RESEARCH ARTICLE

Identifying riparian vegetation as indicator of stream water quality in the Gilgel Gibe catchment, southwestern Ethiopia

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Abstract

Riparian land use has substantial effects on aquatic habitats and biological communities resulting in a dramatic loss of natural riparian vegetation and affecting the physicochemical properties of streams. *The study investigates the relationships among indigenous riparian plants and water quality in the upper Gilgel Gibe catchment in southwestern Ethiopia. The floristic composition of the riparian vegetation and the water quality of streams were studied at selected sites, ranging from first to third order streams. We quantified relationships between disturbance level and both physicochemical characters and traits of riparian plant species during two sampling periods (December 2013 and April 2014). Data were collected from a priori designated three land use types (forest, plantation and agriculture) and ranked along nine streams. Ranks were based on surrounding land use characteristics and deforestation categories. We used analysis of variance (ANOVA) and the Tukey's post-hoc test to conduct pair-wise comparisons among different land use types. Both species richness and diversity values of forest sites were significantly ($p<0.001$) higher than agricultural sites. Whereas, stream water quality deterioration indicator gradient such as total suspended solid (TSS), water turbidity, and orthophosphate were significantly ($p<0.001$) higher in agricultural sites than forest sites. We identified species such as Croton macrostachyus, Ficus sur, Maytenus arbutifolia,* and *Millettia ferruginea as indicator species of water quality ($p<0.05$). Our study is the first assessment of the role of indigenous plant species as indicator of highland stream water quality in the tropical area. The study contributes to the on-going discussion on the assessment and monitoring of stream ecosystems and for following stream restoration projects in tropical regions around the globe.*

Key words: Diversity, Indicator species, Land use, Riparian vegetation**,** Stream, Water quality**.**

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Introduction

Among the components of freshwater ecosystems, riparian vegetation is the component that is shaped by human land-use (Paine and Ribic 2002). Riparian land use has substantial effects on aquatic habitats and biological communities (Jun et al., 2011). Various studies have reported that riparian land use change has resulted in a significant deterioration of water quality that has induced serious environmental and ecological problems in rivers and lakes in various parts of the world, for example Meek et al. (2013) noted that riparian plant communities have been heavily impacted and degraded by human activities. Other research report indicated that land use affects the structure and diversity of riparian vegetation (Fernandes et al. 2011). Besides its direct effect on riparian vegetation, land modification and agricultural activities have led to water quality deterioration (Bu, et al. 2014), and has substantial effects on aquatic habitats and biological communities (Jun et al. 2011; Lu et al. 2014).

In Africa, deforestation of the riparian areas associated with streams as well as the use of fertilizers and pesticides have become major environmental issues (Barry et al. 2009). Similarly, in Ethiopia, the exploitation of riparian vegetation alters stream ecosystems (Bewket and Sterk 2005) and leads to a gradual decline in tree and shrub species in the catchment (Sisay and Mekonnen 2013), which in turn accelerates the siltation of rivers, lakes, and dams (Devi et al. 2008; Wolka 2012).

The establishment and maintenance of riparian vegetation along stream sides supplies multiple ecosystem services such as nutrient reduction (Sutton et al. 2010), stream bank stability (Milner and Gloyne-Phillips 2005), and stream temperature regulation (Dosskey et al. 2010). Riparian corridors maintain physical, biological, and ecosystem functions, and there are strong causal linkages between biodiversity and ecosystem functioning (Cavaillé et al. 2013). Such linkages can be systematically assessed using the riparian species floristic composition and diversity. Furthermore, the use of plant as indicator species to evaluate freshwater ecosystem condition has been applied broadly in ecological research (Carbiener et al. 1990; Nichols et al. 2000; Clayton and Edwards 2006; Triest 2006).

Riparian plants can act as measurable indicators of ecological conditions and to respond rapidly to changes in the riparian habitat (Miller et al. 2006). For this reason, riparian plants have been used as biological indicators to signify positive changes in water quality (Nichols et al. 2000).

The study of riparian vegetation of running streams offers information on the feature of the environment (Thiébaut and Muller 1998; Riis et al. 2000) and increase the knowledge related to bioindication systems (Daniel et al. 2006). Riparian vegetation are strong causal linkages between biodiversity and ecosystem functioning (Cavaillé et al. 2013). Such linkages can be systematically assessed using metric based on diversity (Junyan et al. 2014; Pourbabaei et al. 2014; Řepka et al. 2015), and metric based on indicator species (Johnston 2003; Jovan and Mccune 2006). As such, some studies have addressed the impact of surrounding land-use on the Gilgel Gibe catchment in detail (Ambelu et al., 2010; Demissie et al., 2013; Mertens, 2013; Abate and Lemenih, 2014; Adela, 2015). However, the ecological aspect of riparian plant diversity, biological indicator values of riparian plant and their relation to the water quality of these streams has not been addressed. Furthermore, we know that there is no previous study so far that has explored riparian plants along the stream using field-based data in this catchment. Thus, this study serves as a useful case study to evaluate highland streams water quality by using riparian plants as indicator species. We expect that indigenous plant species such as *Ficus sur*, *Maytenus arbutifolia, Maesa lanceolate, and Millettia ferruginea* will be good indicator of water quality because these plants inhabit relatively less disturbed streamside (Sisay and Mekonnen 2013) and are important for catchment management (Bekele 2007). The aim of the study was to (1) characterize and quantify the relationship between riparian plant species and the physicochemical properties of stream water and (2) identify plant species that can be used as ecological indicators for water quality monitoring.

Methods

Catchment description

The Gilgel Gibe catchment is located in the Jimma Zone of southern Ethiopia (latitude 7°25′–7°55′ North and longitude 36°30′–37°22′ East)(Fig 1),with an altitude that ranges from 3259 to 1096 m.a.s.l. (Ambelu et al. 2010). The land use in the catchment includes cropland and pasture, grassland, savanna, and mixed forest (Demissie, et al. 2013). For this study, nine permanent streams ranging from first to third order were selected following the classification of Rosgen (1985). In each stream two to four sites were surveyed.

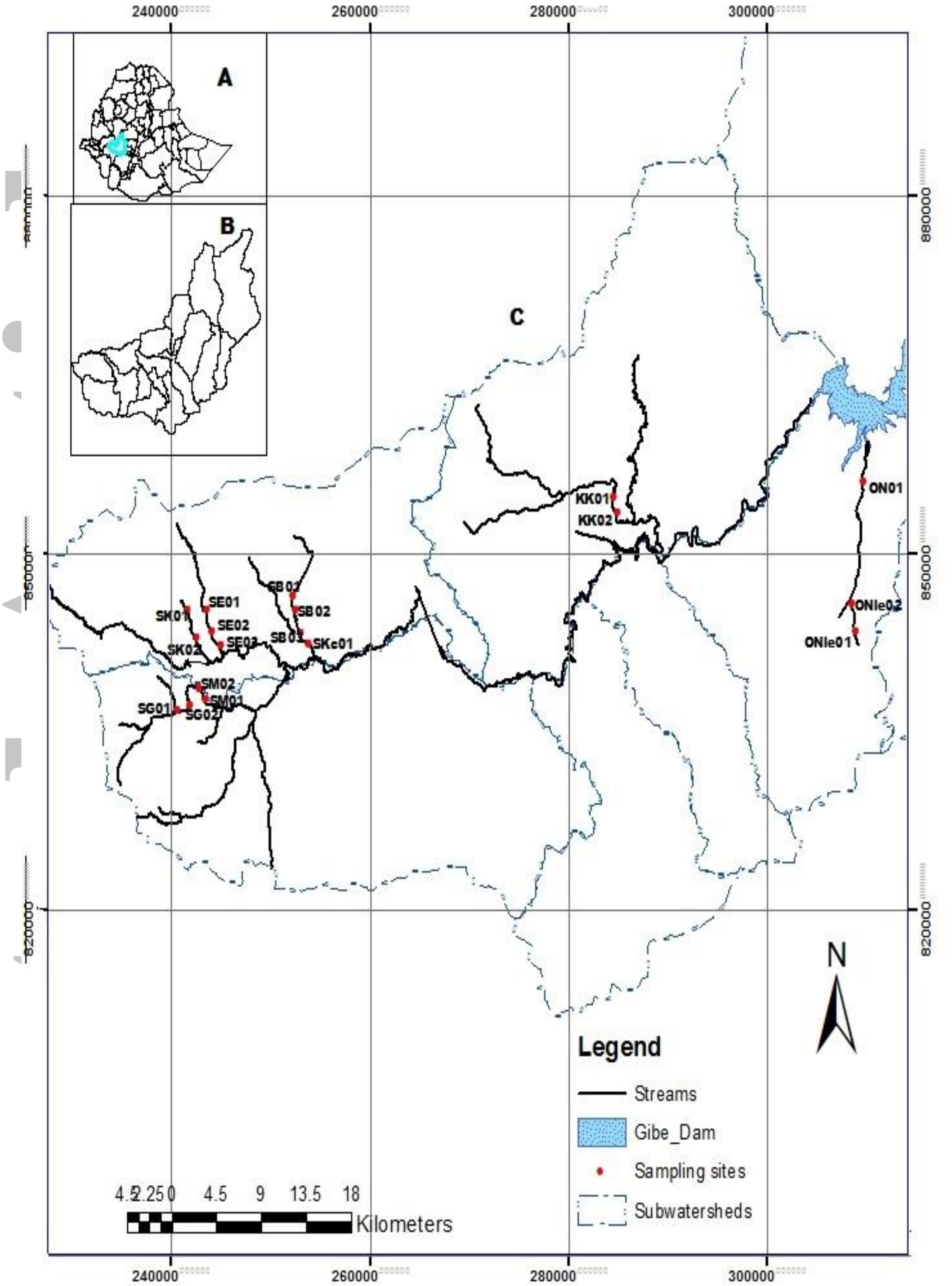

Fig. 1 Map showing (A) Location of the study site, (B) Gilgele Gibe watershed and (C) study streams and sampling sites in the upper Gilgel Gibe catchment for riparian vegetation and water sampling.

Following Burton and his colleagues (2005),transects were established on both sides of the selected stream that extended from the stream edge to the uplands perpendicular to the stream. The sampled sites were located at various locations to encompass the range of a priori land uses categories (Forest, plantation and agriculture). Hereafter riparian embedded in primary forest land uses were called forest sites; riparian embedded in primary eucalyptus plantation were called plantation sites; and riparian embedded in primary pasture and agricultural land use were called agricultural sites. This information was used to construct a numerical classification ranking of sites based on land use category (1= agriculture, 2= plantation, 3= forest after) Kasangaki et al., (2008).

An average of two to three successive transects were located 100 m apart in the downstream direction from the first transect. Within each transect, 50 m^2 (5 m × 10 m) rectangular plots were placed at 15-m distances with the long edge parallel to the stream. Within each plot, all woody stems ≥0.50m height were recorded. The plot numbers varied from one to two per transect, depending on the width of the riparian zone and number of sample plots at each site were range from four to twelve. Herbaceous species were collected within a1 m×1 m (1 m^2) plot placed at the center of the main plot. The local name of each plant was recorded in the field, and voucher specimens of all plants in the study area were collected and taken to the national herbarium of Addis Abeba University for identification. Among 72 plant species, 67 plants were identified to lowest taxonomic level (species) whereas 5 species were identified to genera level. Plant identification was done using taxonomic key and published volumes of the Flora of Ethiopia and Eritrea (Hedberg and Edwards 1989; Hedberg 1989; Edwards 1995; Edwards 1997; Hedberg 2003; Hedberg 2006; Tadesse 2000).The riparian plant survey was conducted in the mid of February 2014.

Water quality sampling strategy and analytical procedure

Eighteen monitoring stations were selected (Fig 1), and samples were collected during two different seasons: the dry season (February) and the wet season (May). The dataset collected in this study includes eight parameters. At the sites, water temperature, pH, dissolved oxygen (DO), and electrical conductivity (EC) were measured using a multi-probe meter (HQd4 Single-Input Multi-Parameter Digital Meter, Hach) and turbidity was measured using a Wagtech turbidity meter (Wag-WT3020). The total suspended sediment (TSS), nitrate and orthophosphate were measured in the laboratory of Environmental Health at Jimma University according to the standard methods as prescribed by APHA et al., (1995). The stream flow rate was measured using a flow meter, and the average velocity (m/s) was calculated. The stream depth and widths were measured using a metal measuring tape.

Data analysis

Species presence/ absence data for each of transect in the sites pooled to create a single list of identified species per sites. Means and standard deviation were calculated from the samples collected during the two sampling periods. Data was tested for normality and equal variances. Except pH all data were log transformed to improve normality. We conducted a one-way ANOVA and the Tukey's post-hoc test to conduct pair-wise comparisons between land use and environmental variables (water quality and buffer width). The same procedure was used to test diversity indices along land use type. Furthermore, forward stepwise regression of species richness was performed against land use, buffer width, stream order, and altitudes. All of the ANOVA test and regressions adequately met assumption of normality and equality of variance. The forward stepwise regression and ANOVA were performed using Sigma plot version 12.0. We also used the PCA to assess the relationships between the environmental variables and riparian plant species. Ordination analyses were performed in the Canoco software (version 4.5, Biometric, Wageningen, NL)

Lastly, an Indicator Species Analysis (ISA) was conducted according to Dufrêne & Legendre (1997). ISA can be used to detect and describe the value of taxa indicative of environmental conditions it requires *a priori* groups and data on the abundance or presence of taxa in each group. These groups were commonly defined by categorical environmental variables, levels of disturbance, experimental treatments, presence and absence of a target species, or habitat types (McCune et al., 2002). The ISA calculation combines information on the concentration of species abundance and the faithfulness of occurrence of a species in a group. An indicator value was calculated by the formula $IVij = RAij \times RFij \times 100$,Where $IVij$ is the indicator value of species I in group j, $RAij$ is the mean abundance (% cover) of species i in group j, and $RFij$ is the relative frequency of occurrence of species i in the plots of group j. IV ranges from 0 (no indication) to 100 (perfect indication). The calculated indicator species values were based on two standards, faithfulness and exclusion. Faithfulness was defined mathematically by a particular taxon always being present in a particular group. Additionally, the perfect indicator taxa would be exclusive to that group, meaning it never occurred in other groups (Dufrêne and

Legendre, 1997). The significance of the value was analyzed using a Monte Carlo test with 1,000 permutations, and only the significant values ($p < 0.05$) are presented here. The ISA was used to identify taxa with significant associations to forest sites. The resulting *p*-value represents the probability that the calculated indicator value for any species is greater than that found by chance (Rogers et al., 2007).

Results

Effect of land uses on streams

Water samples were analyzed for 18 sites. Table 1 shows mean values ± the standard deviation (SD) for water quality parameters for the three land use categories (forest, plantation and agriculture). Agricultural sites had significantly ($p<0.05$) higher turbidity, TSS, and orthophosphate, than forest, and plantation sites. Whereas forest sites had significantly ($p<0.05$) higher dissolved oxygen than plantation sites. However, water pH, conductivity and water temperature were not significantly ($p>0.05$) different among land use types. Water nitrate was significantly ($p<0.05$) different only between plantation and agricultural sites. Both forest and plantation sites had significantly wider buffer width than agricultural sites ($p<0.05$: Table 1).

Table 1. The mean and standard deviation (SD) the water quality parameters among three *a priori* land use categories, values across the rows with the same letter code are not significantly different (The Tukey's post hoc test; $p <0.05$).

	Forest	Plantation	Agriculture
pH	7.32 ± 0.27[a]	7.02 ±0.38[a]	7.32±0.18[a]
Buffer width	15.4±6.77[a]	5.88±2.17[a]	2.44±2.34[b]
DO	6.95±0.04[a]	4.88±1.75[b]	5.96±0.36[ab]
EC	86.84±17.1[a]	117.56±45.93[a]	93.3±16.29[a]
Temperature	23.74±1.27[a]	25.91±2.23[a]	24.5±1.74[a]
Turbidity	49.68±11.92[a]	25.69±26.29[a]	139.48±73.8[b]
TSS	43.7±11.05[a]	30±19.9[a]	102.08±43.54[b]
Nitrate	1.63±0.37[a]	0.99±1.73[b]	3.09±1.0[a]
Orthophosphate	0.05±0.04[a]	0.09±0.07[a]	0.23±0.1[b]

Multivariate analysis

The PCA performed with 9 abiotic parameters explained 54.1% of variation in the data of first two axes (Figure 2, Table 2). The linear relationship (Pearson's r) between the PCA scores and the individual variables indicated that axis 1 was positively correlated with higher values of EC (r=0.50) and water temperature (r=0.68), with which *plantation* sites were associated. On the negative side of this axis, agricultural sites were associated with higher values of nitrate (r= -0.82), pH (r= -56), turbidity (r= -0.55) and TSS (r= -0.50). Component 2 reflects the buffer width (r= 0.60) and dissolved oxygen (r= 0.50) having a positive relationship with this axis and a negative relationship with Orthophosphate (r= -0.411), with which forest sites were associated.

Table 2. Principal component loadings for water quality variables from the PCA of physical data from 18 river sites.

Environmental variable	PCl	PC2	PC3
pH	**-0.557**	0.209	0.179
Buffer width	0.002	**0.595**	-0.138
DO	0.085	**0.500**	0.016
EC	**0.500**	0.112	-0.143
Water temperature	**0.682**	-0.178	0.055
Turbidity	**-0.552**	-0.302	-0.150
TSS	**-0.502**	-0.471	-0.101
NO_3^-	**-0.820**	-0.046	-0.046
Po4	-0.087	-0.411	-0.117
Eigenvalue	2.53	1.51	1.1
Cumulative %	25.3	40.4	51.4

Bold values represent strong and moderate loadings.

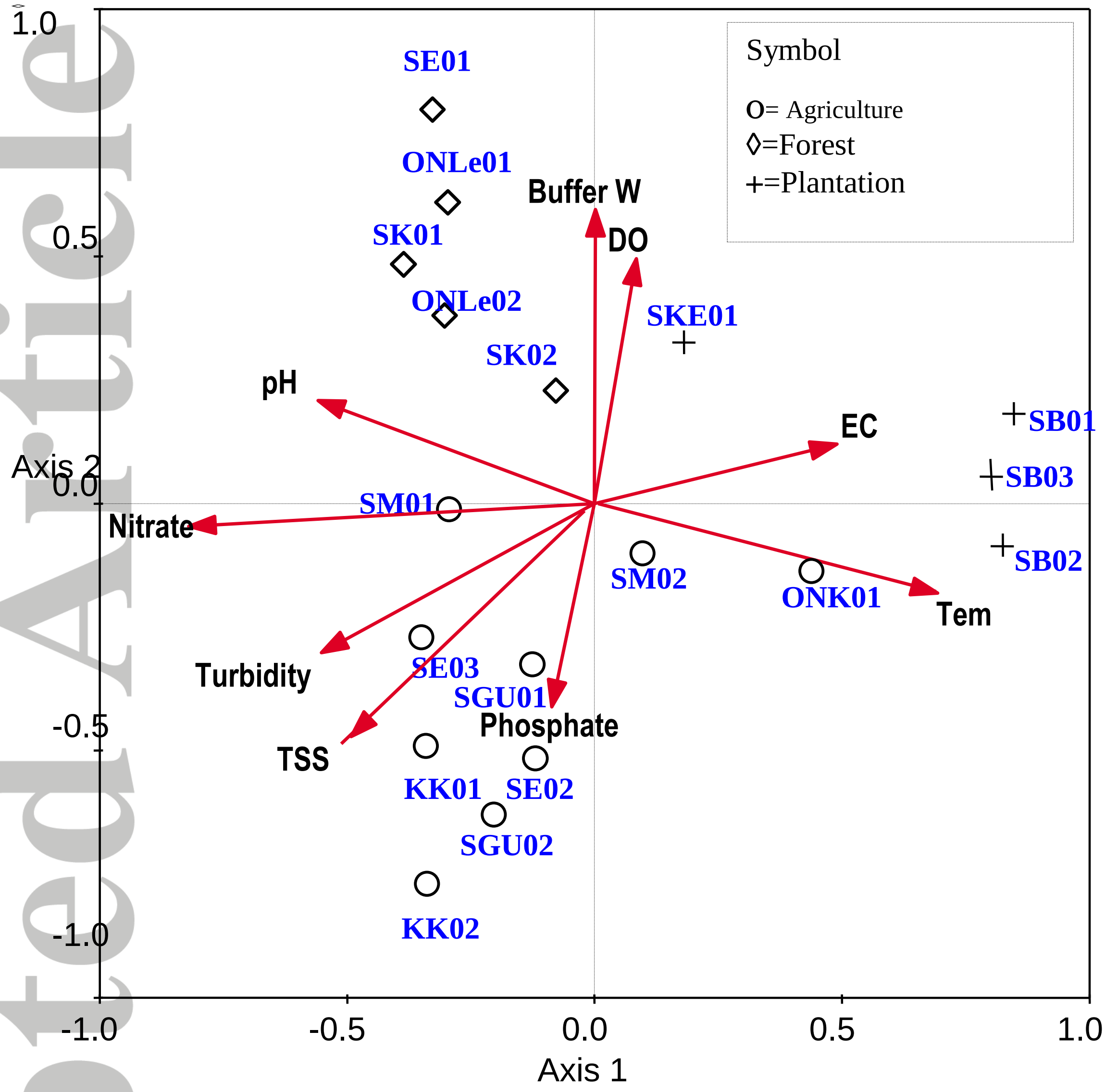

Fig. 2. PCA biplot of environmental variables measured across 18 sites in the upper Gilgel Gibe river, southwestern Ethiopia.

Riparian plant species

A total of 72 plant species belonging to 38 families and 65 genera were recorded. Of these, 4.1% were exotic and 1.3% were endemic. The largest family, with more than ten species and the highest frequency was Fabaceae (11 species). The other families were Euphorbiaceae (five species), Lamiaceae (five species), followed by Moraceae, Rubiaceae, Asteraceae and Solanaceae having three species each (Appendix 1). Both the total species richness and diversity followed a decline along differences in land use. The number of species per sites was lower on agricultural and plantation sites ($p<0.001$, one-way ANOVA, Table 3). Similarly, forest site had a significant ($p<0.001$) greater Shannon diversity indices than both plantation and agricultural sites.

Table 3. Comparison of species richness and diversity indices between three land use types values across the rows with the same letter code are not significantly different (The Tukey's post hoc test; p <0.05).

Indices	Forest	Plantation	Agriculture
Species richness	15.8±2.77[a]	5.25±2.62[b]	4.33±3.64[b]
Simpson's index	0.93±0.01[a]	0.75±0.11[a]	0.61±0.27[b]
Shannon index	2.74±0.19[a]	1.56±0.53[b]	1.18±0.79[b]

Forward stepwise multiple regressions revealed that land use and altitudes explained 55% and 69% of variation in species richness with the best predictor standardized partial regression coefficients b'=0.501 and 0.477 respectively (P<0.001) (Fig 3). No other variables tested (stream order and buffer width) was significant at p > 0.001.

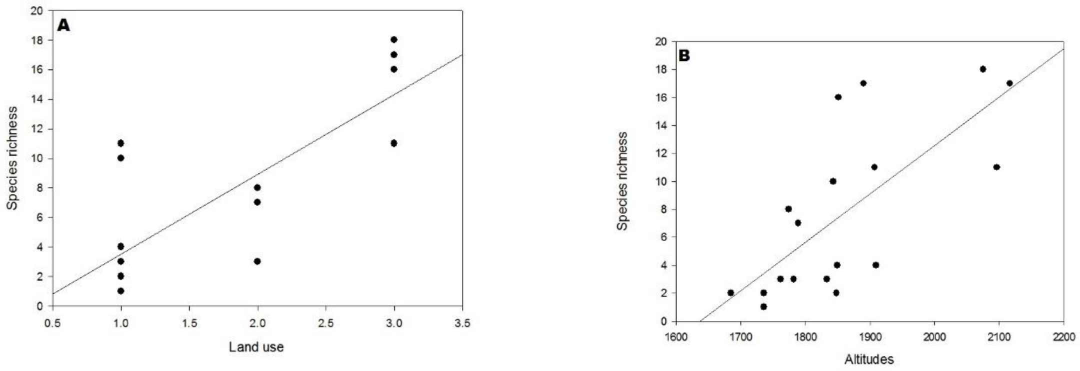

Fig. 3. Regression (a) between species richness and land use (b) between species richness and altitudes. Each point represents the corresponding values of species richness along land use and altitudes (p<0.001).

Meanwhile, the species-environment correlation was very high (> 84%) for the first two PCA axes (Fig. 4). This suggests that the measured environmental variables were strongly correlated with riparian land use. There were strong relationships between the buffer width, DO, and the abundance of *Vernonia auriculifera*, *Senna petersiana*, *Croton macrostachyus and Coffee arabica*. Alternatively, high TSS, turbidity, nitrate and phosphate corresponded to agricultural areas with dominant plant species of *Senna didymobotrya*, *Phytolacca dodecandra*, *Lagenaria abyssinica*, and *Salix mucronata*.

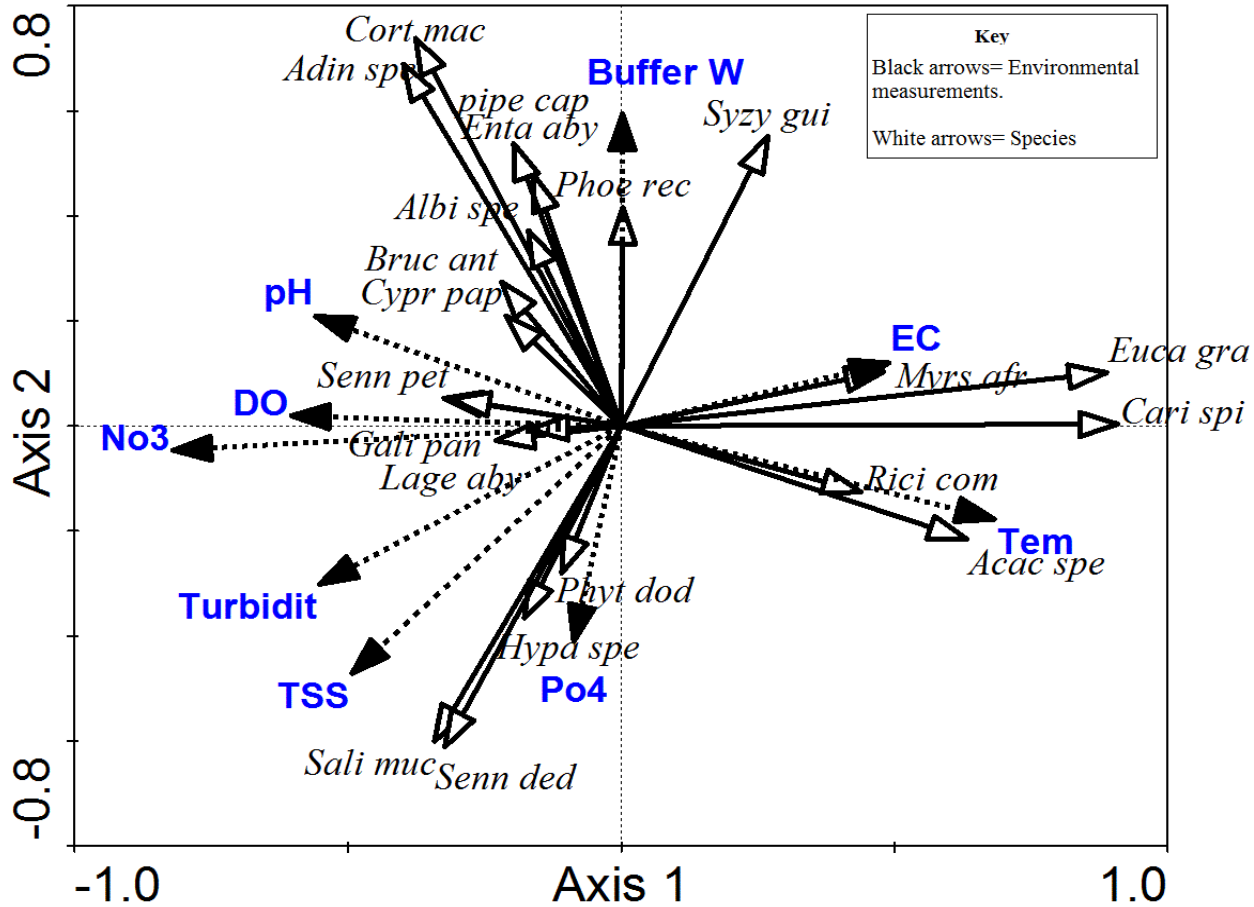

Fig. 4. Ordination diagram for the PCA of riparian plant species of the upper Gilgel Gibe river, southwestern Ethiopia.

Indicator species

Ecological indicators are primarily used either to assess the condition of the environment (e.g., as an early warning system) or to diagnose the cause of environmental change. In this study, an indicator species analysis (ISA) was used to identify which plant species strongly correlate, and thus potentially indicate different in stream water quality. The ISA identified eleven plant species as indicators (*Adiantum* spp, *Brugmansia suaveolens, Croton macrostachyus, Cyperus papyrus, Ficus sur, Maesa lanceolata, Maytenus arbutifolia, Millettia ferruginea, Rytigynia neglecta, Senna petersiana,* and *Vernonia auriculifera* (Table 4).

Table 4. Monte Carlo permutation test of significance for the observed maximum indicator value (IV) for of each species, based on 1000 randomizations. All indicator species were significant ($p<0.05$).

Plant species	Code	Indicator value (IV)	P
Adiantum species	Adispe	56.4	0.0460
Vernonia auriculifera	Veraur	61.6	0.0240
Senna petersiana	Senpet	62.1	0.0390
Croton macrostachyus	Cromac	77.6	0.0210
Brugmansia suaveolens	Brusua	66.7	0.0140
Ficus sur	Ficsur	66.7	0.0140
Rytigynia neglecta	Rytneg	66.7	0.0140
Maesa lanceolata	Maelan	66.7	0.0200
Cyperus papyrus	Cyppap	66.7	0.0200
Maytenus arbutifolia	Mayarb	66.7	0.0200
Millettia ferruginea	Milfer	66.7	0.0200

Discussion

Riparian area disturbance can affect the surface water quality and channel morphology and the biological properties of streams. The water quality of the assessed streams shows a pattern that is linked to riparian land use change associated with agriculture. For example, the agricultural sites generally had the highest turbidity, TSS and orthophosphate values, while the forest sites generally exhibited low turbidity, TSS and orthophosphate values. The mean turbidity at agricultural site was two times higher than the mean value at forested site despite comparable elevations at the two sites. The high turbidity, TSS, and orthophosphate in the agricultural sites are most likely due to the high load of suspended materials in increased runoff from agricultural fields on the steep-sided slopes and riverbank erosion. An increase in TSS, and turbidity as a result of human impacts has been reported in other studies (Busulwa and Bailey 2004; Melaku et al. 2007; Monteiro et al. 2016). Similarly, buffer width was generally wider at forested sites, and this finding was consistent with (Méndez-Toribio and Ibarra-Manríquez 2014) and (Wasser et al. 2015), who reported wider buffer width in forest streams than agricultural streams of Mexico and USA, respectively. The narrow buffer width in agricultural sites could be a result of deforestation and land modification (Scott et al. 2009; Meek et al. 2010). The observations of water quality variation in the studied streams suggest that riparian vegetation plays a role in the partial sequestering of ions and pollutants from adjacent agricultural fields. Meanwhile, the riparian plant composition data revealed a large number of families that were represented by a few species each, which indirectly reflects then environmental heterogeneity of the catchment. It is well -documented that the species diversity of natural communities is often strongly related to land use (Townsend et al. 2004). This study also provides indications that anthropogenic pressures may be responsible for the observed vegetation diversity, and this pattern may be apparent at broad scales. For example, forest streams with limited human impact are characterized by high species richness and the presence of several forest species. In contrast, the most degraded agricultural streams were characterized by lowest species richness. We observed a significant difference both in species diversity and species richness between forest and agricultural sites. The decrease in species diversity along agricultural sites could be attributed to the increase in anthropogenic activity (Méndez-Toribio and Ibarra-Manríquez 2014). Furthermore, the multivariate analysis indicated the clustering of plant species based on land use categories and identified clearly distinct plant compositions according to riparian land use. It also revealed that changes in riparian vegetation and composition mirrored changes in water quality. For example, *Salix subserrata* and *Senna didymobotrya* were the best indicators of agriculturally impacted sites with poor water quality, whereas plant species such as *Adiantum spp, Albizia gummifera and Croton macrostachyus* were indicators of moderate water quality.

Because streams and rivers accumulate and absorb the impacts of terrestrial degradation over large spatial scales (Meek et al., 2010), there is growing interest in exploring the predictive value of biological indicators in detecting the long and short-term impacts of land use. Vascular plants are known to be sensitive to habitat characteristics and to respond rapidly to changes in the riparian habitat (Miller et al. 2006). For this reason, vascular plants have been used as biological indicators to signify positive changes in water quality (Nichols et al. 2000). Despite the knowledge of their importance, the vast majority of the work on vascular plants as biological indicators has focused on temperate systems. Interestingly, the distribution of indicator species indeed differed among land use categories and showed the intriguing trend of a higher abundance in forest sites. The PCA analysis revealed that plant species such as *Croton macrostachyus, Ficus sur, Maytenus arbutifolia,* and *Millettia ferruginea* were positively correlated with the buffer width and dissolved oxygen. Moreover, these plant species were among riparian plant having significant higher indicator values. Previous research has also reported that these plant species are streamside plants, which indicates that they inhabit relatively protected areas (Sisay and Mekonnen 2013),whereas (German et al. 2010; Haregeweyn et al. 2012) reported that plants such as *Ficus* species are important woody plant species in catchment management.

Therefore, with respect to their distribution and indigenous nature, the previously mentioned plant species were the best biological indicators of relatively healthy streams. Thus, it may be possible to use them as biological indicators for monitoring riparian habitat health and stream water quality.

Conclusion

The result of the study highlights that indigenous plant species such as *Croton macrostachyus, Ficus sur, Maytenus arbutifolia, Maesa lanceolate,* and *Millettia ferruginea* were inhabited relatively less disturbed streamside and they are good indicator of water quality. The distributions of these species were differed among land use categories and showed the intriguing trend of a higher abundance in forest sites. Alternatively, plant species such as *Salix mucronata* and *Senna didymobotrya* were the common riparian plants at the agricultural sites. Therefore, it can be concluded from response of ingenious plant species to surrounding land use and specific stream degradation that it may be a useful to apply these riparian plant species for detecting impact of anthropogenic activities along tropical highland streams and rivers. Even though, our study is the first assessment of the role of indigenous plant species as indicator of highland stream water quality in the tropical area. The study contributes to the on-going discussion on the assessment and monitoring of stream ecosystems and for following stream restoration projects in tropical highland regions around the globe.

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Appendix 1
Lists of plant species identified in the study sites

Code	**Scientific name**	**Family**
Aca pol	*Acanthus polystachius* Delile	Acanthaceae
Aca sp	Acacia species	Fabaceae
Adi sp	Adiantum species	Adiantaceae
Alb gum	Albizia gummifera (J.F Gmel.) CA.Sm.	Fabaceae
Ber aby	*Bersama abyssinica* Fresen subsp. *abyssinica*	Melianthaceae
Bru ant	*Brucea antidysenterica* J.F. Mill	Simaroubaceae
Bru sua	*Brugmansia suaveolens* (Humb. & Bonpl. ex Willd.) Bercht. & Presl	Solanaceae
Cal aur	*Calpurnia aurea* (Ait.) Benth	Fabaceae
Car edu	*Carissa edulis* (Forssk.) Vahl	Apocynaceae
Cas mal	*Cassipourea malosana* (Baker) Alston	Rhizophoraceae
Cla ani	*Clausena anisata* (Willd.) Hook.f. ex Benth.	Rutaceae
Cle myr	*Clerodendrum myricoides* (Hochst.) Steane & Mabb.	Lamiaceae
Clu aby	*Clutia abyssinica* Jaub. & Spach	Euphorbiaceae
Coe afr	*Cordia africana* Lam	Boraginaceae
Cof ara	*Coffea arabica* L	Rubiaceae
Com pan	*Combretum paniculatum* Vent.	Combretaceae
Cro mac	*Croton macrostachyus* Hochst. Ex Delile	Euphorbiaceae
Cyp pap	*Cyperus papyrus* L	Cyperaceae
Cyp spp	Cyperus spp	Cyperaceae
Dal lac	*Dalbergia lactea* Vatke	Fabaceae
Dat str	*Datura stramonium* L.	Solanaceae
Eer cym	*Ehretia cymosa* Thonn	Boraginaceae
Eke cap	*Ekebergia capensis* Sparrm.	Meliaceae
Ent aby	*Entada abyssinica A. Rich*	Fabaceae
Ery tri	*Erythrococca trichogyne* (Muell. Arg.) Prain	Euphorbiaceae
Euc gra	*Eucalyptus grandis* W.Hill	Myrtaceae
Euc rac	*Euclea racemosa L.*	Ebenaceae
Fic sur	*Ficus sur* Forssk	Moraceae
Fic tho	*Ficus thonningii* Blume	Moraceae
Fic vas	*Ficus vasta* Forssk.	Moraceae

Gal par	*Galinsogo parviflora* Cav	Asteraceae
Gal sax	*Galiniera saxifraga* (Hochst.) Bridson	Rubiaceae
Hib ber	*Hibiscus berberidifolius A.Rich.*	Malvaceae
Hib mac	*Hibiscus macranthus Hochst. exA. Rich*	Malvaceae
Hyp cym	*Hyparrhenia cymbaria* (L.) Stapf	Poaceae
Ind spp	Indigofera sp.	Fabaceae
Lab pur	*Lablab purpureus* (L.) Sweet	Fabaceae
Lag aby	*Lagenaria abyssinica* (Hook.f.) C.Jeffrey	Cucurbitaceae
Lip ado	*Lippia adoensis* Hochst.	Verbenaceae
Lud aby	*Ludwigia abyssinica* A. Rich.	Onagraceae
Mae lan	*Maesa lanceolata* Forssk	Myrsinaceae
Man but	*Manilkara butugi* Chiov.	Sapotaceae
May arb	Maytenus arbutifolia (A. Rich.) Wilczek	Celastraceae
Mil fer	*Millettia ferruginea* (Hochst.) Bak	Fabaceae
Mim kum	*Mimusops kummel Bruce ex* A.DC.	Sapotaceae
Myr afr	*Myrsine africana L.*	Myrsinaceae
Oci lam	*Ocimum lamiifolium* Hochst. Ex Benth	Lamiaceae
Ole wel	*Olea welwitschii* (Knobl.) Gilg & Schellenb.	Oleaceae
Onc spi	*Oncoba spinosa* Forssk.	Flacourtiaceae
Pho rec	*Phoenix reclinata* Jacq.	Arecaceae
Phy dod	*Phytolacca dodecandra* **L**'Her.	Phytolaccaceae
Pip cap	*Piper capense* Lf.	Piperaceae
Pit vir	*Pittosporum viridiflorum* Sims	Pittosporaceae
Ple pun	*Plectranthus punctatus* (L.f.) L'Her	Lamiaceae
Pod fal	*Podocarpus falcatus* (Thunb.) R.Br. ex Mirb.	Podocarpaceae
Pyc aby	*Pycnostachys abyssinica* Fresen	Lamiaceae
Pyc emi	Pycnostachys eminii Gürke	Lamiaceae
Rha pri	*Rhamnus prinoides* L'Hér.	Rhamnaceae
Ric com	*Ricinus communis* L.	Euphorbiaceae
Rub spp	*Rubus spp*	Rouceae
Ryt neg	*Rytigynia neglecta* (Hiern) Robyns	Rubiaceae
Sal muc	*Salix mucronata Thunb.*	Salicaceae
Sap ell	*Shirakiopsis ellipticum* (Hochst.) Esser	Euphorbiaceae

Sen did	*Senna didymobotrya* (Fresen.) H.S. Irwin& Bameby	Fabaceae
Sen pet	*Senna petersiana* (Bolle) Lock	Fabaceae
Ses ses	*Sesbania sesban* (L.) Merr	Fabaceae
Sol ang	*Solanum anguivi* Lam.	Solanaceae
Suz gui	*Syzygium guineense* (Willd.) DC	Myrtaceae
Tec nob	*Teclea nobilis* Del.	Rutaceae
Tri dre	*Trichilia dregeana Sond.*	Meliaceae
Ver amy	*Vernonia amygdalina* Dellile	Asteraceae
Ver aur	*Vernonia auriculifera* Hiern	Asteraceae