Journal of Aquatic Biology & Fisheries | 2020 | **8** | S | pp. 62-67
Special Issue on Rivers
ISSN 2321–340X

Phytosociological Study of Riparian Trees in Panchganga River System at Kolhapur District, Maharashtra, India

Mohite Mane, S.A

Hariom, plot no, 8, Visawa society, Dhankawadi,
Pune 411043, MS, INDIA
**Email: mohitesarika500@gmail.com*

Abstract

Narrow riparian areas along river banks are critical habitats and potential conservation areas. The ecologically sensitive Western Ghats region is crucial to riparian biodiversity. River Panchganga, in Kolhapur district, is one of the important upper catchment tributaries of river Krishna, in south India. Phytosociological study of trees in riparian habitats was done in twelve selected sites, along Panchganga river system where a total of 67 tree species have been recorded. Results reveal a high abundance of tree species in upper catchment sites, with *Syzygium cumini, Memencylon umbellatum, Salix tetrasperma,* and *Ficus religiosa* as dominant species. Higher species diversity (0.98) is recorded in the upper catchment as compared to the middle (0.65) and lower (0.68) catchments. *Salix tetrasperma* is dominant in middle and lower catchments. Highest species richness (15.07) was observed at Asane site in upper catchment while lowest species richness (2.39) was at Kuditre site in middle catchment in the Panchganga river system. Upper catchments of five tributaries in the Panchganga river system still have sizeable riparian trees with good diversity. This provides reasonably intact riparian habitats for floral and faunal diversity belonging to the adjoining aquatic as well as terrestrial habitats. Increasing urbanisation and industrialisation in the lower Panchganga basin has drastically reduced natural riparian vegetation as a result of major landuse changes such as removal of natural vegetation, agriculture encroachment, discharge of untreated sewage and industrial effluents.

Keywords: Riparian habitat, Importance value index, Tree diversity, Landuse change

1. Introduction

Riparian vegetation connects terrestrial and aquatic habitats and functions as corridors (Heartsill-Scalley and Aide, 2003) between these systems (Paine and Ribic, 2002). Riparian vegetation plays an important role in the ecological balance of river ecosystems. According to Sunil *et al*. (2010) the riparian plant community is influenced by moisture, erosion, endemic plant species, and present and past land use. Healthy riparian habitats are essential to maintain water quality and the biological integrity of a river, and their destruction leads to the degradation of the aquatic ecosystem (Ishida *et al*., 2010). Riparian vegetation typically occupies a small portion of the landscape, but it often plays an important role in controlling water and chemical exchange between adjacent lands and river systems (Dosskey *et al*., 2010). Flooding also exerts a strong influence on riparian plant communities (Stromberg *et al*., 2009). Indiscriminate land use changes have altered the riparian landscape drastically causing problems like bank erosion, silting, stream widening, and deforestation (Krishan *et al*., 2009; Ayivor and Gorden, 2012). There are increasing reports of flood damage, bank erosion, siltation, pollution and mass fish mortalities in the degraded tributaries of the Panchganga river system. Changing land use practices in the catchment, such as deforestation, mining and quarrying, soil erosion, agriculture expansion, and urban development are known to alter riparian vegetation, and affect biodiversity. Panchganga River System (PRS) is facing similar conditions with main problem being agriculture expansion along river banks, which is more aggravated in the middle and lower catchments of the river basin. Good riparian vegetation, particularly trees, reflects a healthy riparian habitat. Therefore, present study on riparian trees was expected to help in understand the present status of the riparian habitats in Panchganga river system.

2. Materials and Methods

Description of the study site

The Krishna is a major river in the Indian peninsula. The Panchganga (in local language 'five sacred rivers') is one of the important tributaries of the Krishna in its upper catchment in Maharashtra state. Panchganga river basin (2730 sq km) lies between 16° 19' 12'' and 16° 55' 21'' N latitudes and 73° 44' 10'' and 74°42' 20'' E longitudes, located in the mountainous Western Ghats region in Kolhapur district (Figure.1). The Panchganga River System (PRS) is formed, in the hilly western part of Kolhapur district, by five tributaries namely Bhogawati (83km), Tulshi (34 km), Dhamni (41 km), Kumbhi (48 km) and Kasari (69 km). These tributaries unite as the Panchganga River at Prayag, upstream of Kolhapur city. After confluence, the Panchganga river flows for about 67 km and joins the river Krishna at Narsinghwadi. The total length of the PRS is 338km (Shinde, 1992).

For study purposes, the Panchganga river basin was divided into three parts -upper, middle and lower catchments – based on annual precipitation. In the upper catchment the annual average rainfall varies from 6875 to 3125mm, in the middle catchment it is 3125 to 1000 mm and in the lower catchment the rainfall is below 1000 mm. Rainfall data collected from map of Panchganga river

Received on: 02-01-2020; Revised on:16-03-2020; Accepted on: 25-03-2020

basin published by Maharashtra Krishna Valley Development Corporation. Broad attributes such as local geomorphology, riparian biodiversity and catchment land use activities were considered in the selection of the site. In order to study quality and distribution of tree species in riparian habitats, sampling was carried out in twelve selected sites along the five tributaries in the PRS. Table 1 shows the distribution of sites and names of villages where the sites were located.

The five sites and the rivers in the upper catchment were namely Temburnewadi (Kasari), Asalaj (Kumbhi), Kandalgaon (Dhamni), Dhamod (Tulshi) and Asane (Bhogawati). Four sites in the middle catchment were at Bajarbhogaon (Kasari), Are (Tulshi), Parite (Bhogawati) and Kuditre (Kumbhi). The three in the lower catchment were on the Panchganga River at Wadange, Ichalkaranji and Narsinghwadi.

Sampling methods

The quadrate method was used for tree sampling within the riparian areas of river catchments. The plots were laid at all twelve sites, on both river banks. A total of 60 plots, each comprising 5 quadrates of 10 m × 10 m, were studied. In each quadrate, trees (30 cm girth at 130 cm above ground height) were recorded according to species. For the study, 50 m area along the river bank was considered as the riparian zone and vegetation in that area was studied using the quadrate method. For qualitative and quantitative purposes, the Species Diversity Index (SDI) and Importance Value Index (IVI) were calculated for these selected riparian habitats in PRS. Species diversity was determined by Shannon-Wiener index (Shannon and Wiener, 1963); this index reflects both the evenness and species richness. The Importance value index (IVI) (Curtis and McIntosh, 1951) is used in ecological studies to determine importance of each species in a community. Similarity of species in all sampling sites was calculated using Jaccard's Similarity Coefficient (Jaccard, 1912).

Frequency = Number of quadrate in which species occurred/ Total no. of quadrates studied ×100

Relative dominance = Total basal area of a species/ Total basal area of all the species × 100

Relative density = Number of individuals of the species/ Total no. of individuals of all species× 100

Relative frequency = Number of occurrences of species/ Number of occurrences of all species × 100

Importance Value Index (IVI) for one species = Relative density + Relative frequency + Relative dominance

Shannon – Wiener index (H) = - Σ Pi log Pi

$$Pi = \frac{\text{Number of individuals of one species}}{\text{Total number of all individuals}}$$

Species richness = (S-1) / log N

S = Total number of species

N = Total number of individuals of all species.

Evenness index = H / log S

H = Shannon-Wiener diversity index

S = Total number of species

Index of dominance= $\Sigma (ni/N)^2$ or $\Sigma (Pi)^2$

Jaccard's Similarity Coefficient = a / (a+b+c)

a = Number of species common to quadrates

b = Number of species unique to first quadrate

c = Number of species unique to second quadrate

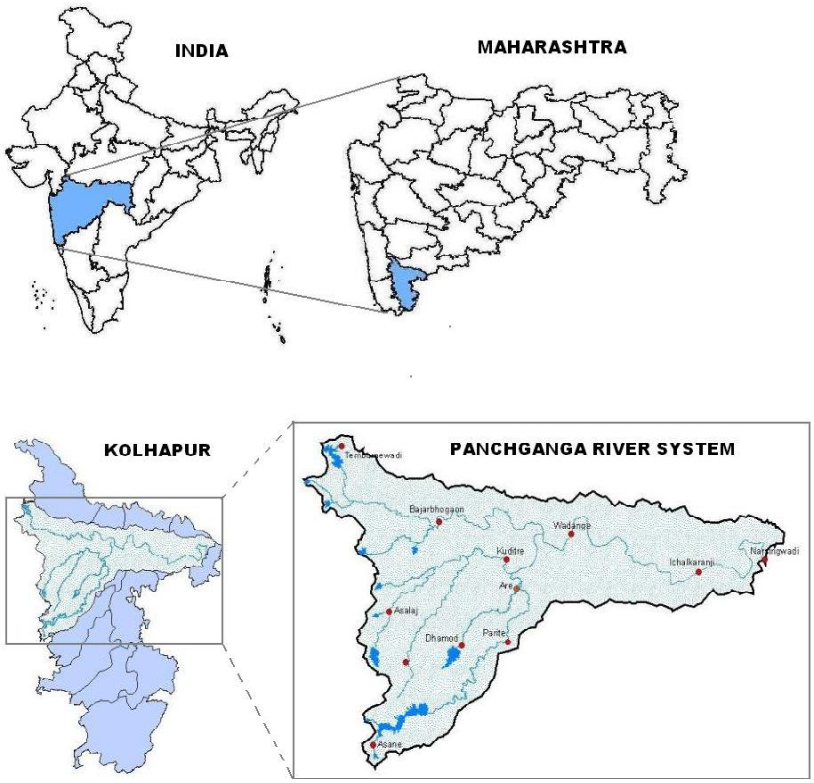

Fig. 1. Location map of study region showing with study sites in the Panchganga basin

Table 1. Study sites in the three catchment categories in Panchganga River System, Maharashtra

River	The three catchments			Number of Sites
	Upper	**Middle**	**Lower**	
Kasari	Temburnewadi (N 16.39091°, E 73.79584°)	Bajarbhogaon (N 16.75687°, E 73.98276°)	——	2
Kumbhi	Asalaj (N 16.56798°, E 73.88323°)	Kuditre (N 16.68948°, E 74.11409°)	——	2
Dhamni	Kandalgaon (N 16.58053°, E 74.02599°)	—-	——	1
Tulshi	Dhamod (N 16.58052°, E 74.02599°)	Are (N 16.59188°, E 74.07517°)	——	2
Bhogawati	Asane (N 16.58072°, E 74.02699°)	Parite (N 16.59454°, E 74.15181°)	——	2
Panchganga	——	——	Wadange (N16.73498°, E74.17901°) Ichalkaranji (N16.63649°, E74.50520°) Narsinghwadi (N16.71016°, E 74.33809°)	3
Total Sites	5	4	3	12

3. Results and Discussion

A total of 67 tree species were recorded during the study from the twelve sampling sites along riparian habitats in the Panchganga River System. The average number of species recorded at a study site in each catchment and between the three catchments reveals that upper catchment had more number of tree species than middle and lower catchment sites respectively.

Importance Value Index (IVI)

Tree species status in the riparian habitats was studied based on Importance Value Index. The species having highest IVI value are considered as dominant in the community. Highest number (# 31) of different tree species as well as highest total number of trees (#130) was recorded in Temburnewadi site in the upper catchment of Kasari river. In Temburnewadi, *Syzygium cumini*, an evergreen tree species, has highest IVI value (57.33) followed by *Memencylon umbellatum* (46.43) and *Mangifera indica* (39). *Mangifera indica* has high (28.48) relative dominance while *Syzygium cumini* and *Memencylon umbellatum* both had high relative frequency. Low IVI value is observed for *Artocarpus heterophyllus* which also reflected very low relative dominance. Aslaj site on Kumbhi river were recorded 76 trees belonging to 23 species, shows high IVI value for *Salix tetrasperma* followed by *Mangifera indica*, *Pongamia pinnata*, *Ficus religiosa*, and *Leea spp*. As compare to all other species *Salix tetrasperma*, *Pongamia pinnata*, and *Leea spp.* have high relative density. Other species namely *Trema orientalis*, commonly called charcoal tree, *Memencylon umbellatum*, *Lantanaregam spinosa*, *Phyllanthus emblica* are observed with low relative density (1.32) and relative frequency (2.94). *Lantanaregam spinosa* is a small tree mostly common in stream sides in hills and on mountain slopes.

In Kandalgaon site, located in upper catchment of the Dhamni river, 57 trees belonging to 21 species were recorded. *Ficus religiosa* has highest IVI value (62.70) followed by *Syzygium cumini*, *Mangifera indica*, *Memencylon umbellatum* and *Ficus hispida*. High relative density is observed in *Syzygiun cumini* and *Mangifera indica*. Other species mainly observed along the river are *Cretava magma*, *Pongamia pinnata*, *Terminalia tomentosa*, and *Glycosmis pentaphylla*. In Dhamod site on river Tulshi 80 trees belonging to 12 species were recorded. Tulshi river shows highest IVI value for *Salix tetrasperma* (68.27), followed by *Pongamia pinnata*, *Mangifera indica*, *Syzygium cumini* and *Ficus recemosa*. Relative frequency is higher in *Pongamia pinnata* and *Salix tetrasperma* (17.39). High relative dominance is observed in *Salix tetrasperma* while low relative dominance is observed in *Glycosmis pentaphylla* (0.83), *Memencylon umbellatum* (0.59), *Mallotus phillippensis* (0.43), and *Ziziphus oenoplia* (0.11). *Glycosmis pentaphylla* is a flowering plant in citrus family Rutaceae commonly known as orange berry. *Mallotus phillippensis* grows on slopes and is found mostly in scrub and deciduous forest where as *Ziziphus oenoplia* is found in moist and dry deciduous forests.

Asane site on river Bhogawati with 84 trees belonging to 30 species shows high IVI value for *Memencylon umbellatum* (60.61), followed by *Artocarpus heterophyllus* (27.49), *Syzygium cumini*, *Glochidion malabaricum* and *Dendrophthoe falcata*. High relative density is observed in *Memencylon umbellatum* (27.38) followed by *Syzygium cumini* and *Diospyros nigresceas*. While relative dominance is high in *Artocarpus heterophyllus* followed by *Memencylon umbellatum* and *Dendrophthoe falcata*. Low IVI Value is observed for *Paramignya monophylla*, *Flugia spe.*, *Carissa inermis*. Species *Paramignya monophylla* is evergreen woody climber, commonly known as climbing atalantia, *Carissa inermis* is also climbing shrub. *Dendrophthoe falcate* is an evergreen stem parasite plant grown on different host plants.

From this it was observed that species diversity and number of trees are more at Temburnewadi and Asane sites which are undisturbed sites in reserved forest areas.

As compared to other sites Dhamod site on Tulshi river shows low species diversity which was dominated by only four to five species. From above results it was observed that in upper catchment sites in PRS, *Syzygium cumini, Memencylon umbellatum, Salix tetrasperma,* and *Ficus religiosa* are dominant species. Riparian tree species distribution patterns are thought to depend on their flooding tolerance (Osawa *et al*., 2010). Moist and damp condition is favourable for *Syzygium cumini* and it can tolerate prolonged flooding, the species belongs to family Myrtaceae. Species *Memencylon umbellatum,* belonging to family Melastomataceae, is an under storey small tree commonly found in semi evergreen and evergreen forests in the Western Ghats. Species *Salix tetrasperma* belonging to family Salicaceae, is commonly called Indian willow.

In the middle catchment more species were recorded at Bajarbhogaon (#12), followed by Are (#11), Parite (#7) and Kuditre (#5). Bajarbhogaon, site in middle catchment of Kasari river shows high IVI value for *Salix tetrasperma* (154.07) followed by *Pongamia pinnata*, *Syzygium cumini*, *Bridelia retusa* and *Oroxylum indicum*. Species *Bridelia retusa* is common in forests and open land. Species *Oroxylum indicum* is a night-bloomer and its flowers are adapted to pollination by bats. In this site relative dominance and relative density is higher in *Salix tetrasperma*. Low relative density (1.72) is observed in *Ficus hispida, Artocarpus heterophylla, Ficus recemosa, Ligustrum perrottetii* and *Grewilia robusta*. *Ligustrum perrottetii* is endemic to the Western Ghats and is commonly found in semi evergreen forests. Kuditre site located on Kumbhi river shows high value of IVI for *Salix tetrasperma* (165.24), followed by *Ficus recemosa, Crateva megna, Ficus carica* and *Mangifera indica*.

Are site on Tulshi river shows high IVI value for *Pongamia pinnata* (74.28), followed by *Ficus recemosa, Salix tetrasperma, Eucalyptus globulus, Syzygium cumini*, and *Carella branchiate*. Relatively low density in case of *Mangifera indica, Pogostermon bengalensis, Azadirachta indica.* Parite site on Bhogawati river is dominated by *Satlix tetrasperma* (101.81), *Ficus recemosa* (88.86), and *Pongamia pinnata* (53.48). Low IVI value is observed in *Eucalyptus globules*, *Ficus religiosa* and *ficus benghalensis*. At this site riparian vegetation was fragmented along meandering curves of the river. Agricultural expansion was responsible for decrease in riparian trees along the river banks; the situation was aggravated due to extraction of bank soil for brick kilns. According to a study of environmental impact of brick industry in Kolhapur district, river Panchganga and its tributary river Kumbhi basin riparian habitats is the major source of bank soil for brick production; where clay mining had led to the formation of deep trenches and pits ranging from3-12 m depth in the riparian habitats (Lad, 2013).

It is also observed that vegetation in the middle catchment riparian areas is dominated by *Salix tetrasperma*, *Pongamia pinnata* and *Ficus recemosa*. At Are and Bajarbhogaon sites *Pongamia pinnata* was more dominant species. Biological and landuse strongly influence habitat diversity and water quality of the rivers within the surrounding area (Bhaskar and Kartick, 2015). In PRS as compare to upper catchment sites middle catchment vegetation is grossly replaced by agriculture, resulting into low tree species diversity. It is also reported that changing agriculture practices in adjoining Dudhganga river basin, where about 90% land was brought under sugarcane cultivation (Patil, 2014). Similar picture was observed almost in the entire Panchganga river basin.

In the lower catchment of PRS at Wadange site *Salix tetrasperma* shows high IVI value (105.8), followed by *Pongamia pinnata*, *Ficus recemosa*, and *Mangifera indica*. Relative density is also higher in *Salix tetrasperma* and *Pongamia pinnata* with higher relative dominance in *Salix tetrasperma*, *Ficus recemosa* and *Pongamia pinnata*. In Ichalkaranji site *Ficus recemosa* shows high IVI value of 171.91 followed by *Mangifera indica*, *Pithocelobium ducei*, *Salix tetrasperma*, and *Creteva magna*. Species *Pithocelobium ducei* is drought resistant and belongs to family Fabaceae. Site Narsinghwadi, located at confluence of Panchganga and Krishna rivers, shows high IVI value for *Salix tetrasperma* (98.26) followed by *Pongamia pinnata, Sesbania bispinosa, Ficus recemosa, Creteva magna, Syzygium cumini* and *Ricinus cuminus.* Vast agriculture expansion along river banks has resulted in to very sparse and fragmented riparian vegetation.

Shannon- Wiener Index

Species diversity of a site is represented by heterogeneity indices. During the investigation, Shannon-Wiener diversity index is used for species diversity. In the upper catchment sites, diversity index (H) is high in Asane site followed by Asalaj, Kandalgaon, Temburnewadi and Dhamod. In contrast, species richness is high in Asane, followed by Temburnewadi, Asalaj, Kandalgaon and Dhamod (Figure 2, 3).

As compared to other study sites, Dhamod has a high index of dominance and low evenness index (Figure 3) with *Salix tetrasperma* as dominant species. While in other sites species are more evenly distributed. It is observed that amongst the five upper catchment sites, Temburnewadi and Asane fall in reserved forest area and thus show higher species richness. Whereas there is a marginal drop in Kandalgaon and Asalaj sites owing to traces of agricultural encroachment and expansion. Compare to these sites agricultural expansion is considerably more in Dhamod and is reflected in significant negative impact on species richness and species diversity. Dhamod also shows low evenness index, as it is observed that farmers increasingly cultivate horticultural trees like *Mangifera indica* and *Artocarpus heterophyllus*.

In the middle catchments, Shannon- Wiener index value is high 0.90 at Are, followed by Bajarbhogaon, Parite and Kuditre. While Species richness is also high 6.28 in Are but low 2.39 in Kuditre. Similarly, Evenness index is high in Are and low in Kuditre. Index of dominance is high in Kuditre,where *Salix tetrasperma* is a dominant species, and low value 0.15 was recorded at Are as species evenness index is high, species are evenly distributed as compare to other sites (Fig. 2, 3). In middle catchment area low species diversity and low species richness was observed, particularly in Kuditre site, as riparian vegetation is

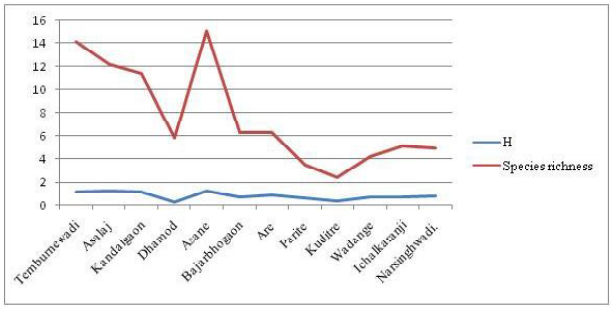

Fig. 2. Shannon-Wiener index and Species richness at the study sites along the Panchganga River System

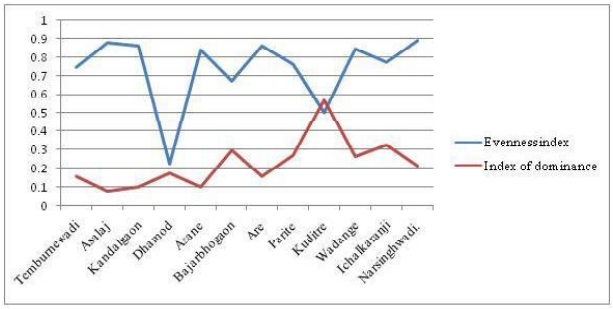

Fig. 3. Evenness index and Index of dominance at the study sites along the Panchganga River System

disturbed by river bank clay excavation for brick kilns. Study shows that in middle catchment sites the vegetation was dominated by few or at places only single species *Salix tetrasperma*. The existing vegetation is also under risk of being destroyed due to clay excavation along riparian habitats at the site.

In the lower catchment number of species is less as compared to upper and middle catchments. In lower catchment, Shannon-Wiener index is higher at Narsinghwadi, at site of confluence of Panchganga and Krishna rivers, while at Ichalkaranji and Wadange sites it is low. Species richness is higher 5.10 at Ichalkaranji followed by Narsinghwadi 4.87 and Wadange 4.15. Evenness index is higher at Narsaobawadi than at Ichalkaranji. Index of dominance is high at Ichalkaranji, followed by Wadange and Narsobawadi. Dominated species at Ichalkaranji site is represented by *Ficus recemosa* (Fig. 2, 3). Generally, riparian vegetation in lower catchment was very limited in density and diversity, which is also described by Naiman *et al*. (2000), agriculture expansion in these catchments was seen to be further affecting the riparian vegetation. Streams in catchments with dominant agricultural landscape tend to have poor habitat quality, and it is reflected in low habitat indexes and bank stability (Richards *et al*., 1996). In lower catchment sites riparian vegetation is fragmented and restricted to only a few species like *Ficus recemosa* and *Ficus religiosa*, this was perhaps due to invasion of agriculture up to the river banks and as these two tree species were speared because of they had local cultural rather than ecological significance.

As compared to the upper and middle catchments, lower catchment of Panchganga River System shows very low diversity of trees along riparian habitats. In Wadange site only few species (#6) were recorded, and in Ichalkaranji and Narsinghwadi sites (#7) species were reported. Species *Salix tetrasperma*, *Ficus recemosa*, *Mangifera indica* and *Pongamia pinnata* are commonly recorded trees in the lower catchment. According to a study, dominance of *Pongamia pinnata* is not a good sign of a naturally balanced riparian forest as the species performs very few ecological functions than native riparian species and they may increase in number and expand into new areas of riparian zone (Sunil *et al*., 2016).

Jaccard's Similarity Index

Numerous similarity indices have been proposed to measure the degree to which species composition of quadrates is alike. Jaccard's coefficient is a simplest and more accurate index developed to compare regional floras and is widely used to assess similarity of quadrates. The range of Jaccard's similarity coefficient is supposed to be 0 (no similarity) to 1(complete similarity (Jaccard, 1912). The Dendrogram (Fig. 4) shows the site clusters based on the Jaccard's index of similarity. Upper and lower catchment sites are separated by two main clusters. Broadly four clusters are found; out of them one cluster included Narsingwadi, Ichalkaranji and Kuditre sites. Second was comprised of Bajarbhogaon, Wadange, Parite and Are sites. The third cluster included Kandalgaon, Asalaj, Dhamod and the fourth had Asane and Temburnewadi sites. These clusters showed similarity in species composition. It is observed that there is close resemblance between sites Parite and Wadange followed by Kuditre and Ichalkaranji and poor comparison between Asane and Temburnewadi sites, also similarity was observed in case of Dhamod and Asalaj site (Fig. 4). From above result it could be concluded that in middle and lower catchment sites similar riparian tree species diversity existed. In the upper catchment species richness was high and similarity index between two sites namely Temburnewadi and Asane was very low.

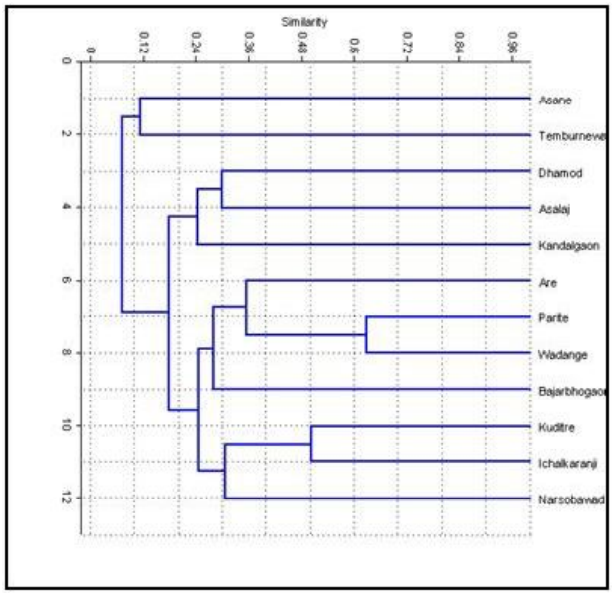

Fig. 4. Jaccard's Index of Similarity between the riparian sites in Panchganga basin

4. Conclusions

During this study, it was observed that in most places, particularly in the upper and middle catchments of the five tributaries of the Panchganga River System, deforestation, agricultural expansion, destruction of riparian vegetation and removal of river bank soil for brick kilns is a common feature responsible for the increase in river bank erosion and flooding in large areas. Upper catchments of the five tributaries in the Panchganga River System still have sizeable riparian vegetation with good diversity as compare to middle and lower catchments. This provides reasonably intact riparian habitats for floral and faunal diversity belonging to the adjoining aquatic as well as terrestrial habitats. However, in the middle catchments of PRS, the riparian vegetation is reduced considerably in diversity and density. River Panchganga basin, mainly in upper and middle catchments, is getting more exposed and vulnerable due to the rapidly changing land use and crop patterns from traditional dominant food crops like paddy and millet to cash crop like sugarcane. Wherever riparian vegetation is present in PRS it is mostly fragmented due to agricultural encroachment and expansion on banks. Also increasing urbanization and industrialization in middle and lower Panchganga basin catchment area has drastically reduced natural riparian vegetation as a result of major landuse changes in the neighbouring catchment areas such as removal of natural vegetation, agriculture encroachment, dumping of municipal solid waste and debris, discharge of untreated sewage and industrial effluents, etc. Despite this, there is still potential to conserve and rejuvenate the existing fragmented riparian tree vegetation to near natural status in many areas, particularly in the upper and middle catchments of PRS.

5. References

Ayivor, J.S., and Gordon, C. 2012. Impact of land use on river system in Ghana. *West African Journal of Applied Ecology*, 20(3), 83-95.

Bhaskar, A. and Kartick, M.N. 2015. Riparian forests for healthy rivers. *Current Science*, 108(10), 1788-1789.

Curtis, J.T., and McIntosh, R.P. 1951. An Upland Forest Continuum in the Prairie-Forest Border Region of Wisconsin. *Ecology*, 32(3), 476-496.

Dosskey, M. G., Philippe V, P., Gurwick, C. J., Allan, T. P., and Richard L. 2010. The role of riparian vegetation in protecting and improving chemical water quality in stream. *Journal of the American Water Resources Association* (JAWRA), 46(2), 261-277.

Heartsill-Scalley, T., Aide, T.M. 2003. Riparian vegetation and stream condition in a tropical agriculture-secondary forest mosaic. *Ecological Applications*, 13(1), 225-234.

Ishida, S., Yamazaki, A., Takanose, Y., Kamitani, T.2010. Off-channel temporary pools contribute to native riparian plant species diversity in a regulated river floodplain. *Ecological Research*, 25(6), 1045–1055. DOI: 10.1007/s11284-010-0731-1.

Jaccard, P. 1912.The distribution of the flora in the alpine zone. *New Phytologist*, 11(2), 37-50.

Krishan, G., Kushwaha, S.P.S. & Velmurugan, A.J. 2009. Land Degradation Mapping in the Upper Catchment of River Tons. *Journal of Indian Society of Remote Sensing*, 37(1), 119–128. DOI:10.1007/s12524-009-0003-0.

Lad, R.J. 2013. Studies on the Impact of Mining Activities on Environment in Kolhapur District. (Unpublished doctoral dissertation), Department of Environment Science, Shivaji University, Kolhapur.

Osawa, T., Mitsuhashi, H., Niwa, H., Ushimaru, A. 2010. Differences in distribution patterns around river confluences among hydrophilic vegetation groups. *Ecological Research*, 25, 1161–1169. DOI: 10.1007/s11284-010-0741-z.

Paine, L., and Ribic, C. 2002. Comparison of riparian plant communities under four land management systems in south western Wisconsin. *Agriculture, ecosystem and environment*, 92(1), 93-105.

Patil, R.B. 2014. Displacement and Rehabilitation: A study of change in agricultural practices of Dudhaganga dam affected people in Kolhapur District (MH).*Research Directions*, 1(10).

Richards, C L., Johnson, B. G., Host E .1996 Landscape-scale influences on stream habitats and biota. *Canadian Journal of Fisheries and Aquatic Sciences*, **53** Suppl. 1 295–311 DOI/pdf/10.1139/f96-006

Shannon, C.E., and Weiner, W. 1963. The Mathematical Theory of Communication Urbana: University of Illinois Press, 14-15.

Shinde R. V. 1992. Studies on hydrology of the Panchganga river system in the Western Ghats, Ph.D thesis, Shivaji University, Kolhapur

Stromberg, J.C., Hazelton, A.F., White, M.S. 2009. Plant species richness in ephemeral and perennial reaches of a dryland river. *Biodiversity and Conservation*, 18(3), 663–677. DOI:10.1007/s10531-008-9532-z.

Sunil, C., Somashekar, R.K., Nagaraja, B.C. 2010. Riparian vegetation assessment of Cauvery River Basin of South India. *Environmental Monitoring and Assessment*, 170(1-4), 543-553. DOI:10.1007/s10661-009-1256- 3.

Sunil, C., Rayasamudra, K.S., and Badenahally, C.N. 2016. Diversity And Composition of Riparian Vegetation Across Forest and Agroecosystem Landscapes of River Cauvery, Southern India. *Tropical ecology*, 57(2), 343-354.