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Provisioning ecosystem services provided by the Hadejia Nguru Wetlands, Nigeria – Current status and future priorities

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ABSTRACT

The Hadejia Nguru Wetlands (HNWs) located in the Sahel zone of Nigeria support a wide range of biodiversity and livelihood activities. Providing strategic management information that aids understanding of the changing values of the wetlands is a key principle for their prudent use. This is even more important in a society where the value of wetlands is not fully appreciated. This study assesses the status (resource users, monetary values, threats to and management options) of the HNWs with a view to providing important information for their sustainable management. Data was collected through questionnaire survey, focus group discussions, informal interviews and field observations. The main services provided by the wetlands include farming (mainly rice, maize, cowpeas and millet in the wet season and sorghum, tomatoes and wheat in the dry season), collection of materials (mainly doum palm – *Hyphaene thebaica* and fuelwood), fishing, grazing and hunting of water birds. The monetary contribution of fishing to participating households was highest at US$5864/household/year while that of fuelwood at US$427/household/year was the lowest financial contributor. The study found that the monetary value of doum palm collection has declined by 23% and farming by 45% over a 20 year period, while fuelwood value has increased by 119%. The impacts posed by invasive Typha grass and dam construction were identified as the major threats to the HNWs. These have led to scarcity and competition for resource and hence conflicts. Therefore, we suggest a management approach that designs a resource use calendar especially for farmers and herders as a means of reducing conflicts.

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Introduction

Wetlands support diverse ecosystem services that contribute directly and indirectly to human well-being. Ecosystem services are the goods and services that are important for human well-being [23] and have been categorized into provisioning, regulating, supporting and cultural ecosystem services [35]. Recently, there has been greater attention to wetlands management, especially in providing information to ensure their services are managed and used in a wise manner [21,26].

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One classic approach is the use of the monetary value of ecosystem services as a tool for their prudent management [55]. The hugely influential article by Costanza et al. [18] valued global wetlands at US$14,785/ha/year. In a more recent study, estimates for different types of wetlands (tidal marsh, mangroves, swamps, and floodplains) range from US$13,786/ha/year–US$193,843/ha/year [19]. Comparing monetary values of ecosystems over two time periods offers a powerful means to assess the temporal changes in the flow of ecosystem services. This is necessary for decision-making, helping decision makers build a more comprehensive and balanced picture of the assets that support human well-being [14,42].

Understanding such temporal changes is even more important for African wetlands which has often been overlooked in policy and planning [2,6], especially implication of changes/degradation to local communities. Davidson et al. [20] has called for improved knowledge of the change in wetland areas worldwide, particularly for Africa. Such information will be essential to managers and policymakers when making strategic decisions towards management objectives [29].

This paper draws on the background provided by these studies, calls to understand changes in African wetlands [20] and attempts to address critical gaps in research on temporal changes in value of wetland ecosystem services in Nigeria. Our study looks specifically at changes in the monetary value of the Hadejia Nguru Wetlands (HNWs) by comparing value estimates from a previous study (i.e., Eaton and Sarch [25]) with estimates generated from this study. Another aim is to understand the social security value, potential threats and their implications for the wetland ecosystem. These forms the gap that this study intends to fill. To do this, the study intends to provide answers to the following questions: (i) what are the direct and indirect uses of HNWs provisioning services? (ii) what are their monetary values and how this changed? (iii) what role does the wetland services play in securing livelihoods of local communities? and (iv) what are the potential threats affecting the HNWs and what are their implications?.

The choice of the HNWs for this study is predicated on their multifunctional use and the fact that they have one of the earliest existing ecosystem service valuation studies of any Nigerian (or African) wetland for which temporal variation in values can be compared. Barbier et al. [9] assessed the economic importance of the wetlands and the opportunity cost of their loss to the nation. Amans et al. [4] assessed the productivity, stability, and sustainability of farming systems in the wetlands. Hollis et al. [30] conducted a more general study of the natural resources of the HNWs and the hydrology. For Eaton and Sarch [25], the focus was on the economic importance of wild resources in the HNWs.

Hadejia Nguru Wetlands

In Nigeria, wetlands cover about 28,000 km^2 (about 3%) of the 923,768 km^2 of the country's land area [54]. One of these is the HNWs named after two major towns (Hadejia and Nguru) in the area and are surrounded by many villages. They are extensive floodplain wetlands in the dry lands of northeastern Nigeria. In 2000, the Nguru Lake and Marma Channel Complex Wetlands (located within the HNWs) were designated the first Nigerian wetlands of international importance under the Ramsar Convention.

The HNWs is located at a point where Rivers Hadejia and Jama'are flow through a fossil dune field before converging and draining into Lake Chad [10] and lie between longitude 10°15′E and 11°30′E, and latitude 12°13′N and 12°55′N (Fig. 1). The wetlands extend for approximately 120 km from West to East within Jigawa State and for a further 60–70 km downstream in adjacent Yobe State [51]. In width, the wetlands range from l0km to more than 50 km from North to South, with approximately 8000 km^2 of floodplain covering three Nigerian states (namely Bauchi, Jigawa and Yobe). The extent of the floodplain varies considerably from year to year depending on rainfall and complex interactions of river flow, dam releases, flood regimes and topography [13].

Annual rainfall ranges between 200 mm and 600 mm and is confined to late May to September. The dry season normally sets in October and remains until late May. The temperature record in the dry season ranges between 35 °C and 40 °C. Significant water flows to the wetlands begin in late June or early July with peak discharges in August. The natural hydrological regimes in the area have been modified by the construction of large-scale irrigation schemes and associated dams, notably the Tiga and Challawa dams, which are designed purposely for domestic water supply and irrigation. The Tiga Dam was constructed in 1974 with a storage capacity of 1989×10^6 m^3 while the Challawa was constructed in 1992 with a storage capacity of 972×10^6 m^3 [27]. Barbier [7] estimated that losses from upstream dams and large-scale irrigation schemes would be in the region of US$20.2–US$20.9 million.

The wetlands support the livelihoods of about 1.5 million farmers, herders and fishermen [32], thereby providing essential income and nutritional benefits for local populations. They are also notable as an important breeding ground for various migratory bird species [11,49]. They are an important water resource, thus serving as a catalyst for socio-economic activities and, as a result, enhancing social security. The soil of the wetlands, which is basically loamy, supports dry season farming, widespread wetland irrigation farming widely referred to as Fadama in the northern region of Nigeria. The wetlands also serve wider regional economic purposes such as providing dry-season grazing for semi-nomadic pastoralists and groundwater recharge [8,11,24].

In Nigeria, federal, state and local governments have responsibility for the environment, including environmental management. However, under the Nigerian constitution (formal law) the Land Use Act of 1978 nationalized all land and vested its management in state governments [17]. Though, the actual rule in use is such that both state government and traditional institutions still manage resources. The governance of HNWs rests on the Hadejia – Jama'are River Basin Development Authority, which is a Federal agency. Its main responsibility is to manage all surface and underground water resources development within the River Basin. However, other entities such as the Nguru Emirate Council, Nguru Integrated Farmers

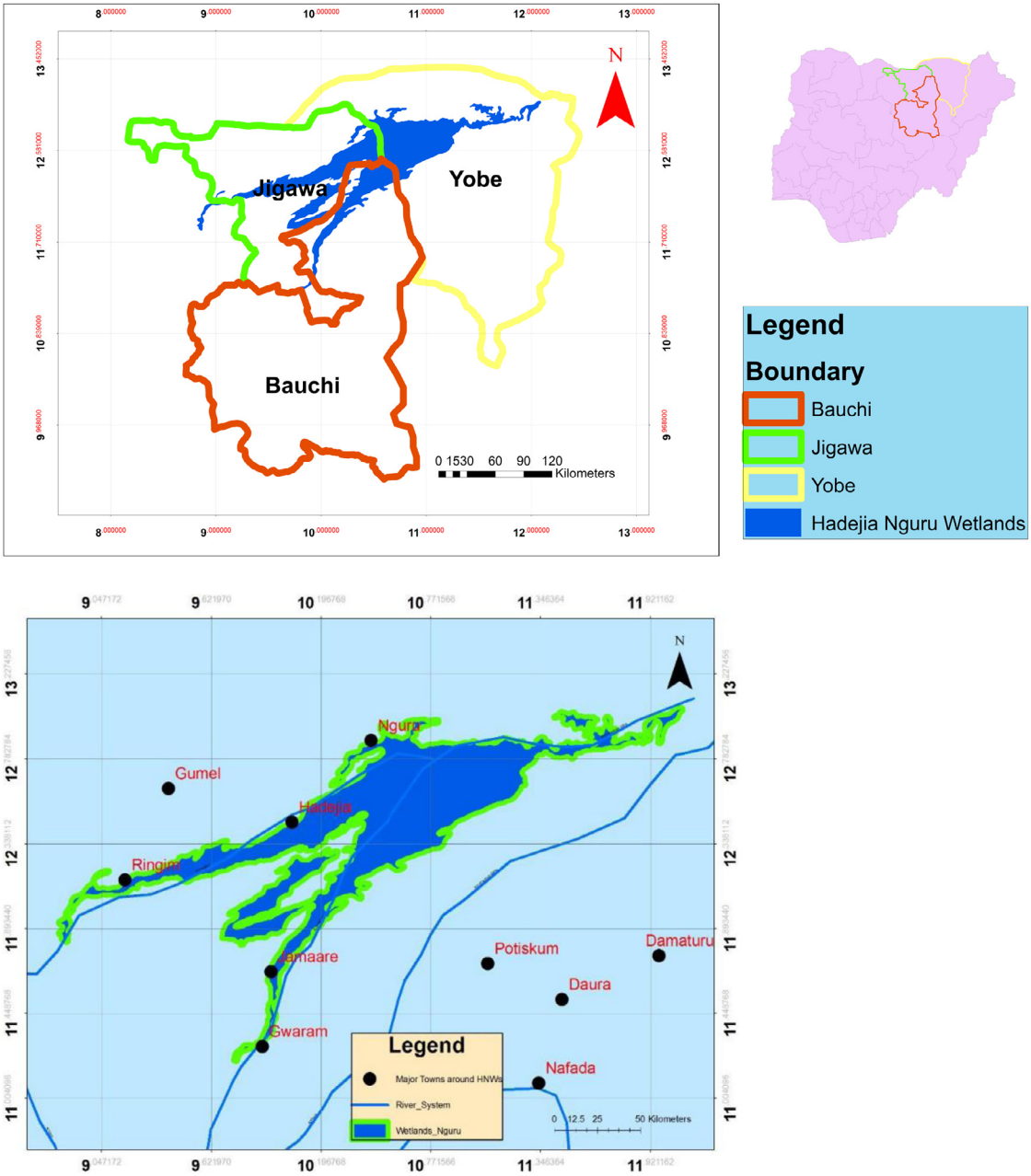

Fig. 1. Nigeria showing Hadejia Nguru Wetlands.

Association, and Nigerian Conservation Foundation are involved in day to day running of the wetlands. For instance, the Emirate Council is instrumental in managing access to the wetlands, conflict resolution, zoning of the resources and market regulation [48].

Methods and data

Study approach

The concept of ecosystem management approach [28] associated with biodiversity, water resources and ecosystem servicing was adopted in this study. The approach enables simultaneous focus on the biophysical, social, and economic issues; assessing policy implications for stakeholders and profer management alternative management approach to the utilisation of wetlands' resources. The study was also participatory to the extent that it integrated stakeholder engagement in project

Table 1
Selected villages, population and questionnaire distribution pattern.

	Communities				
	Adiani	Dabar Magini	Matara –Uku	Kasaga	Total
Projected Population based on 2006 census	3558	1670	2145	2851	**10,224**
Number of households	508	239	306	407	**1461**
Questionnaire administered	35	16	21	28	**100**

decision-making. This ensures inclusivity and a two way communication between stakeholders and researchers. Taken together, this approach ensured that our study explored the environmental, social and economic sustainability of wetland use from the perspective of all stakeholders.

Case study sites

The study was conducted in four purposively selected communities (Dabar-Magini, Matra-Uku, Adiani and Bambori) within the wetlands. These communities were selected because they are the major communities around the Ramsar site and located close to the Marma Channel that in turn receives a large amount of the water flowing into the Hadejia River. In addition, each of the four communities have a sub-channel that contributes to the major channel of the HNWs. The selected communities also show a good representation on the basis of general location within the Wetlands, distance from main roads and markets, type of natural environment and ethnic groups present which are major criteria used by Eaton and Sarch [25]. The communities are of similar size and have an estimated population of about 10,000 people (Table 1) in about 1400 households [37]. The land area of the four communitites accounts for about 35% of wetlands within the HNWs – Marma Channel which has a land area of 58,000 ha [41]. This translates to about 20,000 ha for our study area.

Data collection

The information necessary for this study is mainly from the communities' members - resource users' groups, community leaders and NGOs – Nigeria Conservation Foundation (NCF) and Nguru Integrated Farmers' Association (NIFA) in the HNWs. The required information was gathered using a combination of data collection methods including interviews, Focus Group Discussion (FGD), questionnaires and field observations. These methods were combined in this study as a means of triangulating in order to check the results of one and the same subject [39]. The key information collected includes types of resources, resource access, and availability, socio-economic activities of the users, market value and threats to these resources.

The study began with a reconnaissance visit conducted between July and August 2013 to get first-hand information on resource user groups and available wetland resources, management and uses. This afforded the opportunity to interact, secure confidence of the community by explaining the project and gather more information (such as dominant activities, location relative to the wetlands etc.) through field observations and interactions. Subsequently, a series of consultative meetings were held with the traditional heads of the selected communities to seek their opinions on the most important wetland resources to the communities and challenges and opportunities for better management. These informal interviews generated data on an approximate number of users harvesting each resource, quality, and quantity of resources for users and significant local benefits of the observed resources. The information was useful in structuring four Focus Group Discussions (FGDs) in each of the communities, conducted in November 2013. The FGD's focus was to identify various resource user groups in each of the four selected communities as well as to get their views on salient points that are useful in categorisation of the resources' potentials and values and to generate information on the potential value(s) of the resource(s). 4–6 participants were selected for each FGD based on suggestions made by village heads as to individuals' knowledgeable about the wetlands. Effort was made to include a range of socio-economic groups within each FGD. The FGDs were held in a neutral location but within close proximity to the village head's compound as participants suggested this will make them feel comfortable and relaxed because we are outsiders. The FGD was used to double check price of resources, the relative importance of wetland resources, threats to the wetlands, and resource use calendar and management options. The FGD adopted a participative ranking methodology [3]. For example, identification, categorization and valuation were done together with the selected communities' members.

Monetray valuation

In order to estimate the monetary value of the resources collected from the wetlands, data were collected on the value attached to wetland goods and services using a structured questionnaire. The data required include quantity of wetland products collected, the cost of production, price information and number of households depending on each wetland service. Considering the time available for the study, the essence was not to conduct a full economic valuation and we have therefore not factored in elements such as depreciation of inputs. Although, the survey provides useful information on values of

the wetlands and contribution to livelihoods, it could appear brief and oversimplified. A total of 100 questionnaires were administered using a systematic random sampling technique whereby households were selected diagonally. Respondents' households were selected after every nth (e.g. 5th) household (depending on the size of the village). The number of respondents from each village is based on the proportion of households in the village – on a pro-rating basis (Table 1). We included all visible households during the period of the questionnaire administration, covering permanent and semi-nomadic households. The questionnaire was administered to household heads. The survey was carried out in between December 2013 and February 2014, which coincided with the dry season. This was not deliberate but due to convenience and the peak period of HNWs resources' harvest which are mainly during the dry season. It is possible that conducting the survey in another season would yield different results. Perhaps a study that collects data in both wet and dry seasons would yield even better comparative results.

Monetary estimates of the main provisioning ecosystem services collected from the HNWs were calculated using information gathered during various stages of the data collection. The average weekly amount of each service was calculated using information from the FGD and questionnaire. During each FGD, participants used a participatory process to arrive at a consensus on the average amount each household collected per week. We then also estimated the average weekly quantity harvested from questionnaire responses. The average weekly quantity arrived at from the FGD and questionnaire was then used to estimate average weekly collection of each ecosystem service per household. This was extrapolated to a year by multiplying by 52 (number of weeks in a year). For example, the average quantity of doum palm collected by each household is between 30 and 51 bundles depending on access and availability. The average value of quantity from a questionnaire survey and FGD at 41 dundles is used as the average weekly quantity for this ecosystem service. This is then extrapolated to annual values by multiplying by 52 weeks. A similar approach was used in estimating the total number of households engaged in each activity. This was based on information provided during the FGD and that provided by key informants during the initial field reconnaissance. We have taken this approach rather than simply cross-checking values provided. The market value for each service was estimated based on average price over the two main seasons suggested during the FGD and that suggested by traders during visits to the local market. The average number of households engaged in each activity, average yearly quantity collected by each household and the average market price was then used to estimate the monetary value for each service. The monetary value used in this study was converted into US$ using an exchange rate of NG₦158.2 = 1US$ [16] prevailing in 2014 when our study was conducted. The monetary value in our study is then compared with that of three main services also valued by Eaton and Sarch [25], whose field work was conducted in July 1995, making it twenty years before our own study and hence providing a good temporal comparison of values. The study by Eaton and Sarch [25] conducted in Adiani, assessed the financial values, economic values and returns to labor of the wild resources that are of major importance within the HNWs using participatory appraisal techniques. The monetary value from Eaton and Sarch [25] was corrected for inflation to current value using the average 12.24 inflation rate during the period [52]. This is similar to the approach taken by Karanja and Saito [31]. We also discuss our results in the light of other inland wetlands/floodplain ecosystems stored in the Ecosystem Services Value Database (ESVD) (http://www.fsd.nl/esp/80763/5/0/50) [22].

During the FGD, each participant was asked to rank the five major threats identified as threatening the HNWs. The highest threat had a value of 5 and the lowest a value of 1. This was then aggregated. The threats were ranked on the magnitude of highest and lowest subject to the rate of natural and socio-economic damage.

Results

Direct and indirect uses of HNWs

The main ecosystem services provided by the HNWs and on which local communities depend were identified, quantified and evaluated. There are no defined boundaries for each of the identified activities. That said, while all services are open to all members of the community, farm lands are private properties allocated to individuals/families based on communal arrangements by the emirate council. The most widely identified and used ecosystem services provided by the HNWs include direct use services such as farming (cultivation of sorghum, rice), collection of materials such as potash, doum palm (*Hyphaene thebaica*) and fuelwood, water collection, fishing and hunting of water birds. Our results showed that these resources are available in all four communities studied. Although the number of households engaged in each activity differs, estimated quantity of each service collected in each community was not significantly different. Generally speaking, there is not much significant difference in the proportion of households using each service in each community except for a few instances. For example, there are more farmers than fishermen in Adiani compared to the other three villages where there are more fishermen than farmers. While we did not investigate the reason behind such disparities, it may be due to the population make-up of the area.

Fishing is the most popular wetland activity within the four study villages. Respondents identified about 46 species of fish including catfish and tilapia as commonly harvested from HNWs. This is followed by farming and material collection, respectively. Animal grazing is another important activity in the wetlands. Respondents pointed out that the pastures in the surrounding area often dry up quickly, especially during the dry season, making almost all cattle migrate to the wetlands area, where they feed until the rainy season. Although we have not valued activities of herders, Andrade et al. [5] suggested that over 250 herds of cattle are supported by the wetlands. The importance of HNWs as domestic water sources was also highlighted by respondents. Water collection, although not valued in this study, is one use almost every household benefits

Table 2
User groups within the HNWs.

User Groups		Adiani ($n=508$)	Dabar Magini ($n=239$)	Kasaga ($n=306$)	Matara Uku ($n=407$)	Total ($n=1461$)
Fishermen		308	196	292	400	1196
Farmers		488	92	231	323	1134
Material Collection	Fuelwood	277	143	126	289	835
	Non-Timber Forest Products users	92	57	77	77	303
	Weavers	154	31	31	46	262
	Fishing Traps Producers	46	31	46	31	154
Cattle Rearers (Herdsmen)		31	10	15	46	102
Hunting		7	11	7	19	44

from the wetlands. Respondents showed appreciation of the fact that the wetlands water system replenish various streams, wells, boreholes, dams and natural wells from which they collect water for domestic use. The importance of the wetlands as water sources for livestock is mostly of high value during dry seasons when large herds of cattle concentrate on wetlands water. In addition to direct services, 26% of respondents recognize indirect benefits including local climate regulation, a nursery for migratory birds, water regulation and purification, flood abatement and ecotourism services provided by the HNWs. This is interesting because it suggests that at least a quarter of the local communities recognie the indirect benefits derived from the wetlands.

All respondents in the HNWs depend on the wetlands for one direct use ecosystem service or the other. However, there was no household using the wetland for all the services. We found that the main socio-economic activities within the four communities were based on available resources as explained during the FGD and questionnaires administration.

Wetlands resources and users within Hadejia–Nguru Wetlands

Going further, respondents were asked to indicate the main ecosystem services collected from the wetland that best describe their household. On the basis of this, respondents were categoried into resource user groups. Five user groups were identified within the HNWs (Table 2). Overall, the fishermen is the most predominant group and accounted for 81.7% of all respondents. This is followed by farmers, material collectors, and grazers respectively. The result thus revealed that fishing and farming are the most important user groups in the four communities except for Dabar Magini, where the material collection is next to fishing, and in Adiani, where farming is the most important wetland activity (Table 2).

On a community basis, Adiani has the highest harvested fish and fuelwood on average (about 80 kg and 150 stacks, respectively). This may be attributed to the quantity of fish caught that also requires higher quantity for smoking. Matara-Uku recorded the highest doum palm quantity (about 51 bundles). The result is an indication that access to these resources is based on the volume of resources in each of the communities.

Results showed that the main socio-economic activities within the four communities were based on provisioning ecosystem services collected from the wetlands. For example, fish processing is noted as the main commercial activity, particularly during the dry season when the HNWs' water level reduces and therefore provides easy fish harvesting. We also identified the prevalence of associated economic activities such as the production of fishing traps.

Socio-economics and social security within the HNWs

Resource harvesting in the HNWs takes place throughout the year; for most uses, there are periods of higher intensity in the harvesting of wetland resources. Based on the response from a questionnaire survey complemented by FGD, Fig. 2 presents a calendar of activities in the wetlands. For example, cultivation takes place in the wetlands throughout the year. Irrigation farming is done in the first and last quarter of the year while rain-fed agriculture is between May and September of each year. Between the months of May and September, people rely on rain-fed cultivation, which is a farming practice that relies on rainfall for water. The crops cultivated during this period include corns. During the drier months of December to March, the wetland is relied on for irrigation. The main irrigation crops include vegetables. About 7.9% of respondents collect materials such as doum palm from the wetlands from March to October. The intensity of grazing activity in the wetlands is highest in the dry season; this corresponds to the period when grazing forage has reduced or is nonexistent from other nearby marginal fields. This period could be a potential conflict season between grazers and farmers. As such, this should be a period wetland managers focus on in terms of conflict management between these two groups. Although fishing is an all year round activity within the HNWs, it is highest between March and November, corresponding to wet cropping season when croppers are present in the wetland, and lowest in the dry season when most croppers are not there.

Socio-economic endeavors associated with each of these activities are also recorded and in most instances, are carried out simultaneously with the activity. Fishing and processes occur simultaneously starting in February and ending in November. (The months of January and December are always too cold for fishing.) These socio-economic activities are linked to the wetlands' resources, thus further contributing to sustaining the livelihoods of communities. While men are generally

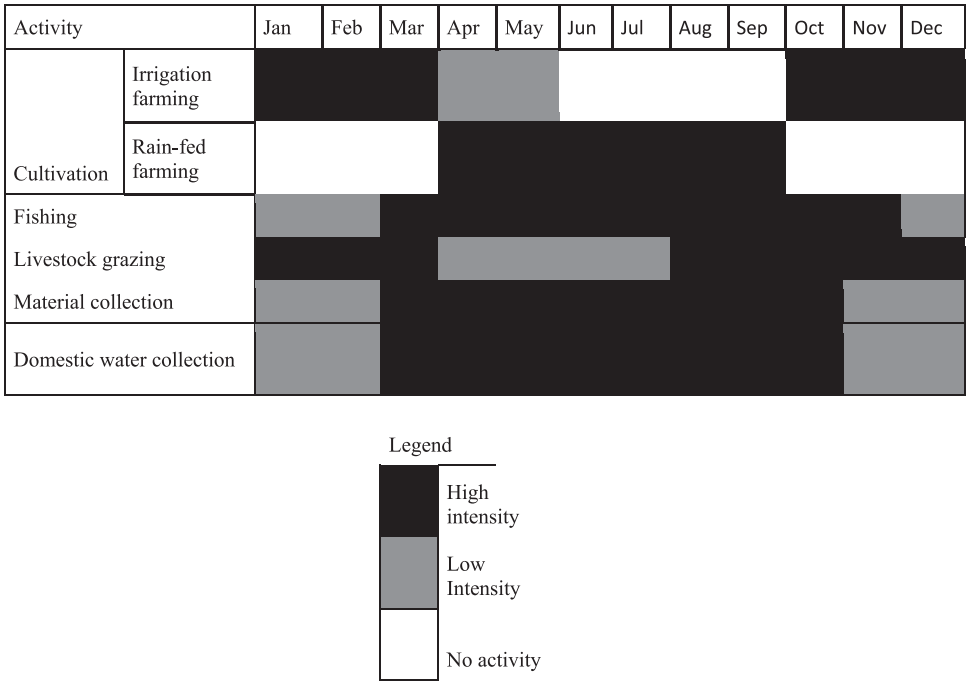

Fig. 2. Socio-economic activities within and around the HNWs.

Table 3
Household user groups' weekly average income per activities.

Ecosystem service		Total no of households (hh)	Average quantity collected/ hh/year	Average Price/ Unit (US$)	Value/household/ year (US$)	Value/ha/ year (US$)
Fishing		1196	4160	223	5864	351
[!]Farming		1134	1404	325	2884	164
Material collection	Fuelwood	835	5200	13	427	18
	[^]Non-Timber Forest Products	303	2184	340	4694	71
	Weavers	262				
	Fishing Trap products	154		**Not valued**		
Cattle Rearing		102				
Hunting		44	624	175	690	2
Total				1076	14,559	605

*1US$ = 158.2 in 2014.
[!] Mainly sorghum.
[^] Mainly Doum palm.

involved in primary production such as fishing, farming, and cattle rearing, women are engaged in secondary income generating activities such as fish processing and milking of cattle.

Monetary value of HNWs service

Our main interest is not to present a total economic value of the HNWs. Rather, our focus is to estimate a monetary value of the main ecosystem services provided by the wetlands that will be comparable with previous studies. This will provide up to date information that can spur decision managers to understand and not underestimate the value of the wetlands.

The monetary value for each ecosystem service is shown in Table 3. Fishing accrued the value of about US$5864/household/year. This is followed by doum palm harvesting at US$4694/household/year. The implication of this is that fishing serves as the most lucrative business on the HNWs and is contributing about 40% of income from all activities. Fuelwood contributes the least with 3%.

The study area is estimated to be about 20,000 ha and the total value of services valued is estimated as US$ 12,100,000. Therefore, we estimate that the wetland yields about US$605/ha/year.

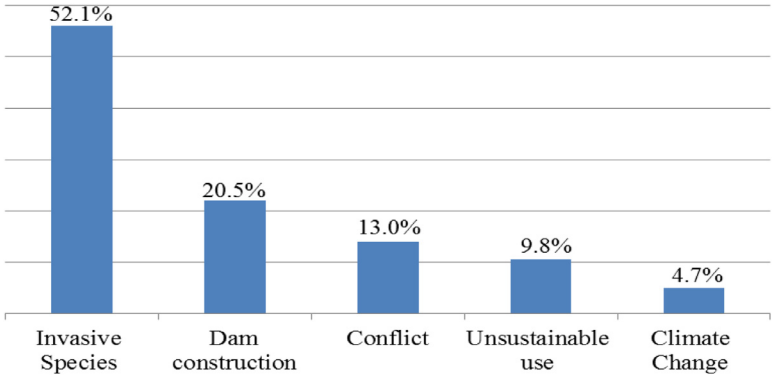

Fig. 3. Wetlands threats across the study area.

Fig. 4. Invasive typha grass blocking the waterway on the HNWs.

Observed threats and their impacts on the HNWs

The HNWs are very productive and widely used by local people; however, the wetlands are still subjected to many threats which may reduce their potential functions. Respondents were asked to identify the threats and assess their impact on people and biodiversity (Fig. 3).

The communities ranked invasive species (Typha – also known as "Kachala" by the people living around the HNWs) as the main threat (Fig. 3). Typha grass is suspected to have invaded Nigerian inland wetlands from East Africa [44]. The plant has caused damage to most of the waterways and bodies in the HNWs schemes and floodplains (Fig. 4). Further discussion revealed that it disturbs fishing, impedes navigation and has led to a reduction in a fish catch as well as an increase in malaria due to stagnated water. There is also a perception that Typha grass aids flooding as it often impedes the flow of rainwater. The floods then lead to the destruction of farmlands, which in turn exacerbates conflict between farmers and herdsmen that now compete for the land available. Previous efforts by governments to effectively manage or develop a plan to control this invasive species seem unsuccessful [12].

The second major threat identified by respondents is dam construction across the river systems. The locals explained, damming of the various river systems that feed the HNWs has led to a decline of available wetlands resources. It is generally believed that the reduction in water and issues with flooding became more pronounced after the construction of dams [10,30]. In the locals' perception, this has also hampered the movement of fish and some water resources along the channels, hence creating a limitation to the functions of channels. As a result, these resources cannot reach downstream communities, which consequently leads to conflicts between the downstream and upstream communities.

Conflict borne out of competition for resources by the different users is the third perceived most important threat to the wetlands. This has been variously reported in other studies [38,43]. A typical example of these conflicts is that between farmers and Fulani herdsmen resulting from flooding that reduces pasture area and farmlands. The first two threats are believed to be the root cause of conflicts in the wetlands, especially among farmers and herdsmen. For instance, floods resulting from blocked river channels and dam construction restrict available land for both farmers and herdsmen and exacerbate conflict between the two groups of resource users.

Climate change was identified by participants in terms of changing rainfall and temperature patterns. They believe this poses threats to human activities such as excessive heat and that they can manage this through local knowledge if most of the earlier mentioned threats can be curtailed. According to one of the FGD participants, "Yes, there is a change in temperature but we have been dealing with temperature all our life. The main problem is this dam and Kachala".

Table 4
Comparing value from previous study and this study.

Ecosystem service	Eaton and Sarch [25]		This study	% Change in monetary value
	1994 value (₦)	2014 value (₦)	2014 estimate (₦)	
Doum palm	8,800,000	88,600,431	68,315,520	−23
Fuelwood	850,000	8,557,996	18,725,200	+119
Agriculture	40,000,000	402,729,230	222,674,400	−45

Comparative analysis

We also wanted to know how the value of provisioning ecosystems services in HNWs have changed for nearly two decades. Table 4 shows a comparison of our values with the values from Eaton and Sarch [25]. We found that the monetary value of doum palm and agriculture appear to be declining, that of fuelwood is on the increase. We also found that the number of participating households seems to have declined. For instance, Eaton and Sarch [25] estimated the number of doum palm collectors in Adiani at 150. In our study, we estimated 92 households, which is around a 39% reduction in a number of participating households.

Discussion

Importance of the HNWs to livelihoods

This study underscores the fact that provisioning services provided by African wetlands contribute a great deal to the sustenance of the livelihoods of many local communities. Most of the services collected are used directly for household consumption with a portion sold for income or processed into secondary products (i.e., weaved mats) that are also mostly sold. Ecosystem services from the HNWs were for all households the main source of food (sorghum and millet), protein (fish and hunted game), cooking energy (fuelwood) and other goods needed for day to day life (such as the material used to weave sleeping mats and fish traps). This is in tandem with other studies of African and Nigerian wetlands [1,33] that have found to a large extent a majority of the population living around the wetlands rely on them for one use or the other. Although we found that most of the provisioning services provided by the HNWs are seasonal and periods of abundance vary throughout the year (corresponding to wet and dry seasons), all households indicated they do get at least a benefit from the wetlands during both seasons [30,51]. This implies that, considering the arid nature of the environment, even when, for example, it is not possible for farming households in the dry season to cultivate, they resort to fishing to sustain their livelihood in the wet season. This provides alternatives for households in seasons when their quantity of resources or their main household service might have reduced. Thus, provisioning services from the HNWs are critical to the livelihoods of local households and ensure livelihood security throughout the year. For instance, respondents generally sell caught fish at local markets or to wholesalers. They also often process fish dried or smoked, which may bring in higher returns. This further buttress the fact that the HNWs support a wide range of income-generating activities that enhance the people's ability to engage in other productive ventures such as employment as canoe carvers or fishing net weavers. As Adekola et al. [1] pointed out, income generated from wetland services support other livelihood needs such as sending children to school and taking care of medical needs. The HNWs are important not only for food security and the other wide array of economic activities in communities but also income generated from wetland activities plays an important role in meeting other livelihood needs. As pointed out by one of the respondents, even though he does not have herds of cattle grazing the wetlands, he has a goat he bought for upcoming Islamic festivities which he does not need to bother buying feed for because it can easily graze in the wetlands.

Aside from provisioning services provided by the HNWs, participants identified other non-provisioning services. In a study of the Niger Delta wetlands, up to 31% of respondents relate wetlands to some indirect benefits [1]. This suggests that although indirect non-provisioning services derived from the wetlands are not as widely recognied as provisioning services, a substantial number of respondents are beginning to recognie the former. In order to adequately protect African wetlands, information linking wetlands and indirect benefits such as regulating and supporting values need to be enhanced. The fact that a majority of studies assessing ecosystem services of African wetlands focus on provisioning services which are of direct use without much work on indirect uses may be responsible for a lack of local level appreciation of indirect values. Though, studies have identified indirect uses of the HNWs including climate modification, flood control, water regulation/discharge and how they contribute to wider benefits beyond the local context [34,49]. For instance, the nursery function of the HNWs, which provide a rich habitat for migratory birds during the wintering period. However, valuation of such indirect uses has not been given very much attention. While this underscores a need for co-management of such globally important ecosystems involving organizations beyond national boundaries, it is perhaps also time for local and international researchers to extend work on documenting and valuing indirect uses provided by regulating, cultural and supporting services in the HNWs.

Comparison with literature and future outlook

In our study the value of the provisioning ecosystem services estimated to be US$604/hr/yr is about three times less than US$1894/hr/yr (2014 value) estimate by De Groot et al. [22] for Provisioning services of inland wetlands. It is important to note that we have not valued all provisioning ecosystem services provided by the HNWs, as such this value is certainly an under-estimate of the economic importance of the HNW. When per hectare value estimates from our study is compared with standardized values of similar wetlands from the Ecosystem Services Value Database (ESVD), there appear to be no definite pattern. For example, in our study, fish valued at US$351/ha/year is higher than those from other comparable studies which ranged between US$143/hr/year–US$261/ha/year [46,47,53]. Likewise, the value of food from farming estimated in this study to be US$164/hr/year is higher than that estimated by Schuijt [46] for the entire Hadejia Nguru Wetlands at US$134/hr/year. However, the value of fuelwood estimated in this study to be US$18/hr/year is ovr seven times less than the US$138/hr/year estimated by Schuijt [46] for the entire Hadejia Nguri Wetland. While we found that the per capita value of fuelwood has increased by 119%, the value per hectre had drastically reduced. This increase in per capita value could be because the number of participating households have reduced. The implication of the increased deforestation is probably seen in the reduction in the value of other wetland services including farming and material collection. This in itself is socially unsuatainable as some member of the community engaged in fuelwoord collection are able to increase their benefits from the wetlands but at the detriments of the majority of the community. While we have made these broad comparisms, we do recognize that all wetlands are different and various variable infleunces their value. De Groot et al. [22], pointed out that the variables that influences the value of inland wetlands "included the area of the study site, the type of inland wetland, GDP/capita, and population of the country in which the wetland occurred, the proximity of other wetlands, and the valuation method used for the study".

While the importance of the HNWs cannot be overstated, the current management approach does not appear to be sustainable. This has direct implications for the local communities and nature. Our study suggests it could lead to new conflicts among wetland user goups (e.g., between fuelwood collectors and doum plant collectors). Rather rather than be the center of conflicts, a sustainably managed HNWs is strategically positioned to play a role in reducing southward movement of herdmen, thereby curtailing the frequent herdmen-farmer conflicts in Nigeria [40]. Furthermore, in the context of the impacts of climate change, the wetlands are even more critical than ever to achieve sustainable development. Our study further underscore the interlinkages between various wetland functions and ecosystem services. For example, the unsustainable use of one ecosystem service could disrupt the entire ecosystem. When there is uncontrolled felling of tree for firewood, could affect the provision of other services such as material collection which in turn, affects the food security of local populations and may lead to conflicts.

This study serves as an addition to other studies that have highlighted the importance of understanding temporal changes in the monetrary value of ecosystem services. This is important in showing the extent to which the value of the wetlands might have depreciated or appreciated over a period of time. In addition, this understanding was important in identifying potential conflict areas among various wetland users. Such information will be useful to decision makers and wetland managers (i) to understand the possible implications of their decisions today on the value of the wetlands in years to come and (ii) to plan and manage potential conflicts in the use of multifunctional wetlands.

Management of the HNWs

In our study, the menace of invasive species and impact of dams are perceived as being the greatest threat to benefits derived from the wetlands. This is mostly felt by those depending on fishing, which is the most important service and source of socio-economic security in the HNWs area. Thus, any threat to fishing will have the potential of disrupting the livelihoods of locals. The menace of invasive Typha grass has been widely reported in the literature [32,45]. Most of the efforts at controlling Typha grass have been mainly championed by the government and have not yielded much result [12]. There are recent suggestions of alternative use of these invasive plants as fuelwood by converting them into briquettes and charcoal for cooking energy [15]. With increasing human encroachment into the wetlands and various threats degrading them, resource users, especially farmers and grazers, often compete for scarce resources, leading to conflict. The conflicts may persist due to increasing populations (more pressure on resources) and result to decline in resources [36]. Farmer-grazer conflicts in the area are widely reported as often leading to loss of lives and properties [40,50]. Our findings suggest that considering that part of the farming season coincides with a period of scarce foraging in the wetlands because of the dry season, most livestock grazers could encroach into farmland in the process of finding forage for their cattle. Therefore, it is important in the management of the wetlands for managers to explore options that vary resource use access to the different groups. For instance, in periods (using the calendar) wherein farmers are harvesting their crops, herders can use the wetlands to graze their crops. According to some farmers, they are happy to preserve some of the waste products during harvesting and give to cattle grazers for free and in turn the droppings of the animals aid the fertilization of the soil. These are potential avenues the wetland managers can explore by creating a mechanism through which farmers and grazers can collaborate. This suggestion is based on the fact that harvesting is completed towards November which allows the cattle to graze and feed on the maize and millet stacks while their dropping becomes source of manure for the farms. This idea supports the proposed calendar usage of the HNWs.

Conclusions

This study evaluated the monetary value of the HNWs and compared the values to previous study. It adds to the growing number of economic valuation studies of wetlands in Nigeria and provides an updated monetary value of some provisioning ecosystem services provided by the HNWs. Comparing our estimates to those from previous work underscores the need for comparative studies of ecosystem services at various time periods as this could shed further light on changes in ecosystems, which could provide a powerful tool for wetland managers and decision-makers. While we have used values from Adiani which we were able to compare to those of Eaton and Sarch [25], our valuation is not complete as we have not valued all services provided by the wetlands (i.e., value from grazing, water collection, etc.) and we have taken a somewhat simplistic approach to the valuation as we have discounted cost (i.e., of labor and inputs) in our estimates. Furthermore, it would have been interesting to explore more the possible reason for the change in value and see if this corresponds with actual services on the ground. A study using remotely sensed data could yield better insight into this.

This study also highlighted the fact that inhabitants of the HNWs are to a large extent dependent on the wetlands for subsistence and income. In order to ensure continued benefits of the HNWs, managers will need to find solutions to the twin threats of invasive plants and impacts of dams, which have resulted in resource shortage causing conflicts, especially among herders and farmers. A way out of this could be using a wetland activity calendar in arranging allocating/planning periods for each user group to have priority in areas of the wetlands. Developing a workable resource users' calendar through participatory methods could be explored. Having an understanding of resource use calendars is important to the proper and fair management of natural resources, especially in multifunctional ecosystems like wetlands where there are competing need and groups. Furthermore, controlling the menace of invasive Typha grass should be a priority for governments and other stakeholders. However, future studies will be needed to understand how the idea of implementing wetlands use calender and zoning will work in reality and potential use of the invasive Typha grass.

Declaration of Competing Interest

None.

CRediT authorship contribution statement

A.O. Ayeni: Conceptualization, Formal analysis, Supervision, Writing - original draft. **A.A. Ogunsesan:** Conceptualization, Data curation, Formal analysis, Writing - original draft, Methodology. **O.A. Adekola:** Writing - original draft, Methodology, Writing - review & editing.

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