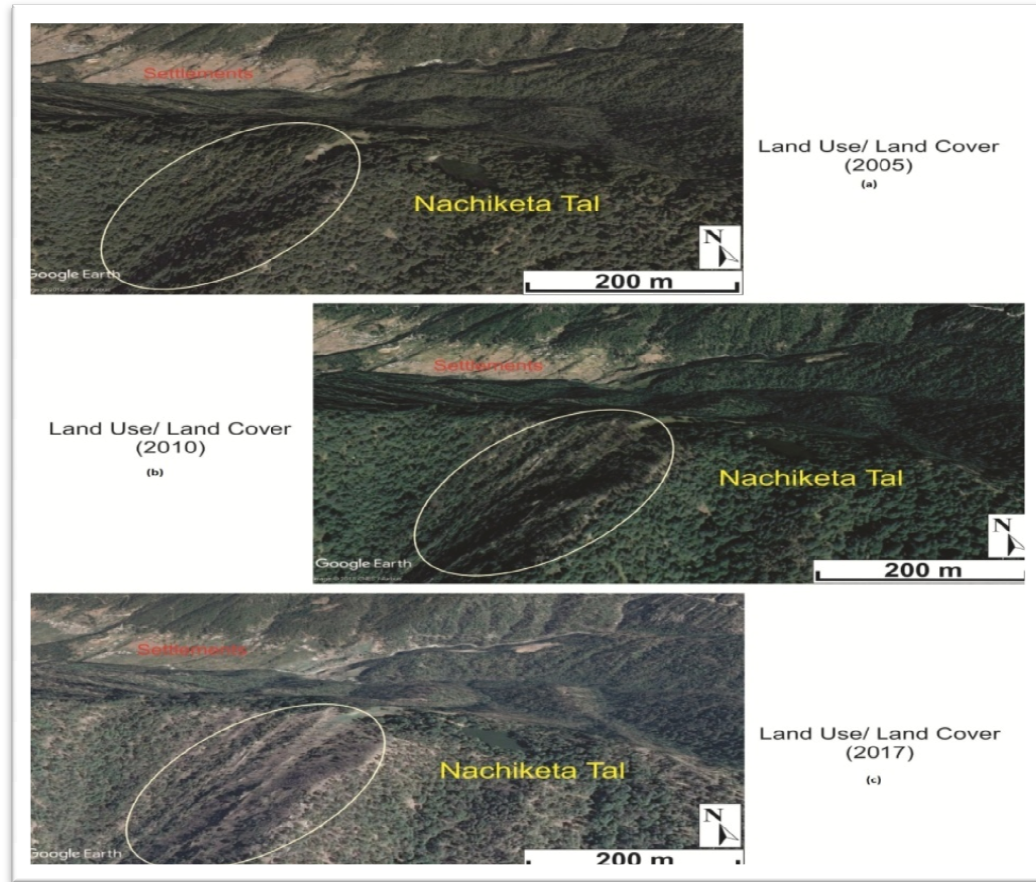

Figure1 Location map and sampling sites of Nachiketa Tal

Figure 2 Riparian vegetation of Nachiketa Tal in 2005 (a), 2010 (b), 2017 (c).

Results and Discussion

Riparian plant diversity

A total of 38 plant species represented by 10 species of trees (Table 1) , 14 species of shrubs (Table 2) and 14 species of herbs (Table 3) in the riparian zone of Nachiketa Tal belonging to 33 genera of 23 families was recorded. Rosaceae was the dominant family with seven plants species. However, Asteraceae and Fagaceae followed with three plants species each. Rutaceae, Ericaceae, and Athyriacae were represented by two species in the riparian zone. Two climber species (*Hedera nepalensis* K. Koch and *Rubia manjith Roxb.ex Fleming*) were recorded from the riparian zone. Two fern species (*Diplazium caudatum (Cav.) Jermy* and *Diplazium melanochlamys* (Hook.) T. Moore) were also documented. The distribution analysis of the tree species in the riparian zone of Nachiketa Tal showed that the highest (81.4) IVI was of *Quercus semecarpifolia* with 100 % frequency and the lowest (12.1) IVI was calculated for the *Ilex dipyrena* with 40% frequency. *Rhododendron arboretum* showed 100% frequency, while 80% frequency was shown by three species (*Lyonia ovalifolia, Neolitesa serobiculata* and *Quercus floribunda). Quercus leucotrichophora* showed 70% frequency. The density of *Neolitesa serobiculata* was 5.4 ind. m^{-2} which was highest among all the tree species; while *Ilex dipyrena* had the lowest density (1.5 ind. m^{-2}). The total basal area was found highest (15.29) for *Quercus semecarpifolia* among the riparian tree species. (Table 1). 14 shrub species were recorded in the riparian zone of Nachiketa Tal.

Table 1 Density, frequency, abundance and IVI of riparian tree species of Nachiketa Tal

Tree species	Local Name	Family	DS (m^{-2})	FQ (%)	AB	TBS	RD	RF	Rdo	IVI
Betula alnoides Buch. -Ham.ex D.Don	Saur, Sore	Betulaceae	3.3	50	6.6	0.44	9.9	6.8	1.5	18.3
Ilex dipyrena	Kandara, kanel	Aquifoliaceae	1.5	40	3.75	0.61	4.5	5.5	2.1	12.1
Lyonia ovalifolia (Wall.) Drude	Anyar	Ericaceae	3.2	80	6.74	0.84	9.6	11.0	2.9	23.5
Neolitesa serobiculata (Meisn.) Gamble	Gadmweda	*Lauraceae*	5.4	80	6.75	3.69	16.3	11.0	12.7	39.9
Pyrus pashia Buch. -Ham.ex D.Don	Mol	Rosaceae	3.5	60	5.83	0.69	10.5	8.2	2.4	21.1
Quercus floribunda Lindl. ex Rehder	Moru	Fagaceae	2.4	80	4.23	1.42	7.2	11.0	4.9	23.1
Quercus leucotrichophora A.Camus	Banj	*Fagaceae*	3	70	4.29	4.33	9.0	9.6	14.9	33.5
Quercus semecarpifolia Sm.	Karsu	*Fagaceae*	5	100	15.25	9	15.1	13.7	52.7	81.4
Rhododendron arboretum Sm.	Burans	Ericaceae	2.5	100	2.5	1.07	7.5	13.7	3.7	24.9
Symplocos paniculata (Thunb.) Miq	Lodha	Symplocaceae	3.4	70	4.86	0.65	10.2	9.6	2.2	22.1

DS: density; FQ: frequency; AB: abundance; TBS: total basal area; RD: relative density; RF: relative frequency; Rdo: relative dominance; IVI: Important Value Index

The IVI ranged from minimum of 12.2 *(Berberis lyceum)* to 90.4 *(Sarcococca saligna)*. The highest value of abundance (45) was recorded for *Sarcococca saligna* with 100% frequency. The lowest frequency (30%) was recorded for *Daphne papyracea* and *Rosa macrophylla* (Table 2). The herbaceous plant community in riparian zone of Nachiketa Tal was represented by the *Agrimonia pilosa, Artmisia vulgaris, Euphorbia hirta, Bergenia ciliate*, *Ainsliaea apter and Anaphalis contorta.* Distribution analysis of the herb species in the riparian zone of Nachiketa Tal revealed that the dominating species was *Agrimonia pilosa* with an IVI value 45.1. The species followed the dominace after *Agrimonia pilosa* were *Anaphalis contorta* (IVI 30.5), *Euphorbia hirta* (IVI 28.5), *Duchesnea indica* (IVI 23.6*)*. The highest density (7.6 ind. m^{-2}) of *Agrimonia pilosa* was recorded followed by *Euphorbia hirta* (4.5 ind. m^{-2}).

The lowest density (0.80 ind. m^{-2}) was recorded by *Bergenia ciliate* with (IVI 9.3). 80% frequency was recorded in one species, *Euphorbia hirta;* followed by 70% frequency by four species, *Diplazium melanochlamys,* (fern), *Hedychium spicatum, Impatiens scabrida* and *Anaphalis contorta* (Table 3). Shannon-Wiener index was calculated for trees (2.15), shrubs (2.57) and herbs (2.37). As compared to trees and herbs, shrubs community showed the maximum diversity in the riparian zone. Nachiketa Tal receives litter from the riparian plant species especially from *Quercus leucotrichophora and Q. floribunda.* Spain (1973) studied the conifer forest The vegetation of riparian zone is of great significance. Plants growing in the riparian zone sometimes faces the submergence in the monsoon season, yet in certain time it is exposed to the drought stress (Svejcar, 1997).

Table 2 Density, frequency, abundance and IVI of riparian shrubs species of Nachiketa Tal

Shrub species	Local Name	Family	DS (m^{-2})	FQ (%)	AB	RD	RF	RA	IVI
Berberis aristata Roxb.ex. DC.	*Kirmor*	*Berberidaceae*	3	80	3.75	3.2	9.6	2.8	15.7
Berberis lyceum	*Kingore, rasaut dams.*	Berberidaceae	2.4	50	4.8	2.6	6.0	3.6	12.2
Caesalpinia decapetala (Roth) Alston	*Kingari,Kunju*	*Caesalpiniaceae*	3.2	70	4.57	3.4	8.4	3.4	15.3
Cotoneaster affinis Lindl	*Ruins*	*Rosaceae*	3	40	7.5	3.2	4.8	5.6	13.6
Daphne papyracea Wall. ex Steudel	*Satpura , Bhanchoi*	Thymelaeaceae	2.6	30	8.67	2.8	3.6	6.5	12.9
Hedera nepalensis K.Koch	*laguli*	Araliaceae	4	40	10	4.3	4.8	7.4	16.6
Mahonia borealis	*Haldia, Bara totar, khosu*	Berberidaceae	4.4	60	7.33	4.7	7.2	5.5	17.4
Rosa macrophylla	*ban-gulab*	Rosaceae	2.5	30	8.33	2.7	3.6	6.2	12.5
Rubia manjith Roxb.ex Fleming	*Lichkuri, Indian Madder*	*Rubiaceaae*	6	80	7.5	6.5	9.6	5.6	21.7
Rubus foliolosus	*Kali Hisar*	Rosaceae	5.7	70	8.14	6.1	8.4	6.1	20.6
Sarcococca saligna (D.Don)	*Geru, Paliyala*	Buxaceae	45	100	45	48.4	12.0	33.5	94.0
Skimmia laureola	*Nairpatti*	Rutaceae	2.8	50	5.6	3.0	6.0	4.2	13.2
Urtica dioica L.	*Kandali*	Urticaceae	4.5	60	7.5	4.8	7.2	5.6	17.7
Viburnum mullaha Buch. - Ham.ex D.Don	*Malyo*	*Caprifoliaceae*	3.9	70	5.57	4.2	8.4	4.1	16.8

DS: density; FQ: frequency; AB: abundance; TBS: total basal area; RD: relative density; RF: relative frequency; RA: relative abundance; IVI: Important Value Index

The roots of the plants in the riparian zone increase substrate cohesion, and stems and leaves modify bed roughness, in that way controlling sediment erosion, transport and deposition, both in the channel and in the floodplain (Gurnell and Petts, 2002; 2006; Corenblit et al. 2008; 2009). The riparian zone of Nachiketa Tal is very small. But, it comprises of 38 riparian plants species. These riparian plant species are also important for the health of the ecosystem of Nachiketa Tal. As some of plant species prevent soil erosion and some other species enhances the nutrient value of the lake ecosystem.

Degradation of Riparian Vegetation

A significant degradation in the riparian vegetation of Nachiketa Tal has been observed. This may be due to habitat destruction by the influx of tourists, exploitation of riparian plant species for fuel, fodder and overgrazing by local people. Forest fire is also contributing to the degradation of vegetation. Satellite images of 2005, 2010 and 2017 have proved the degradation of the riparian vegetation of Nachiketa Tal (Fig. 2). A vegetation shift from the mid-Holocene period by Trivedi *et al.,* (2011).

Change in plant diversity in long run could affect the water of the Nachiketa Tal. Therefore, it is an urgent need to take remedial measures to control degradation of the watershed to conserve the riparian plant diversity. Considering the value of rich riparian plant diversity in the watershed of Nachiketa Tal, the Government of Uttarakhand must take necessary actions to conserve and manage the riparian plant diversity and health of the beautiful lake, Nachiketa Tal.

Table 3 Density, frequency, abundance and IVI of riparian herbs species of Nachiketa Tal

Herb species	Local Name	Family	DS (m^{-2})	FQ (%)	AB	RD	RF	RA	IVI
Agrimonia pilosa Ledebour	*Lisukuri*	*Rosaceae*	7.6	50	15.2	18.4	6.3	20.5	45.1
Ainsliaea aptera	*Kauru*	Asteraceae	3.2	50	6.4	7.7	6.3	8.6	22.6
Anaphalis contorta	*Bugla*	Asteraceae	5	70	7.14	12.1	8.8	9.6	30.5
Artmisia vulgaris	*Kunja*	Asteraceae	2.8	40	7	6.8	5.0	9.4	21.2
Bergenia ciliata (Haworth) Sternberg	*Silphara*	Saxifragaceae	0.8	30	2.67	1.9	3.8	3.6	9.3
Boenninghausenia albiflora (Hook.) Reichb.	*Upniya ghass*	Rutaceae	1.6	50	3.2	3.9	6.3	4.3	14.4
Diplazium caudatum (Cav.) Jermy	*Una*	*Athyriacae*	1.4	60	2.33	3.4	7.5	3.1	14.0
Diplazium melanochlamys (Hook.) T.Moore	*Una*	*Athyriacae*	1.7	70	2.43	4.1	8.8	3.3	16.1
Duchesnea indica ((Andrews) Th. Wolf	*Bhiuna kaphal*	Rosaceae	3.4	50	6.8	8.2	6.3	9.2	23.6
Euphorbia hirta L.	*Dudhi*	Euphorbiaceae	4.5	80	5.63	10.9	10.0	7.6	28.5
Hedychium spicatum Buch.-Ham.	*Ban-Haldi*	*Zingiberaceae*	2	70	2.86	4.8	8.8	3.9	17.4
Impatiens scabrida DC.	*chaul*	Balsaminaceae	2.4	70	3.43	5.8	8.8	4.6	19.2
Potentilla sp.	*Bajradanti*	Wounds treatment	2.2	50	4.4	5.3	6.3	5.9	17.5
Rumex nepalensis Spreng.	*Khatur*	Polygonaceae	2.8	60	4.67	6.8	7.5	6.3	20.6

DS: density; FQ: frequency; AB: abundance; TBS: total basal area; RD: relative density; RF: relative frequency; RA: relative abundance; IVI: Important Value Index

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