Pak. J. Bot., 44: 187-197, Special Issue March 2012.

LINKAGES BETWEEN SPATIAL VARIATIONS IN RIPARIAN VEGETATION AND FLORISTIC QUALITY TO THE ENVIRONMENTAL HETEROGENEITY A CASE STUDY OF RIVER SOAN AND ITS ASSOCIATED STREAMS, PAKISTAN

RIFFAT NASEEM MALIK[1*], ZABTA KHAN SHINWARI[2] AND HINNA WAHEED[3]

[1]*Environmental Biology and Ecotoxicology Laboratory, Department of Environmental Sciences, Quaid-i-Azam University, Islamabad, Pakistan*
[2]*Environmental Biology Laboratory, Department of Plant Sciences, Quaid-i-Azam University, Islamabad, Pakistan*
[3]*Department of Biotechnology and Bio-informatics, Faculty of Biological Sciences, Quaid-i-Azam University, Islamabad, Pakistan*
[*]*Corresponding author's e-mail: r_n_malik2000@yahoo.co.uk; 00925190643017*

Abstract

This study attempts to develop Floristic Quality Index (FQI) as a biological indicator of human influence to evaluate ecological conditions of the River Soan and its feeding tributaries and establish the link between spatial distribution of plant communities to natural and anthropogenic gradients using classification and ordination methods. Plant species abundance data, water quality parameters, physical habitat, land-use types and climatic parameters were collected from 63 sites. Cluster Analysis (CA) identified five spatial groups of sites based on the floristic composition. Correspondence Analysis revealed the impact of urbanization, habitat degradation, and water quality as environmental predictors of anthropogenic stress. Floristic Quality Index (FQI) showed negative correlation with parameter associated with anthropogenic activities. Canonical Correspondence Analysis (CCA) axes were strongly related with FQI scores (r=>0.9) and showed sites with least impact from man-made activities had higher FQI values. FQI values were lower for sites surrounded by agricultural or urban land-use types, with hydrologic modification and habitat deterioration. The results can provide a means of using an integrated approach of FQI, vegetation classification and ordination methods to evaluate riparian conditions, suggest continuous monitoring framework for biological indicators over time and assist to evaluate future conservation efforts.

Introduction

The vegetation along the river or stream banks is termed as riparian vegetation, riverbed vegetation or floodplain vegetation (Masahito *et al*., 2001) and forms a fundamental component of the wetland ecosystem (Gregory *et al*., 1991; Decamps, 1997). The riparian ecosystems are highly diverse in species composition due to variability in topography, sediments nature and hydrological processes (Tabacchi *et al*., 2000). The riparian vegetation functions as a nutrient filter for water flowing to rivers from agricultural watersheds; acts as a buffer to reduce nutrient (Malik *et al.,* 2010; Malik & Nadeem 2011) and sediment load in water bodies (Tabacchi *et al*., 1998), and influences the water chemistry (Ometo *et al*., 2000). Width of the riparian vegetation cover and fluvial areas determines the composition and structure of biological assemblages such as fish (Qadir & Malik 2009), macro invertebrates and plants (Jones *et al*., 1999; Spackman & Hughes 1995). Riparian vegetation cover is reduced widely due to clearing, grazing and their use for recreational purposes which have resulted the deterioration overall ecological conditions (Corbacho *et al*., 2003). Increased human population, construction processes on/around banks and water use by local inhabitants influence the distribution patterns in riparian zones (Qadir *et al*., 2008).

Studies based on distribution patterns of riparian vegetation in riparian corridors and use of riparian vegetation as an indicator of health of freshwater ecosystem is fewer. Plant communities of riparian corridors behave differently to anthropogenic stresses and can serve as reliable indicators of ecological health of riparian habitats (Miller *et al*., 2006) as compared to use of individual plant species as an ecological indicator. For example, Shandas & Alberti (2009) revealed the role of vegetation fragmentation in riparian habitats in Puget Sound Lowland, U.S.A and indicated the importance of vegetation patterns on stream biological conditions. Looy & Meire (2009) studied spatial habitat characteristic of riparian zones of River Meuse, Belgium. Magner *et al*., (2008) studied the impact of non-grazing on vegetation patterns and bank stability in the Southeastern Minnesota riparian habitats. Hejda & Pysek (2006) studied effects of invasive species (*Impatiens glandulifera*) on floristic composition of riparian habitats in Czech Republic. Schnitzler *et al*., (2007) investigated forest properties which promoted the establishment of exotic species which changes the riparian plant communities. Floristic Quality Index (FQI) which is a quantitative measure to expresses the floristic quality (Bourdaghs *et al*., 2006) had been used to determines the significance of floristic composition and represents the biological condition of the sites in wetland regions (Herman *et al*., 1997; Lope & Fennessy 2002). Floristic quality assessment depends on the features of regional flora and assumes that native species are found only in peculiar set of ecological conditions and have use in detecting vegetation changes in restoration and re-construction along environmental and disturbance gradient. FQI serves as a comparison tool between different sites irrespective of plant community type and relates anthropogenic impacts with ecological integrity based on species composition (Lopez & Fennessy 2002; Nazir *et al.,* 2011). FQI assessment methods have widely been developed and adopted in America (Miller *et al*., 2006); e.g., in Wisconsin Lakes, FQI was used to monitor long term changes in plant communities (Nicholas, 2001). FQI for central Pennsylvania wetlands was developed by Miller & Wardrop (2006) to relate floristic quality with anthropogenic activities. Wetland mitigation standards for Illinois were established using FQI (Mathews, 2003). United States Environmental Protection Agency (Anon., 2002) has also adopted FQI for bio-assessment of wetland habitats.

In Pakistan like other developing countries anthropogenic activities such as land clearing, digging of ditches and canals, siltation, channelization of rivers and streams, grazing and browsing, sandstone quarries, water mining for urban and agricultural consumption, contamination from organic and inorganic pollutant, and eutrophication, and anoxia have resulted in extreme ecological degradation of aquatic ecosystem (Qadir *et al*., 2008). Increase in urban development and extensive agricultural operations pose significant challenges to the survivability and sustainability of riparian ecosystems and thus the ecological assessment remains the most important tasks facing ecologists today. This study focuses on development of riparian vegetation quality index as an ecological indicator to determine environmental health and integrity of River Soan and its associated tributaries such as Nallah Korang, Baroha, Shahdra, Rumli, Mallach, Ling, and Lei streams. The study area receives solid waste, industrial and municipal effluents along with surface runoff throughout the year. The study assesses to characterize the riparian vegetation assemblages and their relationship with FQI and underlying environmental gradients which influences the ecological processes and functional and structural parameters of the plant communities. Any change in structure and composition of riparian vegetation can serve as an ecological indicator of decline in ecological condition of aquatic ecosystem (Tabacchi *et al*., 1998). It is hypothesized that indirect ordination methods such as DCA can detect ecological communities and interpret their environmental linkages. Riparian corridors may contain different vegetation assemblages closely associated with different hydrological, edaphic and climatic conditions, and anthropogenic disturbances. Plant assemblages of these habitats could reveal more about their ecological status as compared to the response of individual species. The composition of plant communities which is characterized by species with specific adaptations, ecological tolerances, functional characteristics and life history strategies can reflect the biotic integrity of the riparian habitats. The results will highlight the importance of riparian vegetation in aquatic processes and attempts to identify anthropogenic activities affecting ecological integrity of River Soan and its associated tributaries. The study also emphasizes future monitoring and management of the riparian vegetation for healthy fresh water ecosystems. It is first such attempt to apply FQI on hilly streams and highlight the need for better future protection of riparian habitats affected by anthropogenic stresses.

Materials and Methods

The River Soan originates from springs of village Bun in the Murree Hills, approx., 250Km long and drains much of the Potohar plateau. Simly dam is constructed when it enters Islamabad from north. Korang, Lei, Khad, Rumli and Ling are important tributaries of the River Soan. Khad Nallah is the main tributary which originates from springs in Pabuchhian and joins the river near Chappar. Ling stream arises from many springs in Kotli Sattian and travels through Rawalpindi and Chakwal Districts, joins River Soan near Sihala Mirzian. Nallah Korang is another tributary of River Soan which is divided into upper Korang (originates from spring of Charra Pani and Bastaal) and lower Korang (originates from Gumrah Kas) whereas Nallah Lei originates from springs in Margallah Hills, travels through the cities of Islamabad and Rawalpindi before joining River Soan at Soan Camp. River Soan joins River Indus near Jand. The river contributes in hydro-geography of Potohar region of Pakistan. The soils are darker in colour with high mineral content. Limestone, Gypsum, coal and shale are present in large quantities. The study area lies in the Monsoon belt and witnesses two rainy seasons i.e., pre-monsoon and post-monsoon. Annual rain fall is highly variable with mean annual rain fall of 39 inches, most of which falls in summer. Maximum temperature in summer may rises up to 45°C and in winter may drop to a minimum of 3°C. Relative humidity recorded (55%) in this region for the months of May-August is very high.

A preliminary survey was conducted for the selection of sites for recording species abundance and environmental data. A total of 63 sites were selected (Fig. 1) as a part of long term monitoring program of EBL, Quaid-i-Azam University, Pakistan to assess the ecological health conditions of studied stream using biological organisms as an ecological indicator. Floristic species abundance was recorded during March-September, 2008 using 10 m long, 2 m wide plots as a percentage cover along the stream length. Sampling sites were selected after visually inspecting the accessibility of banks so that all the plant communities present in the riparian habitats were included. Plant cover was assessed as the vertical projection onto the ground of all the above ground parts of the individual plant species expressed as a percentage. All vascular plant species were identified to the lowest taxonomic division. For the species identification and nomenclature Flora of West Pakistan (Stewart, 1972) and Flora of Pakistan (Nasir & Ali, 1970) were used.

From each sites, surface water and habitat parameters were collected. For water sampling survey reach length was defined which was ten times the channel width. Sampling was done from downstream to upstream. Grab method was used to collect surface water samples in plastic bottles from a depth of 25 cm where applicable. Water containers were pre-cleaned with 10% HNO_3 and filled with water sample up to neck without trapping any bubble. Portable Hydro Lab Surveyor (MS 5 Surveyor® Hach® Environmental) was used to measure temperature (Temp), pH, electrical conductivity (EC), Total dissolved solids (TDS), Dissolved oxygen (DO), and salinity (Sal) in the field. Water samples were stored in dark at ~4 degree centigrade during the trip to Environmental Biology Laboratory, Quaid-i-Azam University, Islamabad (APHA, 1998). Water quality parameters i.e. alkalinity (ALK), ammonia-nitrogen (NH_4–N), sulfates (SO_4^{2-}), chlorides (Cl^{1-}), nitrate-nitrogen (NO_3-N) and soluble reactive phosphates (SRP) were analyzed at Environmental Biology Laboratory using standard methods (APHA, 1998). Alkalinity was measured through titrometric method. Chloride concentration was measured using titration of silver nitrate using potassium chromate as an indicator. Phenol-disulphonic acid method was used to measure NO_3–N concentration at 410 nm using the HACH Spectrophotometer (Model: DR 5000). Ammonium molybedate method was used to determine SRP or ortho-phosphate concentration in the water samples at 690nm. Phenate method was used to determine NH_4–N concentration in the water samples at 640nm. Barium chloride method was used to determine SO_4^{2-} concentration in the water samples at 420nm.

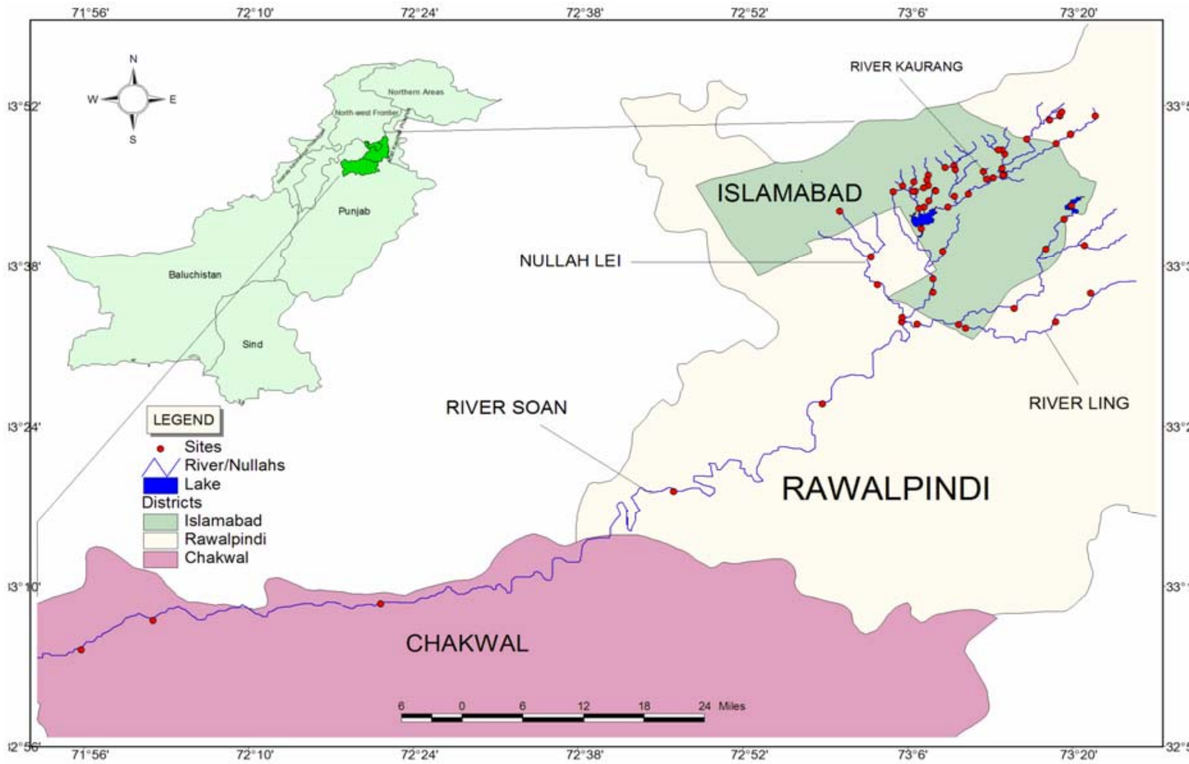

Fig. 1. Study area showing the location of sampling sites

Air temperature and elevation were measured by Kestrel Weather Station whereas light intensity was measured by Lux Meter. Water channel depth was measured on both sides of survey reach length by taking readings at three points. One point was taken at the centre while the other 2 at 1/3 distance from each bank of the stream and an average values was used. Water channel velocity was measured by fixing two bamboo sticks in the substratum of channel and a cork was thrown at upstream. Time taken by the cork to travel between 2 bamboo sticks was recorded. Three set of readings were taken and averaged to obtain velocity. Proximity to villages, urbanization pressure, presence of solid waste, farming and agricultural activities, sand, extraction, washing and bathing (animal and human) and mining, grazing, browsing, logging and plantations were considered as causes of degradation.

Statistical analyses: Cluster analysis (CA) was used to group sites on the basis of similar floristic composition (Fig. 2). Ward's method was used as a linkage method and Euclidean (Pythagorean) as a distance measure to group sites on the basis of floristic composition.

Detrended Correspondence Analysis (DCA) was used to identify ecological gradients that influence the spatial variations in plants assemblage (Fig. 3). Canonical Correspondence Analysis was used to relate association of plant assemblages to natural and anthropogenic environmental drivers (Fig. 4). For CCA, Hill's scaling was used to rescale ordination axes as standard deviations of species frequency values. For graphs of ordination biplots, axes were scaled, by percent, from the lowest on the axis to the highest score. Monte Carlo simulation (499 randomizations) was applied to test the null hypothesis of no relationship between species abundance and environmental attributes such as water physical and chemical, climatic and habitat and land-use type matrices. CA, DCA and CCA ordination analyses were performed using PC ORD ver. 4.0.

The FQI is widely used unit-less index to assess the conditions of wetlands and was calculated for each site as given in Bourdaghs *et al*. (2006), Swink and Wilhelm (1994), and Taft *et al*., (1997) using equation 1.

$$\mathrm{FQI} = \bar{C}\sqrt{S} \text{ --------------------- } (1)$$

where $\bar{C}$ is mean coefficient of conservatism (C) of a native plant species and S= Species richness or number of species.

FQI computation weights plant species based on their coefficient of conservatism (C-value). A C-value is a measure of how conservative or intolerant a native species is to disturbance. C-values are only assigned for the native plant species of an area and range from 0 to 10 indicating a plant's fidelity to remnant natural plant communities, a value of 10 signifying a plant that almost certainly comes from an un-degraded natural plant community. Introduced or naturalized species do not receive a C-value. C-values were assigned to plant species, with the help of herbarium botanist and plant taxonomist in the Department of Plant Sciences, Quiad-i-Azam University Islamabad. The greater the C-values and FQI values, the greater is the condition (or closer to a natural state) of the evaluated area. Based on the index value sites were characterized into three categories i.e. least disturbed, moderately disturbed and highly disturbed sites based on anthropogenic disturbance (Table 1) with slight modifications according to this region (Miller & Wardrop 2006).

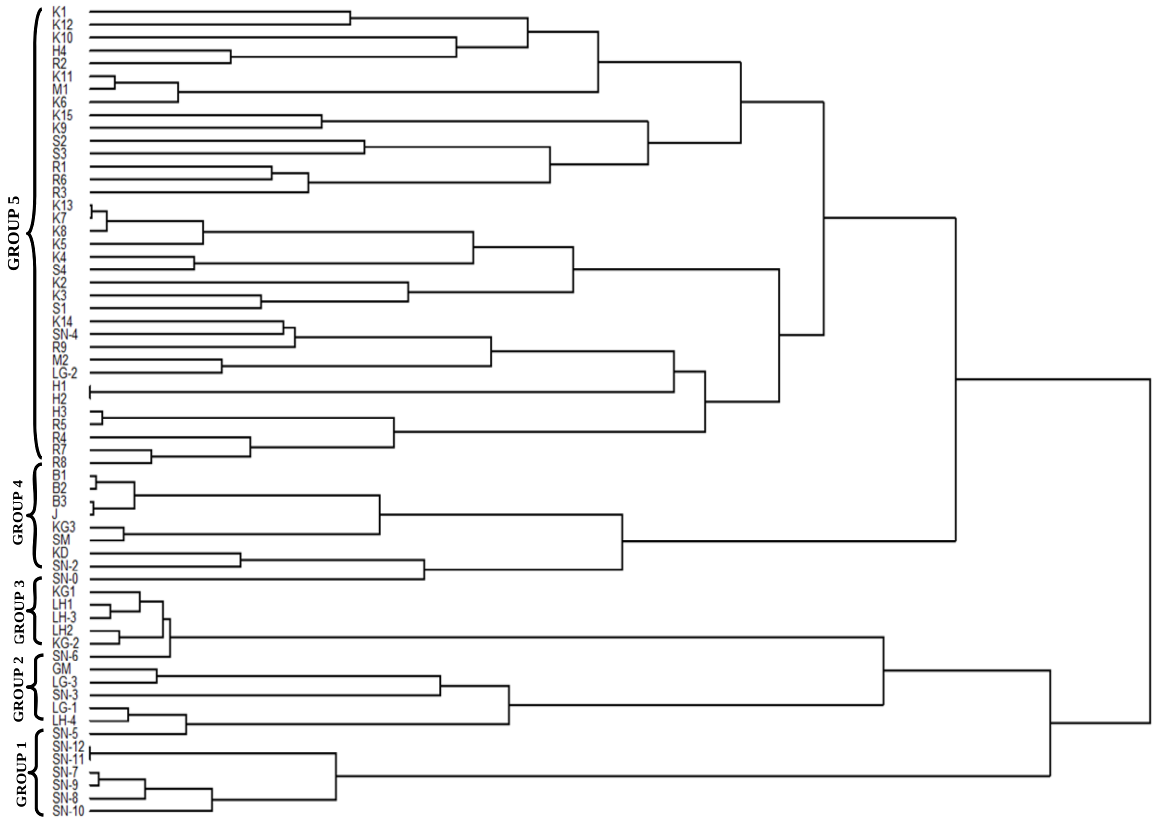

Fig. 2. Classification of vegetation groups using cluster analysis

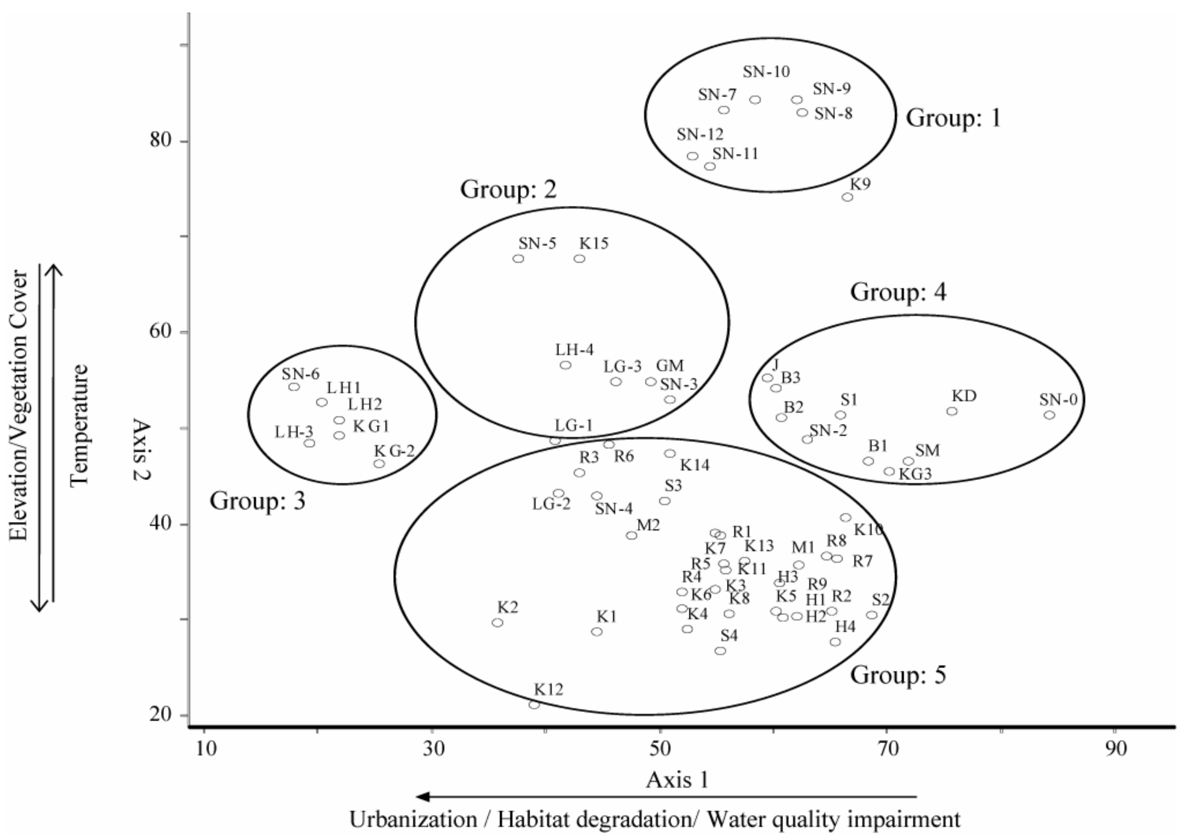

Fig. 3. DCA plot ordination overlaid with vegetation groups identified by CA.

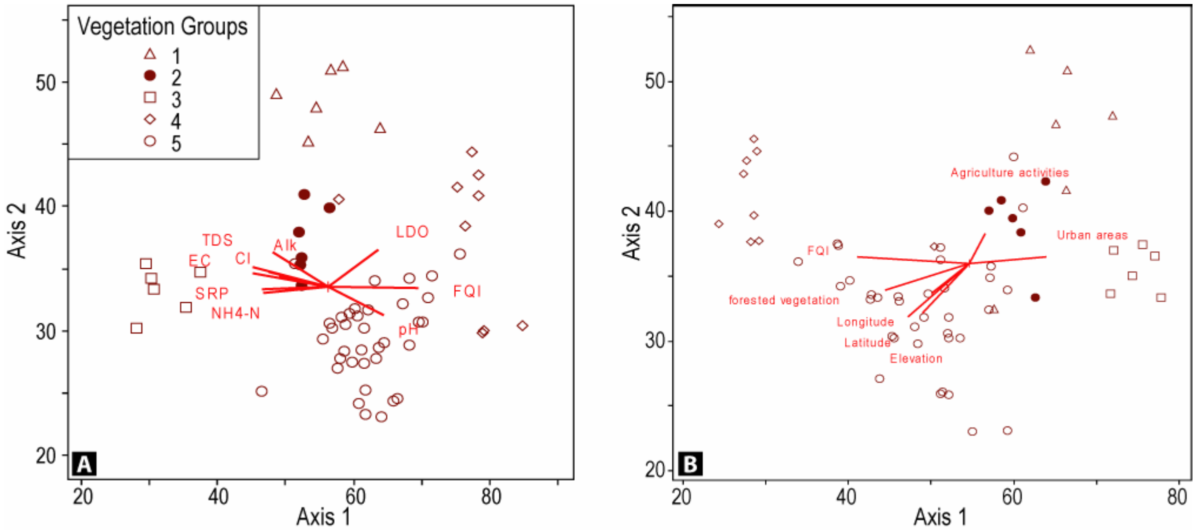

Fig. 4. CCA plot ordination overlaid with vegetation groups identified by CA.

Table 1. Index classes, Ranking, Description and values

Category	Ranking	Description
LD	Least Disturbed	Sites with very less changes in natural habitats characterized by relatively thick vegetation cover. The ecosystem is natural, unchanged and relatively intact with least anthropogenic input
MD	Moderately Disturbed	Sites with moderate loss of natural habitat with significant reduction in the vegetation cover and have moderate impact from anthropogenic activities
HD	Highly Disturbed	The ecological integrity of sites is greatly impaired with critical loss of riparian vegetation. Basic ecosystem functions are highly disturbed

Pearson correlation matrix was used to correlate FQI scores with environmental parameters using Statistica ver. 5.0 (Fig. 5). FQI scores were validated to identify significant differences between vegetation groups identified using CA and ordination analysis in relation to FQI scores (Fig. 6). One-way ANOVA tests using were performed for this purpose. The Tukey's post hoc test was used to distinguish significant results between the vegetation groups.

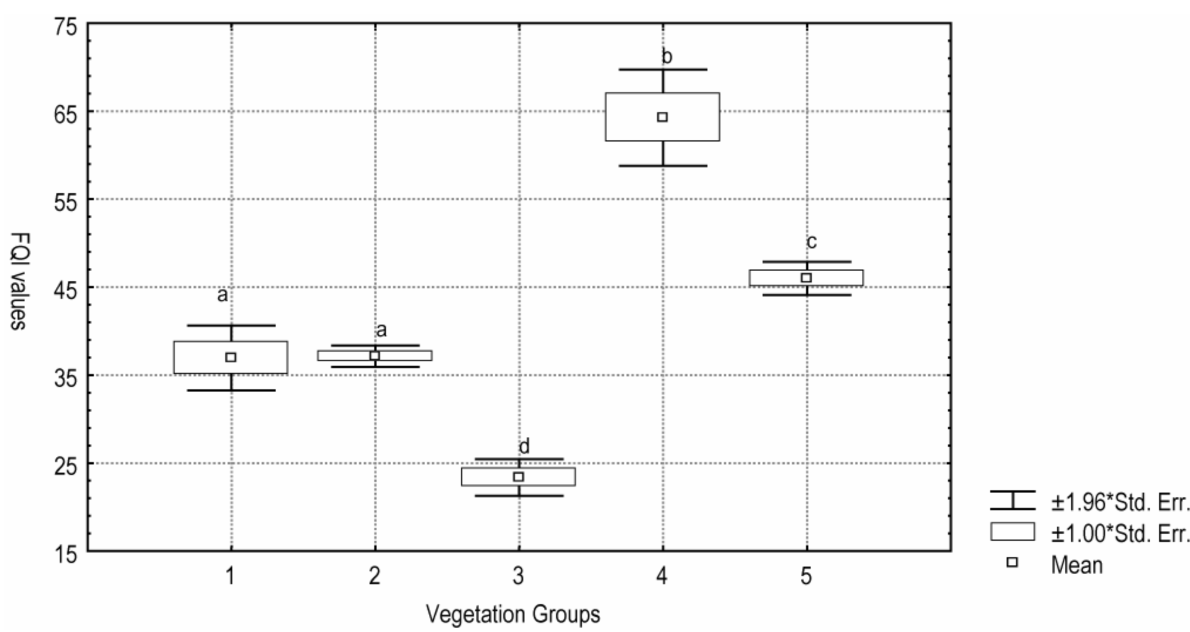

Fig. 5. Box and whisker plots indicating relationship of floristic quality index values with vegetation groups identified by CA. vegetation groups with the same letter code are not significantly different (The Tukey's post hoc test; p=<0.05).

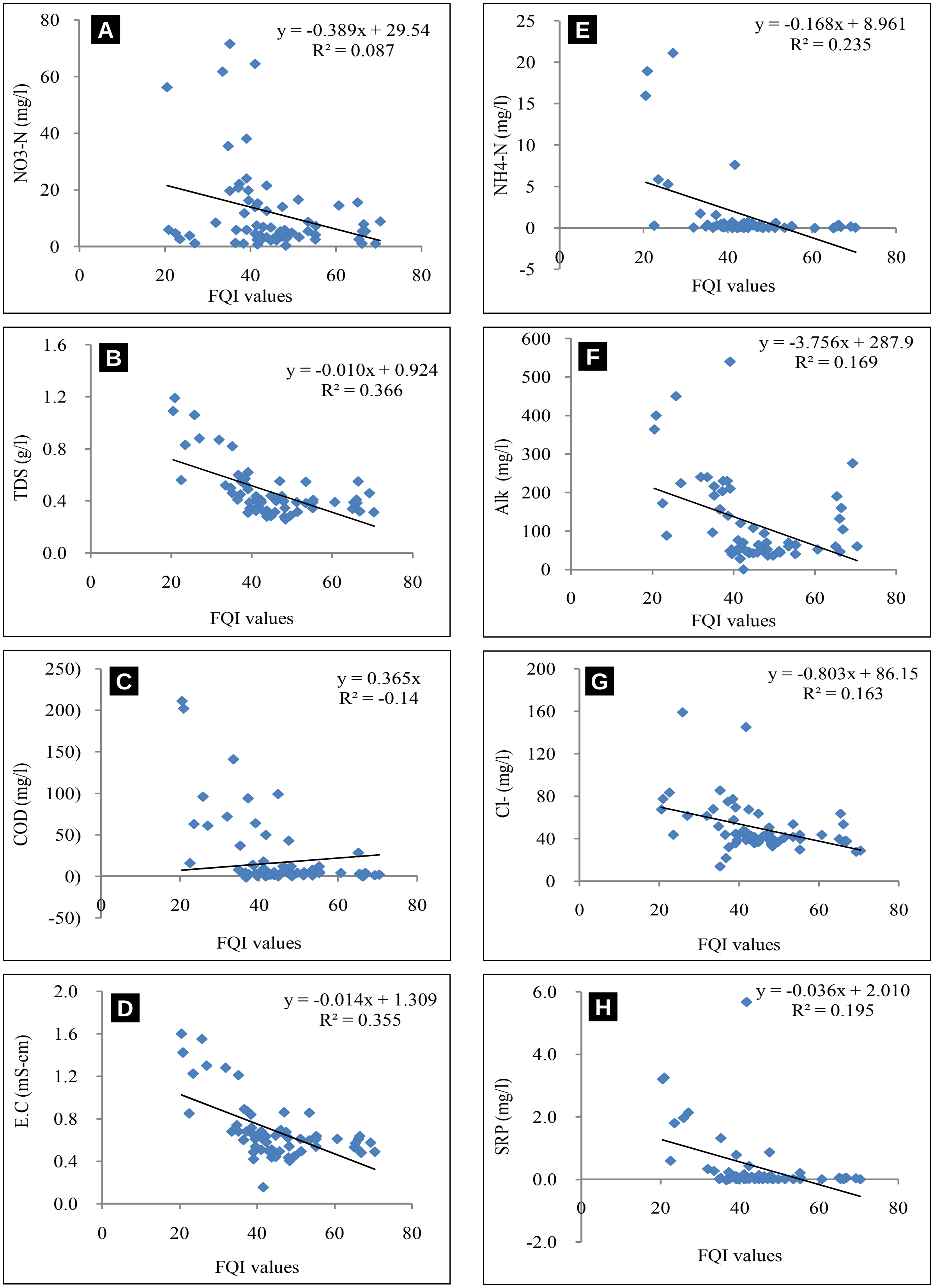

Fig. 6. Relationship between FQI values and water quality parameters, where a). NO_3-N, b). TDS, c). COD, d). EC, e). NH_4-N, f). Alk, g). and Cl^- h). SRP.

Floristic composition and spatial grouping of sites into vegetation communities: A total of 137 species were recorded from 63 sites which belonged to 41 families. Among plant species recorded, 39 were non-native represented 28.2% of the total number of the recorded species while 98 were native (71.8%). On the basis of life form, 65 species were described as herbs, 36 as graminoids, 25 as shrubs and one as a fern species (*Adiantum veunstum)* belonged to Pteridophytes. On the basis of growth form, 39% 39.1% were annual 70% were characterized as perennial. Plant species such as *Cynodon dactylon, Parthenium hysterophorus, Lantana camara, Cyperus rotundus, Justicia adhatoda, Cyperus glomeratus, Carissa ovata, Conyza bonariensis, Cannabis sativa, Euphorbia hirta, Juncus filiformis, Malvastrum coromendelianum, Polygonum barbatum, Paspalum paspaloides, Setaria glauca, Saccharum spontaneum*, and *Amaranthus spinosus* showed wide distribution. Plant species such as *Crotalaria medicaginea, Corchorus capsularis, Corchorus olitorius, Dodonaea viscosa, Dactyloctenium aegyptium, Erigeron annuus, Euphorbia prostrata, Echinocloa colona, Imperata cylindrica, Lepidium apetalum, Lemna minor, Leucas capitatis, Ocimum basilicum, Oenothera rosea, Portulaca oleracea*, and *Salix babylonica* showed sparse distribution.

Results

Five clusters of sites were identified on the basis of spatial variations in floristic composition (Fig. 2). Group-1 consisted of 6 sites i.e. SN-7, SN-8, SN-9, SN-10, SN-11 and SN-12 and constituted a total of 5.8% of species abundance. This group was characterized by the presence of *Woodfordia fruticosa* which were absent in other groups. These sites were mostly located at downstream of River Soan. Widely distributed plant species include *Cynodon dactylon, Cyperus rotundus* while plant species such as *Dactyloctenium aegyptium*, *Physalis longifolia*, *Potentilla supina* and *Ranunculus muricatus* were less abundant. Sites categorized in this group were less diverse and exhibited small number of plant species with slight to moderately eroded banks. Agriculture was the most prominent land use and sites had moderate impact from livestock grazing. Group-2 consisted of 6 sites i.e. GM (Gumrah Kas), LG-3, LG-1 on Ling Nallah, SN-3, SN-5 on River Soan and LH-4 on Nallah Lei. A total of 14.4% of the total number of plants were recorded in this group. This group was characterized by the presence of *Artemisia scoparia* and *Mnesithea laevis*. Plant species such as *Justicia adhatoda, Bacopa moniere, Cyperus glomeratus, Polygonum barbatum, Cynodon dactylon,* and *Euphorbia prostata* were dominant. *Portulaca oleracea*, *Solanum nigrum*, *Salix babylonica*, and *Celosia argentea* showed sparse distribution. These sites were located in suburban areas and showed relatively moderate level of disturbance. Human and animal washing were most dominant activities along the stream banks. Group-3 was comprised of 6 sites i.e. KG-1 and KG-2 on Nallah Korang, LH-1, LH-2, LH-3 on Nallah Lei and SN-6 on River Soan and were characterized by presence of *Eleusine indica* and *Medicago polymorpha.* These sites were characterized by highly degraded habitats with 8.6% of the total vegetation abundance. The dominant plant species included: *Amaranthus spinosus*, *Alternanthera pungens*, *Cyperus glomeratus, Carissa ovata, Cynodon dactylon, Cyperus rotundus* and *Eclipta prostrate.* These sites were located in midstream segment and were found in highly urbanized areas where stream passes through twin cities of Islamabad and Rawalpindi. Direct discharge of raw sewage and industrial effluent and urban surface runoff were main anthropogenic sources of contamination and had impact on ecological integrity of studied streams. Riparian vegetation corridor was greatly reduced. Group-4 consisted of 9 sites (B-1, B-2, B-3 on Baroha stream, KG-3, J on Korang, SN-2, SN-0, KD and SM on River Soan) which were located in upstream and accounted 15.2% of the total vegetation abundance. These sites were least disturbed from human related activities, characterized by intact habitat with good water quality, located in forested areas and supported diverse vegetation. Agricultural activities were insignificant. Widely distributed species were trivial in number while species restricted to one site only were abundantly recorded in the sites of this group e.g. *Convolvulus arvensis, Digitaria ciliaris , Juncus maritimus , Physalis minima , Solanum pseudocapsicum*. Group-5 was the largest group which included 36. Most of sites were located on Korang, Shahdra, Rumli and University streams. This group accounted 56% of the total vegetation abundance. Species such as *Amaranthus spinosus , Cyperus glomeratus, Conyza canadensis , Carissa ovata, Cynodon dactylon, Cyperus rotundus Cannabis sativa , Echinocloa crus-galli , Ipomea cairica, Lantana camara , Nerium indicum , Polygonum glabrum , Polygonum barbatum, Parthenium hysterophorus , Setaria glauca , Saccharum spontaneum, Saccharum munja* and *Xanthium strumarium* were abundant and showed wide distribution. This group was characterized by the presence of plant species such as *Adiantum venustum, Broussonetia papyrifera, Cassia occidentalis , Debregeasia saeneb , Dalbergia sissoo, Debregeasia salicifolia , Ficus palmata , Ipomoea hederacea , Justicia adhatoda , Myrsine africana, Mentha royleana* and *Ziziphus jujuba* **.** Most of the sites showed good water quality except K-2, S-4, H-1, H-3, R-5 and R-9 had point sources of organic pollution. These sites are experiencing moderate impact from construction activities, grazing, laundry, animal and human washing, discharge from local village viz., Bara Kahu, Bari Imam and Bani Galla and Quaid-i-Azam University and solid waste.

Identification of ecological gradients and their relationship with plant assemblages: DCA plot ordination is presented in Fig. 3. DCA axis 1 provided information related to habitat degradation, water quality impairment and impact from urban processes. The strength of the gradients increases from right to left along axis 1. Sites such as SN-0, KD, SN, KG-3, B-1, B2 and B-3 which were categorized in vegetation group 4 were least disturbed from human related activities. In contrast, sites (KG-1, KG-2, LH-1, LH-2, LH-3 and SN-6) belonged to group 3 occupied left side of the ordination plot had greater impact from urban surface runoff, direct discharge of municipal effluent, solid waste into the streams, and impaired water quality. The least disturbed sites had relatively less impact from anthropogenic activities, with good water quality, and intact habitat. Scattered dwellings were found in the catchment of the sites; however, these sites were surrounded by forest vegetation. Sites viz., SN-8, SN-9, K-9, LG-3, GM, LH-4, K-8, K-12, M-1, S-3, H-2, H-4, and LG-2 were located in the middle of the first axis had intermediate disturbance from human related influences.

Second axis identified climatic and geographical gradient as an important predictor of vegetation distribution. Climatic gradient directly influence the spatial extent of vegetation communities. Sites belong to vegetation group 5 were found in upstream segment at higher elevation with low temperature. These sites were located on the lower side of ordination diagram. Vegetation group 1 comprised of sites located along the downstream of the river where it passes through the agricultural landscape with moderate impact from human population.

Relationship of vegetation groups and environmental parameters: CCA ordination with water quality parameters explained 11.70% of the total variation explained (Table 2) with eigenvalues of 0.50, 0.41 and 0.34 along three axes. CCA plot ordination indicated strong correlation of vegetation groups with FQI (r =>0.90). Axis 1 showed negative correlation with Cl^- (r= -0.50), alkalinity (r=-0.58), SRP (-0.66), NH_4-N (r=-0.68), COD (r= -0.62), and EC (r=-0.78), whereas positive correlation with LDO (r=0.51) and pH (r=0.57). Axis 2 was related with pH, temperature, LDO and alkalinity (r = -0.35, -0.40, 0.44 and 0.41).

Table 2. Eigen values, variance explained and Pearson correlations.

		Axis 1	Axis 2	Axis 3
Nutrients	Eigenvalue	0.50	0.41	0.34
	Variance in species data % of variance explained	4.70	3.80	3.20
	Variance in species data cumulative % explained	4.70	8.50	11.70
	Pearson Correlation, Species-Environment*	0.96	0.90	0.89
Other parameters	Eigenvalue	0.51	0.41	0.31
	Variance in species data % of variance explained	4.50	3.40	2.90
	Variance in species data cumulative % explained	4.60	8.00	10.80
	Pearson Correlation, Species-Environment*	0.96	0.88	0.84

*Correlation between sample scores for an axis derived from the species data and the sample scores that are linear combinations of the environmental variables

CCA ordination of physical habitat parameters, land-use types and geographical coordinates, explained a total variance of 10.80% with eigen values of 0.51 and 0.41 for axis 1 and 2. These axes also described strong species and environmental parameters relationship (r=0.96 and 0.88). Land-use types were positively associated with axis 1 and FQI showed negative association. Along Axis 2 longitude showed strong association. Sites such as KG1, Kg2, LH1, LH2, LH3 and SN6 belong to vegetation group 3 showed lower FQI values as compared to other vegetation groups. Physical habitat was highly degraded with impaired surface water quality. These sites were located in urban areas and receive input from municipal and industrial activities. Surface water showed high level of COD, NH_4-N, SO_4, TDS, EC, alkalinity and lower level of LDO in comparison to other vegetation groups (Fig. 4). Sites characterized in vegetation group 4 and 5 were located in upstream at higher altitude in particular to those habitat where intact forest vegetation cover was present and less disturbance from human related activities was encountered. Along the downstream of the river Soan, greater impact from agricultural practice was found. However, sites characterized in group 1 and 2 were located in downstream of the River Soan and were relatively less impacted as compared to group 3.

Spatial variability in mean of Coefficient of Conservatism (Ć) and Floristic Quality Index: Taxa with low Ć values were tolerant and have little fidelity to specific vegetation community or habitat. In contrast, species with greater Ć values were less tolerant to habitat degradation and were rare in habitats with greater impact from anthropogenic activities. Sites which scored relatively higher Ć values were classified as least disturbed while highly disturbed sites scored lower Ć values. Moderately disturbed sites secured intermediate range of Ć values. Highest Ć value was recorded for site B-3 which was least impaired. The results showed that 73% sites scored Ć values ranged from 3.0-4.7 with relatively intermediate level of anthropogenic activities. A total of 29% of sites were highly disturbed with Ć value <3 and were located in thickly populated areas facing severe habitat degradation.

Nine sites (B-3, KD, SN-0, SM, SN-2, B-1, B-2, KG-3 and J) showed greater Ć values and FQI values >60. Highest FQI value of 70.4 was recorded for site B-3. Moderately disturbed sites scored FQI values ranged from 30-60 and form the largest group of sites. Three sub-groups of FQI can be recognized. Subgroup-1 consisted of sites such as S-3, R-2, K-3, M-1, S-2, R-9 and H-4 with FQI values in 50-59 range whereas subgroup-2 comprised of twenty five sites (M-2, H-1, H-2, R-5, K-11, R-7, K-5, K-6, S-4, K-1, H-3, R-3, R-4, K-2, R-8, K-4, SN-2, K-9, K-7, K-10, K-14, K-12, SN-12, K-13 and R-1) with FQI values of 40-49. Subgroup-3 contained sites (K-15, K-8, R-6, LG-2, SN-4, GM, LG-1, LG-3, SN-3, SN-7, SN-8, SN-9, SN-5, LH-4, SN-10 and SN-11) with FQI values varied from 30-39. Highly disturbed sites (KG-1, LH-1, LH-2, KG-2, SN-6 and LG-3) had FQI values <30. These sites were mainly located in thickly populated areas, and receive point as well as non-point sources of pollution.

Discussion

Riparian plants act as biological processors of terrestrial-aquatic interfaces and are responsive to different environmental gradients related to climatic processes, hydrological modifications, sediment and nutrient input from floodplains, land-use types, physical habitat impairment and other anthropogenic perturbations (Lowrance *et al*., 1986). The results indicated that topographic, habitat impairment and land-use have greatly influenced the quality and floristic composition of riparian vegetation of the River Soan and its associated tributaries. Longitudinal pattern was also apparent. Local geomorphological conditions originated by erosion and transport processes created heterogeneity, with areas subjected to a continuous disturbance. According to Coller *et al*., (2000) environmental heterogeneity in riparian ecosystem is integral to understand spatial distribution of vegetation communities. Environmental heterogeneity occurs both as strong environmental gradients that extend vertically (height above the channel), laterally (horizontal distance away from the channel) and longitudinally (distance down river) in riparian landscapes (Tabacchi *et al*., 1990). Vertical, lateral and longitudinal gradients are composite gradients in riparian landscape and represent change in a several environmental parameters such as flooding, water availability, morphology, geology, substrata, soil composition and nutrients.

In this study an approach was developed that unify plant community analysis with methods to identify and develop environmental drivers and linkages which have influence on the spatial extent of plant communities and floristic quality. Cluster analysis and ordination techniques identified very similar riparian vegetation types and predicted underlying environmental gradients which have strong relationship with the spatial extent of sites, species distribution and floristic quality. To describe the heterogeneity of species and environments in space and time ordination methods proved useful. Indirect ordination techniques provided insight ecological processes and identified vegetation communities with sites having greater impact from human related activities to those of fewer disturbances. Spatial variations of studied riparian vegetation had strong correlation with habitat impairment. Degradation of surface water quality and physical habitat due to anthropogenic activities in the catchment of the study sites had directly or indirectly affected plant assemblages of riparian habitats. The CCA indicated pollution gradient associated with land-use types and longitude. Nutrients (Cl^-, NH_4-N, $PO_4^{-,}$ alkalinity), COD, EC, longitude, land-use, and elevation were identified main variables which explained variations in species data.

The results indicated that FQI can identify natural areas with high floristic significance and can be helpful to compare the floristic quality between vegetation community types prevailing in different habitat. Plant communities identified varied significantly in floristic quality as measured by FQI (Fig. 5). FQI can be used as a tool to assess habitat degradation and has the ability to distinguish among sites present in one ecosystem or community type. The 'C values and FQI scores are species specific based on the fidelity of plant species (Bowers and Boutin 2008) and are more superior in their use as compared to other indices based on species richness. FQI showed negative correlation with water quality and habitat parameters associated with impairment of the sites. Physio-chemical parameters such as alkalinity (r=-0.41), Cl^- (r=-0.40), COD (r=-0.54), PO_4 (r=-0.44), NO_3^--N (r=-0.30), NH_4 –N (r=-0.49), EC (r=-0.61) and TDS (r=-0.61) were negatively correlated with FQI values. Sites with high level of LDO and lower level of nutrient and COD with intact habitat had high species richness with greater number of sensitive species and FQI values. The results showed high correlation of FQI scores with less impact from disturbance, and scores decrease with an increase in disturbance related to habitat degradation and deterioration of water quality. Sites with impairment from anthropogenic activities may score lower mean 'C values and FQI owing to low tolerance levels of sensitive species (Miller & Wardrop 2006). FQI scores decreases with increasing stress from human related activities which may lead to the failure of sensitive species to survive at disturbed sites (Miller & Wardrop, 2006). Anthropogenic activities may cause changes in structure and function of the plant assemblages that can result in high number of tolerant species. Presence of sensitive species at sites with intact habitats and less human activities may results in high values of C values and FQI scores. Sites along the Lei and Korang Nallah (LH-1, LH-2, LH-3, SN-6, KG-1 and KG-2) were categorized as highly disturbed sites located in the urban areas of Rawalpindi and Islamabad city with high anthropogenic input. These sites receive contaminants from point and non-point sources and highly impaired water quality. Riparian vegetation corridor was greatly reduced and largely comprised of *Amaranthus spinosus, Cyperus glomeratus, Carissa ovata, Cynodon dactylon, Cyperus rotundus* and *Eclipta prostrata* which have the ability to survive in degraded habitats. Ecological integrity of these sites is greatly impaired with critical loss of riparian vegetation and basic ecosystem functions. These sites showed significantly lower level of DO and higher level of COD, alkalinity, PO_4-, NO_3-N, NH_4 –N, EC, TDS, COD and Cl^- in surface water. The results also revealed decreased number of sensitive taxa at these sites and lowered Ć values. Minimum Ć value of 1.8 was scored by sites viz., LH-1 and LH-2 and 1.9 for SN-6. Lower Ć values were related to the presence of tolerant species with low conservation precedence. FQI scores revealed least index values. Due to lower index values these sites were characterized as highly disturbed sites. LH-2 was located in Liaqat Bagh on Lei Nallah where it receives municipal wastes from Rawalpindi city. High population stress in the catchment area of this site was major factor that contributed to the poor habitat quality. LH-1 and SN-6 were located near Soan Camp where Nallah Lei joins River Soan. Barbour *et al*., (1999) indicated that number, frequency and intensity of major anthropogenic stressors i.e. erosion, cutting, construction activities along stream banks, animal washing, laundry and municipal wastes can possibly change the composition of biotic communities and have impact of stream quality. Anthropogenic activities in the riparian zones may lead to changes in water chemistry. Physical habitat affects surface water quality and native aquatic community structure (Swaine *et al*., 2006). Alterations in physical habitat can be related to anthropogenic mis-management, improper animal practices and vegetation fragmentation which ultimately disturb water quality and native aquatic communities (Magner *et al*., 2008). Nerbonne & Vondracek (2001) highlighted that physical habitat affect directly aquatic communities. Human related disturbance was important phenomenon that shapes plant communities in riparian zone of the study area. Death (1996) also reported that in riparian landscapes anthropogenic disturbances are insidious factors which bring changes in species composition of these habitats. Anthropogenic activities encounter natural plant assemblages by alterations in riparian corridors by irrigation, cultivation and obstructions along with the water channels affecting floristic composition (Corbacho *et al*., 2003). Tolerant and exotic species showed wide range of habitat conditions, and can survive in high level of degradation and disturbance in comparison to sensitive species which disappear first under conditions of declining biological integrity of the aquatic ecosystem. The results showed sensitive species abundance increased significantly at those sites with good habitat quality. Least-impacted sites had greater number of sensitive species and less number of tolerant species. Sites viz., B-1, B-2, B-3, KG-3, J, SN-0, SN-2, KD and SM were characterized as least disturbed and were characterized least disturbed habitat conditions with low level of TDS, COD, and nutrients (Ali & Malik, 2011). Highest Ć and FQI value was recorded for B-3 which was due to the presence of greater number of sensitive plant species.

Habitat degradation creates conditions favorable for invasion and high relative abundance of exotic species (Hejda & Pysek 2006). The results indicated that stream banks associated with agricultural, urban land-use types are highly susceptible to colonization by non-native plants and species of low conservation interest and that the presence of wooded areas surrounding streams were associated with higher numbers of native and disturbance sensitive plant species present in the bank. Exotic species are known for their negative impact on habitat quality. The results indicated that least impacted sites which were located in wooded area had relative abundance of exotics less whereas sites in urban and agricultural areas had higher relative abundances. The impacts of non-native on the natural flora may be more intense if such species displace the native species. Non-native species scored lower Ć values and FQI scores of B-1, B-2, KG-3, J SN-0, KD and SM.

Land-use may influence the structure and function of plant communities (Shandas *et al*., 2009) and florist quality of riparian habitats (Lopez & Fennessy 2002). FQIs are generally negatively related to index of land-use types disturbances on local watershed (buffer) conditions. The results indicated that effect of urbanization was most obvious in Group-3 characterized as highly disturbed sites and secured lowest FQI scores and were located in the highly urbanized areas of Rawalpindi and Islamabad cities. Group 1 and 2 also showed relatively lower FQI values and had influence from agricultural related activities. Agriculture and urbanization affect the riparian and wetland vegetation is related to nutrient enrichment of runoff (Qadir *et al*., 2008). The sites with lower FQA values tended to be dominated by plant species which have the affinity for heavily degraded landscapes impacted either from agricultural practices or urban areas. Sites belonged to group 4 (B-1, B-2, B-3, KG-3, J, SN-2, SN-0, KD and SM) were least impacted from urbanization and scored highest Ć values and FQI scores.

The results supported the use of Ć values and FQI scores for the assessment of riparian habitats and establish link of vascular plants with water chemistry and physical habitat parameters. Plant species are sensitive with respect to water, nutrients and habitat requirements. Sensitive plant species were restricted to a narrow range of habitat conditions with good water quality, and least habitat degradation. Plant species viz., *Cynodon dactylon, Cyperus rotundus* and *Parthenium hysterophorus* showed preference to wide range of habitats. Sites located upstream of the sampled area were least disturbed, having relatively intact physical habitat, good water quality and supported greater number of plant species. On the other hand highly disturbed sites viz., LH-1, LH-2, LH-3 and SN-6 were present in highly urbanized areas where human activities influenced the ecological conditions of the streams. Application of FQI required taxonomic expertise with relative simplicity and low cost. Ć values assigned to the plant species were dependent upon the habitat fidelity of species. The use of FQI proved reliable tool for ecological assessment and its efficacy may increase greatly if temporal aspects of riparian vegetation are also taken into account along with the spatial aspects. This aspect of FQI will help long term monitoring of sites and conservation of threatened species. Accuracy of FQI can be comparable to other assessment systems using macro-invertebrates or fishes. It is also suggested to implement the methods adopted is study to other eco-regions to determine the consistency of this assessment method with other commonly used assessment methods.

Acknowledgments

This study was financed by the Higher Education Commission Project No. 02-828/R&D/07. The authors are grateful to Pakistan Wetlands Programm (PWP) for providing transport during field visit. Special thanks to technical staff of the Faculty of Biological Sciences, Quaid-i-Azam University for providing facility for laboratory analyses.

References

Ali, S.M., and R.N. Malik. 2011. Spatial Distribution of Metals in Top Soils of Islamabad City, Pakistan. *Environmental Monitoring and Assessment,* 172:1–16.

Barbour, M.T., J. Gerritsen, B.D. Snyder, J.B. Stribling. 1999. Rapid bioassessment protocols for use in streams and wade able rivers: Periphyton, Benthic Macroinvertebrates and Fish, 2nd ed. EPA 841-B-99-002. U.S. Environmental Protection Agency; Office of Water; Washington, D.C. USA.

Bourdaghs, M., C.A. Johnston and R.R. Regal. 2006. Properties and performance of the floristic quality index in great lakes coastal wetlands. *Wetlands*, 26: 718-735.

Bowers, K. and C. Boutin. 2008. Evaluating the relationship between floristic quality and measures of plant biodiversity along stream bank habitats. *Ecological indicators*, 8: 466-475.

Corbacho, C., J.M. S´anchez and E. Costillo. 2003. Patterns of structural complexity and human disturbance of riparian vegetation in agricultural landscapes of a Mediterranean area. *Agriculture, Ecosystems & Environment*, 95: 495-507.

Death, R.G. 1996. The effect of habitat stability on benthic invertebrate communities: the utility of species abundance distributions. *Hydrobiologia*, 317: 97-107.

Decamps, H. 1997. The renewal of floodplain forest along rivers: a landscape perspective. Verh. Internat. *Verein. Limnol*., 26: 35-59.

Ferreira, M.T., P.M. Rodrı´guez-Gonza´lez, F.C. Aguiar and A. Albuquerque. 2005. Assessing biotic integrity in Iberian rivers: Development of a multimetric plant index. *Ecological Indicators*, 5: 137-149.

Gregory, S.V., F.J. Swanson and W.A. McKee. 1991. An ecosystem perspective of riparian zones. *Bio Science*, 41: 540-551.

Hejda, M. and P. Pysek. 2006. What is the impact of Impatiens glandulifera on species diversity of invaded riparian vegetation. *Biological Conservation*, 132: 143-152.

Herman, K.D., L.A. Masters, M.R. Penskar, A.A. Reznicek, G.S. Wilhelm and W.W. Brodowicz. 1997. Floristic quality assessment: development and application in the state of Michigan (USA). *Natural Areas Journals*, 17: 265-279.

Jones, III. E.B.D., G.S. Helfman, J.O. Harper and P.V. Bolstad. 1999. Effects of riparian forest removal on fish assemblages in Southern Appalachian streams. *Conservation Biology*, 13: 1454-1465.

Looy, K.V. and P. Meire. 2009. A conservation paradox for riparian habitats and river corridor species. *Journal for Nature Conservation*, 17: 33-46.

Lopez, R.D. and S.M. Fennessy. 2002. Testing the floristic quality assessment index as an indicator of wetland condition. *Ecological Applications*, 12: 487-497.

Lowrance, R., J.K. Sharpe and J.M. Sheridan. 1986. Long term sediment deposition in the riparian zone of a coastal plain water shed. *Journal of Soil and Water Conservation*, 41: 266-271.

Magner, J.A., B. Vondraceck, K.N. Brooks. 2008. Grazed riparian management and stream channel response in Southeastern Minnesota (USA) streams. *Environmental Management*, 42: 377-390.

Masahito, I. and N. Nakagoshi. 2001. The effects of human impact on spatial structure of the riparian vegetation along the Ashida River Japan. *Landscape and Urban Planning*, 53: 111-121.

Matthews, J.W. 2003. Assessment of the floristic quality index for use in Illinois, USA, wetlands. *Natural Areas Journal*, 23: 53-60.

Malik, R.N. and M. Nadeem. 2011. Spatial and temporal characterization of trace elements and nutrients in the Rawal Lake Reservoir, Pakistan using multivariate analysis techniques. *Environmental Geochemistry and Health,* 33:525-41.

Malik, R.N., Husain, S.Z., I. Nazir. 2010. Heavy metal contamination and accumulation in soil and wild plant species from industrial area of Islamabad, Pakistan. *Pakistan Journal of Botany.* 42: 291-301.

Miller, S.J., D.H. Wardrop, W.M. Mahaney and R.P. Brooks. 2006. A plant-based index of biological integrity (IBI) for headwater wetlands in central Pennsylvania. *Ecological Indicators*, 6: 290-312.

Miller. S.J. and D.H. Wardrop. 2006. Adapting the floristic quality assessment index to indicate anthropogenic disturbance in central Pennsylvania wetlands. *Ecological Indicators*, 6: 313-326.

Nasir, E. and S.I. Ali. 1972. *Flora of West Pakistan*. Fakhri Press, Karachi.

Nazir A., Malik, R.N., Ajaib, M. N. Khan, M. F. Siddiqui. 2011. Hyperaccumulators of heavy metals of industrial areas of Islamabad and Rawalpindi. *Pakistan Journal Botany*, 43: 1925-1933.

Nerbonne, B.A. and B. Vondracek. 2001. Effects of local land use on physical habitat, benthic macroinvertebrates, and fish in the Whitewater River, Minnesota, USA. *Environmental Management*, 28: 87-99.

Nichols, S.A. 2001. Long-term change in Wisconsin lake plant communities. *Journal of Freshwater Ecology*, 16: 1-13.

Ometo, J.P.H.B., L.A. Martinelli, M.V. Ballester, A. Gessner, A.V. Krusche, R.L. Victoria and M. Williams. 2000. Effects of land use on water chemistry and macroinvertebrates in two streams of the Piracicaba river basin, southeast Brazil. *Freshwater Biology*, 44: 327-337.

Qadir, A. and R.N. Malik. 2009. Assessment of an index of biological integrity (IBI) to quantify the quality of two tributaries of river Chenab, Sialkot, Pakistan. *Hydrobiologia*, 621: 127-153.

Qadir, A., R.N. Malik and S.Z. Hussain. 2008. Spatio-temporal variations in water quality of Nullah Aik-tributary of the River Chenab, Pakistan. *Environmental Monitoring and Assessment*, 140: 43-59.

Rooney, T.P. and D.A. Rogers. 2002. The modified floristic quality index. *Natural Areas Journal*, 22: 340-344.

Schnitzler, A., B.W. Hale and E.M. Alsum. 2007. Examining native and exotic species diversity in European riparian forests. *Biological Conservation*, 138: 146-156.

Shandas, V. and M. Alberti. 2009. Exploring the role of vegetation fragmentation on aquatic conditions: Linking upland with riparian areas in Puget Sound lowland streams. *Landscape and Urban Planning*, 90: 66-75.

Spackman, S.C. and J.W. Hughes. 1995. Assessment of minimum stream corridor width for biological conservation: species richness and distribution along mid-order streams in Vermont, USA. *Biological Conservation*, 71: 325-332.

Stewart, R.R. 1972. An Annotated Catalogue of the Vascular Plants of West Pakistan and Kashmir. Gordon College, Rawalpindi.

Swaine, M.D., J. Adomako, G. Ameka, K.A.A. de Graft-Johnston and M. Cheek. 2006. Forest river plants and water quality in Ghana. *Aquatic Botany*, 85: 299-308.

Swink, F.A. and G.S. Wilhelm. 1994. Plants of the Chicago Region, 4th ed. Indiana Academy of Science, Indianapolis.

Tabacchi, E., D.L. Correll, R. Hauer, G. Pinay, A.M. Planty-Tabacchi and R.C. Wissmar. 1998. Development, maintenance and role of riparian vegetation in the river landscape. *Freshwater Biology*, 40: 497-516.

Tabacchi, E., L. Lambs, E. Guilloy, A.M. Planty-Tabacchi, E. Muller and H. Décamps. 2000. Impacts of riparian vegetation on hydrological processes. *Hydrological Processes*, 14: 2959-2976.

Taft, J.B., G.S. Wilhelm, D.M. Ladd and L.A. Masters. 1997 Floristic quality assessment for vegetation in Illinois: a method for assessing vegetation integrity. *Erigenia*, 15: 3-95.

van Coller, A.L., K.H. Rogers and G.L. Heritage. 2000. Riparian vegetation-environment relationships: complimentarily of gradients versus patch hierarchy approaches. *Journal of Vegetation Science*, 11: 337-350.

(Received for publication 12 February 2011)