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Biodiversity and productivity of two lacustrine wetlands of the upper Benue River Basin, Adamawa State, Nigeria

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Abstract: Plant species diversity of a natural (Gyawana) and a man-made (Kiri) lakes in the Upper Benue River Basin of Nigeria was carried out at monthly interval from January 2004 to December 2005, and a biological inventory of the plant species was conducted using the Direct Tally Method (DTM) and Point Centered Quarter (PCQ) plot less sampling techniques. A total of 84 plant species were recorded during the studies in Kiri and Gyawana lakes. Forty six (46) plant species belonging to 20 families were identified at Kiri Lake, while 38 plant species belonging to 17 families were identified at Gyawana Lake. There was a significant ($p<0.01$) difference in the number of aquatic macrophytes between the sites with Gyawana wetland ecosystem satisfying the criteria 1 and 2 for designation as Ramsar site. It is imperative therefore, that the Federal Ministry of Environment considers the designation of the site as Ramsar site.

Key words: Aquatic macrophytes, Gyawana, Kiri, Species diversity, Lacustrine wetlands

Introduction

Wetlands are described as areas of marsh, fen, peat land or water, whether natural or artificial, permanent or temporary, with water that is static or flowing, fresh, brackish or salty, including areas of marine water, the depth of which at low tide does not exceed six metres (Dugan, 1990).

Prior to the Ramsar Convention (2010) on Wetlands of International Importance, wetlands were generally regarded as wastelands, probably because of some problems such as disease vectors associated with them (Odum *et al*. 1985; Kio and Ola-Adams, 1990).

The awareness generated by the Ramsar Convention (2010) resulted in studies that have led to the recognition of wetlands as very important and valuable ecosystem (Fiselier, 1990; Barbier *et al*. 1991). However, in 1972 at

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Ramsar, Iran, wetlands were the main issue at an international environmental convention, organized specifically to deliberate on conservation of the world's wetlands.

At that Convention, the following criteria were adopted for identifying wetlands that are of international importance:

1) Criteria for representative or unique wetlands

A wetland should be considered internationally important if any of the following apply:

a) It is a particular good representative example of a natural or near-natural wetlands, characteristics of the appropriate biogeographycal region; b) It plays a substantial hydrological, biological or ecological role in the natural functioning of a major river basin or coastal system, especially where it is located in a transborder position or c) It is an example of a specific type of wetland, rare or unusual in the appropriate biogeographical region.

2) Criteria based on plants or animals

A wetland should be considered internationally important if any of the following apply:

a) It supports an appreciable assemblage of rare, vulnerable or endangered species or subspecies of plant or animals, or an appreciable number of individuals of any one or more of these species;b) It is of special value for maintaining the genetic and ecological diversity of a region because of the qualify and peculiarities of its flora and fauna;c) It is of special value as the habitat of plants or animals at a critical stage of their biological cycle or d) It is of special value for one or more endemic plant or animal species or communities.

Wetland studies have revealed that in many parts of the world with developing economy, the livelihoods of many rural settlements are often intimately linked to wetland ecosystems (Odum *et al*.1985; Dugan, 1990). For example, in the Hadejia-Nguru Wetlands, Lake Kainji and other wetlands in Nigeria, researchers have identified a variety of functions, products, services and thriving socio-economic activities associated with wetland ecosystems. These include fishing, water-based traditional festivals like regattas and fishing festivals, timber, Non-Timber Forest Products (NTFPs), water-based transportation, recession or draw-down and *Fadama* agriculture, wildlife conservation, floodplain livestock husbandry, hydroelectric power generation, water purification, and water for domestic and industrial uses (Akpata and Okali, 1990; Hollis *et al*. 1993; Ezealor, 1995 and 2002).

The value of aquatic plants as energy source centres mainly on their use as fuel for fish smoking and for domestic energy by subjecting the plants to bio-chemical reaction which could be an energy source (fuels) whether in liquid, gaseous or solid forms. For example, stems of *Eichhornia* spp. and *Cyperus papyrus* among others are used as fuel especially for cooking and fish smoking (Kio and Ola-Adams, 1987). Water hyacinth has been reported to be useful in the production of biogas (Eyo, 2000). A variety of aquatic plants is also used in curative therapy in traditional communities and between 75 and 80% of the Nigerian populace patronizes the traditional healers that make use of these plants (Bubayero, 1986; Okojie, 1998). Quite a number of these ethno-botanic materials have been reported to yield compounds, which could be of use as modern drugs and pharmaceuticals. The presence of aquatic plants has favoured the possibilities of most Nigerian water bodies being developed into recreational centres that will include sport, hunting, fishing bird watching and nature photography (Okojie, 1998).

A study was conducted to evaluate nutritional potential of three local aquatic plants, *Nymphaea alba* (Bum) water lily, *Nymphoides peltata* (Khor) and *Hydrilla* species (Khel) which grow abundantly in the Dal and other lakes and water bodies of Kashmir, Pakistan. Proximate analysis revealed that all the three plants had dry matter below 10%. Crude protein content of *Hydrilla*, *Nymphaea* and *Nymphoides* was 17.10, 20.28 and 21.87% respectively. Ash content varied from 8% in *Nymphaea* to 19.45% in *Hydrilla*. Calcium content was 1.29, 1.10 and 1.56% in *Hydrilla*, *Nymphaea* and *Nymphoides* respectively. Fiber content was lowest (13.34%) in *Hydrilla* and highest (21%) in *Nymphoides* (Shah *et al*. 2010).

Wetland vegetation may respond to topography and hydrology with a distinct zonation pattern formed by the dominant species, particularly in tidal situations, or may produce a complex variety of plant communities around the minor local variations in height. Many wetland plants or hydrophytes grow in dense and abundant stands, for example *Typha australis* and Papyrus (*Cyperus papyrus*) in Lake Naivasha, Kenya (Jones, 1983). Nigerian aquatic plants occurring in most water bodies are similar to those in other tropical regions. They are usually strictly zoned across the land/water ecotone and generally follow a pattern such as the fringe, seasonal flooded zone, mud zone and permanently flooded (open water) zone (Obot, 1987). Aquatic plants help in the nutrient cycle accumulating and slowly releasing such nutrients as phosphorus and nitrogen which are the causes of eutrophication of flood plain associated Lakes, swamps and ponds (Obot, 1985). This is the basis of biofertilizers, in which minor crops that provide nutrients to a major crop are grown together. Biological data on the lakes associated with the Upper Benue River Basin in Nigeria are scanty and botanic surveys in Adamawa by Hepper in 1958 only crossed the Benue at Yola and Numan without any particular interest in either wetlands or their plants (Hepper 1962a; 1962b). Obot (2000), during a survey of biodiversity of the Upper River Benue recorded fifty-three (53) useful plants which is the only known documented surveys of the area area. Therefore, this study was carried out to determine the plant resources of man-made lake (Kiri) and natural lake (Gyawana) to assess their productivity.

Materials and methods

Study area

The study was carried out in Upper Benue River Basin complex of Adamawa State (Fig. 1a). Kiri Lake (09° 40'N 12°00'E; Fig. 1b) and Gyawana Lake (09° 33'N 11°49'E; Fig. 1c) are situated in the Guinea Savanna ecological zone, though most of it is typically degraded as a result of farming and other anthropogenic activities (Mbinkar, 2007). The River Benue and its tributary (the River Gongola) are the main physical features of the area. In addition, there are some knolls, which are southern extensions of the Adamawa Highlands that loom in the background (Obot, 2000).

Kiri Lake is an artificial man-made lake which was created as a result of the impoundment of River Gongola, just before its confluence with the River Benue. At full capacity, it has a surface area of about 112km^2 with a normal top-level water of 170.5m above sea level and a flood water level of 171.5m above sea level (Bawden and Tulley, 1967). The dam was built in 1982 to reserve water for irrigation of the sugar cane fields of the Savanna Sugar Company in Numan.

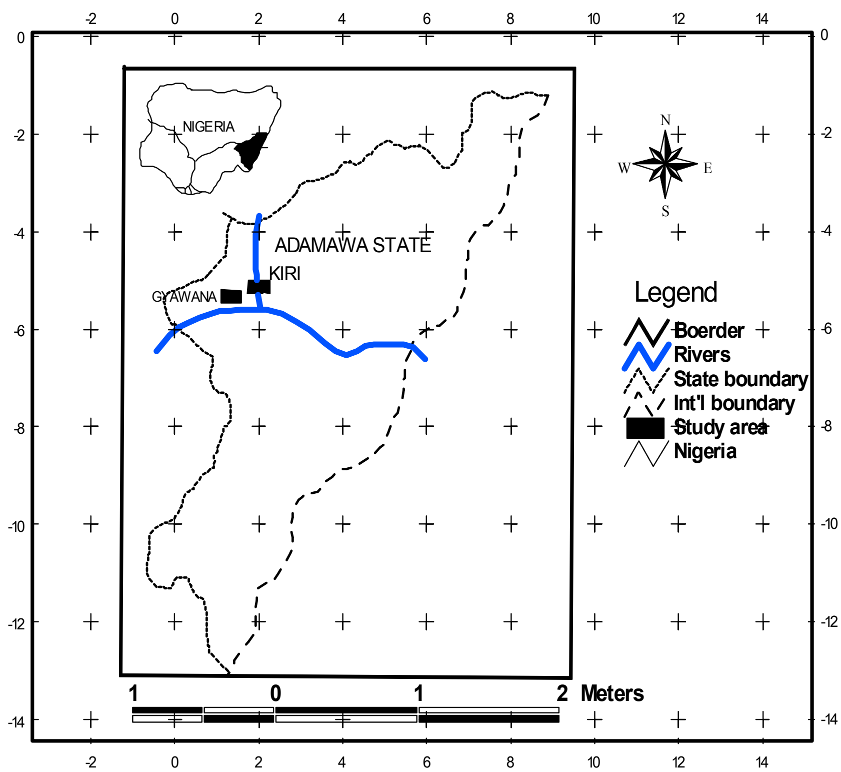

Fig. 1a: Map of Adamawa State showing Study Sites.

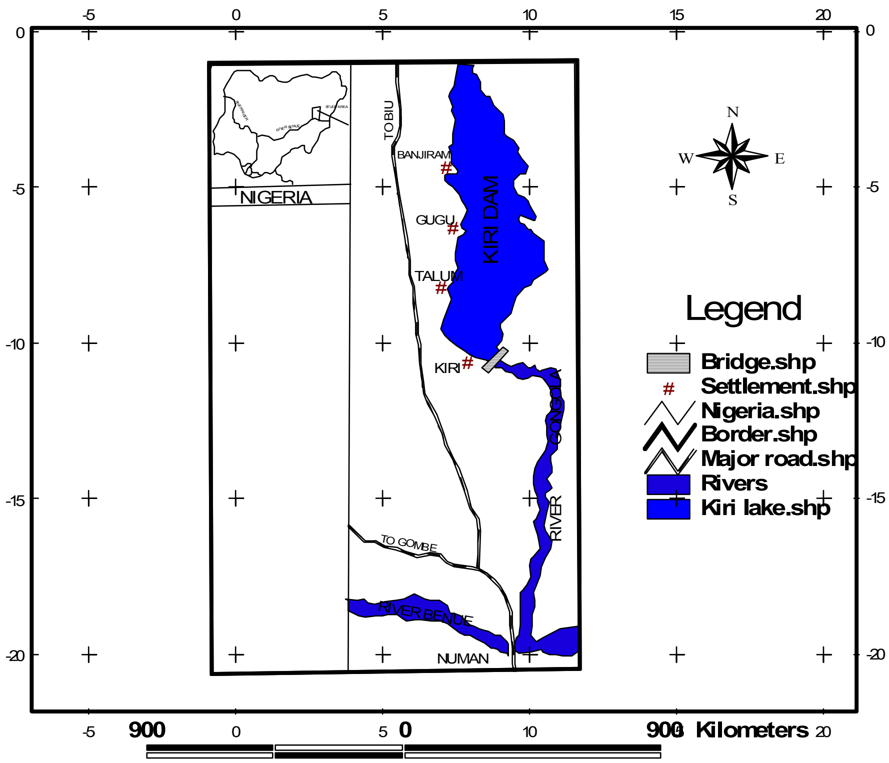

Fig. 1b: The Location of Kiri Study Site.

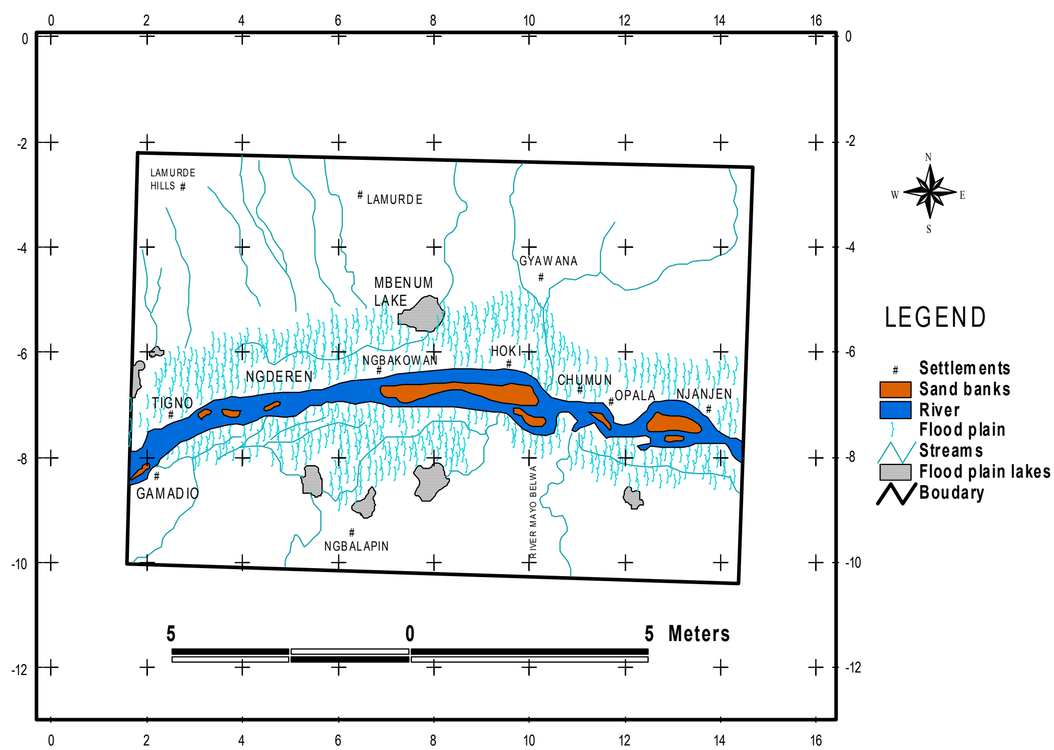

Fig. 1c: The Location of Gyawana Study Site.

Gyawana Lake on the other hand, is a natural floodplain lake, which fills up to full capacity during the wet season. It has a surface area of about 4 km^2 with a mean depth of 3m. The water that drains into the lake comes mostly from the Pire Hills and other nearby highlands. It supports a number of local economic activities such as artisanal fishing and subsistence farming (Mbinkar, 2007).

Sample collection

For each of the two lakes, the following monthly activities from January 2004 to December 2005 were undertaken. Species of the various categories of aquatic plants (i.e. submerged, free- floating, floating leaf and emergent) present in each lake were recorded. The Direct Tally Method (DTM) as described by Ezealor (1995) and the Point Centre Quarter (PCQ) plot less sampling technique described by Higgins *et al*. (1994) and Bullock (1998) were used to determine the density of aquatic and woody fringe vegetation of the lakes at full capacity. In addition, three transects perpendicular to the lake shores were established at each of the site for the purpose of describing the physiognomy and structure of the woody fringe vegetation. Local uses of plant species were sought through informal discussion with the local people. Field guides of Gledhill (1972) and Akobundu and Agyakwa (1998) were used to identify plants of the study sites. Some of the plants that could not be positively identified in the field were preserved in plant-presses and taken to the Herbarium of the Department of Biological Sciences, Ahmadu Bello University, Zaria for confirmatory identification.

Statistical analysis

Student's *t*-test was used to compare the two lakes and ecological explanation advanced for any differences recorded as described by Sokal and Rohlf (2000).

Results

A total of 84 species of aquatic macrophytes belonging to 22 families were recorded at Kiri and Gyawana lakes during the study period. Forty six (46) species in 20 families and 38 species in 17 families were recorded at Kiri and Gyawana lakes, respectively. A total of 20 woody plant species in 11 families were recorded in Kiri and Gyawana lakes during the study period out of which 19 species in 11 families were recorded at Kiri Lake and in 1 family at Gyawana Lake (Tabs 1 and 2).

Fifteen (15) woody species were documented out of which 14 species were recorded at Kiri Lake and a species at Gyawana Lake. The density of trees at Kiri Lake was higher- 43ha^{-1}, while that of Gyawana Lake was 21ha^{-1} (Tab. 3).

Table 4 gives a summary of the density, percentage cover and *t*-test analysis of the plants encountered. The density of trees per

Tab. 1: Checklist of the common aquatic macrophytes and their uses at the two lakes. (+ present, - absent)

Family/Species	Plant form	Kiri Lake	Gyawana Lake	Comment/uses
Amaranthaceae				
Alternanthera sessiles (Sessile Joy Weed)	Emergent	+	-	Dry season fodder; used for medicine
Araceae				
Pistia stratoites (Water Lettuce)	Free floating	+	+	Used for medicine, fertilizer, dry season fodder; potentially invasive, use for stable pollution control.
Azollaceae				
Azolla africana (Mosquitos Fern)	Free floating	+	+	Used for fertilizer, fixes nitrogen, thus used extensively to replace nitrogen needed to fuel high yielding rich crops.
Convolvulaceae				
Ipomoea aquatica (Swamp Morning Glory)	Flood tolerant	+	+	Used for medicine; flood tolerant plant, livestock fodder.
Ipomoea asarifolia	Flood tolerant	+	+	No comment
Ipomoea carica	Flood tolerant	+	+	No comment
Cyperaceae				
Cyperus iria	Flood tolerant	+	-	Dry season fodder
Cyperus naudicaulis	Flood tolerant	+	+	Dry season fodder
Cyperus pustulatus	Flood tolerant	+	+	Dry season fodder
Mariscus lugularis	Flood tolerant	+	+	No comment
Mariscus alternifolia	Flood tolerant	+	+	Dry season fodder
Fuierena umbellate	Flood tolerant	+	+	No comment
Schoenoplectus supinus	Flood tolerant	+	+	No comment
Dulichium arundinaceum	Flood tolerant	+	-	No comment
Kyllinga sp.	Flood tolerant	+	+	No comment
Poaceae (Graminae)				
Vossia cuspidate	Large floating grass	+	+	Dry season fodder, hippo grass.
Sacciolepis africana	Flood tolerant	+	+	No comment
Spartina pectin	Emergent	+	+	Dry season fodder, used for medicine.
Oryza barthii	Emergent	+	+	No comment
Pseudoraphis spinescens	Emergent	+	-	No comment
Eragorastis atrovirens	Emergent	-	+	No comment

Tab. 1: continued

Family/Species	Plant form	Kiri Lake	Gyawana Lake	Comment/uses
Poaceae (Graminae)				
Laudetia simplex	Flood tolerant	+	-	No comment
Vetivera nigritana	Flood tolerant	+	+	No comment
Echinochloa stagnina	Emergent	+	+	Excellent fodder for thatching; flood tolerant
Panicum phragmitoides	Emergent	+	+	Dry season fodder
Lamiaceae (Labiatae)				
Leonotis nepetifolia	Emergent	+	-	No comment
Solenostemon monastachyus	Emergent	-	+	No comment
Leguminosae: Papilionoideae				
Aeschynomene uniflora	Emergent	+	-	No comment
Indigofera arrecta	Emergent	+	-	No comment
Leguminosae: Caesalpinoideae				
Coffea senna	Emergent	+	-	No comment
Senna obtusifolia	Emergent	+	-	No comment
Caesalpinia bonduc	Emergent	-	+	No comment
Leguminosae: Mimosoideae				
Neptunia oleracea	Floating leaved	+	+	Nitrogen fixing plant, use for medicine, fertilizer, dry season fodder
Mimosa pigra	Floating tolerant	+	+	Used for firewood, flood tolerant plant, stem used for fencing
Lemnaceae				
Lemna pausicostata (Duckweed)	Free floating	+	+	Used in experimental animal feed especially *Tilapia sp.*, indicator of high nutrient load in water, which they convert into edible tissue of high protein content.
Malvaceae				
Urena lobata	Emergent	+	-	No comment
Menispermaceae				
Cissampelos murunata	Emergent	-	+	No comment
Nymphaeaceae				
Nymphea alba (Water Lily)	Floating leaved	+	+	No comment

Tab. 1: continued

Family/Species	Plant form	Kiri Lake	Gyawana Lake	Comment/uses
Malvaceae				
Nymphea lotus (Water Lily)	Floating leaved	+	+	Used for medicine; the fruits are eaten by birds; leaves used as nesting platform by lily-trotters; used for shelter by some aquatic insects.
Onagraceae				
Ludwigia fruticosa	Emergent	+	+	No comment
Ludwigia suffruticosa	Emergent	+	+	No comment
Ludwigia repens	Emergent	+	+	No comment
Ludwigia stolonifera	Floating	+	+	Used for medicine
Ludwigia hyssopifolia	Emergent	+	+	No comment
Pedaliaceae				
Myrtynia annua	Float tolerant	+	-	No comment
Polygonaceae				
Polygonum limbatum	Emergent	+	+	No comment
Pontederiaceae				
Eichhornia crassipes (Water hyacinth)	Free floating	+	+	Potentially invasive; haven for production of disease vectors such as mosquitoes and aquatic snails.
Salviniaceae				
Salvinia nymphellula (Duckweed)	Free floating	+	+	Use for fertilizer; potentially invasive, dry season fodder.
Solanaceae				
Physalis angulata (Gooseberry)	Emergent	+	-	No comment
Typhaceae				
Tyha australis	Emergent	+	+	Invasive; use for bedding.
Verbenaceae				
Stachytarpheta cayenesices	Emergent	-	+	No comment

hectare for Gyawana Lake was higher -23,685 ha^{-1} than that of Kiri Lake- 69, 252 ha^{-1}, while the percentage cover for Kiri and Gyawana lakes were 63 and 37% respectively. The *t*-test analysis showed significant differences in plant density between the two lakes ($p<0.01$).

Tab. 2: Checklist of the Common Woody Plants and their uses at the two Lakes. (+ present, - absent)

Family/Species	Kiri Lake	Gyawana Lake	Comment/Uses
Anacadiaceae			
Lannea schimperi	+	-	No comment
Araceae			
Hphaene thebiaca (Dom palm)	+	-	Timber
Borassus aethiopium	+	-	Timber
Asclepiadaceae			
Leptadenica hastate	+	-	No comment
Calotropis procera	+	+	Presence indicates overgrazed land
Balanitaceae			
Balanites aegytiaca (Jericho plum; Desert date)	+	-	Fencing material
Bignoniaceae			
Stereospermum kunthianum	+	-	No comment
Euphorbiaceae			
Jatropha gossypifolia	+	-	No comment
Caperonia palustris	+	-	No comment
Securinega virosa	+	-	
Leguminosae: Caesalpinoideae			
Piliostigma reticulatum	+	-	No comment
Piliostigma thonningii	+	-	Used as fodder
Leguminosae: Mimosoideae			
Acacia hockii	+	-	No comment
Acacia polyacantha	+	-	No comment
Mimosa pigra	+	-	No comment
Meliaceae			
Azadirachta indica	+	-	No comment
Rhamnaceae			
Ziziphus mucronata (Jujuba)	+	-	Fencing material
Rubiaceae			
Mitragyna inermis	+	-	Poles

Tab. 3: Density of woody fringe vegetation at the two lakes. (+ present, - absent)

Species	Kiri Lake	Gyawana Lake	Density/ha
Azadirachta indica (Neem)	+	-	7
Acacia sieberiana	+	-	5
Acacia polyacantha	+	-	4
Acacia hockii	+	-	4
Bauhinia rufescens	+	-	4
Piliostigma thonningii	+	-	3
Ziziphus mucronata	+	-	3
Balaanites aegyptiaca	+	-	3
Securinega virosa	+	-	2
Lannea schimperi	+	-	2
Calotropis procera	+	-	2
Leptadenica hastate	+	-	2
Stereospermum kunthianum	+	-	1
Piliostigma reticulatum	+	-	1
Mimosa pigra	-	+	21

Tab. 4: Comparative density, percentage cover of aquatic macrophytes in the drawdown zones of the two lakes

Vegetation type	Density/ha		Percentage cover		*t*-test
	Kiri	Gyawana	Kiri	Gyawana	*t*=7.655
Aquatic macrophytes	23,685/ha	69,252/ha	63%	37%	p<0.01

The biotic characteristics of the two wetlands against the criteria used in assessing sites for designation as Ramsar site is evaluated in Table 5. One of the sites-Gyawana Lake (the natural floodplain lake) qualifies for designation as a Ramsar site under categories 1 and 2.

Discussion

Wetlands plants are a major source of materials on which a large number of people depend, particularly in the subsistence economies of tropical countries (Bacon, 1996), and in addition to the goods and services (Tab. 1), the quantities exploited are enormous. Seven plants including *Alternanthera sessile*, *Ipomea aquatic*, *Spartina pectinata*, *Nymphea oleracea* and *Ludnigia repens* were used as medicine. Some trees frequently recorded in the Kiri wetland were *Acacia sieberiana, Acacia polyacantha, Azadirachta indica, Baalanites aegyptiaca* and *Piliostigma reticulum* which were variously used for timber and as fencing materials. In East Africa seasonal wetlands were dominated by grasses that are perennial while in Uganda, there are 22 species of edible wetland plants and 35 species of medicinal plants frequently used by people to cure various ailments (Chapman *et al*. 2001). Four plants consisting of *Pistia stratoites*, *Azolla africana*, *Neptunia oleracea* and *Salvinia nymphellula* were locally used as fertilizers. Plants such as *Mariscus alternifolia*, *Vossia cuspidate*, *Echinochloa stagnina*, *Paniculum phragmitoides*, *Neptunia oleracea*, *Salvinia nymphellula*, *Piliostigma reticulatum* and *Cyperus* species are used as dry season fodder, while *Alternanthera sessile*, *Pistia stratoites*, *Ipomea aquatica*, *Spartia pectinata* are used both as dry season fodder and medicine. Some plants were used variously as feeds and shelter for birds and aquatic animals. It is not only people who benefit from the high plant productivity in wetlands. In the Kafue flats of Zambia, the local herdsmen graze their cattle on 40% of the highly productive *Vossia/Echinochloa* vegeta-tion, while the endemic Kafue Lechwe *Kobusleche kafuensis* grazes more than 80% of the *Paspalidium* water meadow.

Table 5: Weighing of the biotic characteristic of the Lakes against the Ramsar Criteria.

Ramsar Criteria	Kiri Lake	Gyawana Lake
	No	Yes(naturalness)
Criteria 1: Criteria for representative or unique wetland	No	Yes (sump for flood water)
	No	No
	No	No
Criteria 2: General criteria based on plants or animals	No	No
	No	Yes (habitat for plants)
	No	No
	No	No
Criteria 3: Criteria based on waterfowl	No	No
	No	No
Criteria 4: Criteria based on fish	No	No
	No	No

Gyawana Lake qualifies as a Ramsar site under criteria 1 and 2.

Adams (1996) stated that African's flood plains have often been looked at as places that may provide resources to alleviate poverty and hunger in the continent due to its richness in biodiversity. In Uganda people harvest *Cyperus papyrus* to make mats and baskets. In Rwanda *Cyperus papyrus* is compressed into fuel briquettes with a high calorific content. In the Okavango Delta roots, palm *Hyphae*, *Phragmites*, and palm hearts are harvested for subsistence foods, wine and in southern Africa, the vegetation is rich and diverse, and water lily tubers, bulrush building material. In the inner Niger Delta, rice, millet, maize and wheat are cultivated in the highly productive soils of wetland areas.

The plant growth form was generally from free floating, emergent to flood tolerant. Other less-severely waterlogged soils were characterized by trees such as *Acacia* spp., *Combretum ghasalense*, and *Baalanites aegyptiaca* (Thompson, 1976). *Mimosa pigra* was the only dominant woody plant recorded around the fringes of Gyawana Lake.

The presence of *M. pigra* is an indication of acid soils (pH<5). It can therefore be expected that this floodplain soils are predominantly of acid reaction which is in agreement with (Obot, 2000). Conversely, the vegetation of Gyawana Lake is extensively converted, leaving an open landscape dotted with *Mimosa pigra, Ipomoea aquatica, Typha australis* and so on, especially at the peak of the dry season. At Kiri Lake, part of the forest patch has been converted into farmlands. The riparian woody vegetation along the lake course has undergone landslide caused by heavy torrential rains and the opening of the spillway to reduce the water upstream. Along the shoreline of these lakes, herbaceous and woody hydrophytes have established themselves. Frequent shoreline hydrophytes and shoreline vegetation included *Nymphaea lotus, Salvinia nymphellula, Eichhornia crassipes, Azolla africana, Ludwigia fruticosa and Oryza barthii*. Two plants including *Salvinia nymphellula* and *Eichhornia crassipes* were noted as potentially invasive species. There has been report that non-indigenous wetland plants are also common in West Africa, and one of the most invasive species has been the water hyacinth, *Eichhornia crassipes*. The invasion by this plant has also been a major perturbation due to wetland ecotonal areas of infested lakes. Water hyacinth has a number of potential negative effects on lakes by reducing light penetration, limiting water-column mixing, and increasing detrital inputs. By shading out the sun, it is likely to provide concealment of ambush predators that feed on indigenous species. This plant is a free floating macrophyte, which normally floats on the water surface and its distribution is largely dependent on wind and water movements (Muthuri, 1992). This group of aquatic macrophytes includes members of Lemnaceae (duckweeds), such as *Lemna*, *Spirodela* and *Wolffia* as well as aquatic weeds, *Eichhornia crassipes*, *Salvinia molesta* and *Pistia stratiotes*. These last three aquatic weeds have infested the Wetlands of Kenya at different times and with varying degrees of spatial extent; and all three have infested Lake Naivasha (Njuguna, 1992). Useful plants including livestock fodder especially during the dry season, dominate this aquatic vegetation. The lake shores are intensively grazed by nomadic and resident livestock leading to over grazing of vegetation. The presence of *Calotropis procera* indicates overgrazing around both lakes intensified by flood plain agriculture.

The density of trees per hectare in Gyawana Lake was 69,252 ha^{-1}, higher than that of Kiri lacustrine wetland 23,685 ha^{-1} while the percentage cover for Kiri Lake was higher than that of Gyawana Lake. This could be as result of Gyawana being a natural flood plain which is capable of supporting quite a number of plant species as it qualifies for Ramsar site.

Conclusion

The socioeconomic importance of wetland ecosystems to rural dwellers in the Upper Benue river basin is emphasized. One of the sites (the natural flood plain lake- Gyawana Lake) qualifies for designation as a Ramsar site under categories 1 and 2. There should be collaboration between local medicine practitioners and “modern” and “alternative” medicine institutions for research on local herbs. This practice is yielding good results that benefit all concerned parties.

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