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Table of Contents: Volume 7 Number 7 July, 2015

ARTICLES

Research Articles

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International Journal of Biodiversity and Conservation

Full Length Research Paper

A preliminary study on fish fauna of the Passur River in Bangladesh

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The ichthyofauna, their occurrence and conservation status in the Passur River of Khulna district have been studied for a period, from November 2011 to April 2012. A total of 95 finfish species contributing to 14 orders, 45 families and 77 genera were identified. The most dominant fish order was Perciformes with 38 species in 35 genera. Maximum number of species were recorded under the family Gobiidae (14 species) followed by the family Cyprinidae (8 species). Out of 95 species, 14 belonged to the threatened and 3 to the near threatened. The occurrence of majority of the fishes (50%) was recorded as available followed by less available (26%), rare (16%) and very rare (8%). Considering all the findings it is concluded that the Passur River can be considered as a refuge for conservation of threatened freshwater fishes of Bangladesh. Finally, the establishment of fish sanctuaries for both threatened and non-threatened species as well as counter survey is recommended to cross check the fish diversity for their proper management and conservation.

Key words: Fish biodiversity, perciformes, vulnerable, occurrence, conservation.

INTRODUCTION

Bangladesh is a riverine country and home of at least 265 freshwater fish species (Rahman, 2005). Bangladesh is the third biggest country in aquatic fish biodiversity in Asia, after China and India, with about 800 species in fresh, brackish and marine waters (Hussain and Mazid, 2001). The Passur River is one of the major rivers in Bangladesh and considered home to a large number of aquatic species and livelihood for many fishermen living on it. This river is an important feeding and breeding ground for many riverine fishes of the country.

At present time, reduction in the abundance of fish species from the inland waters of Bangladesh is a burning issue in the country (Galib et al., 2009; Imteazzaman and Galib, 2013). Even so, a total of 54 fish species of Bangladesh have been declared threatened by IUCN (IUCN, 2000) and most of the wild populations have seriously declined in rivers and streams of Bangladesh due to overexploitation augmented by various ecological changes and degradation of the natural habitats (Galib et al., 2009, 2013).

Though a very few research works have been conducted on fish fauna in different water bodies of Bangladesh (Galib et al., 2009; Galib et al., 2013; Imteazzaman and Galib, 2013; Mohsin et al., 2013; Saha

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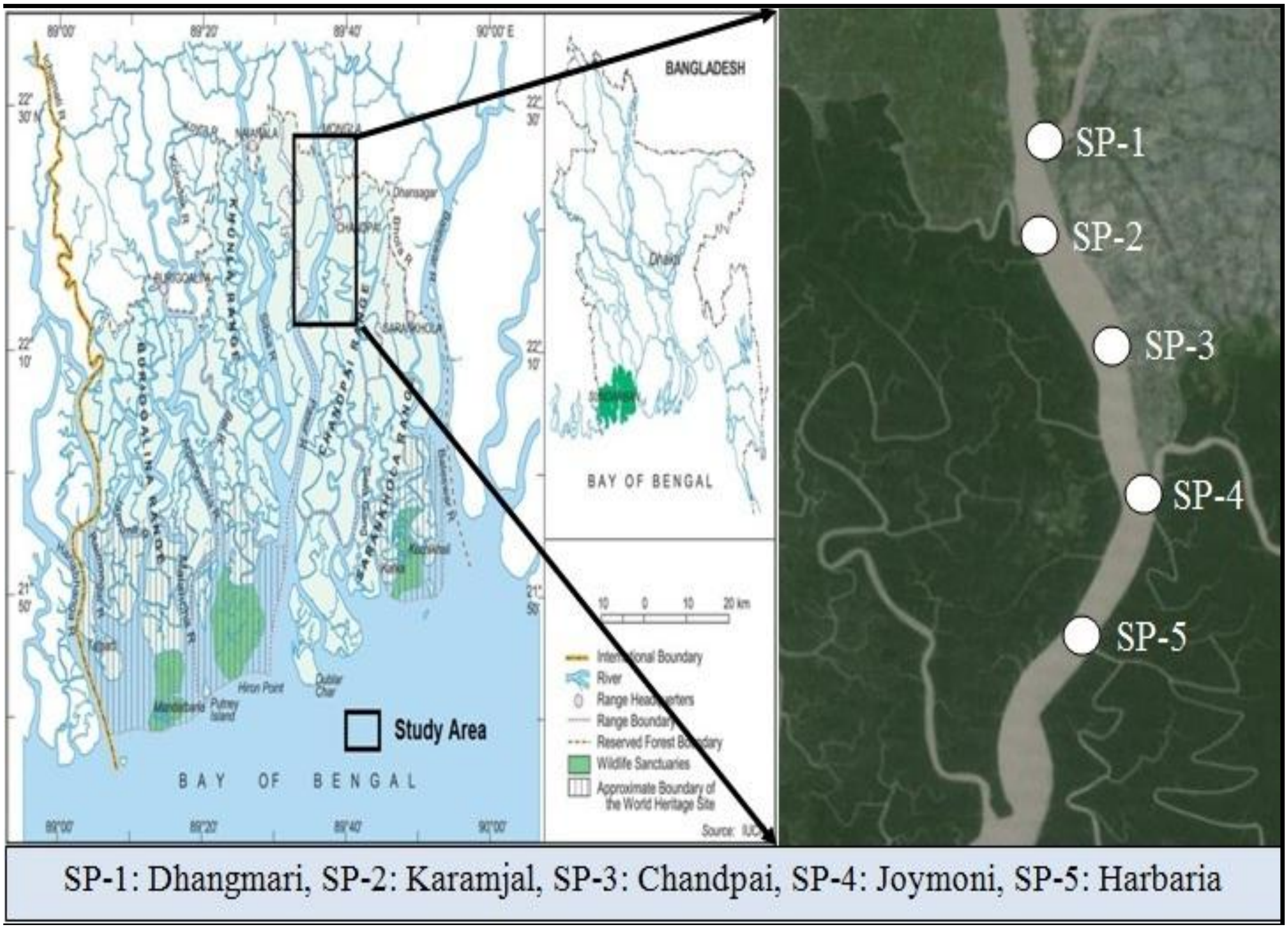

Figure 1. Map showing the study area and sampling points in the Passur River, Khulna, Bangladesh.

and Hossain, 2002) and no previous research work has been conducted on fish fauna of the Passur River, Khulna. This effort is the first study on fish diversity of this river. Thus the present study was carried out in order to prepare and updated the checklist of fish species focusing on their relative abundance and global and national conservation status. The information from this investigation might serve as a baseline data for carrying out further study on ecology, conservation and sustainability management of fisheries resources of this water body.

MATERIALS AND METHODS

Study area

The present study was conducted over a period of six months from November 2011 to April 2012 in the Passur River which is in the middle part of the Sundarbans, Bangladesh. Five sampling points, namely, Dhangmari (22º75.448´N; 89º24.168´E), Karamjal (22º25.550´N; 89º35.579´E), Chandpai (22º49.518´N; 89º64.299´E), Joymoni (22º21.038´N; 89º37.800´E) and Harbaria (22º18.000´N; 89º36.536´E) were selected at the middle of the river and at river-canal meeting points (Figure 1).

Sampling

The fish samples were periodically collected from the local fishermen and also from fish landing centers and fish markets. The specimens were collected fortnightly during daytime from the nearby fishermen and identified directly at the five selected points during the study period (Figure 1). Samples were preserved in 10% formalin to save from spoilage (Simon and Mazlan, 2010). The specimens were identified to the species level according to Talwar and Jhingran (1991) and Rahman (2005).

Occurrences of fish

The abundance of fishes was measured on the basis of interview and catch records of 100 fishermen that is, Available (61-100% of the total catch); Less Available (31-60% of the total catch); Rare (15-30% of the total catch); and Very Rare (1-14% of the total catch).

Global and local conservation status

Global conservation status and population trend were detected following IUCN (2014); whereas following IUCN (2000), conservation status of recorded fish in Bangladesh was noted.

RESULTS AND DISCUSSION

Fish diversity

A total of 95 fish species belonging to 77 genera, 45 families and 14 orders were recorded at the Passur River during the study period (Table 1 and Figure 2). Perciformes were the most leading fish order constituting 40% of the total of fishes sampled, followed by Siluriformes (17%), Clupeiformes (12%), Cypriniformes (9%), Pleuronectiformes (8%), Beloniformes and Mugiliformes (3%), Tetraodontiformes (2%) and 1% to Anguilliformes, Aulopiformes, Batrachoidiformes, Cyprinodontiformes, Scorpaeniformes and Synbranchiformes each (Figure 2). Fish orders, families, species, their abundance and local and global conservation status are presented in Table 1.

There is no previous study on fish fauna of the Passur River therefore it is not possible to compare the present findings with previous one. However, this problem is not rare in other part of Bangladesh and has been already reported by Galib et al. (2013) and Mohsin et al. (2013) who carried out researches on fish fauna in the Choto Jamuna River and the Padma River, respectively. The recorded fish species were lower than some other rivers of Bangladesh (Islam and Hossain, 1983; Hossain et al., 2007) but presence of similar number of fish species was also reported in the Halda River (Azadi and Alam, 2013). However, all the above mentioned researchers concluded with gradual loss of biodiversity in their considered rivers due to both natural and man-made causes. In that sense, it is also true for the river Passur. But, the environmental parameter of the Passur River is completely different compare to other rivers for example, Padma. The Passur River flows inside the largest mangrove forest and the water quality parameters such as salinity, temperature, dissolve oxygen (DO), biological oxygen demand (BOD), turbidity, nutrient dynamics (Rahman et al., 2013a, b; 2014) fully differs with the others for example, Padma River. Salinity fluctuation of the river water is an important environmental parameter and act as a limiting factor which influences the distribution of natural food web (Sridhar et al., 2006). However, in brackish water river especially in estuarine or coastal river water, the environmental conditions are highly dynamic and variable in nature which is an indicator of the availability of fish species in a certain ecological niche (Rahman et al., 2013 a, b).

There are great differences in numbers of species in different orders. For example, in the five major orders (Table 1, Figure 2), there are 38 species belonging to the Perciformes, while merely 11 species belong to the Clupeiformes, the differences being over 2 times. The difference is even greater for the Cypriniformes and Pleuronectiformes. The order Perciformes was found to be the most diversified fish group in terms of both number of species and individuals followed by Siluriformes. Similar finding was reported by Mohsin et al. (2014) in the Andharmanik River in Patuakhali, Bangladesh. This is because these two groups are the most dominant groups in freshwater bodies of Bangladesh (Rahman 2005). Again, some orders have very few species, for example, Mugiliformes, Beloniformes, Tetraodontiformes etc (Table 1).

Conservation status

A total of 54 species of Bangladesh were declared threatened in the red book of threatened fishes, published by IUCN Bangladesh (2000). According to this Redlist data, 3 critically endangered, 4 endangered and 7 vulnerable fish species were present in Passur River, representing 3, 4 and 8% of the total species recorded, respectively (Figure 3). The number of threatened fish species found in the present study was similar to the findings of Mohsin et al. (2009) and 2014 who recorded 9 threatened species in the Bookbhara *Baor* of Jessore district, Bangladesh and 10 threatened species in the Andharmanik River of Patuakhali district, Bangladesh. A greater number of threatened fishes were recorded in some other water bodies, for example, 28 species in the Chalan *Beel* (Galib et al. 2009), 26 species in the Padma River (Mohsin et al., 2013) and 22 species in the Halti *Beel* (Imteazzaman and Galib, 2013).

There are 41 species (43%) been considered as not threatened (IUCN, 2000) (Figure 3). The status of 42% (40 species) of the fish species recorded in this study was not mentioned in the Redlist of fishes of Bangladesh by IUCN (2000). Among them, some species are commonly found in many water bodies of the country (for example, Gagata sp.) (Mohsin et al., 2013; Chaki et al., 2013). Global conservation status of the fish species are shown in Figure 4. The majority fish species were belonging to least concern and not evaluated categories (43%) followed by near threatened (3%) and data deficient (11%) categories.

Occurrences of fish species

Of the total 95 species, relative abundance of the majority of the fish species (50%) was recorded as available followed by less available (26%), rare (16%) and very rare (8%) (Figure 5). The occurrence of the fish species reflects the current scenario of fish species in open water bodies of Bangladesh. Numerous causes like overfishing, fishing by illegal gears, and indiscriminate fishing of fry to

Table 1. Fish diversity in the Passur River, Khulna, Bangladesh.

Order (No. of species)	Family (No. of species)	Scientific name	Conservation Status		Occurrence***
			Bangladesh*	Global**	
Anguilliformes (1)	Ophichthidae (1)	*Pisodonophis boro* (Hamilton, 1822)	NO	LC	VR
Aulopiformes (1)	Synodontidae (1)	*Harpadon nehereus* (Hamilton, 1822)	NO	NE	VR
Batrachoidiformes (1)	Batrachoididae (1)	*Allenbatrachus grunniens* (Linnaeus, 1758)	NO	NE	LA
Beloniformes (3)	Zenarchopteridae (1)	*Dermogenys brachynotopterus* (Bleeker, 1853)	DD	DD	A
	Adrianichthyidae (1)	*Oryzias melastigma* (McClelland, 1839)	DD	LC	LA
	Hemiramphidae (1)	*Hyporhamphus limbatus* (Valenciennes, 1847)	DD	LC	A
Clupeiformes (11)	Clupeidae (4)	*Anodontostoma chacunda* (Hamilton, 1822)	DD	NE	LA
		Corica soborna (Hamilton, 1822)	NO	LC	A
		Gonialosa manminna (Hamilton, 1822)	NO	LC	A
		Gudusia chapra (Hamilton, 1822)	NO	LC	A
	Engraulidae (3)	*Coilia dussumieri* (Valenciennes, 1848)	NO	NE	A
		Coilia ramcarati (Hamilton, 1822)	NO	NE	A
		Coilia reynaldi (Valenciennes, 1848)	NO	NE	A
	Pristigasteridae (2)	*Ilisha megaloptera* (Swainson, 1839)	DD	NE	A
		Pellona ditchela (Valenciennes, 1847)	DD	NE	A
	Engraulidae (2)	*Setipinna phasa* (Hamilton, 1822)	NO	LC	A
		Setipinna taty (Valenciennes, 1848)	NO	NE	A
Cypriniformes (8)	Cyprinidae (8)	*Aspedoporia morar* (Hamilton, 1822)	DD	NE	A
		Megarasbora elanga (Hamilton, 1822)	EN	LC	LA
		Chela cachius (Hamilton, 1822)	DD	LC	A
		Labeo calbasu (Hamilton, 1822)	EN	LC	R
		Labeo rohita (Hamilton, 1822)	NO	LC	A
		Rasbora rasbora (Hamilton, 1822)	EN	LC	LA
		Salmostoma phulo (Hamilton, 1822)	NO	LC	A
		Puntius guganio (Hamilton, 1822)	DD	LC	A
Cyprinodontiformes (1)	Aplocheilidae (1)	*Aplocheilus panchax* (Hamilton, 1822)	NO	LC	LA
Mugiliformes (3)	Mugilidae (3)	*Rhinomugil corsula* (Hamilton, 1822)	NO	LC	A
		Liza subviridis (Valenciennes, 1836)	DD	NE	A
		Liza parsia (Hamilton, 1822)	NO	LC	A
Perciformes (38)	Eleotridae (1)	*Eleotris lutea* (Day, 1876)	DD	NE	LA
	Polynemidae (1)	*Elutheronema tetradactylum* (Shaw, 1804)	NO	NE	A

Table 1. Contd.

	Scombridae (1)	*Euthynnus affinis* (Cantor, 1849)	DD	LC	R
	Leiognathidae (1)	*Gazza minuta* (Bloch, 1795)	DD	LC	A
	Gobiidae (14)	*Glossogobius giuris* (Hamilton, 1822)	NO	LC	A
		Gobiopsis macrostoma (Steindachner, 1861)	DD	NE	R
		Odontamblyopus rubicundus (Hamilton, 1822)	NO	NE	A
		Parapocryptes batoides (Day, 1876)	NO	NE	A
		Periophthalmus koelreuteri (Pallas, 1770)	DD	LC	A
		Pseudapocryptes elongatus (Cuvier, 1816)	DD	LC	LA
		Stigmatogobius sadanundio (Hamilton, 1822)	DD	NE	VR
		Acentrogobius viripunctatus (Valenciennes, 1837)	DD	DD	R
		Trypauchen vagina (Bloch & Schneider, 1801)	DD	NE	A
		Taenioides cirratus (Blyth, 1860)	DD	DD	A
		Brachygobius nunus (Hamilton, 1822)	NO	NE	A
		Awaous guamensis (Valenciennes, 1837)	DD	LC	A
		Boleophthalmus boddarti (Pallas, 1770)	DD	LC	A
		Apocryptes bato (Hamilton, 1822)	DD	NE	A
	Sciaenidae (4)	*Johnius coitor* (Hamilton, 1822)	NO	LC	A
		Macrospinosa cuja (Hamilton, 1822)	NO	NE	LA
		Otolithoides pama (Hamilton, 1822)	NO	NE	A
		Pennahia anea (Bloch, 1793)	DD	NE	LA
	Latidae (1)	*Lates calcarifer* (Bloch, 1790)	NO	NE	A
	Leiognathidae (1)	*Leiognathus decorus* (De Vis, 1884)	DD	NE	LA
	Polynemidae (1)	*Polynemus paradiseus* (Linnaeus, 1758)	NO	NE	A
	Ambassidae (3)	*Pseudambassis baculis* (Hamilton, 1822)	DD	LC	A
		Pseudambassis lala (Hamilton, 1822)	DD	DD	LA
		Pseudambassis ranga (Hamilton, 1822)	VU	LC	A
	Nandidae (2)	*Nandus nandus* (Hamilton, 1822)	VU	LC	A
		Coius quadrifasciatus (Sevastianof, 1809)	DD	DD	LA
	Sparidae (1)	*Acanthopagrus latus* (Houttuyn, 1782)	NO	NE	LA
	Carangidae (1)	*Trachinotus blochii* (Lacepède, 1801)	DD	NE	LA
	Toxotidae (1)	*Toxotes chatareus* (Hamilton, 1822)	DD	NE	R
	Sillaginidae (1)	*Sillaginopsis panijus* (Hamilton, 1822)	NO	NE	LA
	Eleotridae (1)	*Butis melanostigma (Bleeker, 1849)*	DD	NE	LA
	Channidae (2)	*Channa striatas* (Bloch, 1793)	NO	LC	A

Table 1. Contd.

		Channa punctatus (Bloch, 1793)	NO	LC	A
	Ariommatidae (1)	*Ariomma indicum* (Day, 1871)	DD	NE	R
Pleuronectiformes (8)	Cynoglossidae (7)	*Cynoglossus arel* (Bloch & Schneider, 1801)	DD	NE	A
		Cynoglossus bilineatus (Lacepède, 1802)	DD	NE	A
		Cynoglossus cynoglossus (Hamilton, 1822)	NO	NE	A
		Cynoglossus lingua (Hamilton, 1822)	DD	NE	A
		Cynoglossus puncticeps (Richardson, 1846)	DD	NE	LA
		Cynoglossus versicolor (Alcock, 1890)	DD	DD	A
		Paraplagusia bilineata (Bloch, 1787)	DD	NE	LA
	Soleidae (1)	*Brachirus orientalis* (Bloch & Schneider, 1801)	NO	NE	R
Scorpaeniformes (1)	Platycephalidae (1)	*Platycephalus indicus* (Linnaeus, 1758)	NO	DD	LA
Siluriformes (16)	Siluridae (1)	*Wallago attu* (Bloch & Schneider, 1801)	NO	NT	VR
	Bagridae (2)	*Sperata aor* (Hamilton, 1822)	VU	LC	VR
		Mystusaor (Hamilton, 1822)	VU	DD	VR
	Pangasiidae (1)	*Pangasius pangasius* (Hamilton, 1822)	CR	LC	VR
	Ariidae (3)	*Arius arius* (Hamilton, 1822)	NO	DD	LA
		Arius gagora (Hamilton, 1822)	NO	NT	LA
		Arius maculatus (Hamilton, 1822)	NO	DD	LA
	Schilbeidae (4)	*Ailia coilia* (Hamilton, 1822)	NO	NT	LA
		*Clupisoma garua (*Hamilton, 1822)	CR	LC	R
		Eutropiichthys murius (Hamilton, 1822)	NO	LC	R
		Eutropiichthys vacha (Hamilton, 1822)	CR	LC	R
	Sisoridae (1)	*Gagata gagata* (Hamilton, 1822)	NO	LC	R
	Chacidae (1)	*Chaca chaca* (Hamilton, 1822)	EN	LC	R
	Bagridae (2)	*Mystus gulio* (Hamilton, 1822)	DD	LC	A
		Mystus cavasius (Hamilton, 1822)	VU	LC	LA
	Plotosidae (1)	*Plotosus canius* (Hamilton, 1822)	VU	NE	VR
Synbranchiformes (1)	Synbranchidae (1)	*Monopterus cuchia* (Hamilton, 1822)	VU	LC	VR
Tetraodontiformes (2)	Tetraodontidae (2)	*Tetraodon cutcutia* (Hamilton, 1822)	NO	LC	R
		Chelonodon patoca (Hamilton, 1822)	DD	NE	R

*as per IUCN Bangladesh (2000), **as per IUCN (2014), *** occurrences of fish fauna (IUCN, 2014). Conservation status: CR, Critically Endangered; DD, Data Deficient; EN, Endangered; LC, Least Concern; NE, Not Evaluated; NO, Not Threatened; NT, Near Threatened; VU, Vulnerable. Relative abundance: A, Available; LA, Less available; R, Rare; VR, Very rare.

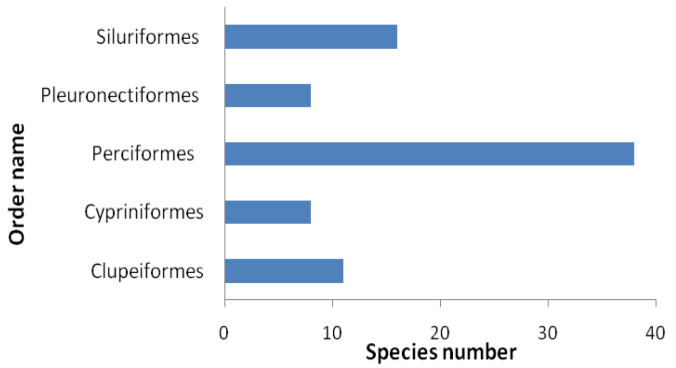

Figure 2. Species number of the dominant fish orders in the Passur River, Bangladesh.

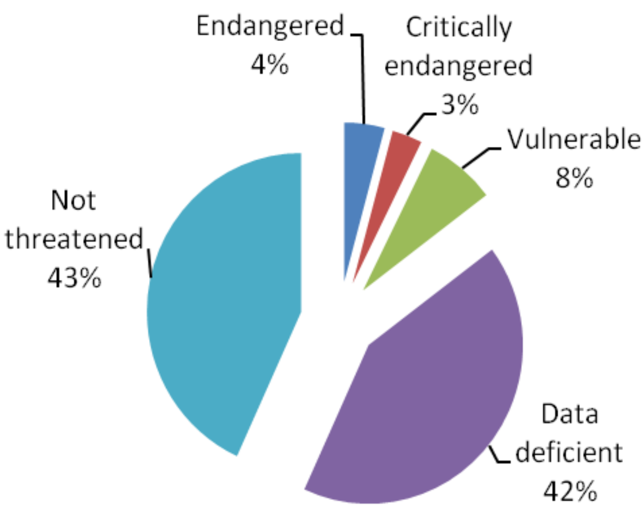

Figure 3. Conservation status of the fish species recorded in the Passur River, Bangladesh.

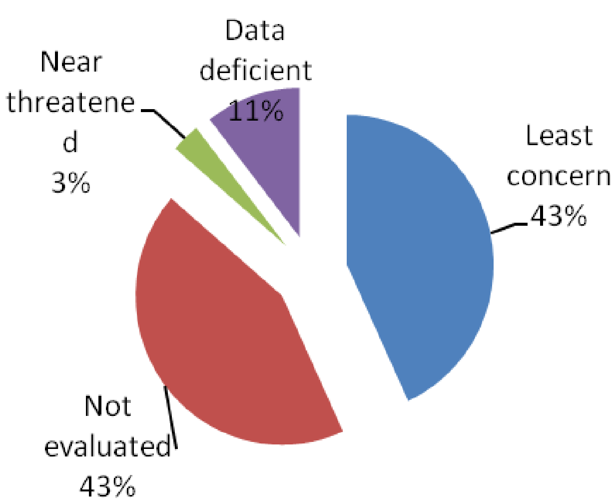

Figure 4. Global conservation status of fish species from the Passur River, Bangladesh.

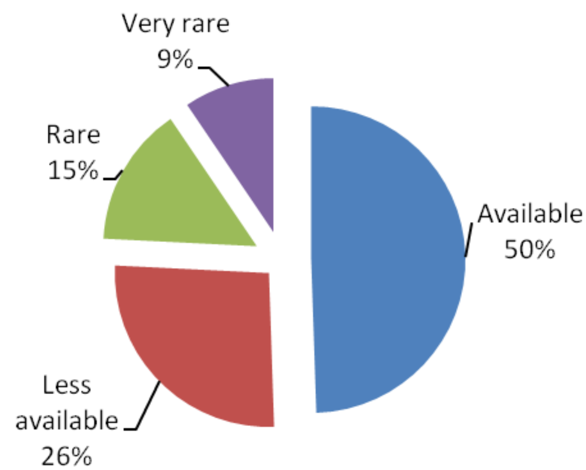

Figure 5. Occurrences of fish species in the Passur River, Bangladesh.

brood fish have led abundance of indigenous fish population lead to stake that results the threatened condition.

Conflict of interest

Authors did not declare any conflict of interest.

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Threat of agricultural production on woody plant diversity in Tankwidi riparian buffer in the Sudanian Savanna of Ghana

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Riparian forest buffers (RF) are integrative part of the savanna agricultural landscape. However, they are under threat of deforestation from agricultural intensification. To ascertain the impact of the deforestation, this study used remote sensing techniques and field inventorying to assess riparian woody plant diversity on farmland (FA) and forest reserve (FR) along Tankwidi rivercourse in the Sudanian savanna of Ghana. Post-classification analysis of Landsat images revealed a reduction in forest cover from 1986 (23%) to 2014 (7%) in the river basin. Ground survey of sixty randomly selected plots (500 m^2 per plot) equally divided between FA and FR along the river in a 50 m buffer zone showed a reduction in the number of woody species (diameter ≥ 5 cm) from FR (40) to FA (19). *Anogeissus leiocarpus* and *Mitragyna inermis* were the most abundant species in both FR and FA. Shannon-Wiener Index for species diversity reduced from FR (2.5±0.09) to FA (1.8±0.14). Within FR, there were more species (58%) in the lower diameter class (5 to 15 cm) than the higher diameter classes (15 to 50 cm) suggesting successful regeneration. The reverse was observed in FA where the individuals in the lower diameter class were fewer (26%) than the higher diameter classes. Reduction in species density from FR (355±21) to FA (146±11) will increase the surface exposure of the riparian area in farmland to heighten risks to climate disasters such as fires and flooding. Managing the risks will not be possible unless a conscious effort is made to educate farmers on the roles of RF, replanted to enhance diversity or riparian buffer excluded from farming for vegetation recovery.

Key words: Riparian buffer, biodiversity, Sudanian savanna, agricultural watershed.

INTRODUCTION

Grassland riparian habitats in savanna or any other wooded grassland-type biomes can be seriously impacted by broadcast effects of climate change, especially due to changing river hydrology and altered animal movement

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Abbreviations: SWI, Shannon-Wiener; **SI,** Simpson; **RF,** riparian forest; **FA,** farmland; **FR,** forest reserve; **TM,** thematic mapper; **ETM+,** enhanced thematic mapper plus; **OLI,** landsat operational land imager; **SR,** species richness.

patterns (Sambare et al., 2011). However, certain outcomes of climate change can be mitigated by maintaining intact riparian landscapes- including retaining soil moisture, regulation of localized fire, and provision of refuge and dispersal corridors for fauna (Goetze et al., 2006; Azihou et al., 2013). Ecologically, riparian forests (RF) are important as they protect farmlands from flooding, drying and sedimentation (Gray et al., 2014). They provide shade and moderate stream temperatures for aquatic life. Their litter production from trees is an important component of the river foodweb. Further, the forest cover reduces erosion and stabilises river banks (Surasinghe and Baldwin, 2015). Riparian forests also serve as habitat for fauna such as birds, insects and other organisms that are essential for crop pollination, seed dispersal and nutrient cycling (McCracken et al., 2012; Gray et al., 2014). Social benefits including oppor-tunities for tourism, medicines, nutrition, firewood, and raw material for different crafts and construction are derived from riparian forests (Ceperley et al., 2010). Culturally, riparian forests are sometimes designated as sacred groove (Ceperley et al., 2010). Due to these functions and many others, some RF are protected by Ramsar convention, other national laws and policies (McCracken et al., 2012; Gray et al., 2014).

Within the water-limiting savanna environment, riparian basins are suitable for agricultural production (Natta et al., 2003; Goetze et al., 2006). As a result, the riparian forests are under threat of deforestation which could change their microclimatic conditions to increase climate change effects on species and associated functions (Callo-Concha et al., 2012). In this savanna region, land areas dedicated to agricultural production are much greater than protected forest reserve areas (Traore et al., 2012; Gray et al., 2014). This means that the agricultural landscapes cannot be excluded from plant diversity conservation (Gray et al., 2014). With appropriate management, agricultural landscapes can contribute to the preservation of plant diversity and delivery of ecosystem services (McCracken et al., 2012; Gray et al., 2014). However, in spite of the knowledge on the threat of agricultural production to riparian forests, our understanding in this area is limited in the tropical savannas of Ghana and West Africa in general (Natta et al., 2003; Ceperley et al., 2010; Sambare et al., 2011).

Studies have shown that the intensification of farming and commercialization of agriculture cause deforestation and reduce the plant diversity on farmlands (Ceperley et al., 2010; Okiror et al., 2012). In other studies, the mosaic nature of heterogeneity of farmlands supports high plant diversity (Fahrig et al., 2011; Traore et al., 2012; Morelli, 2013). This suggests that not all farming practices have negative effects on plant diversity (Gray et al., 2014). To assess the impacts of agricultural production activities on riparian forests in the savanna agricultural landscape of the Tankwidi river, this study compared woody plant diversity in riparian buffer of farmlands and forest reserve of the Tankwidi river basin in the Sudanian savanna of Ghana. Because of agricultural activities, it is hypo-thesized; firstly that riparian buffer in reserve area would have higher woody plant diversity than in farmland. Secondly, it is expected that the tree size distribution of the woody plants would differ between forest reserve and farmlands. It is envisaged that the study will serve as an important baseline for the management of farmland woody plant diversity as well as the enforcement of the freshwater buffer zone policy of Ghana.

MATERIALS AND METHODS

Study area

The study was conducted in farmland (FA) and Tankwidi forest reserve (FR) along the Tankwidi rivercourse in the Sudanian savanna of the Upper East region of Ghana (Figure 1). The climate is influenced by tropical monsoon (Callo-Concha et al., 2012). The area has unimodal type of rainfall with a mean annual rainfall of 800 mm and a mean annual temperature of 36°C. The soils consist of light top soils with variable texture and coarse sandy loams to heavier sub-soils with varying amount of gravel (Callo-Concha et al., 2012; BirdLife, 2014). The topography is flat to gently undulating with maximum elevation of 150 m (BirdLife, 2014). The Tankwidi forest reserve has an area of 19,221 ha. It protects the tributaries of the Tankwidi river. Logging is not allowed in the reserves. Communities fringing the reserve, however, have special use rights in the collection of non-timber forest products. The reserve is a key habitat of migratory birds from Europe (BirdLife, 2014). The farmlands are affected by various anthropogenic activities including extensive livestock grazing, bush fires, and various harvestings of timber and non-timber forest products such as wood, leaves, bark, flowers and fruits (Callo-Concha et al., 2012).

Forest cover dynamics of Tankwidi riparian basin (1986-2014)

Selection of Landsat images for broad landscape assessment

Medium resolution satellite data inputs for multi-temporal studies of forest cover were obtained from the Landsat Thematic Mapper (TM), Landsat Enhanced Thematic Mapper Plus (ETM+), and Landsat Operational Land Imager (OLI). The images (Table 1) were downloaded from the United States Geological Survey National Center for Earth Resources Observation and Science via the GLOVIS data portal (http://glovis.usgs.gov/). Images with no cloud cover and which were available within the time frame in 1986, 2000 and 2014 were downloaded. All the dates of the selected images were within the dry season when the grassy layers have been scorched thereby increasing the detectability of forests. The satellite images had the same flight path (path = 194, row = 53). Universal Transverse Mercator was the projection system of the images WGS 84.

Collection of ground control points

During the fieldwork from September to December, 2013, ground control points and forest canopy density data were collected within the Tankwidi river basin using GPS and spherical densitometer, respectively. The data from this fieldwork was used to classify the 2014 Landsat image into “forest” and “non-forest” areas. Further, ground control points for the classification of the 2000 Landsat image was also collected on the field with the aid of historic

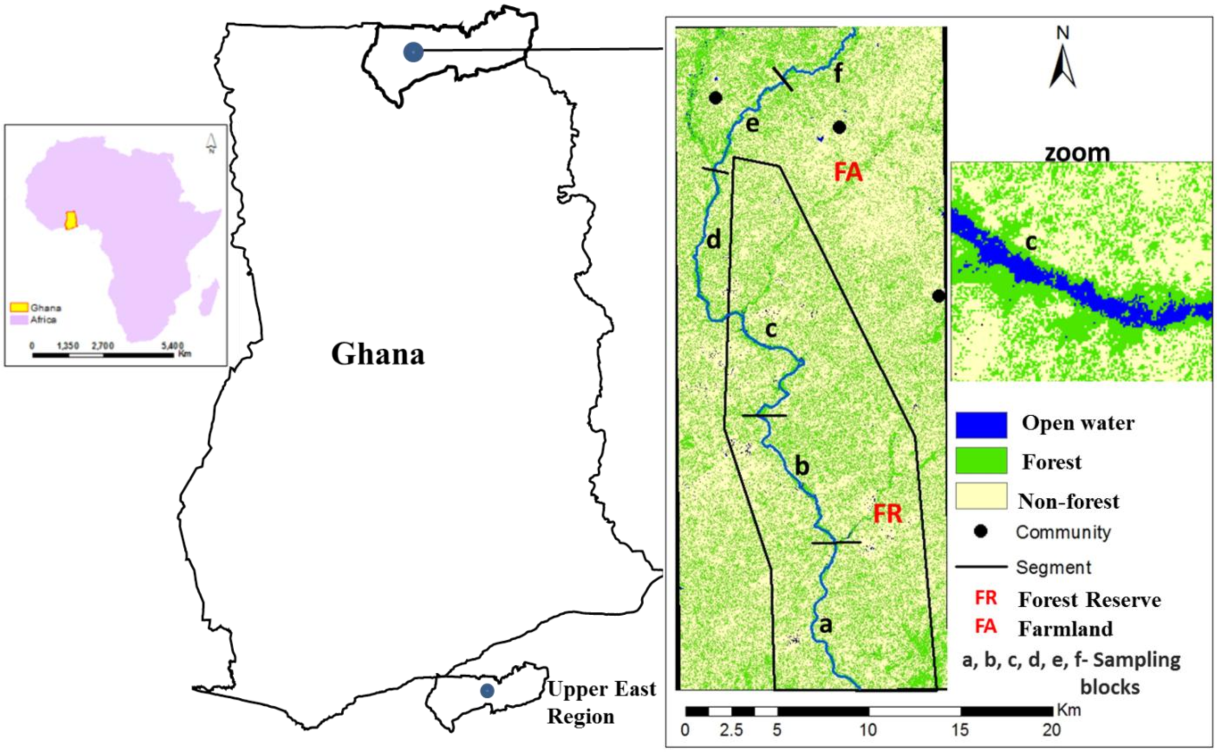

Figure 1. Map of Ghana (Africa) showing the Tankwidi river, forest reserve and farmlands.

Table 1. Attributes of the Landsat TM, ETM+ and OLI imagery used in the study.

Acquisition date	Sensor	Spatial resolution (m)
11/01/1986	TM	30
26/01/2000	ETM+	30
24/01/2014	OLI	30

Landcover map prepared for the study area under the GLOWA-Volta Project (Volta Basin Authority Geoportal, 2000). This was done by first identifying the features on the Landcover map prepared in 2000 and which could still be verified during fieldwork. This entailed identifying stable landcover in the forest reserve, along the Tankwidi river, farms and settlements, which had been in existence since 2000. In the case of the 1986 image, “forest" was selected from stable vegetation along rivers.

Forest classification in Tankwidi river basin (1986-2014)

Supervised classification procedures using ERDAS Imagine 2011 software were implemented to classify the Landsat images of 2000 and 2014 using Maximum Likelihood Classification algorithm. Areas with tree canopy of 20% and greater were located on the image and signature were selected and used as training set for classifying “forest areas”. Areas with less than 20% of canopy were classified as “non-forests”. This procedure was undertaken with reference to Potapov et al. (2009). Qualitative assessments of the classified images were further done by examining the classified images visually and relating it to the knowledge obtained from the interview of local people. This ensured that the classified map output reflected reality on the ground. Forest reserve boundary layout was obtained from the geodatabase of the Forestry Commission of Ghana. Analysis of forest cover in terms of area (ha) for 1986, 2000 and 2014 were carried out in ArcGIS 10.1.

Accuracy assessment of forest classification

Fifty percent (50%) of the collected ground control points (test data set) were used for the accuracy assessment of the Landsat map of 2000 and 2014. The classified images were then crossed with the test data to generate confusion matrix. The confusion matrix was used to calculate the different accuracy measures, that is, producer’s, user’s accuracy, class mapping accuracy for each class and the overall accuracy. Kappa statistics were also calculated as additional information for evaluating the accuracies of the maps. It was not possible to carry out accuracy assessment for the 1986 map because of the lack of satellite derived historical reference map. It is however, assumed that the accuracy assessments for the Landcover maps of 2000 and 2014 are sufficient to shed light on the overall classification procedures adopted for this study.

Woody vegetation inventory

Sampling along Tankwidi river

The study used high resolution satellite image (ALOS AVNIR) for mapping riparian forests to support the field sampling. This is because riparian forests are too small to be detected using traditional satellite remote sensing data such as Landsat (at 30 m resolution) or broad scale GIS data (Johansen et al., 2010). The ALOS AVNIR image comprises 4 bands from visible to the near infra-red range (0.42 to 0.89 µm) and has spatial resolution of 10 m. It is managed by Japanese Aerospace Exploration Agency (Bagan et al., 2012). The ALOS AVNIR image was obtained through the Forestry Commission of Ghana. The date of the space acquisition of the satellite image is 27 February, 2011. Maximum likelihood classification algorithm was used for mapping "forest" along the Tankwidi river. The classification accuracy was 84% and the Kappa was 0.73 (confusion matrix not shown). This mapping was done to facilitate the inventory of the riparian woody species with stratified randomized design in farmland (FA) and forest reserve (FR). It was also used for selecting the position of random plots along the riverine area. Whether in FR or FA, the rivercourse was divided into 3 segments; each of length of approximately 8 km. Small variations in the length of the segments were done to accommodate the effects of the roads and bridges on the river. The study was restricted within a buffer zone of 50 m on each side of the river channel. The 50 m buffer zone was chosen as it is a prescribed width for perennial rivers enshrined in the Ghana Riparian Buffer Zone Policy for managing freshwater bodies (Government of Ghana, 2011). The inventory for species with diameter at breast height (DBH) ≥ 5 cm was conducted in sixty random rectangular plots (500 m^2 per plot), 30 each in FR and FA and 10 plots per segment. Tree caliper was used to measure the DBH of the species and the height was measured with Vertex IV and Transponder III, Haglof Sweden. Specimens of the species recorded were taken to the herbarium of the Forestry Research Institute of Ghana for confirmation of identification.

Data analysis

Species richness and diversity of woody species

Shannon-Wiener (SWI) (Shannon, 1948) and Simpson (SI) (Simpson, 1949) indices were calculated as measures of woody species diversity. Shannon-Wiener is an index of overall diversity; combining both species richness and abundance, and sensitive to sampling size (Soetaert and Help, 1990). Simpson is an index of heterogeneity of species distribution. Further Pielou Equitability index (Natta et al., 2003) was used to assess the evenness of the species distribution. The selected indices of this study have been used for species diversity assessment in Ghana and West Africa in general (Traoré et al., 2012; Tom-Dery et al., 2013). They were adopted in the research to facilitate comparison of the findings. Species richness (SR) used in this study refers to the number of different species recorded in a plot.

Density, basal area and size-class distribution of woody species

For each landuse management regime (FR or FA), the following structural parameters were calculated:

(i) Woody species density (Zeide, 2005); the average of the number of individuals per hectare.
(ii) Basal area (Zeide, 2005); the average cross-sectional area of woody species per hectare was calculated from the DBH below:

Basal area = $\sum (DBH^2 \pi 4^{-1})$ where $\pi = 3.14$

To establish the size-class distributions, diameters of all species were used to construct histogram with size classes of 5 cm interval. This was similarly done for the heights of species at 5 m interval classes. Student's t-test was used to estimate the significance of the differences between the protected area and farmland after testing for normality using Statistical Package Software for the Social Sciences, Version 17. Results were considered significant at P < 0.05.

RESULTS

Accuracy assessments and landcover dynamics

The overall accuracy of the 2000 image of 71% was lower than 2014 image classification accuracy (74%). Kappa coefficient followed a similar trend and in that case the 2000 and 2014 had values of 0.43 and 0.45, respectively. Producer accuracy of the "forest" for 2000 and 2014 were lower than the "non-forest". The user accuracy of "forest" was nevertheless, higher than the "non-forest" for both 2000 and 2014. Results of the classification accuracy assessments for the maps of 2000 and 2014 are presented in Table 2a and 2b, respectively. The assessment of forest cover in the Tankwidi river basin showed increasing deforestation from 1986 through 2000 to 2014 (Table 3 and Figure 2). In 1986, the forest cover was estimated at 23% of the area studied. It was reduced to 11% by 2000. Currently, the area of forest cover is 7% of the study area. The "non-forest" which comprises primarily of farmland and grassland have been increasing in area coverage since 1986 (77%) through 2000 (89%) to 2014 (93%).

Woody species richness and diversity

Forty woody species were recorded along the Tankwidi river in forest reserve (FR), whereas 19 species were observed along the same river in farmland (FA) (Table 4). The most species rich farmilies in the FR were Combretaceae (22%), Rubiaceae (20%), Mimosaceae (11%) and Papilionaceae (9%). In the FA, the dominant families were Rubiaceae (19%), Combretaceae (15%), Mimosaceae (13%) and Moraceae (13%). The total number of specimen recorded along the Tankwidi river was 751 with 532 in FR and 219 in FA. Woody species richness and diversity (SR, SWI, SI, PEI) of riparian forest (RF) in the FA was significantly (P<0.05) lower than in FR (Table 5).

Density, basal area and size-class distribution of woody species

The diameter class distribution of woody species in riparian forest (RF) on forest reserve (FR) showed a reverse "J" shaped curve (Figure 3), whereas the pattern in farmland (FA) showed a deviation from the FR at the lower diameter class (5 to 15 cm). In the FR, majority (58%) of the riparian woody species were in the lower diameter classes (5 to 15 cm) than higher classes (15 to 50 cm). The reverse was observed in the FA where the

Table 2a. Confusion matrix of Landcover map using Landsat 2000.

Landcover	Reference data			Accuracy total			
	Forest	Non-forests	Classified total	Number correct	Producers Accuracy %	User Accuracy %	Kappa
Forest	15	1	16	15	46.88	93.75	0.87
Non-forest	17	29	46	29	96.67	63.04	0.28
Total	32	30	62	44			
Overall Accuracy				70.97			
Overall Kappa				0.43			

Table 2b. Confusion matrix of Landcover map using Landsat 2014.

Landcover	Reference data			Accuracy total			
	Forest	Non-forests	Classified total	Number correct	Producers Accuracy %	User Accuracy %	Kappa
Forest	13	1	14	13	44.83	92.86	0.87
Non-forest	16	36	52	36	97.30	69.23	0.30
Total	29	37	66	49			
Overall Accuracy				74.24			
Overall Kappa				0.45			

Table 3. Landcover proportions from 1986-2014 at the Tankwidi river basin.

Landcover	1986	%	2000	%	2014	%
Forest (ha)	33905	23	17090	11	10681	7
Non-forest (ha)	115755	77	132570	89	138979	93
Total	149660		149660		149660	

individuals in the lower diameter class were fewer (26%) than the higher diameter classes (15 to 50 cm). The height classes' distribution of the woody species followed a similar trend as the diameter (Figure 4). The density of riparian woody species per ha was significantly higher ($t = 8.9$, $df = 58$, $P < 0.0001$) in the FR (355 ± 21) than the FA (146 ± 11). Nonetheless, the mean basal area of woody species per hectare was significantly higher ($t = 3.523$, $df = 58$, $p = 0.001$) in FA (11592 ± 1484) than FR (6022 ± 545).

DISCUSSION

Landcover map accuracies

The confusion matrix of the 2014 classification was an improvement over the 2000 classification map (Table 2a and 2b). This could be as a result of the use of current validation dataset as observed during fieldwork as opposed to the 2000 classification where reference was made to historic Landcover map and local knowledge in the collection of the validation data. For both 2000 and 2014 classifications, errors were minimized by choosing only two landcover classes (forest/non-forest), with spectrally distinct signatures. The classification accuracy values for both 2000 ((71%) and 2014 (74%) were lower than the 85% overall accuracy threshold used by the United States Geological Survey to determine acceptability (Chai et al., 2009). Nonetheless, the accuracy values of both 2000 and 2014 were similar to that reported in other savannas (Ruelland et al., 2010; Schetter and Root, 2011). The lower accuracy of mapping could be as a result of the heterogeneity of forest patches which according to Ruelland et al. (2010) is difficult to detect in the savanna matrix by using medium resolution satellite image such as Landsat.

Forest cover change

The result of the landcover change analysis shows the deforestation of the Tankwidi basin in both forest reserve and farmlands from 1986 through 2000 to 2014 (Figure 2; Table 3). The deforestation could be attributed to farming activities that remove woody vegetation and in turn replace them with crops. Also, the farmers depend on fuelwood as their main source of energy, and the increasing demand by the populace contribute to the reduction in forest area. Again due to the uncontrolled slash-and-burn activities of farmers, wildfire is prevalent

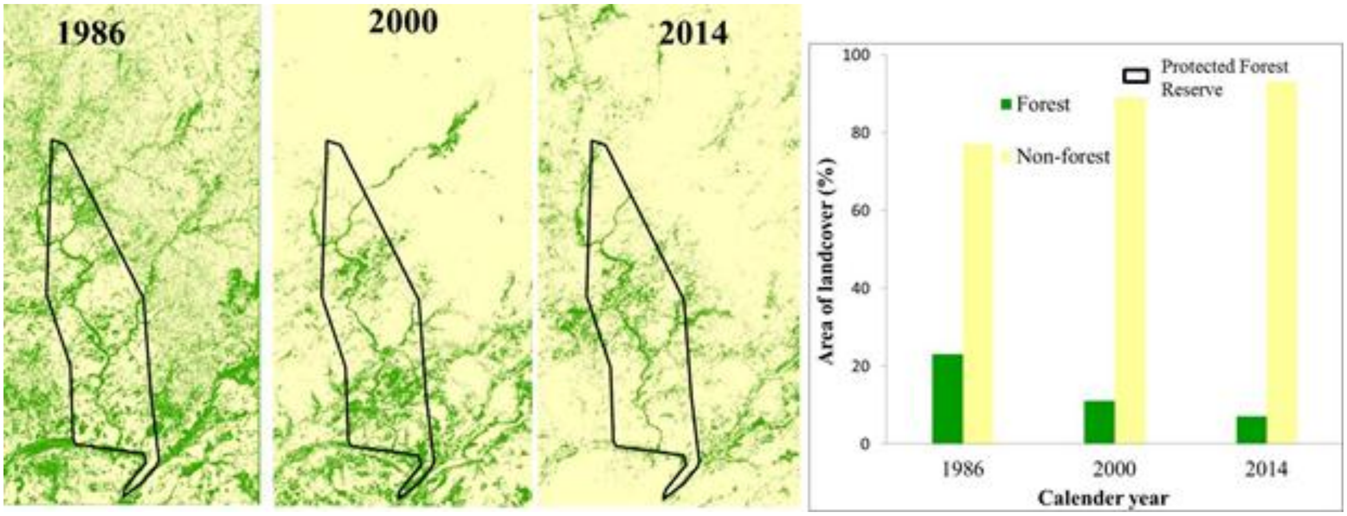

Figure 2. Landcover in the headwaters of Tankwidi river basin for the studied years (1986-2014).

Table 4. Most abundant woody species encountered in Forest reserve and Farmland.

Species	Abundance (%)	
	Forest reserve	Farmland
Acacia sieberiana	-	7
Anogeissus leiocarpus	17	15
Ficus sycomorus	-	13
Mitragyna inermis	16	17
Pterocarpus erinaceus	7	-
Vitex doniana	7	10
Vitellaria paradoxa	7	9

Table 5. Diversity of woody species on farmland (n = 30) and forest reserve (n = 30). SR, SWI, SI and PEI connote species richness, Shannon-Wiener, Simpson, and Pielou equitability indices respectively. sem: standard error, degrees of freedom (58).

Diversity	Landuse	Mean	SEM	t-value	P-value
SWI	FR	2.5	0.09	4.20	0.0001*
	FA	1.8	0.14		
SI	FR	0.85	0.009	2.95	0.005*
	FA	0.70	0.05		
SR	FR	6.47	0.39	3.34	0.001*
	FA	4.83	0.30		
PEI	FR	0.94	0.007	2.35	0.022*
	FA	0.81	0.052		

within the forest reserve and farmlands of the study area, which according to Goetze et al. (2006) contributes to tremendous forest loss. The finding on deforestation is however, not peculiar to the study area. This is because evidence of deforestation has been reported in other sub-Saharan African countries and across the tropics (Chai et al., 2009; Traore et al., 2012). The effect of the deforestation includes changes in elements such as light and wind which influence the microclimatic conditions of forest remnants to exert a strong effect on biological

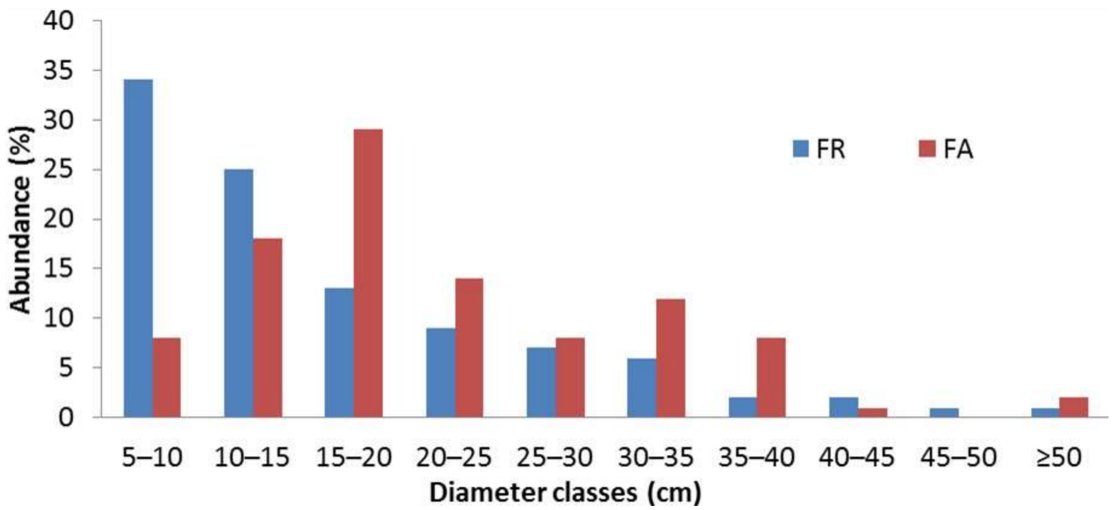

Figure 3. Diameter class distribution of individuals' ≥ 5 cm DBH in riparian forests in forest reserve (FR) and farmland (FA).

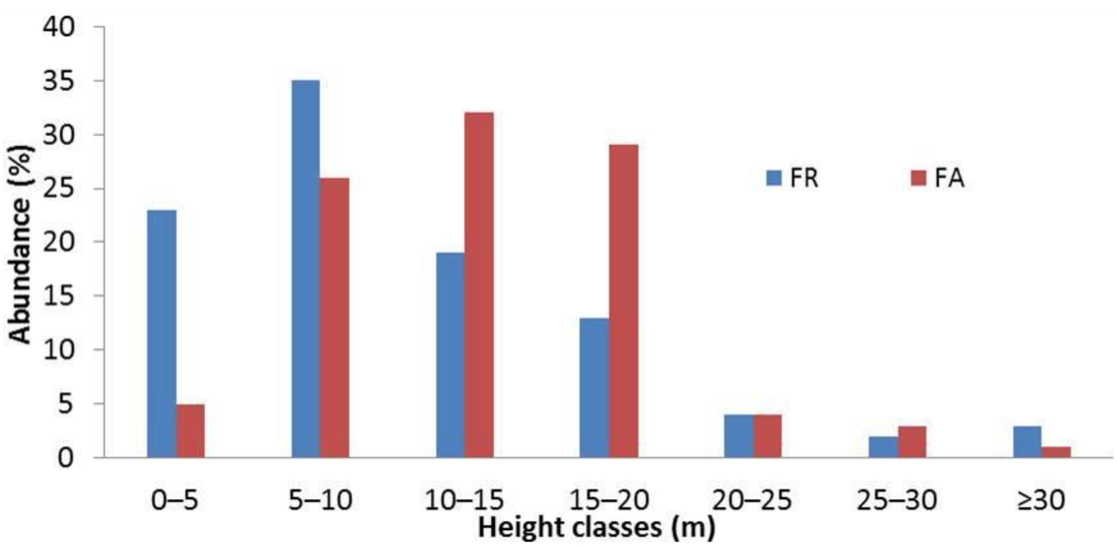

Figure 4. Height class distribution of individuals' ≥ 5 cm DBH in riparian forests in forest reserve (FR) and farmland (FA).

diversity (Goetze et al., 2006). Additionally, the deforestation result in the modification of habitat structure (Goetze et al., 2006), resource availability and distribution (Morelli, 2013), energy and nutrient cycling, temperature and moisture states of the forests (Morandin and Winston, 2006).

Changes in riparian woody species richness and diversity

Although, not all forest cover conversions have negative effects on plant diversity (Traore et al., 2012), field inventory in this study revealed that agricultural activities have reduced the richness of woody plants in the Tankwidi riparian buffer in farmlands. The richness of riparian buffer in disturbed landscapes are normally hindered due to the limitations in the flow of nutrients' and seeds from vegetation in the adjacent landscape (McKinney, 2008; Okiror et al., 2012). The finding was however, surprising as riparian forest is designated as protected area in all landscapes under the freshwater buffer zone policy of Ghana (Government of Ghana, 2011). The poor enforcement of the policy prescription prohibiting agricultural activities within the buffer zone may have heightened the problem of deforestation in the

Tankwidi riparian basin (Government of Ghana, 2011). The result (Table 5) further showed that the riparian forest in forest reserve (FR) has high woody plant diversity than in farmland (FA) (Ceperley et al., 2010; Okiror et al., 2012) and on that basis, the first null hypothesis of the study is accepted. Species diversity is always higher in less disturbed reserves than on farmlands where clearing of land for crop cultivation and burning causes disappearance of woody plants (McKinney 2008; Okiror et al., 2012). The Shannon-Wiener index value recorded for the FR was within the range (2.4 to 5.4) reported in other savannas of West Africa, whereas that observed in the FA was lower (Natta and Porembski, 2003; Natta et al., 2003). In contrast to this research, it has been found in other studies that the species diversity value on agricultural watershed in the tropics is enhanced by the deliberate preservation of trees by farmers (Boakye et al., 2012; Traore et al., 2012; Gray et al., 2014). The fact that the RF on farmland is less diverse is likely to reduce its resilience to disturbance as studies have confirmed that such eco-systems are prone to climatically induced catastrophes such as diseases and alien species invasions (Scherer-Lorenzen et al., 2005). Again the loss of plant diversity results in poor habitats conditions for insects, earthworms and soil micro-organisms that perform such critical ecosystem services as the pollination of crops and breaking down of organic matter in the soil, to the farmland birds facilitating seed dispersal and pollination (Morandin and Winston, 2006; Gray et al., 2014). Changes in any of these services could have damaging effects on crop production and greatly increases concerns over food supply (Eilu et al., 2003; Manning et al., 2006; Okiror et al., 2012).

Changes in riparian woody species density, basal area and size-class distribution

The result on the size class distribution in forest reserve (FR) differs from the farmland (FA) and on that basis the second null hypothesis of this study is accepted. The distribution of the woody species in the FR showed a reverse J-shaped curve suggestive of a stable ecosystem where woody plants are good enough to regenerate naturally and face no danger of extinction (Sambare et al., 2011). According to Lykke (1998), for a population to maintain itself, it needs to have abundant juveniles which will recruit into adult size classes. The reduced number of young individual (5-15cm) on farmlands however, suggests that the riparian forest is poor in recruitment: meaning lower survival of seedlings to sapling stage. This could be as a result of limitation of seed dispersal; which can be due to reduced diversity of animals that are granivores and frugivores or increased abundance of seed predators (Gray et al., 2014). Further, repeated weeding of the riparian area for crop cultivation may have prevented the regeneration of the young individuals (Ceperley et al., 2010) in farmland. Also, the excessive use of chemicals (weedicides) affect regenerative capacity since some of the chemicals kill the seeds that are dispersed (Fischer et al., 2009; Ceperley et al., 2010). The reduction in the regeneration on farmland may affect the ecological succession of riparian forests in farmland and in the long term cause the disappearance of the forests (Okiror et al., 2012).

The high basal area of RF in FA can be explained by the large old trees. From discussion with the local farmers, it could be deduced that those large trees fall into the useful economic tree species that are preserved by farmers. It was observed that *Vitellaria paradoxa* (Jamala et al., 2013) and *Parkia biglobasa* (Kronborg et al., 2013) were among the important economic trees supporting the livelihood of farmers. *Anogeissus leiocarpus* (Agaie et al., 2007), *Mitragyna inermis* (Wakirwa et al., 2013) and *Pterocarpus erinaceus* (Noufou et al., 2012) are important medicinal plant and has several domestic uses for the farmers. The fact that the riparian woody density is lower in FA would result in much drier forests due to the increase in the surface exposure of the riparian area for soil moisture loss. This can increase the vulnerability and frequency of the RF to savanna fires (Azihou et al., 2013). Such fires can break the resilience of the riparian ecosystem to intensify climate change impacts to such a degree that species physiological tolerances can be exceeded and the rates of biophysical forest processes altered. Again, the loss of the woody plant density could increase in-stream temperatures and impact on the survival of the aquatic fauna. Example, there are evidences that increasing in-stream temperature sometimes influence the growth of nuisance algae to affect the health of the aquatic habitat (Schweiger et al., 2011).

Conclusion and recommendation

Time series data show that there has been a decline in riparian woody plant richness, diversity and density in farmland areas. This could be as a result of agricultural practices on the landscape and the ineffective enforcement of buffer retention regulations. This decline in riparian forest cover puts the landscape at greater risk of harm of natural disturbances such as fires and flooding than would be the case if riparian forest cover and diversity had been retained similar to conditions found in reserve areas. Based on this finding, the study recommends the enforcement of the freshwater buffer zone policy of Ghana to ensure that farmers are excluded from the buffer zone. Farmers should also be discouraged from intensive extraction of resources such as fuelwood and non-timber forest products. Landuses in the uplands could be regulated so as to protect nutrient sources and other low order streams. Replanting of degraded area may augment the composition of the species.

Conflict of interest

Authors did not declare any conflict of interest.

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