Application of Remote Sensing/ GIS in Monitoring *Typha* spp. Invasion and Challenges of Wetland Ecosystems Services in Dry Environment of Hadejia Nguru Wetland System Nigeria

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ABSTRACT

Although, the threat posed by *Typha* invasion to wetland utilization has been widely acknowledged in the Hadejia Nguru wetlands, yet little or no monitoring has been done to quantify the extent and time analysis of the threat. Remote sensing and GIS techniques were used in this study to monitor the Spatio-temporal dynamics of *Typha* spp. invasion in the dry environment of the Hadejia Nguru Wetlands of NE Nigeria. Satellite images of Band 1, 2, 3, and 4 from Landsat ETM+ were acquired between 2003 and 2015 and natural color from GeoEye-1 in 2016 where image classification, change detection and spatial statistics were performed. To evaluate the impact of *Typha* grass on the livelihood of the people, a field investigation involving administration of 200 questionnaires was conducted among the two major wetland users: the farmers and the fishermen. The result from the RS/GIS revealed that *Typha* grass recorded an astronomical growth of 1013% between 2003 and 2009 and another incremental of 32% in 2015. The ANOVA test on land cover change in 2003, 2009 and 2015 showed a significant variation in land cover and use changes at $p < 0.05$. The findings from field survey showed that *Typha* grass accounted for 70% decrease in land available for farmland and subsequent reduction in crop output by 90%. It also accounted for 80% reduction in total fish caught as compared to non *Typha* infested land and open water. Strategic and selective weeding by mechanical and manual techniques was therefore suggested as control measures to save the wetland ecosystem and wetland users' livelihood.

Keywords: Wetland/ *Typha* invasion/ Ecosystems/ Land use / Land cover
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1. INTRODUCTION

Water is a major and valuable natural resource of the environment. Most dry environments are inhabited by poor people who have negligible resources at their disposal (Singh, 1998). The major problem of the dry environments is that they suffer from moisture stress and thereby affecting the different types of productions (Amanullah et al., 2016). Given this scenario, the presence of any reasonable water point in the dry environment signifies the presence of life. Wetlands, according to Botkin and Keller (1998) are among the most productive ecological communities in the world and many times more than a heavily fertilized corn field. Wetlands contributed many products to the rural economy; fishing and domestic fishponds are important sources of protein, so was wild fowling (Botkin and Keller, 1998; Cronk and Fennesy, 2001). Wetlands are natural habitat for several species of water birds. About 423, 166 water birds of 68 species were identified in Hadejia Nguru Wetland (NCF, 2014).

Reeds and sedges were harvested for the thatch that was the main roofing materials in many parts of the developing world. The value of wetlands has also been based on economic criteria, the monetary values of cranberries, forest products, peat and other items generated in wetlands have been considerable (Green, 1992). Despite the great value of wetland resource, its existence has been under serious threats over the years in several parts of the world. Davidson (2014) reported a relatively higher level of decline in the size of inland wetlands at 69-75% during the 20th Century with global rates between 64% and 71% in the same period. However, at its 12th Ramsar COP meeting, it was

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noted that its designated wetlands in the tropics are declining in spite of measure to protect them (Gardner et al., 2015; Ramsar, 2016). Kennish (2000) reported that over 50% of the wetland in the United State (US) have disappeared in the last 200 years and as much as 90% of the fresh water wetlands in US as a result of activities and negligence, a situation which prompted the passage of the clean water act in the United States in 1977 (amended in 1987) with the aim of protecting the Wetland from further degradation and destruction. On the other hand, however, wetlands are highly sensitive to changes associated with plant invasions (Zedler and Kercher, 2004; McCary et al., 2016). A similar example was recently reported by Onwuteaka et al. (2016) about the effects of *Nypa fruticans* (Nypa palm) on the Niger Delta Mangrove wetland ecosystem.

Given the fact that the presence of wetlands in an otherwise arid environment is seen as a resource to be jealously guarded not only because it could act as safety nets due to their higher productivity especially during dry periods (Uyanga and Ekop, 2004) but also the biodiversity or eco-balance they provide (Botkin and Keller, 1998). It is therefore necessary that whatsoever may affect this valuable resource demand serious and urgent attention (Barbier et al., 2008).

Application of remote sensing data had been severally used in monitoring wetland health and status over the years. Jensen et al. (1995) had used aerial photograph and satellite remote sensing to detect changes in wetland plant communities as a result of human activities. The determination of vegetation percentage cover and plant succession in the wetland had been carried out successfully with the aid of GIS and remote sensing data (Tiner, 2004). Although the use of satellite remote sensing and GIS data has proven useful in large scale monitoring of various ecosystems, especially in the difficult terrain and inaccessible water bodies, field validation (ground truthing) and good knowledge of plant communities of the wetlands are required for meaningful interpretation of data obtained (Papasterigiadou et al., 2008).

1.1 Wetland ecosystem services and functions

A good understanding of the functions, values and services of wetland will help in appreciating the threats to its existence and utilization. An ecosystems service is broadly defined as benefit obtained from ecosystem (MA 2003, 2005), which can be direct or indirect TEEB (2010) and were classified into four major categories by Millennium Assessments (MA) viz: provisioning services, regulating services, cultural services, and supporting services (EU, 2013). Wetlands have several function and values of which the major ones are discussed here. Basically these functions can be categorized into hydrological and socio-economic functions.

1.1.1 Wetland as natural water storage and flood control

The role of swamps (wetlands) in African hydrology has been partly reviewed by Balek (1977). He emphasized the fact that the presence of wetlands reduced surface run off thus for a catchments with and annual rainfall of 750 mm, the annual run off could be reduced from 56 mm to 3 mm if the swamp area increased from 1% to 10% of the catchment area. Thompson (1974) and Thompson and Hamilton (1983) pointed out the storage value of the swamps (wetlands) of the White Nile which provides 83% of the low flow (dry season) discharge to the lower Nile. Trambauer et al. (2013) also provide a review of models potentially useful for hydrological drought forecasting in relation to African wetlands. The recharge role of the annual floods for the shallow alluvial aquifers around HNW and the Chad formation upstream of the wetlands according to Bdliya (1998), support the vast majority of the populace within the region who are dependent on groundwater for domestic use and agricultural activities.

1.1.2 Wetland as soil and sediment trap

The efficiency of wetlands as sediment traps has been documented by various scholars. Guillarmod (1972) discussed the role of the bogs and sponges of the high altitude areas in Lesotho in the prevention of soil erosion, and points to the disastrous effects of burning and grazing these areas. Soil nutrient deficiency problems are widespread in Africa, but flood plains and other wetlands enjoy the benefits of water borne nutrients. Floodplain and wetland dwellers in Africa do not have to practice shifting agriculture as land is “re-fertilized” by trapped sediment during the annual or biannual floods. The Gezira area on the Nile floodplain (Barnett, 1977), the Rufiji plains in Tanzania (Bernascek, 1981) and the Pongolo floodplain in South Africa and Mozambique (Heeg and Breen, 1982) provide good illustration of this sediment “re-fertilization”.

1.1.3 Wetlands as valuable wild life areas

Wetlands are extensively utilized by wild game of all types. Wetlands usually provide good grazing and shelter during the dry months and are used by both game and domestic animals alike. The value of African wetlands as bird refuges and habitats, especially for migratory species is well known. Batchelor (1978) points out that African waterfowl require two types of wetland, those which offer refuge and a feeding area during the dry season and those which serve as a breeding habitat.

In 1995, there were over 38 water related bird species with a total population of over 259,000 in Hadejia-Nguru wetlands (Bdliya, 1998) and by 1996, a year after over 47 species were counted with a corresponding high number of birds (Bdliya, 1998) The presence of these birds provides a unique opportunity for tourism, education and scientific research and this prompted the designation of parts of the wetlands as a component of the lake Chad Basin National park in 1992. Several wild resources are harvested from the wetlands for food, medicine, fiber and other uses for both domestic and commercial purposes. According to Hadejia-Nguru wetland conservation project (HNWCP), it has been estimated that about N35 million worth of palm fronds is freighted annually out of the area (HNWCP, 1993).

1.1.4 Wetlands as centre for food supply

It is in this context that wetland is believed to have both their greatest value and also face their greatest threat (Denny, 1985). Reimold (1994) describes wetland as area for food chain support. Floodplains/wetlands ecosystems are comprised of two complementary phase; aquatic (during which they are submerged) and terrestrial, following drawdown. During the aquatic phases, wetlands plants can be harvested directly as fodder crops for livestock. During the dry season, African wetlands are used extensively for livestock grazing.

The annual net benefits of fourteen agricultural crops grown in the flood plain of the Hadejia-Nguru wetlands, as found out by Barbier et al. (1993) show that, at 1989 - 1990 prices, each of the 230,000 hectares that were cultivated in the wetlands yielded agricultural crops with a net worth totaling N 54,970,000 for the wetlands as a whole. When converted to the 1996 rate, the total amount was N 604,670,000 if yield remained the same. Wetlands soils are generally suitable for rice cultivation, especially in Nigeria use of wetland, which is indeed limited in areas where rice is not a major or even a minor crop (Akamigbo, 2001).

1.1.5 Wetlands as fish habitat

The fisheries potential of African wetlands is enormous and yet is under exploited (Denny, 1985). An important aspect of fish productivity in the wetland systems is that of interface areas. This interface (moderately emergent vegetation with open water) is essential for providing feeding, breeding and sheltering areas for fish in all of the large shallow African fisheries. The most productive wetlands from wildlife and fishery point of view are those with a complex structure and zonation, with areas of open water interspersed with vegetation (Weller, 1978), Toews and Griffith (1979) found gillnet catches in the Bangweulu Swamps to be three times than the open lake. Also, Barbier et al. (1993) reported that each of the 100,000 hectares that are fished in the HNW gave a catch with a net worth of N 17,900,000 in 1989-1990, and if converted to the rate at the time of report, it means an annual catch is worth of N 196,900,000 (Bdliya, 1998).

1.2 *Typha* grass: the ecology, morphology and distribution in HNW

In recent times, *Typha* grass, otherwise known as “Kachalla” among the natives in the study area, has become a common sight in the wetland. This is particularly noticeable at the Bambori-Nguru section of the Wetland (Figure 1) as one travels along Nguru-Gashua road. Road users and villagers within the vicinity are confronted with an offensive odor coming from the water bodies either due to partly decomposed *Typha* grass and or dead fish and, it is equally reported that aquatic lives notably fish population and numbers of migratory birds are declining while it is progressively providing a suitable habitat for mosquito breeding and high incidence of malaria fever (Salako et al., 2016). Bdliya and Mohammed (2003) reported that the most outstanding impact of the threats on the Wetland is the creation of a conducive condition for *Typha* invasion, which now occupies over 200 km^2 of farmlands and fishing grounds. It has also contributed to the blockage of several channels. Also farmers and fishermen are complaining of their farmland and fishing ground being overtaken by the grass thereby affecting their means of livelihood.

Figure 1. A dense canopy of *Typha* grass in Nguru section of Hadejia Nguru wetlands

Akobundu (1987) identified *Typha* grass as one of the prominent emergent macrophytes in wetlands or flooded areas and perhaps among the notorious plants causing economic hardship in the tropics. *Typha* is an emergent monocotyledon which produces erect, approximately linear leaves from extensive anchoring systems of rhizomes and roots. Epidermal cells are elongated parallel to the long axis of the leaf, which allows flexibility for bending. The cell walls are heavily thickened with cellulose, which provides the necessary rigidity. The root and rhizome systems of *Typha* exist in permanently anaerobic sediments and must obtain oxygen from the aerial organs for sustained development. Similarly, the young foliage under water must be capable of respiring anaerobically for a brief period until the aerial habitat is reached, since the oxygen content of the water is extremely low in comparison to that of the air. Once the foliage has emerged into the aerial habitat, the intercellular gas channels and lacunae increase in size, thus facilitating gaseous exchange between the rooting tissues and the atmosphere.

2. METHODOLOGY

2.1 Study area

The study area is located within the Hadejia-Nguru Wetlands (HNW) system between latitude 12.3829°-12.9036° N and longitude 10.1851°-10.6748° E and occupies an area of 3,500 km^2, bounded by routes linking Hadejia, Katagum, Nguru and Gashua towns (Figure 2). The Hadejia-Nguru Wetlands (HNW) run through the semi-arid environment of north western and north eastern parts of Nigeria, cutting across Kano, Bauchi, Jigawa, and Yobe States of Nigeria and supporting over 7 million population including migrants from Niger Republic (Bdliya and Mohammed, 2003). The climate is generally characterized by distinct dry and wet seasons. The dry season which normally lasts for 7 months usually starts from October to April, punctuated by the cold harmattan condition between December and February. The temperatures in the Wetlands vary with the time of the year reaching the peak (max.) about 41 ^{o}C in April and May and about 29 ^{o}C (min.) during the harmattan in January. Rainfall pattern in HNW has not been stable over the years, but in most cases, rainfall starts from June till September and sometimes October in a rainy year with a long break of up to a month in between the first rain and subsequent ones. Months of July and August are the only reliable periods of rainfall. The total annual rainfall ranges from 500 mm to 700 mm.

The data for this study were obtained from reconnaissance survey, observations, satellite images and questionnaires. The climatic data of the study area were extracted from WorldClim database and the Nigerian meteorological centre at Nguru. Maps and diagrams of Hadejia-Nguru wetland area were prepared from shapefile data. Population data was obtained from the National Bureau of Statistics based on the national population census of 2006.

2.2 Remote sensing and GIS data analysis

Four different bands of revised 2003, 2009 and 2015 USGS Landsat 7 Enhanced Thematic Mapper Plus (ETM+) of the study area on path 187, row 051 at a spatial resolution 28.5 m, and 90% cloud free were acquired (Table 1). GeoEye-1 image of 2016 of natural color was also obtained at resolution of 70 cm. This high resolution images were used as ancillary materials towards images classification by performing image enhancement through histogram equalization. All the images were georeferenced, overlaid and subset into the study area shapefile.

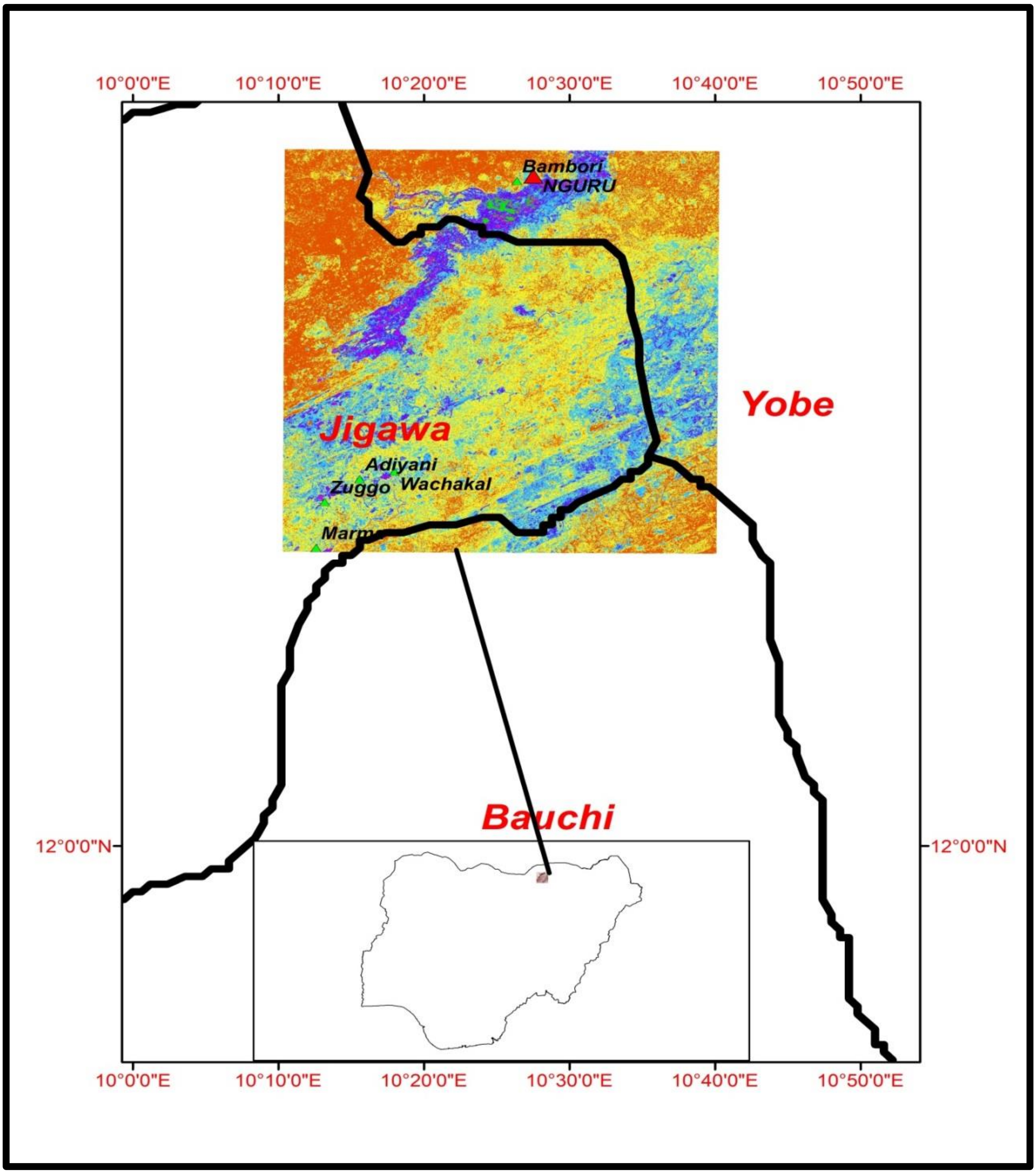


Figure 2. Study area showing sampled settlements

Table 1. Data summary

Satellite sensors	Spectral resolution (μm)	Spatial resolution	Format	Path/ Row	Date of acquisition
Landsat 7	B1 0.45 - 0.515	28.5 m	GeoTiff	187/051	Aug 25, 2003
Enhanced	B2 0.525 - 0.605	28.5 m	GeoTiff	187/051	Aug 15, 2009
Thematic Mapper	B3 0.63 - 0.69	28.5 m	GeoTiff	187/051	Jun 20, 2015
Plus (ETM+)	B4 0.75 - 0.90	28.5 m	GeoTiff	187/051	Jun 20, 2015
GeoEye-1	Natural colour	70 cm	JPEG	Study area shapefile	Aug 21, 2016

To prepare land use/land cover of the selected area in the HNW: First, image band composite were performed on bands 1, 2, 3, and 4 in ArcGIS 10.2. Bands 3, 2, 1 were included in the band composite because of its ability to identify water body and man-made features, with vegetation showing in green natural colour. Band 4 (near infrared) and Band 3 were required for running Normalised Difference Vegetation Index (NDVI) and was used as ancillary data for image supervised classification. NDVI is a Remote Sensing/ GIS techniques used over the years by scientists to quantitatively and qualitatively evaluate the vegetation cover of an area (Neelima et al., 2013).

NDVI as proposed by Rouse et al. (1974) is mathematically defined as:

$$\mathrm{NDVI} = \frac{\mathrm{NIR} - \mathrm{R}}{\mathrm{NIR} + \mathrm{R}}$$

Where, NIR and R are the reflectance in the near infrared and red regions respectively. It is the algebraic combination of red and near infrared bands to represent the amount of green vegetation in the image. In the NDVI, the values for a given pixel are always in a number that ranges from -1 to +1. A zero means sparse or no vegetation and close to 1 indicates the highest possibility of green leaves (Biehl, 2010).

Second, an iterative isodata Maximum Likelihood Classification (MLC) algorithm was run on the combined images bands 4, 3, 2 and 1. This helped in grouping similar pixels in the images into clusters or categories as an unsupervised classification.

Thirdly, we conducted field survey (Ground truthing) using Garmin GPS to capture the geographic coordinates (Lat/Lon) of up to 150 points on the field to identify *Typha* grass and shrubs/forests, wetlands and others adjoining land use/ land cover. 117 of these points were overlaid on the previously unsupervised classes with an average of 30 points randomly selected in each clusters and compared with field samples and were used as training data in running supervised classification in ArcGIS 10.2 version. The combinations of field survey, training data and the result from NDVI (Vegetation index) which indicated the gradient in plant vigour were used as referenced data to validate the classification accuracy.

The MARKOV module in Idrisi 32 was used to create a transition probability matrix. Transition probabilities express the likelihood that a pixel of a given class will change to any other class (or stay the same) in the next time period. As input, two land cover maps of 2009 and 2015 were chosen where a probability matrix (Table 7) was generated.

The questionnaire was designed to extract the following information: types of crop grown, estimated farm size, estimated annual yield and income, species and quantity of fish caught, fishing and farm sites, proportion of farm/ fishing ground under *Typha* infestation, causes of invasion as perceived by the locals, local coping strategies/ weed control.

2.3 Field survey: administration of questionnaire

The sample frame consists of all the villages in the Marma-Nguru Lake Complex of the Wetlands. The target populations were the wetland farmers and fishermen of 16 years and above. A total of 5 villages/settlements out of the estimated 50 villages (representing 10% of the total villages) were selected using simple random sampling techniques (Table 2).

Questionnaires were administered to 200 farmers and fishermen. To determine the distribution of the questionnaires among the sampled villages, proportional allocation techniques (Cochran, 1977) was adopted using this formula:

$$\mathrm{nh} = {}^{\mathrm{Nh}}/_{\mathrm{N}} \times \mathrm{n}$$

Where;
nh = number of sample household in each village
Nh = the population of the individual village

N = the total number of individual in the sample villages
n = the total number of questionnaires to be administered

Farmers and fishermen were visited on their farmland and fishing ground where questionnaires were administered. Where the respondents were not literate, the researcher and his assistant interpreted the quantities and recorded their responses. The administration was done between 08:00 - 12:00 h local time, being the hours the respondents were most likely to be on their respective farmland and fishing site between June - July 2013.

Analysis of variation (ANOVA) was performed using XLSTAT 2014 statistical package on total area coverage by different land use/cover over the selected periods. Percentage change analysis was calculated to determine rate of changes of land cover classes within years.

Table 2. Allocation of questionnaires in sampled villages (2013)

Settlements	Population	Total allocated	Farmers	Fishermen
Wachakal N	3765	44	22	22
Zuggo	2507	29	14	15
Marma	6703	78	39	39
Adiyani	3208	37	18	19
Bambori	1041	12	06	06
Total	17224	200	99	101

3. RESULTS AND DISCUSSION

3.1 Wetland ecosystem classification and *Typha* invasion dynamics in HNW

Typha invasion of the wetlands was monitored at three periods of six year intervals of 2003, 2009 and 2015 in comparison with other land cover/use. Six land cover/ land use classes were identified and classified in the study area namely: dry land, grasslands, rain-fed farmland/ agriculture, residual wetland, wetlands and *Typha* swamp (Table 3). The classification accuracy was 85.47%; however, dry land had the highest classification accuracy of 90% (Table 4).

Table 3. Land cover classes descriptions

S/No	Classes	Description
1	Open dry land	Bare surface, open and dry land including built up area
2	Grassland	Land cover with grass or sparse vegetation
3	Rain-fed farmland	Farmland under cultivation in rainy season; cultivated crop include Millet and rice
4	Residual/shallow wetland	Wetland extent in rainy season but receded in dry season
5	Wetland	Full wetland extent at all seasons
6	*Typha* swamp/trees clusters	Area occupy by *Typha* grass, other tall grasses and tree clusters

Table 4. Classification accuracy (2015)

Classification	Open dry land	Grass land	Rain fed farmland	Residual wetland	Wetlands	*Typha* swamp/ cluster trees	Total	Class accuracy (%)
1. Open dry land	17	03	00	00	00	00	20	85
2. Grassland	01	09	00	00	00	00	10	90
3. Rain-fed farmland	00	00	11	01	00	00	12	91.66
4. Residual/shallow wetland	00	00	00	07	02	01	10	70
5. Wetland	00	02	01	00	30	02	35	85.71
6. *Typha* swamp/trees clusters	00	00	00	01	03	26	30	86.66
Totals	18	14	12	09	35	29	117	85.47

Table 5. Land cover classes in 2003, 2009 and 2015

Class	2003		2009		2015	
	Hectares	%	Hectares	%	Hectares	%
Dry land	78,282.95	24.9	29,998.91	9.51	24,723.00	7.9
Grasslands	132,561.23	42.1	55,818.88	17.7	56,230.74	17.9
Farmlands	78,436.14	24.9	79,412.30	25.2	78,311.07	24.9
R/wetlands	0.00	0.00	74,885.39	23.8	69,411.40	22.1
Typha swamps	4,587.02	1.5	52,415.71	16.7	18,152.82	5.6
Wetlands	20,747.95	6.6	22,084.10	7.09	67,949.73	21.6
Total	314,615.29	100	314,615.29	100	314,778.76	100

In 2003, the wetland in the study area occupies about 20,747.95 hectares of land representing about 6.6% (Table 5) of total land cover for the year. By 2009 the area occupied by the wetland although had gained marginally by 1% with about 22,084.10 ha (Figure 4) representing 7.09% of total land cover for the period.

On the other hand, *Typha* swamp had increased from less than 2% in 2003 (Figure 3) and this was found midway within the Nguru section of the wetland, about 45 km south west of Nguru to over 16% of total land cover in 2009 (Figure 4), covering a total of 67,949.73 ha of land; however, by 2015, *Typha* growth has shrunk to about 6% covering 18,152.82 ha (Figure 5). The Anova test on changes in land use/ cover hectares over the three periods revealed $F=2.734 > F\ crit=2.408$ at $p < 0.05$, which therefore indicate a significant variation in the three periods means.

The percentage change analysis showed that the greater invasion of *Typha* grass occurred between 2003 and 2009 where percentage increase was about 1013 (Table 6), whereas wetlands increased was marginal between 2003 and 2009, but gained significantly in 2015 with about 205 % increase when compared with 2009.

Table 6. Percentage increase of *Typha* swamps and wetlands in the year 2003, 2009 and 2015

Class	Δ% 2003/2009	Δ% 2009/2015
Typha swamps	1013.33	32.33
Wetlands	7.42	204.65

* Percentage change analysis was derived in Table 5 from 2 individual's year land cover class coverage in hectares $\frac{Y2-Y1}{Y1} \times 100$ Where Y1= the previous % value and Y2 = new % value

Transition probability was highest between wetland, *Typha* swamp and farmland. The probability values of wetland to *Typha* swamps ranges from 0.23 to 0.28 (Table 7), wetland to *Typha* (0.2808), R/wetland to *Typha* (0.1726), R/wetland to farmland (0.2285). Likewise most land use/land cover had the high tendency to transit to residual wetlands and rain-fed farmland than the rest.

Table 7. Transition probability matrix of LULC 2009 and 2015

2015						
2009	Wetlands	*Typha*	R/wetlands	Farmland	Grassland	Dry land
Wetlands	0.2609	0.2808	0.1932	0.1192	0.0169	0.1289
Typha	0.167	0.231	0.2144	0.1626	0.041	0.184
R/wetlands	0.0046	0.1725	0.263	0.2285	0.0632	0.2283
Farmland	0.0051	0.1316	0.2807	0.2701	0.0747	0.2378
Grassland	0.0036	0.1066	0.2665	0.2941	0.0824	0.2468
Dry land	0.00925	0.1954	0.2359	0.20014	0.0466	0.2282

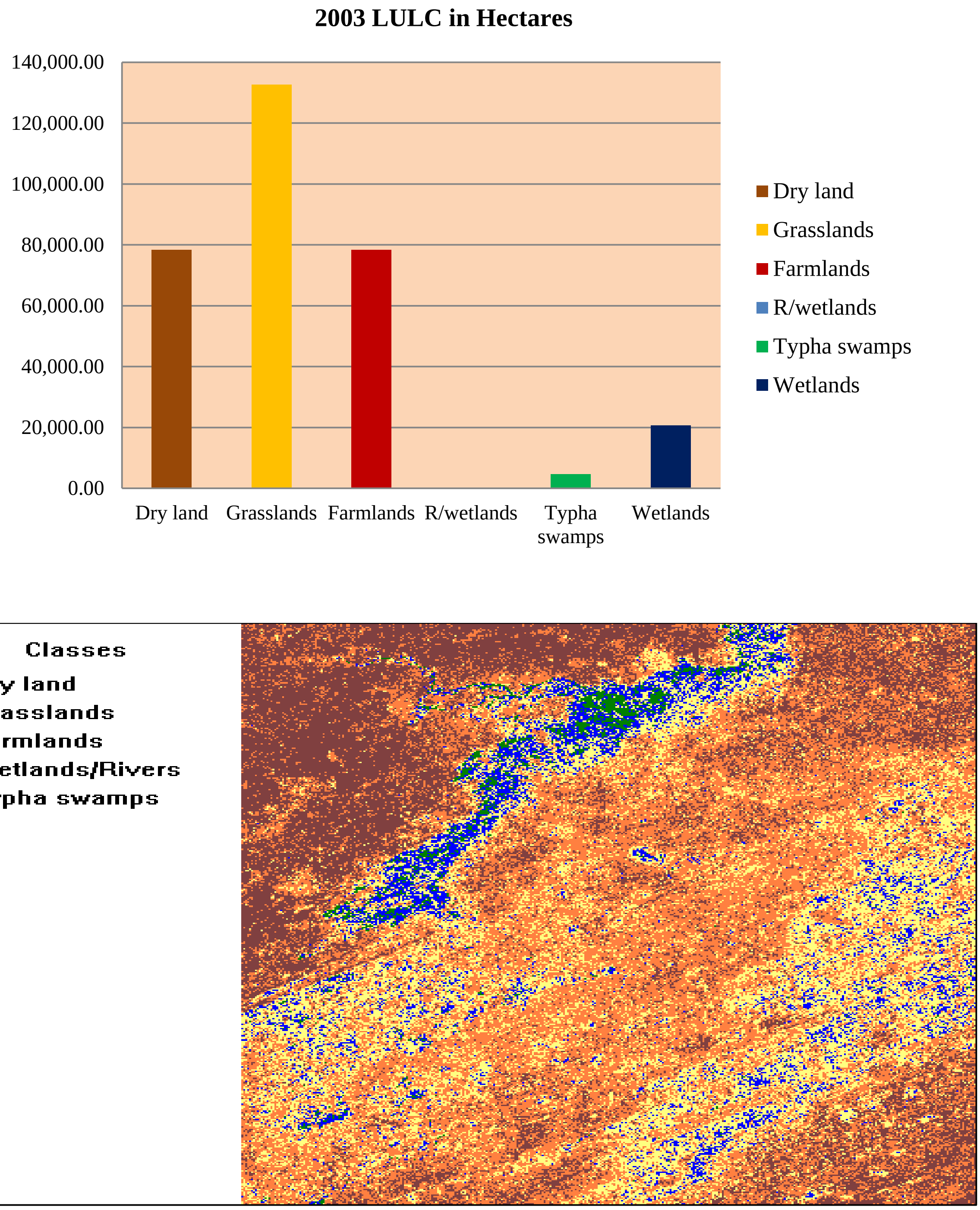
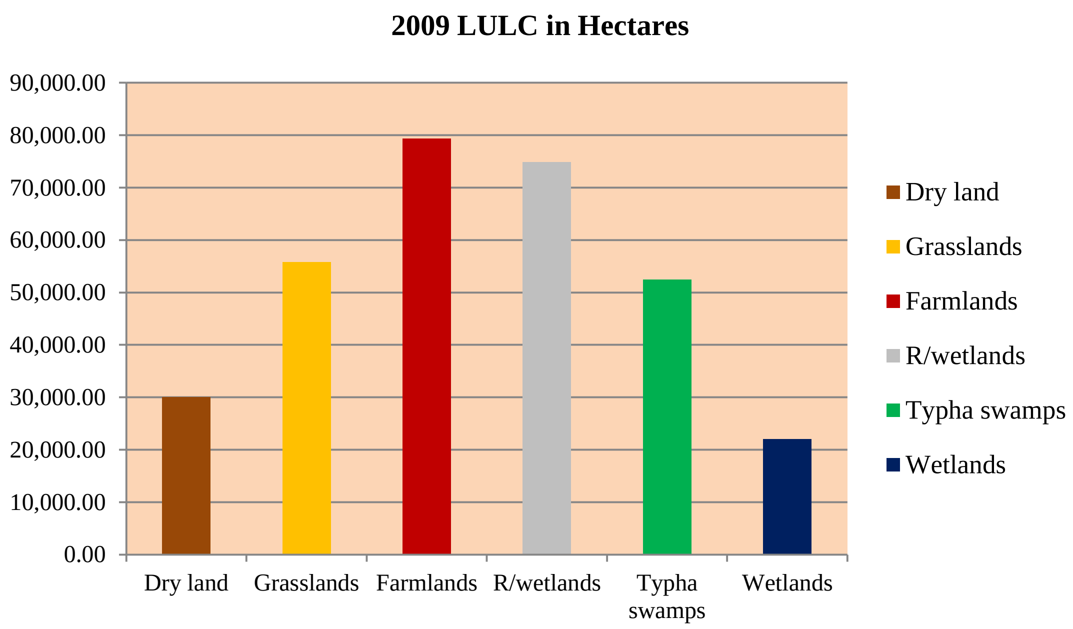


Figure 3. Land use land cover classes in HNW (2003)



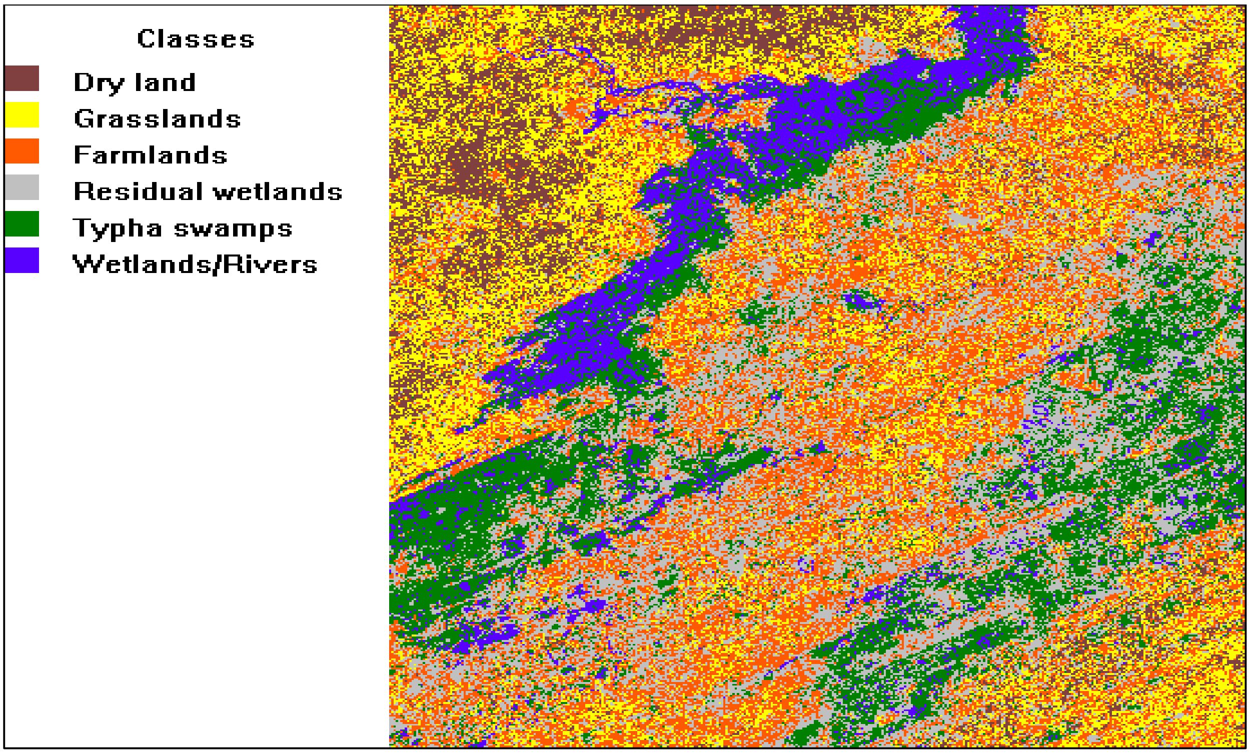
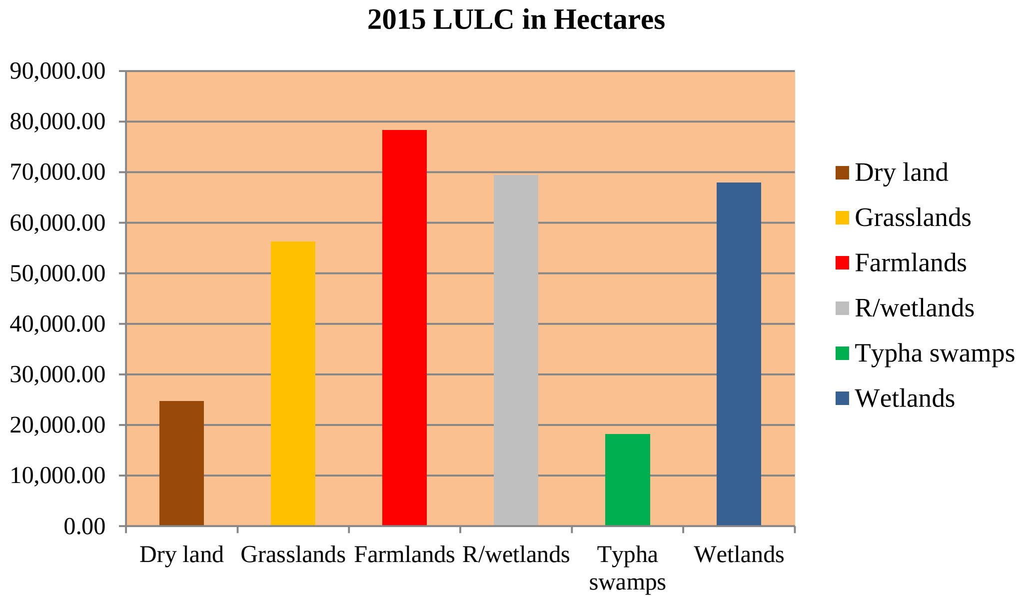
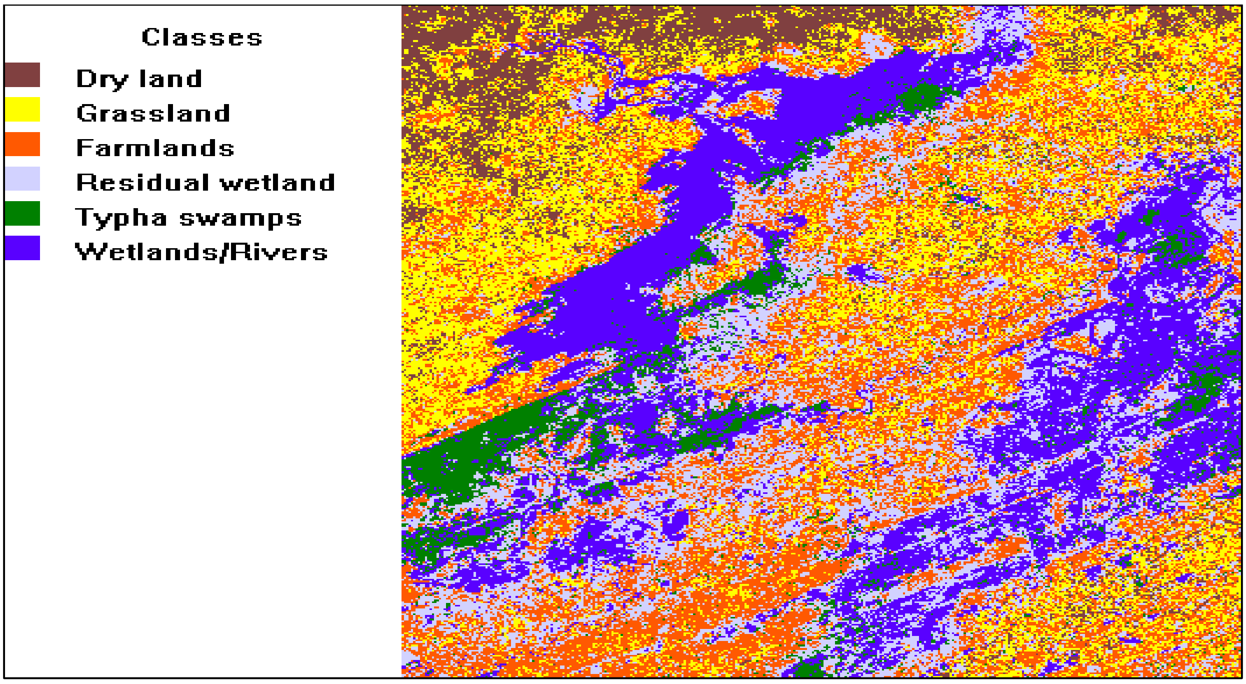


Figure 4. Land use land cover classes in HNW (2009)





* Wetland gained in the eastern segment while *Typha* invaded south western segment.

Figure 5. Land use land cover classes in HNW (2015)

3.2 Challenges of *Typha* invasion in HNW: socio economic implication

3.2.1 Age of respondents by occupation

Majority of the respondents (both farmers and fishermen) in the study area falls within age brackets of 20-44 representing between 75-80% of the sampled population. However, the fishermen were observed to be younger than the farmers. Over 70% of the fishermen are less than 35 years as shown in table as compared to farmers among whom 40% are above 35 years (Table 8). The possible explanation for the age differences could be that fishing being a daily income yielding venture seems more attractive to the youths rather than farming which requires longer period to bring profit.

Table 8. Age distribution of respondents (2013)

Ages	Number of farmers	%	Number of fishermen	%
15-19	04	04.00	04	04.00
20-24	10	10.10	20	19.80
25-29	10	10.10	30	29.70
30-34	30	30.50	20	19.80
35-39	25	25.20	15	14.80
40-44	10	10.10	10	9.90
45-49	06	06.00	02	02.00
50 and above	04	04.00	00	00
Total	99	100%	101	100%

3.2.2 Educational attainment

Most respondents in the study area acquired Koranic/Islamic education (about 60%), while few (10-15%) had primary education while none had tertiary education (Table 9). However, the fishermen appear to be more educated than farmers, about 10% of them had secondary education and only 6% had no formal education at all compared to farmers 1% and 30% respectively.

Table 9. Table educational status of respondents (2013)

Educational qualification	Number of farmers	%	Number of fishermen	%
Primary	08	08.10	15	14.80
Secondary	01	1.00	10	9.90
Tertiary	00	00	00	00
Koranic	60	60.60	60	59.50
None	30	30.30	06	5.80
Total	99	100%	101	100%

3.2.3 Major crops grown in HNW

Rice, wheat, and cowpea are the major crops being cultivated in the wetlands by the farmers of which over 90% of the farmers grow rice as a principal crop (Table 10). Rice is popular in the area not only because of favorable ecological conditions but also of its high returns to investment. This confirmed Barbier et al. (1993) findings on net benefits of selected agricultural crops in the flood plain of the HNW.

3.2.4 Major fish species caught in the study area

There were over 10 different species of fish being caught in the study area of which four are the most commonly caught (Table 11).

Table 10. Types of major crop grown in the wetlands (2013)

Crops	Number of farmers	%
Rice	90	90.90
Wheat	05	5.10
Cowpea	02	2.00
Millet	02	2.00
Total	99	100

Table 11. Major types of fish species caught in the wetlands (2013)

Fish species	Number of fishermen	%
Tarwada (mud fish) (*Clarias* spp.)	42	41.60
Karfasa (*Tilapia* spp.)	40	39.60
Karaya (Cat fish)	15	14.80
Musko (*Baqrus* spp.)	04	4.00
Total	101	100

Tarwada (mud fish) and Karfasa (*Tilapia* spp.) accounted for over 80% of total catch in the study area, especially in Bambori and Wachakal Ngurodi. Two factors could provide possible explanation for this. Firstly, these species are relatively larger than others species, which made it easier to be caught by their nets and secondly, the species are found to have suitably adapted to the environment.

3.2.5 Proportion of farmland / fishing ground under Typha infestation

All the 99 farmers in the five selected settlements affirmed that *Typha* grass is a serious problem on their farmland.

The average proportion of infestation is 80% ranges from over 86% in Wachakal to 90% in Marma farmland (Table 12). Bambori had the lowest percent coverage of 75%.

The fish ponds/streams are commonly owned by fishermen but being administered by *Sarki Ruwa*-Head chief in charge of water, in each of the territory. However, the fishermen were able to identify fishing routes, streams and ponds where fishing activities are carried out. Most of the fishermen equally affirmed that between 60 -70% of fishing routes have been infested by *Typha*.

Table 12. Proportion of farmland under *Typha* infestation (2013)

Settlements	Number of farmers	Total farm size sampled (ha)	Total farm size infested by *Typha* (ha)	Percentage under *Typha*
Wachakal	22	748.69	647.32	86.46
Zuggo	14	242.80	202.35	83.33
Marma	39	809.40	728.46	90
Adiyani	18	202.35	161.88	80
Bambori	06	161.85	121.41	75

3.2.6 Effect of Typha grass on crop yield/ output

The presence of *Typha* grass on farmland and fishing ponds in the study area has become a worrisome phenomenon as over 80% of sampled farmland was under the *Typha* infestation (Table 13) with an attendant consequence on crop yield, with rice yield fell to as low as 2.1 kg/ha in *Typha* swamp as compared with non *Typha* swamp which yield 45 kg/ha (Table 14). 62% fishermen affirmed that between 40-60% of their fishing swamp/ route were *Typha* infested (Table 13).

Table 13. Estimated proportion of fish ground under *Typha* infestation (2013)

Proportion under *Typha*	Number of respondents
0-20%	15
21-40%	34
41-60%	50
Above 60%	12

Table 14. Effect of *Typha* on crop yield (2013)

Crop types	Average yield before *Typha* infestation/ after weeding (kg)	Average yield in *Typha* swamp (kg)
Rice	45 kg/ha	2.1 kg/ha
Wheat	20 kg/ha	1.0 kg/ha
Cowpea	15 kg/ha	1.4 kg/ha
Millet	12 kg/ha	1.2 kg/ha

3.2.7 Effect of Typha grass on fish catch

A comparison between average catch in non *Typha* pond, especially in Bambori and Garbi and *Typha* swamp in Wachakal Ngurodi shows a remarkable difference. An average of seven Daro (basin) which roughly weigh 70 kg (a Daro weighs about 10 kg) was caught per week in non *Typha* pond as compared with one Daro in *Typha* swamps, thus a reduction catch of about 90% was recorded for all fish species sampled (Table 15).

Table 15. Effect of *Typha* on fishing (2013)

Fish specie	Average catch in non *Typha* swamp / open water (kg)	Average catch in *Typha* swamp (kg)	Percent (±)
Tarwada (mud fish) (*Clarias* spp.)	70 kg/week	7 kg/week	-90%
Karfasa (*Tilapia* spp.)	50 kg/week	10 kg/week	-80%
Karaya (Cat fish)	50 kg/week	4 kg/week	-92%
Musko (*Baqrus* spp.)	30 kg/week	3 kg/week	-90%

The percentage change analysis revealed that years 2003 and 2009 witnessed an astronomical increase in *Typha* swamps as it recorded over 1013 percentage when the total coverage rose from

4,487.02 ha in 2003 to 52,415.71 ha in 2009. Although the wetland gained over 205% in 2015 in the eastern segment (Figure 5) as compared with less than 2% of 2009, this gain was negatively affected as *Typha* growth was further increased by 33% in the western segment in 2015.

The Spatio-temporal changes in the remote sensing satellite data revealed that in 2003 there was no distinction between residual and full wetland, the distinction became clearer in 2009 and 2015 possibly due to the increase gained by wetland between the two periods and subsequent reduction in water volume in receding wetlands due to alternate variation in rainfall pattern within the periods. There was a slight decrease in total annual rainfall in 2009 and 2011 by about 20 mm below the preceding years average but there was a subsequent increase of 25 mm above average in 2012 and 2013 (NIMET, 2010). The colonization of *Typha* grass between 2003 and 2009 was partly in the wetlands in the south western section of Marma and Wachakal axis but majorly in the farmlands and residual wetlands on the eastern segments. About 20% of wetland in 2003 transited to residual wetland in 2009 and its subsequent colonization by *Typha*. This supported the findings of study conducted in Mediterranean wetland of Northern Greece that a decrease in wetland open water could provide a good habitat for aquatic plant such as reed (Papasterigiadou et al., 2008).

Anova test on changes in land use/cover hectares over the three periods revealed F=2.734 > F crit=2.408 at $p < 0.05$, which therefore indicate a significant variation in the three periods means. Although residual wetland plays a significant role in the wetland ecology of the study area as it provides opportunity for flood recession cultivation (Kolawole and Abubakar, 1994), a strategy for coping with risks and loss associated with drought and perhaps climate change, it also provided a good habitat for *Typha* invasion and colonization of farm land.

There was no clearly defined size for fishing area like the clearly demarcated farmland. It was quite challenging to empirically confirm the fishermen estimate through field measurement as in the case of farmland due to the terrain which was waterlogged thus making accessibility tasking. However, the result from earlier RS/GIS data and the few ponds that were accessible supported the fishermen estimation that 60% of the fish ponds were being taken over by the *Typha* grass.

The response was quite revealing and interesting on information obtained from the respondents to identify any effect the grass has on the crop yield or output. An average of 1 bag of paddy rice which weighed between 45-50 kg was observed to be harvested per hectare in a non-*Typha* infested farmland, the output however reduced significantly by 90% in a *Typha* infested area and this negatively affect the income level of the farmers. Many farmers said leaving *Typha* on the farmland could result in total crop loss. Farmers with large farm (20-40 ha) particularly noticed a significant reduction in rice yield in any sector of their farmland being overgrown by *Typha* grass. Respondents who cultivated small size of farm land were less threatened because they are able to overcome re-emergence through continuous weeding and burning over a long period of time.

Although both the farmers and the fishermen were negatively affected by *Typha* invasion, the effect was felt much more by the fishermen than the farmers. While the farmers had the advantage of weeding and burning the grass, this option was much more difficult on fish ponds and streams, not only that manual cutting could be tasking but burning was nearly impossible in water logged *Typha* swamp. This finding supported Singh et al. (1976), which reported that *Typha* foliage provides excellent cover for certain wild life such as fish and birds. It was interesting to note that though the grass reduced the quantity of fish caught, this does not necessarily reduce the fish yield or numbers in the ponds as *Typha* grass provided a good habitat for fish to spawn and hide. The reduction in quantity of fish caught is due mainly to inaccessibility of fishermen to the fish ponds due to dense canopy of the *Typha*. It therefore means *Typha* grass could be used as conservative measures to prevent overfishing and protect other threatened species.

4. CONCLUSIONS

Typha grass has become a serious threat to the livelihood of the people as most of their farmland and fish ponds have been taken over by the grass. The findings revealed the followings as direct effect of *Typha* infestation in the study area:

- Reduction in land available for farming by over 80%,

- Reduction in crop yield by over 90% on infested as compared with non-infested area,

- Reduction in quantity of fish caught by 80%, and indirectly, reducing personal household income,

Although satellite remote sensing data of 2015 showed a progressing increase in the areas occupied by wetlands yet the invasion of *Typha* on both the farmland and wetlands has not been fully controlled as significant proportion of land has still been occupied by this invasive grass. It is interesting and revealing to note that although the threat posed by

Typha invasion thereby reducing the ecosystem services capacity of the wetland, *Typha* provides a good cover for fish. Hence, in as much as *Typha* swamp should be cleared for open water and farmlands, a considerable portion should be preserved by leaving them undisturbed and designated as non-fishing area so as to avoid over fishing and as well create a good habitat for spawning, especially in the nearby fishing communities of Garbi, wachackal and Marma. Effective mass literacy programs should be provided for the youths in the area in order to enhance their vocational skills especially as it is related to fishing and farming.

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