Chapter 1

RIPARIAN ECOSYSTEMS - AN INTRODUCTION

Objectives

1. To define and review the ecosystem settings in the riparian ecotones based on the available literature.
2. To describe the importance, structure and composition of riparian vegetation from the available literature.
3. To review the riparian vegetation research and general objectives of the thesis based on the available literature.

1.1 Introduction

1.1.1 Riparian ecosystems

The word ‘Riparian’ originated from the Latin word ‘Ripa’, which means the bank of a river, pond or lake of the surrounding landscape (Tabacchi et al., 1990, Junk & Piedade, 1997; Goebel et al., 2003). Riparian ecosystems are located next to streams, rivers, lakes, wetlands and have direct influence on aquatic and wildlife habitat. It is also known as gallery forests and streamside forests (Brinson, 1990). These can create a mosaic of microhabitats with the coexistence of numerous plant species (Swanson et al., 1982; Gregory et al., 1991). Riparian landscapes are highly threatened ecosystems as they are inherently rare habitats, occupying a mere one-thousandth of the earth’s surface (Hynes, 1970).

1.1.1.1 Geomorphologic settings

Hydrology and its interactions with local geology is the most important factor for the natural development of riparian ecosystems (Hupp & Osterkamp, 1985). Geomorphic surface distribution determined by river channel dynamics and the sediment transport processes occurring at a larger scale and a longer time frame, played an important role in shaping the structure and composition of the riparian forests (Shin & Nakamura, 2005). Riparian ecosystems include swampy areas, wetlands, small streams, side channels and intermittently wetted areas. These areas or zones can be broadly described as the areas of the stream bank, including side channel and associated banks and they include upland areas not normally inundated during high water conditions. The riparian ecosystems can be delineated from the surrounding landscapes by the demarcating the area of stream / river channel during flooding or augmentation of water bodies and water
holding capacity of soils (Naiman et al., 1993). Geomorphic structures and distribution of plants that are tolerant to either flooding or drought are also helpful in delimiting riparian ecosystems (Nilsson, 1983).

2.1.1.2 Functional settings

Riparian ecosystems are functionally three-dimensional zones of direct interaction between terrestrial and aquatic ecosystems (Meehan et al., 1977; Swanson et al., 1982). Dimensions of the riparian ecosystems are determined by its unique spatial patterns and temporal dynamics. Extending this concept in time and space, riparian ecosystems can be viewed in terms of the spatial and temporal patterns of hydrologic and geomorphic processes and terrestrial-aquatic succession. Boundaries of riparian ecosystems extend outward to the limits of flooding and upward into the canopy of streamside vegetation. The characteristics of natural riparian ecosystems vary with the size of the river, from narrow and relatively simple strips of land along the headwater streams to heterogeneous floodplains in many kilometers wide along lower reaches of major rivers.

1.1.1.3 Ecological settings

Riparian zones are the interfaces between aquatic and terrestrial ecosystems. As ecotones, they encompass sharp gradients of environmental factors, ecological processes and plant communities. Natural riparian zones are the most diverse, dynamic and complex biophysical habitats on the terrestrial portion of the planet. They are analogous to a semi-permeable membrane, regulating the flow of energy and materials between adjacent environmental patches (Naiman & Decamps, 1997; Naiman et al., 1998). Riparian zone have a set of characteristics uniquely defined by space and time scales and by the strength of interactions between adjacent ecological systems (Risser, 1993; Naiman et al., 1998). The complex interactions among hydrology, geomorphology, light and temperature influence the structure, dynamics and composition of riparian ecosystems (Brinson, 1990; Malanson, 1993). Riparian plant communities were given an important role in the river continuum concept (Vannote et al., 1980; Minshall et al., 1985) which predicts that the load and quality of organic matter and the biota in the stream / river channel from the headwaters to the lower river courses increases with riparian vegetation and river width.
1.1.2 Riparian vegetation

Plant vegetation seen along the river margins are generally referred as the riparian vegetation. Under normal circumstances riparian ecosystems support a prevalence of vegetation typically adapted for life in saturated soil conditions (Gosselink et al., 1981). A strong connection between the species composition of riparian vegetation and elevation above the channel bed (Bell, 1980; Hupp & Osterkamp, 1985; Aruga et al., 1996) and its correlates, namely flooding frequency (Bell & del Moral, 1977; Bell, 1980; Hupp & Osterkamp 1996), soil texture (Johnson et al., 1976; Hupp & Osterkamp, 1985; Niiyama, 1987, 1989; Ishikawa, 1988; Aruga et al., 1996) and soil moisture (Adams & Anderson, 1980) were observed. Other environmental factors such as light (Hermy & Stieperaere, 1981; Menges & Waller, 1983), downstream variation (Nilsson, 1986; Ishikawa, 1988; Nilsson et al., 1989) and human disturbances, such as land-use history (Hermy & Stieperaere, 1981) and regulation of river flow (Nilsson et al., 1991; Hupp, 1992; Gordon & Meentemeyer, 2006) were also considered for species distribution.

1.1.3 Importance of riparian vegetation

1.1.3.1 Biodiversity – Refuge for flora and fauna in the ecotones

Riparian ecosystems have been harboring higher number of species than adjacent upland habitats within the same geographic location (Naiman et al., 1993). The linear structure, regular floods, strength of competitive interactions, periodical successional stages and shifting mosaic of landforms provides a diversity of microhabitats, resulting high plant species richness in the riparian zones (Kalliola & Puhakka, 1988; Wissmar & Swanson, 1990; Gregory et al., 1991; Décamps & Tabacchi, 1994; Pollock et al., 1998). During the adverse quaternary unfavorable stadial climate cycles, the rainforest flora forced into isolation in pockets as ‘plant refugia’ which existed as riparian vegetation due to soil moisture availability (Meave et al., 1991; Hooghiemstra & Van der Hammen, 1998, 2004) and the current peninsular Indian riparian forest can be considered as topical forest refugia (Farooqui et al., 2010).

1.1.3.2 Water quality – filtering of agricultural, urban and industrial pollution

Riparian vegetation intercepts and detains agricultural runoff from adjacent upland areas and wastewater pollution and maintains the water quality (Chen Hsin-Hsiung & Chen Ming-Jei, 1989; Delong & Brusven, 1998; Jones et al., 1999).
1.1.3.3 Nutrient dynamics – filtering and cycling of nutrient inputs

Riparian vegetation significantly reduces nutrient runoff (Lowrance et al., 1984) and helps nutrient cycling (Johnes, 1996; Meyer et al., 1999; Vörösmarty et al., 2000) and their role in nutrient dynamics (Cummins, 1992) documented. Riparian forests serve as filters, transformers, sources and sinks for nutrients, sediment and pollutants associated with agriculture and urban runoff (Welsch, 199; Malanson, 1993).

1.1.3.4 Bank stability – thick deep root system prevents soil erosion

Riparian forests stabilizing riverbanks by their root system (Cordes et al., 1997), contributing root strength that maintains stream bank integrity (Broderson, 1973, Gregory & Ashkenas, 1990).

1.1.3.5 Flood management – vegetation obstructs, diverts or facilitates water flow

Riparian vegetation provides flood control during high rain events (Welsch et al., 2000). It controls processes related to surface and subsurface flow at the local scale (Pasche & Rouve, 1985; Bren, 1993; Darby, 1999). The living vegetation forms point structures whereas dead plant debris forms mobile, resistant (coarse woody debris) or labile (litter) structures and can obstruct, divert or facilitate water flow.

1.1.3.6 Wildlife habitats and corridors – for species migration and exchange

Riparian vegetation functions as cover for wildlife and corridors for species migration, dispersal (Wegner & Merriam, 1979; Henderson et al., 1985; Merriam & Lanoue, 1990; Cordes et al., 1997), breeding ground for birds and small mammals (Rottenborn, 1999; Blair, 1996; Cockle & Richardson, 2003).

1.1.3.7 Organic inputs - for food chains and food webs

Organic inputs as litter and coarse woody debris (CWD) from riparian vegetation are major food sources for river organisms and help to maintain food chains and food webs (Cummins, 1974; Wootton et al., 1996).

1.1.3.8 Productivity and biomass – differs with vegetation types

The high productivity of riverine vegetation has also been well-documented (Brinson et al., 1981; Day & Megonigal, 1993). Large-magnitude floods remove tree biomass (Stromberg, 1993), maintaining the forest in an early successional stage and creating the potential for positive net ecosystem production (Schade et al., 2002). Biomass production differed significantly between the vegetation types, with a higher production in the forested sites (Hefting et al., 2005).
1.1.3.9 Stream temperature regulation – for habitat and photosynthetic productivity

Riparian vegetation moderates stream temperature and light levels, thereby influencing habitat suitability for fish and other aquatic organisms (Gregory et al., 1991). The canopy and stems of riparian vegetation above the ground provide shade, which controls temperature and in-stream photosynthetic productivity.

1.1.3.10 Reducing agricultural runoff – natural vegetation buffer system

Riparian forests function as buffers to reduce the quantity of agricultural diffuse pollution that reaches streams (Lowrance et al., 1984; Peterjohn & Correll, 1984; Pinay & Decamps, 1988; Osborne & Kovacic, 1993; Vought et al., 1994). Nitrogen removal can be efficient in riparian zones (Cooper, 1990; Gilliam, 1994; Hill, 1996; Mander et al., 2000) by the denitrification process and prevents eutrophication (Collins & Jenkins, 1996; McClain et al., 2003).

1.1.3.11 Microhabitats for fishes and invertebrates – by large woody debris

Riparian forests contributing large woody debris to streams and thereby shaping stream habitats such as pools and riffles and influencing sediment routing (Zimmerman et al., 1967; Cummins 1974; Mosley, 1981; Swanson et al., 1982) and provide substrate for biological activity especially for fishes and other aquatic organisms (Nakamura & Swanson, 1993, 1994). The qualitative impact of coarse woody debris (CWD) on stream hydraulics (Harmon et al., 1986; Gurnell et al., 1994; Maser & Sedell, 1994) causes water flow diversions, congestions in the main channel, reduced connectivity and enhanced local erosion.

1.1.3.12 Plant succession dynamics – by disturbance regime

Riparian forests influenced both by disturbance agents of upland ecosystems and aquatic systems such as wind, fire, debris flows, lateral channel erosion and flooding. Among which, the hydrological processes interacts with the earliest stages of plant succession and has significant impact on pioneer vegetation. The patchiness of pioneer vegetation increases the heterogeneity of water flow patterns over sediment and vegetation mosaics, leading to the development of preferential flow pathways (Thorne et al., 1997).
1.1.3.13 Biological invasions – river regulation and flooding increases exotics

Riparian corridors are landscape elements that are most sensitive to plant invasion (DeFerrari & Naiman, 1994; Stohlgren et al., 1999; Brown & Peet, 2003). The high frequency of open ground for colonization (Malanson, 1993), dispersal networks connecting different landscapes (Forman & Godron 1986), frequent flooding and linear structure makes them highly susceptible to invasion by exotics (Planty-Tabacchi et al., 1996). River regulation drastically alters the floodplain environment resulting reduction of species richness (Nilsson et al., 1991) and increase of relative invasibility of exotic plant species (Decamps et al., 1995).

1.1.3.14 Sedimentation and floodplain development – by grassy riparian species

Grassy riparian areas trap sediments delivered from hill slopes by overland flow (Magette et al., 1989). The colonization of newly deposited sediments by dense herbaceous vegetation also helps to sustain high moisture levels in the upper sediment layers during dry periods because of the sheltering of the sediment surface by the vegetation cover and the capillarity provided by the rhizosphere.

1.1.4 The structure and composition of riparian vegetation

The general structure of riparian vegetation consists of three layered organization of canopy trees, middle stratum of shrubs and woody climbers and herbaceous ground flora. The zonation of above ground vegetation of the riparian ecosystems depends on the regional climate and topography. Trees are considered the most significant component, due to the keystone nature of riparian forests which controls the flood and bank erosion thereby maintaining the integrity of riparian ecosystems (Minore & Weatherly, 1994; Pettit & Froend, 2001). Shrubs provide shade and stream bank stabilization and compete strongly for the resources needed by tree seedlings. The competition indirectly influences production of large woody debris and habitat maintenance for other organisms. Shrub competition may prevent the regeneration of trees in some riparian environments, thereby resulting in gradual succession to a shrub community (Hibbs, 1987). However in the tropical riparian floodplains, seasonal herbaceous annual vegetation dominates, where large flood disturbance prevents the recruitment of woody species.
Table 1.1  Regions and countries where major riparian vegetation research has been conducted

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<th>Region</th>
<th>Country</th>
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<td>Australia</td>
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<td>Roberts &amp; Ludwig, 1991; Johnson et al., 1999; Pettit &amp; Froend, 2001; Nally et al., 2008</td>
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<td>New Zealand</td>
<td>Miller, 2006</td>
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<td>Asia</td>
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<td>An et al., 2002</td>
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<td>India</td>
<td>Johnsingh &amp; Joshua, 1989; Bachan, 2003; Sreedharan, 2005; Subramanian et al., 2005; Chauhan &amp; Gopal, 2005; Sunil et al., 2010</td>
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<td>Japan</td>
<td>Sugimoto et al., 1997; Nakamura et al., 1997; Sakio, 2005; Kamisako et al., 2006</td>
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<td>Nepal</td>
<td>Zomer et al., 2001</td>
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<td>Europe</td>
<td>Austria, Hungary, Romania</td>
<td>Molder &amp; Schneider, 2011</td>
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<td>England</td>
<td>Harper et al., 1997</td>
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<td>Finland</td>
<td>Kalliola &amp; Puhakka, 1988</td>
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<td>France</td>
<td>Tabacchi et al., 1990; Decamps &amp; Tabacchi, 1994; Prevot et al., 1993</td>
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<td>Poland</td>
<td>Wassen et al., 2002</td>
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<td>Portugal</td>
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<td>Spain</td>
<td>Alcaras et al., 1997; Salinas et al., 2000; Corbacho et al., 2003</td>
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<td>Sweden</td>
<td>Nilsson, 1986; 1991; Nilsson et al., 1989; 1994; Renofalt et al., 2005</td>
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<td>Switzerland</td>
<td>Wildi, 1989</td>
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<td>Africa</td>
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<td>Israel</td>
<td>Malkinson &amp; Wittenberg, 2006</td>
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<td>Kenya</td>
<td>Wyant &amp; Ellis, 1990; Magana, 2001; Stave et al., 2005</td>
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<td>Venezuela</td>
<td>Rosales et al., 2001</td>
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<td>South Africa</td>
<td>Higgins et al., 1997; Hood &amp; Naiman, 2000</td>
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<td>South America</td>
<td>Peru</td>
<td>Salo et al., 1986; Junk et al., 1989; Kalliola et al., 1991; McClain &amp; Cossio, 2003</td>
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<td>Brazil</td>
<td>Metzger et al., 1997; Pinto et al., 2006; Wittmann et al., 2008</td>
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<td>Belize</td>
<td>Meave et al., 1991; Meave &amp; Kellman, 1994; Kellman et al., 1998; Urban et al., 2006</td>
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<td>Puerto Rico</td>
<td>Heartsill-Scalley &amp; Aide, 2003</td>
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<td>North America</td>
<td>United States</td>
<td>Thompson, 1961; Baker, 1989; Kovalchick &amp; Chitwood, 1990; Gregory et al., 1991; Smith et al., 1991; Busch &amp; Smith, 1993; Minore &amp; Weatherly, 1994; Auble et al., 1994; Headman &amp; van Lear, 1995; Chambers et al., 1999; Pabst &amp; Spies, 1999; Merritt &amp; Cooper, 2000; Johnson, 2002; Reed &amp; Carpenter, 2002; Lyon &amp; Sagers, 2002; Crawford, 2003; Fleishman et al., 2003; Lacki et al., 2004; Sweeney et al., 2004; Balian &amp; Naiman, 2005; Burton et al., 2005; Uowolo et al., 2005; Fierke &amp; Kauffman, 2005; Tiegs et al., 2005; Stromberg et al., 2006; Gordon &amp; Meentemeyer, 2006; Schilling, 2007</td>
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<td></td>
<td>Canada</td>
<td>Oelbermann &amp; Gordon, 2001; Harper &amp; Macdonald, 2001; Boutin et al., 2003; Willms et al., 2006; Chen et al., 2008</td>
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1.1.5 Riparian vegetation research

The riparian forest vascular plant diversity studies has been conducted in worldwide especially European, North and South American, Mediterranean, Australian and African countries but they lack in the tropical region except Amazonian and few other locations (Table 1.1). The majority of studies on riparian vegetation have been conducted in northern temperate regions, only a small body of work carried out in tropical ecosystems. Consequently, riparian ecosystems in the neotropics and tropics remain poorly known, with little published work available on their floristic composition and ecological structure.

1.1.5.1 Riparian vegetation studies in India

There are few studies in the Indian region dealing with riparian vegetation analysis. Johnsingh & Joshua (1989) categorized the gallery forest of the River Tambiraparani, Mundanthurai Wildlife Sanctuary, South India as threatened due to its species richness and anthropogenic disturbances. Jayaram (2000) indicated that the Cauvery river basin areas have a large floristic wealth enough to constitute as a separate phytogeographic unit. A comparative study on forest zone and agro-ecosystem zone in the riparian forests of Cauvery river basin have been recorded 84 tree species (Sunil et al., 2010). The forest zone comprised of 58 species dominated by Terminalia arjuna, Tamarindus indica, Pongamia pinnata and Diospyros montana. Agro-ecosystem zone comprised of 40 species dominated by Salix tetrasperma, Ficus benghalensis and Eucalyptus torticornis. There was a significant difference between the average number of species recorded between forest zone and agro-ecosystem.

1.1.5.2 Riparian forest studies in Western Ghats

The Western Ghats and Sri Lanka assigned as one of the hottest hotspots at global scale (Myers et al., 2000). The riparian fragments of tropical regions are composed of evergreen, semi evergreen and deciduous matrix due to the edaphic and climatic specificities. Its ecological uniqueness depends on multiple factors viz., its origin, geological past, climate, impact of monsoon and anthropological activities. Even though, the vegetation along the rivers of Western Ghats being a part of world mega biodiversity hotspot, is often reckoned as diagnostic attribute of diversity, paleoendemism and RET species, little studies have been conducted on these riparian forests.
Studies on the threatened gallery forest in the river Tambiraparani of Mundanthurai wildlife sanctuary, South India has recorded 47 tree species including several evergreens, 13 scrub and 15 climber-creeper species in a 0.25ha area at an altitude of c.180m (Johnsingh & Joshua, 1989). Subramanian et al. (2005) studied the impact of riparian land use on stream insects of Kudremukh National Park, Karnataka state, India and found that the diversity and community composition of stream insects varied across streams with different riparian land use types. Bachan (2002) recorded 329 flowering plants of 260 genera and 97 families including 8 species of orchids from the Vazhachal region of the Chalakkudy river basin. Of which, 24 species were endemic to Western Ghats and 10 belongs to Rare and Endangered categories. The richness of riparian species recorded from the Chalakkudy river was 13 species/0.01ha (Bachan, 2003). The impact of river valley projects on this endemic riparian vegetation was analyzed and found that alterations in the ecosystem will destroy the entire riparian habitats and vegetation (Bachan, 2005). Sreedharan (2005) documented the riparian vegetation of Valapattanam river of Kerala and ecology and socio-cultural aspects.

1.2 General objectives

1. To classify the riparian flora of Pamba river based on APG III (Angiosperm Phylogeny Group III) classification system and elucidation of phytogeography.

2. To analyse the alien-endemic flora and the invasive status of alien species in the riparian forests based on concepts of invasion biology.

3. To compare and assess the riparian flora based on Raunkiaer’s lifeforms, biological spectrum and lifeform-landform-functional vegetation type along the elevation gradient.

4. To analyse the richness, diversity and phytosociology of riparian vegetation using ecological methods.

5. To study and map the spatial distribution of riparian RET (Rare, Endangered and Threatened) trees, endemism, invasion and disturbance regime along the elevation gradient in the riparian forests using GIS (Geographical Information System) tools.
1.2.1 Review of objectives

The river Pampa, one among the 44 major rivers of Kerala state, has been witnessed material and cultural progress from the ancient times. Sabarimala, one of the pilgrimage center in India is situated on the upper region, Maramon Convention, Cherukolpuzha Convention, Aranmula ‘Uthruttathi Vallamkali’, and many other religious and cultural gatherings has been held on the banks of the river. The River Pamba originated from the Perumedu plateau of the Western Ghats (Sahyadri), flows west and drains in to the Vembandu Lake before joining the Arabian Sea. The river cuts across a diverse array of ecosystem settings from montane temperate shola-grasslands through evergreen, moist deciduous and riparian forests to mangrove lined estuary with high species richness and endemism. The catchment and riparian zones of Pamba river basin has been disrupted at many places due to anthropogenic interference and needs restoration and conservation measures. Baseline data on diversity, distribution and ecology is essential for conservation and management, since the riparian vegetation influence the morphology and hydrology of the rivers and its aquatic functions. The present research has been intended to gather and analyse the baseline data on taxonomic richness, diversity, distribution, ecology and disturbance of riparian vegetation along the elevation gradient of the Pamba river basin, where no riparian vegetation studies so far conducted.

1. Most of the Indian floristic treatments were restricted to their administrative boundaries such as state, district or protected area and never attempted to ecosystem or landscape settings and followed the outdated Bentham & Hooker’s (1888) classification system. None of them discussed the phytogeographical affinities of plant species and their ecosystem settings. The specific ecosystem settings of the river catchment significantly different from the surrounding landscapes and creating endangered (Bachan, 2003; Natta, 2003), species rich and diverse flora along the riparian ecotones. Considering these ecosystem settings, an inventory of the riparian flora based on APG III (Angiosperm Phylogeny Group III, 2009) system in the watershed landscape settings of Pamba river basin has been created and its phytogeographical affinities analyzed where none of these research so far been conducted.
2. Invasion biology has been attained importance in the ecological and climatological perspectives in the global warming scenario. Only limited studies in India where autecology of some invasive species (Sharma & Raghubanshi, 2009; 2010; Swamy & Ramakrishnan, 1987a; b; Charudattan, 1986; Téllez et al., 2008; Muniappan & Bamba, 2000; Zachariades et al., 2009; Reshi et al., 2008a; b) and cataloging (Khuroo et al., 2007; 2008; 2009; 2010; Reddy, 2008) has been conducted. The initial steps of developing alien plant species management strategy are the compilation of comprehensive lists of the naturalized species, comparative studies of naturalized floras and identification of taxonomic patterns of plant invasion. Therefore the present analysis on the taxonomic similarities between alien and endemic species and invasion status aliens in the riparian forests of Pamba river basin has been conducted.

3. In the fluvial landscapes, the biological spectra have been related to specific climatic, edaphic and elevation factors where certain lifeforms dominated due to succession patterns. Limited studies on the biological spectrum of riparian ecotones in the Indian region (Rao, 1968; Jain, 1978; Prakash, 1982; Singh, 1984) indicated that the disturbed river banks stimulate therophytic flora. Therefore the present research has been conducted to elucidate the biological spectra, landform preference and functional vegetation pattern of the riparian forests of Pamba river basin.

4. The ecology of riparian forests were studied worldwide but only limited studies have been conducted in India and Western Ghats (Johnsingh & Joshua, 1989; Bachan, 2003; Sreedharan, 2005; Subramanian et al., 2005; Chauhan & Gopal, 2005; Sunil et al., 2010). The ecology of riparian vegetation has significant role in the river health and management. The diversity and ecology of riparian flora in the Pamba river basin has been not analyzed so far and there is a lacuna in the knowledge of species richness, diversity, association, stand structure, phenology and regeneration status. The present investigation were conducted to understand the ecological status of the riparian forests along the elevation gradient.

5. The distribution of riparian trees along the river margins has been considered important in the river management and conservation. There have been no distribution studies and mapping of either disturbance or riparian vegetation in India and Kerala. Although a few studies on the distribution of plant species in various forests of South India but none of them from riparian habitats. Therefore, mapping of disturbance and distribution of riparian trees along the elevation gradient in Pamba river stretches has been conducted.
Chapter 1

1.3 References


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