Cause and Impact of Alteration Along Riverine Landscape

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Received: 12 July 2022 Revised: 20 September 2022 Accepted: 18 October 2022
Published: 1 November 2022

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Abstract

The urban river environment not only consists of natural features but also other physical surroundings within the city that fall under the influence of the river. They include the river system, the built form, and the networks within the city. Due to development pressures, the built form and the networks try to exploit the river systems. On the basis of a literature study, it was found that assessment of the alteration of riverine landscapes due to anthropogenic activities like riverfront development and its impact on the ecological processes in the upstream and downstream of the river system reveals profound methodological gaps. In this review paper, the cause of the alteration of riverine landscapes and how it impacts the ecological processes are discussed. Riverine landscapes with reference to Indian contexts are discussed in detail to understand the seriousness of this problem. Due to riverfront development activities, there is a change in the structure of the land-water median/edge, along which most of the ecological processes thrive. Hence, it becomes important to find and suggest sustainable ways to deal with this issue. Newer habitats and systems get established due to changes in the course of rivers and water, which need to be safeguarded from further alteration for the overall health of the river.

Keywords

Riverine ecosystem; altered landscape; riverfront development; impact evaluation; river health; ecological processes

Introduction

Landscapes around the world express a long-standing, intimate relationship between people and their natural environment. They are manifestations of nature's and humans' collaborative efforts. Land used for traditional agricultural and water harvesting practices, reflect specific techniques of land use that guarantee and sustain biological diversity. Others, associated in the minds of communities with powerful beliefs and traditional customs, embody an exceptional spiritual relationship of people with nature. Riverine landscapes represent specific ecosystems, the existence of which is directly dependent on permanent or at least periodic contact with watercourses. Geographically, riverine landscapes can be defined as the spatial extent of an area along the floodplains[1]. The riverine landscape also hosts some of the most important vegetative communities, which support wildlife species[2]in his article "Riverine landscapes: taking landscape ecology into the water", states that riverine landscapes in their natural state (preferably unaltered) demonstrate high levels of complexity across a range of scales. They can be narrowed down in one (or more) of three ways or scales: i) rivers as elements of a landscape setting/region; ii) rivers linked with their surroundings by boundary dynamics; iii) rivers as internally heterogeneous landscapes. He further adds that there are three main aspects of the riparian landscape which one needs to consider while researching: the water body, riparian vegetation, and river landscape planning. They have significant implications for river ecosystems because they play multiscale functional roles in the geomorphological, physical, chemical, and biological conditions of the river system.

Riverine landscapes in India are subject to extreme developmental activities, starting from the very edge of the river to far-reaching extents. These areas embody a rich cultural imagery versatile species diversity, enable the livelihoods of millions and drive the formation of distinct regional identities. The topographic diversity of the watershed and the boundless productive landscape along major rivers have captured the imagination of the national government to undertake river valley development and riverfront development projects. These activities have transformed riverine landscapes into an interstate infrastructural network of water conveyance and energy generation. Over time, these massive government projects have become widely questioned, sparking heated debates about the need for more environmental protection measures to stem the impact of development on contemporary India[3].In most cases, these developmental/anthropogenic activities adversely affect only a section along the river;

while in some cases they impact the overall river system and its associated processes (such as ecological, socio-cultural, hydrological, geological, geomorphological, etc.). This further leads to extreme changes in the structure of the associated elements (which make up these systems). In contrast to that, sometimes these anthropogenic activities add to the uniqueness of certain places within this landscape, which in turn makes the places important culturally and ecologically. There has been a major shift in the ecosystem and biodiversity along the riparian corridor of such altered landscapes, giving rise to many new established processes. As research in such areas of post-developmental activities is very sparse, one fails to understand the measures that need to be taken for this modified landscape, which will help one intervene in a more sensitive manner and work towards regeneration or enhance the newer relationships that have been built after these infrastructural developments. Hence, it becomes important to observe, record, and understand these changes and take sufficient measures to safeguard them from further alterations.

Indian rivers have a strong physical construct as well as a cultural and religious identity, which gets strengthened by the associations of stories of the land, practices, and beliefs. Eminent researcher Mr. Brij Gopal[4,5] and many others have always highlighted and mentioned how Indian rivers have not been understood as ecosystems but are only treated as conduits of water or wastewater. The flow of rivers in cities has been fundamentally changed, and this can be seen in a variety of ways. Today, the approach towards decision-making on how to deal with altering riverine landscapes is confusing government officials, bureaucrats, and designers into complacency about ecological quality where landscapes look natural, and it is provoking people into objecting to ecological landscape protection or innovation where the resulting landscapes do not look natural. The scales of economic, monetary, and financial gains are usually used to measure concepts of development. The ecological and social costs of such unrestrained pollution and degradation have put a big question mark on the perceived notion of economic development[6]. For this reason, there has to be a greater awareness about the need to protect the environment with effective planning and the ability to strike a fine balance between development and environmental protection. Current trends in research[7]and design approaches for riverine landscapes in India reflect morphological changes, which are governed by expert land-use techniques, which claim to guarantee and sustain biological diversity. This is a change from earlier considerations of human linkages to river flows, which focused heavily on recreational uses of rivers or scenic beauty[7].

Literature Research

A systematic search of doctoral research and dissertations, peer-reviewed research papers, and review articles was performed, which helped identify evidence of the impact of anthropogenic modifications on river landscapes and what has been the trend in research related to writing on Indian riverine landscapes. With the help of the electronic database of Google Scholar, with keywords such as "culture and landscape", "visual character and perception of landscapes", "associative cultural landscape", "Indian riverine landscapes", "altered and unaltered landscapes", "anthropogenic alteration along riverine landscapes", "river health", and later "riparian vegetation", "cultural associations", "socio-cultural practices", "riverfront development", etc., against each type of anthropogenic modification were reviewed (refer Table 1). On the basis of this search, articles were scrutinized on the basis of the following criteria: (1) specific reference to altered and unaltered riverine landscapes and patterns associated with these changes; (2) papers specifying evidence of hydrological, ecological, and geomorphological components of the impact on river landscapes; (3) methods used for assessing the heath of rivers and alteration; and (4) ecological processes, which help sustain river ecology and maintain biodiversity.

Riverine landscapes are demarcated as transitions between terrestrial and freshwater ecosystems and include components of topography, vegetation, and soils. But the planning efforts have destroyed and disfigured the natural landscape, topography, agricultural soil, water catchments, and architectural heritage that give the very character of the place[8,9]. There is a methodological gap in assessing the degree of alteration of riverine landscapes.

A pristine landscape (untouched by humans) or "raw scenery" is amongst the most common responses with regards to an unaltered landscape. As per the definition in Cambridge and Oxford dictionaries, "altered" is defined as "change in appearance, character or structure". This is more in relation to the visual character or appearance (with a focus on vegetation). Some researchers have defined altered landscapes as those with habitat loss or habitat fragmentation. This in turn suggests that the biophysical systems present in such landscapes have an inefficient flow of energy or nutrients among species. Hence, the health of a landscape system can be decided by knowing the "degree of alteration": when the system is resilient to long-term effects

of natural perturbations, or when the landscape system need not be "doctored," or "when the system reaches its capacity for self-renewal"[10].

Ecological Processes

Visible traces of patterns and processes associated with riverine ecology can be witnessed along and across the riverine landscape. If their processes are sustained or revived, there is a probability that river ecology can re-establish itself or provide an environment for newer species and processes to establish themselves. Some of these processes, such as formations of various landforms, transformations in flora species and their associated fauna species, help sustain the river ecology and also help one understand the age of the river. Lateral shifts along the banks of a river are different in this character and also have distinct features across river sections at different locations. These imprints are old traces of the rivers and are similar to cardiographs, which suggest that the river is still "alive". The simultaneous cyclic process of uptake of nutrients from water by biota and subsequent release back to water during downstream transport[11]. But due to development projects like riverfront development, the continuity of water breaks. Also, the seasonal cycle of water retention and movement gets disturbed as a section of the river's water flow is highly regulated for aesthetic reasons.

Instances	**Important actions**	**Prominent researchers**
Helps in reducing soil erosion, and taps nutrients and sediments. This enhances quality of soil. Also because of presence of fertile soil – good for agriculture activities can be carried out	• Taps Nutrients and Sediments • Soil quality improves	
It filters pollutants from surface run off coming from agricultural fields and enhances water quality	Water quality improves	Kileyand Schneider (2005)
Retention of water and recharges aquifers and soil moisture.	• Water Retention • Recharge	

The riparian canopy provides organic matter via litter fall	Organic matter	Amitha (2003)
Regulates water temperature, by reduces solar heating of stream water by shading, especially in low order streams	Controls temperature	Nancy et al. (2004).
Serve as substrates for biological activity by microbial and invertebrate organisms	Supports reproduction and biological activities	Nancy et al. (2004); Gloss et al. (2004)
Single most productive type of wildlife habitat –acts as corridor. It maintains and enriches biodiversity	Maintain and enhance biodiversity	Robert et al. (1997).
Grazing land for cattle	Grazing land	Hannah (1997)

Table 1: Indicate various instances supported by ecological processes.

An initial literature review suggested (refer Table 1) that ecological processes are most vulnerable to anthropogenic activities and that they are the primary contributors to sustaining and maintaining river ecology and biodiversity. These processes include those in rivers that have existed for very long periods of time and range from purely physical to more biologically mediated [12,13]processes. We will focus exclusively on biologically mediated processes, which relate to the most ecologically relevant processes to rivers. Based on readings, five dominant processes were identified, based on different aspects of ecosystem functioning, and they proved to be conceptual and methodological references[14]:

1. Exoenzymatic activities, uptake and degradation of dissolved organic matter

2. Uptake of nutrients, primarily by microbes and plants, at the organism or community scale; Individual processes within the cycle of a particular nutrient (e.g. nitrification, denitrification, N fixation)

3. The balance of energy created (primary production) and used (respiration) within a river reach

4. Pollutant Dynamics: The capacity of the river as well as organisms or communities to take up and bio-accumulate dissolved pollutants.

5. Community Dynamics: Reproduction, Biodiversity, and Habitat Establishment

The morphology of rivers, which is defined as the change in shape and direction of water movement or a river; change in the amount and quality of water; habitat fragmentation due to riverfront development along the riverine landscape. This in turn changes the biophysical attributes along the banks. River morphology (change or lack of water/water retention) and soil quality changes as a result of anthropogenic activities such as riverfront development. This leads to altered landscapes, which in turn change the character and structure of flora-fauna biodiversity (community dynamics), one of the important ecological processes. Habitat and biodiversity in an impact area of 0-10 sq.km from the river edge/land and water mediation are destroyed due to riverfront development, and it's this edge where the river can swale, and biodiversity can thrive. This results in lower habitat heterogeneity, reduced refuge habitat, creates locally intolerable conditions, and shifts aquatic communities.

Anthropogenic Activities: the reason for the change

As discussed above, when the physical, chemical, and biological indicators of a river ecosystem are altered, they lead to significant changes in processes that sustain the riverine ecosystem. Riverine landscapes in India are the preferred landscapes for many anthropogenic activities. These activities or practices can be categorized based on the frequency of performance and nature of their alterations: practices which are conducted on a daily basis; practices which contribute towards livelihood or economic growth and hence are performed either on a daily basis or bi-annually or annually; and religious and cultural activities like festivals; rituals and ceremonies; mass gatherings to invoke rituals or worship; harvest festivals; and respect to water bodies; gatherings/"*mela*"; procession/"*parikrama"*. From a literature review, it was identified that the three main reasons why the river system changes are: technological development factors, natural factors, and socio-cultural practices.

- Technological development factors: initiatives or activities that are carried on as part of developmental activities fall under this category. Political ideologies or preferences, or image building, or responding to urban sprawl or economic growth sometimes governs

these activities. Most of these activities are needed by the hour, and so they get prioritized. These activities cause visible changes to the riverine landscapes. Damming of rivers and siltation due to damming; subsurface alteration due to mining, metro rail, etc.; Infrastructure development-riverfront development; Inter-catchment water transfer and Surface Hydrology-connecting rivers projects; Groundwater absorption as a result of wells and bore wells. Deforestation of natural landscapes to clear land for development activities; on-surface alterations—laying out road network; introduction or discharge of industrial wastes/pollutants into water—causing pollution; waterlogging/drainage during heavy rains due to building in low-line areas; and so on are some of the prominent activities that alter riverine landscapes (particularly the land-water median/edge).

- Natural processes/causes: These processes occur during the geological timeline, as physical transformation in landforms is a time-bound activity mainly influenced by lithological, geological, and earth movements. In most cases, these alterations are irreversible. But due to human involvement or impact, these processes do get accelerated. Shifting of river courses, lithological change, and geographic change—mainly related to soil formation and subsurface water level changes; Climate change; sedimentation and siltation of deposits due to river water movement; floods etc. are some of the important natural processes which alter riverine ecology and landscape.

- Socio-Cultural activities/practices: There is strong linkage between river flow to floodplain agriculture, transportation and social exchange, and as acts of reverence, cultural identity, or sense of place. Change in land-use in the land adjacent to the riverbed, by activities like encroachment and illegal construction, Sand mining, agricultural activities, etc. alter the land-water edges. Daily domestic activities like washing clothes, filling water, bathing animals, fishing, other religious activities during festivals and celebrations mainly pollute the water. Commercial activities like boating as means of transport as well as recreation, cutting of forest wood, and harvesting other forest produce, mainly alter the water quality, and vegetation patterns.

For all the mentioned categories, developmental activities like riverfront development or damming impact and alter ecological processes such biodiversity, habitat heterogeneity, habitat

complexity and riparian cover (refer Table 2). In case of riverfront development, the recent trends have encouraged the idea of concretizing the land-water mediation/edge. It is this edge, which sustains most ecological processes. These processes exit at varied scales along the entire river system: starting for habitat scale (0-5sq.km area), to second order and third order streams (5-10 sq.km) and later first order stream (10-100sq.km); up till watershed and catchment areas (100 -10,000 sq.km and above). It is this edge where the river swales, deposits sediments and keeps the ecological processes going. These are extremely important aspects when it comes to assessing the life and health of river systems.

Anthropogenic modifictions	**Modification type (what it modifies)**	**Response/Impacts**
Damming; Sedimentation	Changes the course of the river; Rise in water level in upstream/catchment; flood plain connectivity	Siltation; Water retention; Water quality; Change in water movement; restricts Species movement; livelihood; increase in tourism; change in character of landscape
Riverfront development	Rise in water level in upstream and downstream; flood plain connectivity; land-water mediation/edge concretized; water logging; structure and composition of riparian vegetation	Siltation; Water retention; Water quality; Change in water movement; restricts Species movement; Species diversity; Habitat fragmentation; increase in tourism; change in character of landscape
Inter-catchment water transfer	Uninterrupted water supply for agriculture; supports navigation and transport	Species diversity; Habitat fragmentation; restricts Species movement

Deforestation of natural landscapes; Timber/Forest (ecosystem service)	Livelihood and income of communities depended on ecosystem services; structure and composition of riparian vegetation	Microclimate regulation is patches; soil formation and quality; species diversity; Habitat fragmentation; lower oxygen concentrations; organic matter; water temperature
Industrial wastes – Pollution; Daily domestic activity; Boating/Tourism and Transportation mode	Physicochemical and biological properties	Bioaccumulation and bio magnification; disturbs the food web; soil quality; water quality
Settlements and built environment; Change in land-use: encroachment, illegal construction, etc.	Change in land use; flood plain connectivity; rise in paved surfaces;	Restricts Species movement; habitat fragmentation; ground water recharge; surface runoff; species diversity
Fishing (ecosystem service)	Livelihood and income of communities depended on ecosystem services	Species diversity
Cultural and religious activates	Change in land use; pollution; biodiversity; natural habitat	soil quality; water quality
Sand mining	Greater availability of construction material; riverbed instability; land-water mediation/edge; widening lake/river section	Bank erosion; soil formation and quality; species diversity; ground water recharge
Agriculture activities	Change in land use; flood plain connectivity;	Soil formation and quality; ground water recharge;

	water quantity; nutrient composition, biodiversity; natural habitat; structure and composition of riparian vegetation	chemical composition of water; species diversity

Table 2: Describes various anthropogenic activities and how they modify natural systems.

To further articulate these practices and activities, one needs to record how frequently and to what extent these activities and practices alter riverine landscapes. The daily activities and those associated with livelihood or income generation happen on a regular basis, which leads to more alteration of the landscape; while those like religious festivals or rituals, which happen on a quarterly or annually, alter less (the scope of revival has time). At this point, one must understand that not all practices alter or affect the riverine landscape to a similar degree. Hence, it becomes important to observe, identify, document, and quantify the "degree of alteration-degree of impact" these activities have on the ecology of the riverine landscape.

Impact due to Altered Riverine Landscapes

Due to the above-mentioned activities, factors and practices associated with river ecology undergo change [15,16,17,18]. This in turn alters and impacts patterns and processes along riverine landscapes. Physical changes mainly include shifts in patterns of sediment movement (change in sediment transport; sediment sequence and composition), change in channel pattern, and alteration of flow regime (which includes change in rate of soil and sediment erosion, degradation in downstream flow, channel narrowing, degrading flood plains), loss of habitat availability, change in quality and flow of surface water quality, alteration of biogeochemical cycles, decreased water temperature, and deepening of river section. Chemical changes include changes in water quality, increased organic contaminants, increases in pollutants, changes in nitrogen and phosphorus levels, etc. While biological changes mainly include a decrease in fish diversity, problems of plant colonization, change in community composition and abundance of

alien/invasive species, increase in sedimentation, change in benthic macro vertebrate species composition, etc.

As defined by Maddock[19], river health, or its ability to sustain or develop resilience, can be measured through visible indicators such as ecological status, water quality, hydrology, geomorphology, and availability of physical habitat. Ecological integrity, resilience, and support of ecosystem structure, functions, and services are the characteristic features of healthy rivers[20]. A healthy river system stabilizes stream banks, regulates the thermal regime of the river, sustains food security of river organisms, enhances groundwater recharge, and provides habitat to wildlife. By knowing/post assessing the health of river, we can predict to what extent the system has been altered and what the scope for it to revert back. The health level of rivers is divided into five grades: very healthy; healthy; sub-healthy; unhealthy; and morbid, according to the comprehensive score. These health conditions are defined as below:

1) A very healthy river is the one that has rich water resources, a good water-ecological environment, satisfies the reasonable needs of human society and supports economic development for the basin resources.

2) A healthy system is one that has a relatively good hydrology and water environment status. It satisfies the reasonable demand of human social and economic development for basin resources.

3) An unhealthy system is the one that has threatened the health status of the basin with scarce water resources, a fragile water ecological environment, maladjusted system structure, and damaged function. In spite of all this, some functions are still maintained.

4) The last condition is defined as morbid, which basically means a system, which is devoid of all functions or most physical, chemical, and biological indicators are extremely low.

Research Gaps

A need has risen to strike a fine balance between development and environmental protection[6]. There has been insufficient research work done in dam-impacted catchment areas, where riparian vegetation has potential for regeneration (altered landscapes). Catchment areas

and tributaries can be considered most appropriate scales to improve hydrologic conditions and to assess the potential of riparian zones that are remnants of altered landscapes. As mentioned by some eminent researchers[4,5], "In India, rivers have not been understood as ecosystems but are treated simply as conduits of water or wastewater." If we specifically discuss about riparian vegetation, then there is a sufficient research done in areas of specific species diversity and conservation (like fishes, planktons, aquatic vegetation and so on). There is a need for researchers to conduct research in areas at specific species and interface levels, along the altered landscapes (specifically along the riparian vegetation and streams interface), as these areas are key for regulating aquatic-terrestrial linkages[21,22,23] and that they provide early indications of environmental change[23,24,25]. Identifying appropriates and role of riparian vegetation in altered landscapes; establishment of newer desired ecosystem systems with response to hydrological and geomorphological changes[26]; development of framework for delineating affected riparian vegetation (especially forest and upland vegetation) are few of the many areas which needs to be studies in detailed (especially from time to time). Basic documentation or recording of this data is also insufficient for Indian rivers.

Conclusion

Due to riverfront development activities, the riparian edge or areas of land and water mediation are altered. It's these points, or areas, which sustain all components that support and sustain river ecology and maintain biodiversity. These activities alter the movement, amount, and quality of water. Due to a break in river water flow, habitat fragmentation also occurs (both longitudinal and lateral). This in turn changes the biophysical attributes along the banks. The overall morphology and soil quality of the river get altered. This impacts flora-fauna biodiversity (community dynamics), which is one of the important ecological processes. When development happens in a small stretch of river, a new ecosystem gets recreated, but it is completely man-made and may or may not be sustained by itself. What this development does is that it impacts the entire river ecology. It changes and creates new patterns upstream as well as downstream. Community dynamics (interrelation between flora, fauna and water) are established in these areas (edges (biodiversity). Hence, it is important to further address and discuss the measures that should be taken to safeguard newly established patterns from further degradation. This paper attempts to inform the importance of land-water mediation/edge to

maintain the health of river ecology and suggests the need to record and document the degree of alteration of riverine landscapes as well as monitor developmental activities to avoid further alteration of riverine landscapes.

Future Prospects

This research will draw attention on the current adapted approaches to designing along riverbanks and its edges, and also develop framework under which assessment of river ecology in areas post and pre riverfront development. This will in turn guide designers, stakeholders, and decision makers to safeguard and deal with land water meditation edge more efficiently. This research will connect the aspect of river ecology and biodiversity with strategic design decisions – the actual agglomeration of research and design.

References

1. Jakubínský,J., Herber,V., Cudlín,P.(2019). A comparison of four approaches to river landscape delineation: The case of small watercourses in the Czech Republic.*Moravian Geographical Reports*, *27*(4), 229-240.
2. Wiens, J.A. (2002). Riverine landscapes: taking landscape ecology into the water.*Freshwater Biology*,*47*(4), 501–515.
3. Amte, B. (1989). *Cry, the beloved Narmada.* Maharashtra: Maharogi Sewa Samiti.
4. Gopal, B. (2004). State of degradation and approaches to restoration of floodplain rivers in India. In E. Welcomme R. and T. Petr (Ed.),*Second International Symposium on the Management of Large Rivers for Fisheries Volume II* (pp. 79-89). Bangkok, Thailand: Food and Agriculture Organization of the United Nations (FAO).
5. Gopal, B., Fischlin, A., Midgley, G.F., Price, J.T., Leemans, R., Turley, C. (2007).(Ed) Parry, M., Canzonai, O., Palutikof, J., Linden, van der P., Hanson, C. Ecosystems, their properties, goods and services,Climate Change 2007: Impacts, Adaptation and Vulnerability. Contribution of Working Group II to the *Fourth Assessment Report of the Intergovernmental Panel on Climate Change* (pp. 211-272). Cambridge, UK: Cambridge University Press.

6. Shabeer, A.M. (2012). *Environmental degradation and natural restoration of chaliyar river basin*. [Doctoral thesis, University of Mysore, Department of Geography, India] Shodhganga.https://shodhganga.inflibnet.ac.in/handle/10603/36439

7. Johnson, L. B., & Host, G. E. (2010). Recent developments in landscape approaches for the study of aquatic ecosystems. *Journal of the North American Benthological Society , 29*(1), 41-66.

8. Dempsey, N., Jayaraj, S. R., & Redmond,E. (2017). There's always the river: social and environmental equity in rapidly urbanising landscapes in India. *Landscape Research,43*(3), 275-288.

9. Dengle, N. (2010). Urbanization, farm land and the form of public space. *New architecture and urbanism: Development of Indian traditions* (pp. 160–166). Delhi: Delhi: Cambridge Scholars Publishing in association with GSE Research.

10. Leopold, A. (1968). *A Sand County Almanac: And Sketches from Here and There.* (Original work published 1949). New York: Oxford University Press.

11. Vannote, R. L., Minshall, G. W., Cummins, K. W., Sedell, J. R., & Cushing, C. E. (1980). The river continuum concept. *Canadian Journal of Fisheries and Aquatic Sciences , 37*(1), 130–137.

12. Palmer,M.A., Febria,C.M.(2012). The heartbeat of ecosystems. *Science, 336*(1), 1393–1394.

13. Palmer, M., Bernhardt, E., Allan, J.D., Lake, P., Alexander, G., Brooks, S. (2005). Standards for ecologically successful river restoration. *Journal of Applied Ecology,42*(2), 208-217.

14. Schiller,vanD.,Acuña,V.,Aristi,I.,Arroita,M.,Basaguren,A.,Bellin,A.,Boyero,L.,Butturini,A.,Ginebreda,A.,Kalogianni,E.,Larrañaga,A.,Majone,B.,Martínez,A.,Monroy,S.,Muñoz,I.,Paunović,M.,Pereda,O.,Petrovic,M.,Pozo,J.,Rodríguez-Mozaz,S.,Rivas,D.,Sabater,S.,Sabater,F,Skoulikidis,N.,Solagaistua,L.,Vardakas,L,Elosegi,A. (2017). River ecosystem processes: A synthesis of approaches, criteria of use and sensitivity to environmental stressors. *Science of The Total Environment, 596* (1), 465-480.

15. Reed,J., Vianen,J.V., Deakin,E.L., Barlow,J., Sunderland,T. (2016). Integrated landscape approaches to managing social and environmental issues in the tropics: learning from the past to guide the future. *Global Change Biology, 22*(1), 2540–2554.

16. Johansson, M., & Nilsson, C. (2002). Responses of riparian plants to flooding in free-flowing and regulated boreal rivers: An experimental study. *Journal of Applied Ecology,39*(6), 971-986.

17. Reed, J. (2017). *Integrated landscape approaches for society and environment in the tropics: From premise to practice.* [PhD thesis, Lancaster University]. https://eprints.lancs.ac.uk/id/eprint/89102/1/2017reedphd.pdf

18. Reed, P. (2005). *Groundswell: Constructing the Contemporary Landscape.* New York: Museum of Modern Art.

19. Maddock, I. (1999). The importance of physical habitat assessment for evaluating river health. *Freshwater Biology, 41*(1), 373-391.

20. Singh,P.K., Saxena,S.(2018).Towards developing a river health index.*Ecological Indicators,85*(1), 999-1011.

21. Décamps, H., & Naiman, R. (1990). *The Ecology and Management of Aquatic-Terrestrial Ecotones Volume 4* of Man and the biosphere series,New Jersey: CRC Press.

22. D´ecamps, R. J. (1997). The Ecology Interfaces: Riparian Zones. *Annual Review of Ecology and Systematics,28*(1), 621–658.

23. Naiman, R. J., Décamps, H., Pastor, J., & Johnston, C. A. (1988). The Potential Importance of Boundaries of Fluvial Ecosystems. *Journal of the North American Benthological Society,7*(4), 289-306 .

24. Decamps, H. (1993). River Margins and Environmental Change. *Ecological Applications,3*(3), 441-445.

25. Naiman, R. J., Decamps, H., & Pollock, M. (1993). The Role of Riparian Corridors in Maintaining Regional Biodiversity. *Ecological Applications,3*(2), 209-212.

26. Tabacchi, E., Lambs, L., Guilloy, H., Planty, T. A., Muller, E., & Décamps, H. (2002). Impacts of riparian vegetation on hydrological processes. *Hydrological processes,14*(1), 2959-2976