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REVIEW ARTICLE

Sustaining Riverbank Ecosystems in The Face of Anthropogenic and Climatic Challenges

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ABSTRACT

Riverbank vegetation, predominantly the plants growing along the edge of water are actually a critical ecological indicator of the environmental health. These strips of plants are very important for maintaining the ecosystem balance, which includes stabilization of the bank, filtering the water, and supporting a wide range of different plant and animal biodiversity. It therefore becomes critical to assess the human induced disturbances like pollution, climate change, land degradation, and hydrological alterations. The anthropogenic activities cause water scarcity and lead to a significant threat to riparian zones by limiting the soil moisture, altering the species composition, thus reducing the vegetation cover, leading to enhanced erosion and habitat degradation. Moreover, climate change worsens these stresses by altering the precipitation pattern, escalating temperature, modifying stream flow regimes, and increasing the incidence of wildfires, which contribute to biodiversity shifts in riverbank vegetation and ecosystem functionality. Further, the land use land change dynamics (LULC) also have a remarkable influence on seasonally dynamic riverbank vegetation. Hence, the inter-relationship among the anthropogenic activities, climatic variability, LULC pattern and hydrological processes is crucial for the sustainable riverbank ecosystem management. Moreover, ecological monitoring, planning strategies and policy making is essential, for reducing the environmental pressure and thus the protection of riverbank corridors.

KEY WORDS: Anthropogenic activities; Climate change; Ecosystem; Pollution; Riverbank vegetation

INTRODUCTION

Riparian buffer zone plant communities, which consist of vegetation growing along the streams and rivers, play an imperative role in the establishment and maintenance of freshwater ecosystems (Naiman & Décamps, 1997). Several areas of the transitional zones between water and land facilitate ecological functions such as microclimate regulation, stabilizing banks, filtering sediments and nutrients, and providing habitat corridors for numerous plant and animal species (Gregory *et al.,* 1991; Richardson *et al.,* 2007). Riverbank plant communities proximally owing to the water bodies, though highly sensitive to environmental turbulences, are subsequently identified as indicators of ecosystem health (Sweeney *et al.,* 2004; Naiman *et al.,* 2010). There are indicators of broader environmental changes, which include pollution, water flow alteration, habitat fragmentation, and land-use changes often linked to shifts in the riverbank vegetation (Tabacchi *et al.,* 1998; Allan, 2004). For long, it has been found that human activities such as urban development, agriculture, and water resource management greatly affect the riverbank zones, leading to changes in their functionality and structures (Nilsson & Berggren, 2000; Dudgeon *et al.,* 2006). The effects on riparian vegetation can be determined by the enhanced use of remote sensing and GIS technologies, which have improved the comprehension of land use and land change (LULC) patterns (Nagendra *et al.,* 2013). Furthermore, stressors such as escalating temperature, altered precipitation patterns, and variations in stream flow exacerbate the vulnerabilities to these ecosystems (Seavy *et al.,* 2009). This compilation highlights the importance of riverbank vegetation, their role as indicators, their response to water scarcity, anthropogenic activities and climate change

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providing valuable insights for sustainable ecosystem management and conservation efforts.

Cultivation along the Gomti riverbank in Lucknow

Field visits were conducted during the dry period at the selected sites to observe the cultivated plants along the Gomti River in Lucknow, namely Sekna Ghat, Gauriya Ghat, Sitkiha Khurd, Khadra, Lohramau and Satphita (Fig. 1). At each site, cultivated plants along the riverbank were noted. During the site visits, a diverse and economically important plants were observed, including horticulture crops such as *Cucumis sativus* (cucumber), *Capsicum annuum* (chilli), *Lagenaria siceraria* (bottle gourd), *Coriandrum sativum* (coriander), *Abelmoschus esculentus* (okra), *Solanum lycopersicum* (tomato), *Cucurbita pepo* (pumpkin), *Allium cepa* (onion), *Allium sativum* (garlic), *Luffa acutangular* (ridge gourd), and *Momordica charantia* (bitter melon), all consistently irrigated by the river water, especially during the dry periods. These buffer zone with cultivated plants not only forms a productive element that stabilises the river bank, but also supports the livelihood of the local people.

Vegetation along riverbanks as an ecological indicator and its significance

Riverbank vegetation is an important ecological indicator that plays a crucial role in maintaining ecosystem function. Environmental changes are often reflected by changes in the riverbank vegetation, including alterations in hydrological patterns, water quality, and land-use impacts. Studies have demonstrated that various anthropogenic disturbances, such as pollution and land degradation, highly impact the health and composition of the riverbank vegetation (Johansen *et al.,* 2007). For instance, changes in riverbank plant communities, due to nutrient loading and water quality, make them a reliable indicator of both water pollution and habitat fragmentation (Dufour *et al.,* 2009). Key revelations of hydrological condition and ecosystem health are provided by these communities, by responding to the fluctuations in the stream flow (Richardson *et al.,* 2007). Riverbank vegetation plays an important role in improving ecosystem quality by stabilizing soil, filtering water and providing habitat for numerous species, and these services act as a buffer for the riverbank ecosystem (Naiman & Decamps, 1997). At the time of flood events, the roots of riparian plants help them to stabilize river banks, preventing soil erosion (Gregory *et al.,* 1991). Additionally, riparian zones act as an essential part of biodiversity, which offers habitats and pathways for a diverse array of species, such as aquatic life, avian creatures, and land animals' ecosystem (Naiman *et al.,* 2010). The plant life in these areas is vital for regulating the water flow and temperature, which is crucial for numerous aquatic species, especially fishes that are sensitive to temperature changes (Poole *et al.,* 2001).

Near-natural condition

Riverbank plant communities are characterized under a near-natural (GOOD) condition by a diverse mix of native trees, groundcover, and grasses that form a multilayered canopy. Ecological succession processes in natural structures are typically undisturbed and help in promoting high biodiversity. Both aquatic and terrestrial organism acquires support from such zones that offer nesting sites, food sources, and shelter (Naiman & Décamps, 1997). In stabilizing stream banks and preventing erosion, the deep and extensive root system of this vegetation plays a crucial role (Gregory *et al.,* 1991). The dense vegetation of such areas acts as a sediment trapping system, an effective natural filter and prevents the excess nutrients like nitrogen, phosphorus, and other contaminants from entering the water bodies via the surface runoff (Barling & Moore, 1994). Furthermore, these environmental zones foster healthy aquatic and terrestrial habitats, reducing the temperature, while leaf litter and woody debris mostly enhance the habitat complexity. Hence, visually, these zones feature shaded, green, lush, and high plant species richness and well-vegetated banks with less exposed soil and clean water.

Moderately modified condition

Within the moderately modified zone, the vegetated riverbank margins show evidence of few and limited disturbances, which is featured by the decline in vegetation consistency and sporadic intrusion of invasive or non-native species. Regardless, the decrease in structural diversity exhibits limited ecological niches and a reduction in overall ecosystem functioning. Thus, this degree of disturbance of the zone results in a moderately degraded habitat, where few species continue to persist (Tabacchi *et al.,* 2000). The reduced root depth and loss of vegetation decrease the soil's ability to retain nutrients and trap sediments (Dosskey *et al.,* 2010). Whereas exposed patches of soil and their erosion control are maintained, even though some may be found to be increasingly susceptible to erosion, mainly at the time of heavy rainfall.

Heavily modified condition

In badly altered or degraded riverbank structures, vegetation is scanty, often taken over by bare ground, impervious layers, and invasive species. Similar degradation mostly results from excessive land use activities such as agriculture or stream channelization, and urban development. In the absence of natural vegetation,

Table 1: Stressors, responses, and ecological risks to riverbank vegetation

Condition/ Stressor	Riverbank Vegetation Response	Ecological Impact	Visual Cue	Reference
Reduced soil moisture	Decreased plant growth, survival, and productivity	Stress to vegetation, lowered productivity	Dry patches, wilted plants	Stromberg *et al.* (2005)
Altered species composition	Dominance by drought-tolerant or invasive species	Loss of native biodiversity	Replacement of natives by hardy shrubs	Poff *et al.* (1997)
Decline in vegetation cover	Fewer plants along banks	Increased erosion, degraded habitat	Bare soil, sparse vegetation	Rood *et al.* (2003)
Increased vulnerability	Plants prone to pests, heat, and disease	Reduced ecosystem resilience	Stressed vegetation, pest damage	Lytle *et al.* (2004)
Rising temperature	Heat stress, reduced photosynthesis	Sensitive species decline; invasive species increase	Stunted growth, dry margins	Perry *et al.* (2012)
Precipitation change	Seedling washout or dieback	Reduced regeneration, unstable banks	Gullies, bank erosion	Micheli *et al.* (2004)
Streamflow alteration	Disrupted seasonal cycles	Growth inhibition, erosion	Bank collapse, inconsistent cover	Poff *et al.* (2002)
Increased wildfires	Vegetation loss, increased growth of non-native species	Habitat degradation, loss of function	Burned areas dominance by invasive grasses	Coop *et al.* (2020)
LULC pressure	Fragmented or replaced native vegetation	Pollutant load, biodiversity loss	Settlements, roads, degraded strips	Lambin *et al.* (2001); Roy & Roy (2012)

which significantly impairs ecological functioning, it leads to poor water quality enriched with inorganic fertilizers, sediments, and heavy metals, which enter the water bodies unchecked, often causing toxicity (Allan, 2004). Besides stabilizing the stream banks, plant roots help to reduce erosion and prevent large amounts of sediment from entering the water, especially during flooding events (Pusey & Arthington, 2003). Furthermore, there is a severe reduction in habitat quality, displacing wildlife habitats that depend on riverbank zones for breeding, feeding, and shelter. The alluvial plains have lost their natural ability to slow down and absorb water, which causes quicker flooding, increasing the proneness to water logging and pollution. Visually, such areas are marked by barren or degraded land, eroded streambanks, visible litter or pollutants, a dry and unhealthy appearance, and turbid or often discoloured water.

Riverbank Vegetation and Water Scarcity

A significant threat to the riverbank ecosystem is water scarcity, which directly affects the composition and vitality of riverbank vegetation. Riverbank zones face a reduction in soil moisture due to the lesser availability of water, which can lead to a reduction in vegetation cover and biodiversity (Stromberg *et al.,* 2005). The riverbank vegetation of arid and semi-arid areas undergoes a permanent shift in species composition, depending on consistent water sources and prolonged droughts (Poff *et al.,* 1997). Diverted upstream water results in streamflow reduction, which has been shown to decrease the riparian tree density and increase the prevalence of invasive species (Rood *et al.,* 2005). As the water availability decreases along the riverbank, competition between plant species increases, which often gives an advantage to the drought-tolerant or invasive plants, hence disturbing the ecosystem balance (Lytle *et al.,* 2004). Riparian areas are especially vulnerable to less water because they exist at a point where land and water meet. Water availability and scarcity are linked to the riparian ecosystem, which has significant ecological consequences.

The primary impacts of water scarcity on riparian vegetation include:

1) Reduced Soil Moisture : Riparian plants depend on soil moisture levels, which are often maintained by nearby water bodies. Soil moisture can decrease due to prolonged drought conditions or reduced water flow, stressing the plants and hence reducing their growth, productivity, and survival (Stromberg *et al.,* 2005).

2) Altered Species Composition : The composition of riverbank plant communities can be shifted by water scarcity, which may lead to dominance of drought tolerant or invasive species over those that require consistent water availability. However, this leads to a decline in native biodiversity (Poff *et al.,* 1997).

3) Decline in Vegetation Cover : Reduction in overall plant cover along the riverbanks due to the reduction in water availability causes the plants to die off or fail to establish. Moreover, degradation of wildlife habitat and soil erosion can exacerbate the reduction in vegetation cover (Rood *et al.,* 2005).

4) Increased Vulnerability to Stress : Riverbank vegetation that experiences water scarcity tends to become more susceptible to environmental stressors, like high temperature, pests, and diseases. The combined effect of climate change and other disturbances can reduce the resilience of ecosystems (Lytle *et al.,* 2004). Certain human activities exacerbate water scarcity, leading to water diversion and climate change issues, mostly threatening the long-term health and stability of the riverbank ecosystem, thereby making the protection and management of these areas critical.

Riparian Vegetation and Climate Change

Climate change has profoundly affected the riverbank ecosystems, like rising temperatures, altered precipitation patterns, and the frequency of extreme weather events. These variations can lead to further stress on some plant communities, especially in those areas that experience drought conditions, poor vegetation health, and where the species composition has shifted towards drought-tolerant plants (Kareiva *et al.,* 1993). Plant regeneration is affected by the changes in flooding patterns, which act as a crucial element in riverbank ecosystem dynamics (Tockner *et al.,* 2002). Further, the altered rainfall patterns and snowmelt could lead to limited seasonal flooding, resulting in a reduction of riverbank plant species that rely on these conditions for regeneration (Stromberg *et al.,* 2010).

Rising temperatures have led to a toll on ecological consequences for riverbank vegetation. Rising climatic stress can alter photosynthesis and growth patterns, which lead to a decline in native plant species. Therefore, it creates opportunities for invasive and heat-tolerant species to thrive, which are potentially disrupting the local biodiversity and ecosystem (Perry *et al.,* 2012). Similarly, altered precipitation patterns that trigger intense rainfall events tend to increase the risk of flooding, hence accelerating bank erosion, hampering seedling establishment, whereas prolonged droughts or reduced rainfall cause dieback of vegetation, predominantly affecting the shallow-rooted species that rely on consistent soil moisture (Micheli *et al.,* 2004). Snowmelt changes the hydrograph patterns, which alter the streamflow leading to a mismatch between water availability and plant life cycle, thus destabilizing banks and reducing the vegetative cover along river margins (Poff *et al.,* 2002). The vegetated river corridors are now more vulnerable to natural fire due to the drier conditions, and often the post-fire recoveries are dominated by shrubs and invasive grasses that disturb the ecological functionality (Coop *et al.,* 2020). Further, the habitat fragmentation and biodiversity shift due to climate change events alter the species composition and thus decrease habitat continuity along the river channel. The reduction of indicator species such as Willows and Cottonwoods serves as a clear signal of ecosystem stress and declining

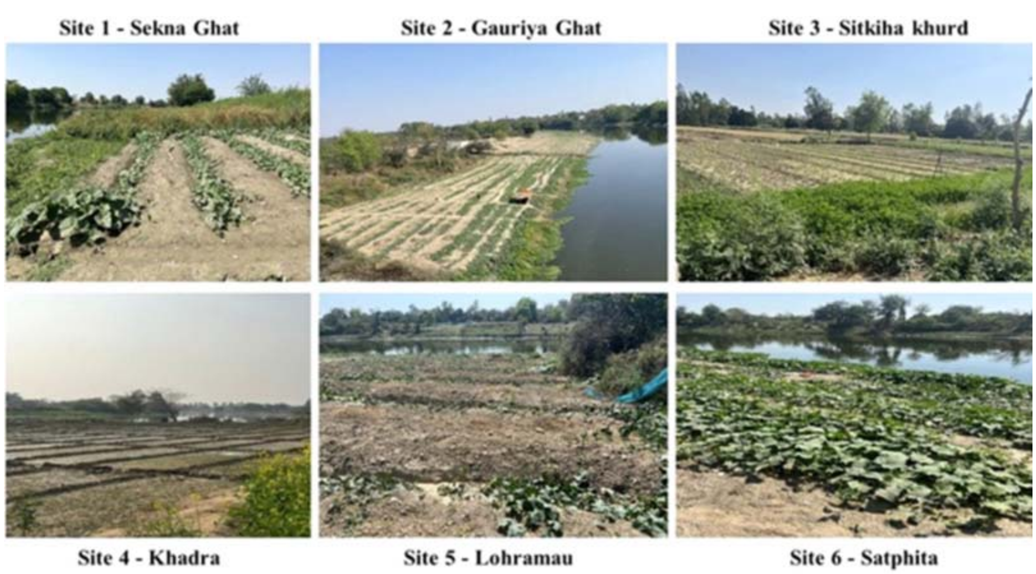

Fig. 1. It shows the riverbank cultivation at different sites of Lucknow

riverbank health, which often corresponds with altered hydrological regimes and sediment dynamics (Merritt & Poff, 2010).

Land use land change (LULC) dynamics

Clawson & Stewart (1965) defined land use as "man's activities on land which are directly tied to the land", and according to Burley (1961), land cover refers to "the plant and artificial structures covering the land surface." Remote sensing enables both qualitative and quantitative assessment of land cover (Roy & Roy, 2012). However, land use and its changes necessitate the integration of social and natural sciences to analyze which human activities are taking place in different parts of the landscape (Lambin *et al.,* 2001). According to Roy & Roy (2012), LULC has been identified as the primary driver of a number of environmental changes, including climate change. The connection between land and river has since been highlighted by a number of limnologists (Hynes, 1963; Kaushik & Hynes, 1971). Understanding how land use and water quality are related is crucial for identifying the main threats to water quality, focusing on important land use areas, and putting in place the necessary measures to reduce pollutant loadings and manage the region's water quality (Abler *et al.,* 2002). The techniques for morphometric analysis, watershed delineation, and monitoring to protect river ecology and functionality include remote sensing and GIS (Patel *et al.,* 2013). Natural resource management is greatly supported by multispectral satellite images from various GIS-based platforms when combined with remote sensing data (Singh *et al.,* 2012). Climaxes in different terrains have been studied by experimenters using remote sensing technologies (Javed *et al.,* 2009). Singh *et al.* (2014) found that the remote sensing DEM data employed for the hydrological analysis of climaxes is significantly advanced than that of the traditional approaches.

CONCLUSION

Plants growing across the river margins are of utmost importance for the river ecosystem as they not only give benefits to the environmental elements but also act as sensitive indicators of the changes in water, land, and weather. Thus, its structure shows the index of riverbank health and the surrounding environment. However, enhanced anthropogenic activities and other changes in the environment create pressure on the riverine vegetation, including increased temperature, water scarcity, altered floodplains, and land-use changes. These pressures reduce the ecological resilience of the riverbank system and also compromise the capacity for supporting biodiversity, filtering pollutants, and stabilizing riverbanks. Hence, the protection of riverbank corridors is important for elevating ecosystem resilience and sustainable balancing of ecology in the face of several critical ongoing environmental challenges.

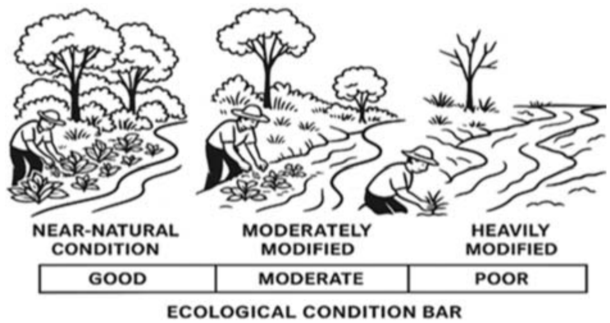

Fig. 2. It indicates the ecological condition of riverbank vegetation (Figure conceptualized from Gonzalez *et al.,* 2006).

REFERENCES

Allan, J.D. (2004). Landscapes and riverscapes: The influence of land use on stream ecosystems. *Ann. Rev. Ecol. Evol. Syst.*, 35: 257-284.

Barling, R.D., & Moore, I.D. (1994). Role of buffer strips in management of waterway pollution: A review. *Environ. Manage.*, 18(4): 543-558.

Burley, T.M. (1961). A cartographic approach to the classification of urban land use. *Reg. Stud.*, 1(1): 25-42.

Clawson, M., & Stewart, C.L. (1965). Land use information: A critical survey of U.S. statistics including possibilities for greater uniformity. Resources for the Future, Inc.

Coop, J.D., Parks, S.A., McClernan, S.R., & Holsinger, L.M. (2020). Wildfire and climate change interact to drive ecosystem transitions in forested landscapes. *Front. Ecol. Environ.*, 18(8): 461-468.

Dosskey, M.G., Vidon, P., Gurwick, N.P., Allan, C.J., Duval, T.P., & Lowrance, R. (2010). The role of riverbank plant communities in protecting and improving chemical water quality in streams. *J. Am. Water Res. Assoc.*, 46(2): 261-277.

Dufour, S., & Piégay, H. (2009). From the myth of a lost paradise to targeted river restoration: Forget natural references and focus on human benefits. *River Res. Appl.*, 25(5): 568-581.

Dudgeon, D., Arthington, A.H., Gessner, M.O., Kawabata, Z.I., Knowler, D.J., Lévêque, C., & Sullivan, C.A. (2006). Freshwater biodiversity: importance, threats, status and conservation challenges. *Biol. Rev.*, 81(2): 163-182.

González delTánago, M., & García de Jalón, D. (2006). Attributes for assessing the environmental quality of riparian zones. *Limnetica*, 25(1-2): 389-402.

Gregory, S.V., Swanson, F.J., McKee, W.A., & Cummins, K.W. (1991). An ecosystem perspective of vegetated river margins. *BioSci.*, 41(8): 540-551.

Hynes, H.B.N. (1963). The biology of polluted waters. Liverpool University Press.

Javed, A., Khanday, M.Y., & Ahmed, R. (2009). Prioritization of sub-watersheds based on morphometric and land use analysis using remote sensing and GIS techniques. *J. Ind. Soc. Remote Sens.,* 37(2): 261-274.

Johansen, K., Phinn, S., & Taylor, M. (2007). Mapping of riverbank zone attributes using high spatial resolution multispectral and hyperspectral imagery. *Photogramm. Eng. Remote Sens.,* 73(8): 935-944.

Kaushik, N.K., & Hynes, H.B.N. (1971). The fate of dead leaves that fall into streams. Arch. *Hydrobiol.*, 68: 46-–515.

Kareiva, P., Kingsolver, J.G., & Huey, R.B. (1993). Biotic interactions and global change. Sinauer Associates Inc.

Lambin, E.F., Geist, H.J., & Lepers, E. (2001). Dynamics of land-use and land-cover change in tropical regions. *Ann. Rev. Environ. Res*., 28(1): 205-241.

Lambin, E.F., Geist, H.J., & Lepers, E. (2003). Dynamics of land-use and land-cover change in tropical regions. *Ann. Rev. Environ. Res*., 28: 205-241.

Lytle, D.A., & Merritt, D.M. (2004). Hydrologic regimes and riverbank forests: A structured population model for cottonwood. *Ecol.,* 85(9): 2493-2503.

Merritt, D.M., & Poff, N.L. (2010). Shifting dominance of riverbank tree species in response to climate change. *Proc. Natl. Acad. Sci. U.S.A*., 107(19): 8259-8264.

Micheli, E.R., Kirchner, J.W., & Larsen, E.W. (2004). Riverbank plant communities' response to altered hydrologic regimes: A modeling approach. *Ecol. Appl*., 14(1): 137-149.

Nagendra, H., Nagendran, S., Paul, S., & Pareeth, S. (2013). Graying, greening and fragmentation in the rapidly expanding Indian city of Bangalore. *Landsc. Urban Plann*., 105(4): 400-406.

Naiman, R.J., & Décamps, H. (1997). The Ecology of interfaces: Vegetated River margins. *Ann. Rev. Ecol. Syst*., 28(1): 621-658.

Naiman, R.J., Decamps, H., & McClain, M.E. (2010). Riparia: ecology, conservation, and management of Streamside Communities. ElsevierAcademic Press, San Diego.

Nilsson, C., & Berggren, K. (2000). Alterations of riparian ecosystems caused by river regulation: Dam operations have caused global-scale ecological changes in riparian ecosystems. How to protect river environments and human needs of rivers remains one of the most important questions of our time. *BioSci.*, 50(9): 783-792.

Patel, D.P., Dholakia, M.B., Naresh, N., & Srivastava, P.K. (2013). Water harvesting structure positioning by using geo-visualization concept and morphometric analysis: A remote sensing and GIS approach. *Water Res. Manag*., 27(8): 3115-3135.

Perry, L.G., Andersen, D.C., Reynolds, L.V., Nelson, S.M., & Shafroth, P.B. (2012). Climate change and riverbank plant communities: Streamflow and temperature influences on plant community dynamics. *Ecol. Appl*., 22(1): 160-173.

Poff, N.L., Allan, J.D., Bain, M.B., Karr, J.R., Prestegaard, K.L., Richter, B.D., & Stromberg, J.C. (1997). The natural flow regime. *BioSci.*, 47(11): 769-784.

Poff, N.L., Allan, J.D., Bain, M.B., Karr, J.R., Prestegaard, K.L., Richter, B.D., Sparks, R.E., & Stromberg, J.C. (2002). Hydrologic variation with climate change and ecological implications for stream ecosystems. *BioSci.,* 52(1): 60-70.

Poole, G.C., & Berman, C.H. (2001). An ecological perspective on in-stream temperature: Natural heat dynamics and mechanisms of human-caused thermal degradation. *Environ. Manag*., 27(6): 787-802.

Pusey, B.J., & Arthington, A.H. (2003). Importance of the riverbank zone to the conservation and management of freshwater fish: A review. *Mar. Freshw. Res*., 54(1): 1-16.

Rood, S.B., Samuelson, G.M., Weber, J.K., & Wywrot, K.A. (2005). Twentieth-century decline in streamflows from the hydrographic apex of North America. *J. Hydro.*, 306(1-4): 215-233.

Richardson, J.S., Naiman, R.J., Swanson, F.J., & Hibbs, D.E. (2007). Riverbank communities associated with Pacific Northwest headwater streams: Assemblages, processes, and uniqueness. *J. Am. Water Res. Assoc*., 43(1): 1-11.

Roy, P.S., & Roy, A. (2012). Land use and land cover change in India: A remote sensing and GIS perspective. *J. Ind. Inst. Sci*., 90(4): 489-502.

Sweeney, B.W., Bott, T.L., Jackson, J.K., Kaplan, L.A., Newbold, J.D., Standley, L.J., & Horwitz, R.J. (2004). Riparian deforestation, stream narrowing, and loss of stream ecosystem services. *Proc.Natl. Acad. Sci.*, 101(39): 14132-14137.

Seavy, N.E., Viers, J.H., & Wood, J.K. (2009). Riparian bird response to vegetation structure: a multiscale analysis using LiDAR measurements of canopy height. *Ecol. Appl.*, 19(7): 1848-1857.

Singh, S.K., Panda, S.N., Kumar, A., & Sharma, C.S. (2012). Morphological characterization of watershed for sustainable Water Resour. Manag. using GIS. *Water Res. Manag.,* 26(8): 2321-2349.

Singh, S.K., Srivastava, P.K., & Gupta, M. (2014). Geospatial modeling of land use/cover dynamics using remote sensing and GIS: A case study of part of Ganga river basin, India. *Environ. Earth Sci*., 72: 2217-2231.

Stromberg, J.C., Lite, S.J., & Dixon, M. . (2005). Effects of stream flow patterns on riverbank plant communities of a semiarid river: Implications for a changing climate. *River Res. Appl*., 21(8): 915-933.

Stromberg, J.C., Lite, S.J., & Dixon, M.D. (2010). Effects of stream flow patterns on riparian vegetation of a semiarid river: implications for a changing climate. *River Res. Appl.*, 26(6): 712-729.

Tabacchi, E., Correll, D.L., Hauer, R., Pinay, G., Planty-Tabacchi, A.M., & Wissmar, R.C. (1998). Development, maintenance and role of riparian vegetation in the river landscape. *Freshw. Biol.*, 40(3).

Tabacchi, E., Planty-Tabacchi, A.M., Roques, L., & Nadal, E. (2000). Impacts of riverbank plant communities on Hydrol. Process. *Hydrol. Process*., 14(16-17): 2959-2976.

Tockner, Klement, & Jack A. Stanford. (2002). Riverine Flood Plains: Present State and Future Trends. *Environ. Cons.*, 29(3): 308-330.