ASSESSMENT OF HEAVY METALS IN AGRICULTURAL SOILS IN SELECTED LOCAL GOVERNMENT AREAS OF KWARA STATE

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ABSTRACT

Assessment of agricultural soils for heavy metal contents is of great concern due to potential health implications and safety issues involved in the uptake of the metals by crops on agricultural soils. This study is aimed at assessing the concentration of heavy metals in agricultural soils of some selected farms in Kwara state. Soil samples were collected from four location (Idofian, Oro, Omu-Aran and Ogbondoroko) and analysed for pH, textural classification and some heavy metals metal contents (Cd, Cr, Pb, Zn, Co, Cu, and Mn) using standard pH meter, hydrometer method and atomic absorption spectrometer (AAS) method respectively. The results of the analysis showed that the pH of the soil ranges from slightly acidic to slightly alkaline (5.40 to 7.50). The textural classification of the soils showed that aside of Oro which can be classified as sandy loam other locations have loamy soil. The mean concentrations of the heavy metals ranged from (0 to 7.67 mg/kg) for Cd, Cr, Pb, Zn, Co, Cu, and Mn. The obtained values for respective metal are below the established limit of FAO and WHO. This implies that the heavy metals considered are not of grave concern at present. The correlation analysis showed a strong correlation between the heavy metals and soil pH.

Keywords: *Agricultural Soils, Heavy Metals, Kwara State, Pearson's correlation analysis*

INTRODUCTION

Soil is an important component of the ecosystem that supports the growth of plants. This vital resource is a subject to short term fluctuations, such as variation in moisture content and pH, and it as well undergoes gradual alterations in response to changes in management and environmental factors (Abubakar et al, 2002). Aside the agricultural function; it is also an important reservoir receiving a significant amount of pollutants from different sources. It does not only serve as sink for the chemical pollutants but also acts as a natural buffer by controlling the transport of chemical elements and substances in the environment (Kabata-Pendias et al., 2011). The chemical reaction between chemical pollutant and soils are usually irreversible leading to undesirable changes in our environment and leaving the soil contaminated (Odoi et al., 2011). Once the soil is contaminated it poses health risk to soils, most biomaterials cultivated on it and to man who ultimately consumed them (Stavrianou, 2007). Soil gets expose to these metals through a number of way which include natural sources, fossil fuel combustion, phosphate fertilizers, wastewater and municipal solid waste incineration (Michael, 2010).

Recently, different groups have produced reports addressing the state of the soils and recommendations have been made for soil protection policy (Qishlaqi and Moore, 2007). Van-Camp et al. (2004) for instance identified the need to measure soil heavy metal concentrations and contamination processes. The excessive use of agrochemicals in agriculture in order to boost production is also noted for the introduction of heavy metals as well as other pollutants into the soil (Facchinelli et al., 2001). The analysis of heavy metal concentrations in agricultural soils is therefore, critical for policy making orientated toward reducing heavy metal inputs to soil and guaranteeing the maintenance or even the improvement of soil quality (Mico et al., 2006). Thus, this study is aimed at assessing the heavy metal content of agricultural soil in Kwara state.

MATERIALS AND METHODS

Description of the Study Area

This study was carried out in some Local Government Areas of Kwara state. Soil samples were collected from four (4) sites. The sites are Idofian in Ifelodun Local Government (Lat 8^{0}23'24"N; Long 4^0 39'53"E), Ogbondoroko in Asa Local Government (Lat 8^0 23'45''N; Long 4^0 35'13''E), Oro (Lat 8^0 13'52"N; Long 4^0 54'3"E) and Omu Aran (Lat

$8^0 8$" 35"N; Long $5^0 6$'48"E) both in Irepodun Local Government. The choice of the sampling points was informed by the types of activities done close to the farm areas and based on the sizes and types of agricultural practice (Fig. 1).

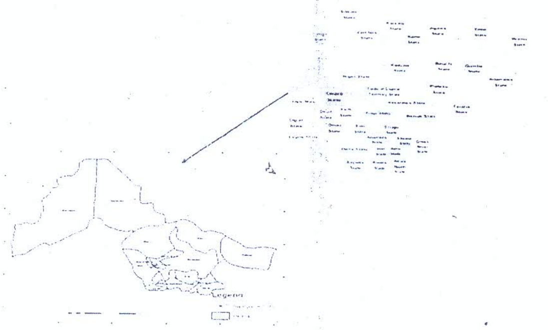

Fig. 1: Map showing the study areas

Soil Sampling

A total of twelve (12) samples were taken from the study areas. Each farm site was divided into three and from each; eight (8) subsamples were taken at a depth of 0-30cm of cultivated farmland with a soil auger. The subsamples were mixed thoroughly in a container to get an accurate representation of the farm, after which a sample was taken from each making a total of three (3) samples from each sites as adopted by Syed *et al.* (2012). Each sampling point on each location has a difference in distance of not less than 10 m (Syed *et al.*, 2012). Some 250 to 300g of soil samples were taken from each site and placed in a pre-cleaned polyethylene container and labelled accordingly before being taken to laboratory for analysis. The collected soil samples were air dried at room temperature for three (3) days. Large debris, stones, and pebbles were removed before being passed through a polyethylene sieve of 2mm size.

Physicochemical Analysis of the Soil Samples

Soil texture and pH

The soil texture was determined using the USDA textural triangle as described by Gee and Or (2002). The pH meter was standardized using buffer 7 and buffer 10 solutions before carrying out the test. A 40 g of the collected soil sample was poured into a plastic cup after which 40 mL of distilled water was added using a pipette, stirred using a glass rod and left for an hour. The sample was then stirred continuously and the soil pH was measured and recorded (Abollino *et al.*, 2002)

Heavy Metals Determination

Some 1g of the air dried and well pulverized soil was weighed using digital weighing balance into a conical flask of 100ml. Distilled water of 10ml was used to moisten the soil and 10ml of aqua rega (1:3 HNO_3 and HCl) was also added. The soil solution was boiled for about 30 minute after which another 10ml of distilled water was added. The boiling was continued for another 10 minutes after which the soil solution was filtered and the filtrate was made up to 100ml with distilled water and then transported to laboratory for analysis using Atomic Absorption spectrometer (AAS) (Brigden *et al.*, 2008).

Statistical Analysis

The results obtained were statistically analyzed using Descriptive Analysis (DA) and Correlation Analysis (CA). CA was used to reveal the relationship between pH and heavy metal concentrations, DA helps in showing the mean and standard deviation of the heavy metals and CA was used to determine the degree of relationship among the parameters considered. The analysis was performed with Palaeontological Statistics (PAST) software.

RESULTS AND DISCUSSIONS

Particle Size Distribution and pH values

The result of the particle size distribution indicates that using the mean value of each site Idofian (83.1±0.8.1 % Sand, 13.81±7.09 % Silt, 2.85± 0.99 % Clay), Omu-Aran (88.7±1.02 % Sand, 11.3±1.02 % Silt, 0.0± 0.0 % Clay) and Ogbondoroko (86.47±4.15 % Sand, 11.93±3.07 % Silt, 1.75±1.28 0. % Clay) have the same textural class (Loamy sand), while Oro (87.88±3.59 % Sand, 7.8±2.11 % Silt, 4.33±1.48 % Clay) has Sandy loam (Table 1). The textural classifications obtained for these locations are in line with what was observed by Affinnih *et al.* (2014) for agricultural soils in Kwara as many of the sites are loamy sand.

Table 1: pH and soil particle size distribution value of the study sites

Sites	Parameters	pH	% Sand	% Silt	% Clay	Textural Class
Idofian	Range	6.80-7.50	73.17-93.02	4.65-21.95	2.07-4.16	Loamy sand
	Mean	7.07	83.1	13.81	2.85	
	SD	0.306	8.104	7.099	0.989	
Oro	Range	5.40-6.90	83.33-92.11	5.26-10.42	2.65-6.25	Sandy loam
	Mean	6.14	87.88	7.8	4.33	
	SD	0.612	3.592	2.107	1.48	
OmuAran	Range	6.00-6.20	87.50-90.00	10.00-12.50	0	Loamy sand
	Mean	6.1	88.7	11.3	0	
	SD	0.1	1.023	1.023	0	
Ogbondoroko	Range	6.20-7.10	81.81-91.89	8.11-15.63	0-3.03	Loamy sand
	Mean	6.5	86.47	11.93	1.75	
	SD	0.391	4.15	3.071	1.282	

pH is an important soil parameter which is responsible for the regulation of chemical and biological activities in soil (Brady and Weil, 2002). Nutrient and heavy metal availabilities are functions of pH level in soil (Solomon, 2008). Thus, soil pH has the tendency for providing a useful index for the potential soil holding capacity for heavy metals, nutrients and fertility of soils (Aheneku and sadiq 2014). In this study, Idofian soil has a mean pH value of 7.07 indicating a neutral state of soil which is tending towards alkalinity. Oro, Omu-Aran, and Ogbondoroko soils are slightly acidic with a mean pH value of 6.14, 6.1 and 6.5 respectively. The obtained pH value in this study is though higher than the value (4.00-6.30) reported by Affinnih *et al.* (2014), it is in line with the value (5.58 -7.16) reported by Ibiremo *et al.* (2010) for agricultural soil in kwara state. This implies that the state of the soil assessed is good for agricultural activities as acidic soil (with pH < 5.5) hinder microbial activities (Animashaun *et al.*, 2015).

Heavy Metal Contents of the assessed agricultural soils

Presence of heavy metals at measurable concentration was observed in all the agricultural farmlands assessed. The mean concentration of Ni in Idofian soil sample was 0.3±0.025 mg/kg which is lower than the soil maximum allowable value of 75 mg/kg by FAO. The observed value (0.01±0.00) for Cd was also below the established limit of 73 mg/kg by FAO (2006). Cr content of the soil was 0.17±0.060, while the respective Pb, Zn, Co, Cu and Mn contents of the soil were 0.37±0.208, 0.32±0.085, 0.16±0.015, 0.25±0.01, 5.54±0.53 mg/kg (Fig. 2). Though Mn was relatively high, all the parameters assessed had values that were lower than the established limit by FAO (Cu= 135, Zn= 300, Ni= 75, Pb= 300) in agricultural soils as reported by Abrahim and Parker (2008)

At Oro, the mean concentration of Mn (5.54±0.53 mg/kg) was also the highest, while Cd had the least value of 0.01±0.00 mg/kg. The mean concentrations for Ni, Cr, Pb, Zn, Co, and Cu were 0.08±0.026 mg/kg, 0.23±0.068 mg/kg, 0.30±0.1 mg/kg, 0.54±0.267 mg/kg, 0.08±0.006 mg/kg, and 0.18±0.044 mg/kg respectively. The observed values for the metals were all within the permissible limits by FAO in agricultural soils. The mean concentration of the assessed metals in Omu-Aran soil sample ranged from 0.01 to 3.10 mg/kg. The order of concentration in this location was also similar with the first two locations Mn recorded the highest mean concentration of 3.10±0.65 mg/kg while Cd has the least (0.01±0.01 mg/kg). Ni, Cr, Pb, Zn, Co, and Cu have respective mean concentrations of 0.12±0.01 mg/kg, 0.24±0.025 mg/kg, 0.20±0.100 mg/kg, 0.60±0.113 mg/kg, 0.17±0.081 mg/kg and 0.16±0.006 mg/kg. At Ogbondoroko a similar trend was also observed in terms of the metals with the highest and lowest concentration. Mn has the highest mean concentration of all the heavy metals assessed (7.67±1.33 mg/kg) while Cd has the least concentration. The mean concentrations of Ni, Cr, Pb, Zn, Co, and Cu were 0.07±0.02 mg/kg, 0.13±0.015 mg/kg, 0.10±0.0 mg/kg, 0.33±0.090 mg/kg, 0.10±0.025 mg/kg, and 0.14±0.015 mg/kg respectively.

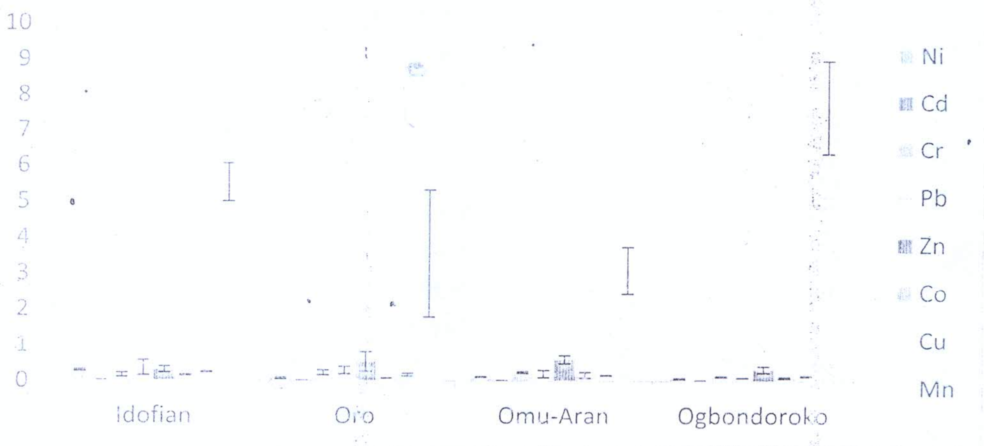

Fig. 2: Mean Concentration of Heavy Metals in Idofian Soils (mg/kg)

All the heavy metals considered in this study can be associated with environment hazard and human health problems especially in areas with high anthropogenic pressure (Singh and Angrawal, 2010; Islam *et al.*, 2007). However, some (such as Zn, Mn, Cu) are essentially needed by the body for growth and development, (Skudi, 2011). Their presence in soil, even in traces can cause serious problems to all organisms as heavy metal bioaccumulation in the body through the food chain can be highly dangerous (Lone *et al.*, 2008).This is because ingestion is the main route of exposure of man to these metals in contemporary period (Singh and Taneja, 2010).

The concentration Ni in the four assessed farmlands ranged from 0.05 to 0.33 mg/L, while that of Cd, Cr, Pb, Zn, Co, Cu and Mn ranged from 0.05-0.33 mg/kg, 0.01-0.03 mg/L, 0.11-0.31 mg/L, 0.1-0.6 mg/L, 0.4-0.84 mg/L, 0.09-0.24 mg/L, 0.13-0.26 mg/L and 2.07-9.1 mg/L respectively. The results obtained (especially for Pb, Zn and Cu) in this study are lesser than the values reported by Ahaneku and Sadiq (2014). This is not unexpected as relatively high pH values recorded on the study areas do not favour heavy metal concentration (Rieuwerts *et al.*, 1998).

Though, Pb concentration is low, it needs to be monitored regularly as it is considered a highly poisonous metal, affecting almost every organ and system (especially nervous system) in the body (Jagadish, 2010). Long-term exposure to it can result in nephropathy, severe brain damage, colic-like abdominal pains and deficiency in the production of blood cells (Needleman *et al.*, 1990; Counter *et al.*, 1998). Zn at a considerate level oversees the efficient flow of body processes, maintenance of enzyme systems and cells (Kipkenboi, 2009) but at a high level it causes vomiting and diarrhea and leads to liver or kidney damage (Bothwell, 2003). Cu also has a tendency to accumulate in the blood and deplete the brain zinc supplies.

The mean content of Ni in the areas under study followed the order Idofian>Omu-Aran>Oro>Ogbondoroko while Mn followed as Ogbondoroko>Idofian>Oro>Omu-Aran. Mean contents of Ni, Cd, Cr, Zn and Co in Omu-Aran were the highest among all sites. Omu-Aran soils contain higher levels of heavy metals compared to other areas assessed. This may be due to the usage of dam water for irrigation. Tahmiscioğlu *et al.* (2011) claimed that soil pollution can be one of the negative consequences of dam.

Correlation Analysis

Pearson's correlation analysis was done to determine the degree of relationship between the soil pH and heavy metal concentrations of the soil. The results of the analysis showed that there is a strong relationship between pH content and heavy metals contents of the soil (Table 2-5). In Idofian soil for instance, pH was negatively correlated Ni (r = 0.888), Pb (r = 0.799), Co (r = 0.851), Cu (0.935) and Mn (r = 0.996) while it has a strong positive correlation with Cr (r = 0.897) and Zn (r = 0.922) (Table 2). This implies that while Ni, Pb, Co, Cu and Mn increase with decrease in pH. Cr and Zn increase with increase in pH. The results also indicated that almost all the heavy metals were significantly correlated ($p<0.05$) with one another in each of the location. Ni was positively correlated with Pb (r = 0.986), Co (r = 0.997), Cu (r = 0.993) and Mn (r = 0.846), while it has strong negative correlation with Cr (r = 0.999) and Zn (r = 0.997)

Table 2: Correlation coefficients (r) between measured parameters in Idofian Soils

	pH	Ni	Cr	Pb	Zn	Co	Cu	Mn
pH	1.000							
Ni	-0.888**	1.000						
Cr	0.897**	-0.999**	1.000					
Pb	-0.799*	0.986**	-0.983**	1.000				
Zn	0.922**	-0.997**	0.998**	-0.970**	1.000			
Co	-0.851**	0.997**	-0.996**	0.996**	-0.988**	1.000		
Cu	-0.935**	0.993**	-0.995**	0.961**	-0.999**	0.982**	1.000	
Mn	-0.996**	0.846**	-0.856**	0.746*	-0.886**	0.804**	0.902**	1.000

In Oro, Ni (r = 0.940), Cr (r = 0.959), Zn (r = 0.943) where positively correlated with pH while Co (r = 0.858), Cu (r = 0.924), Mn (r = 0.996) were negatively correlated (Table 3). Cd (r = 0.866), Co (r = 0.619) and Cu (r= 0.866) were positively correlated with pH in Omu-Aran (Table 4) while all the assessed heavy metal had strong negative correlation with pH in Ogbondoroko soils (Table 5). Strong positive and negative correlation among the heavy metals observed in this study is in line with the findings of Mustapha and Aris (2012) and Ahaneku and Sadiq (2013).

Table 3: Correlation coefficients (r) between measured parameters in Oro Soils

	pH	Ni	Cr	Pb	Zn	Co	Cu	Mn
pH	1.000							
Ni	0.940**	1.000						
Cr	0.959**	0.805**	1.000					
Pb	-0.487**	-0.756*	-0.220	1.000				
Zn	0.943**	0.773*	0.999**	-0.169	1.000			
Co	-0.858**	-0.982**	-0.679*	0.866**	-0.639*	1.000		
Cu	-0.924**	-0.737*	-0.994**	0.115	-0.999**	0.596*	1.000	
Mn	-0.969**	-0.995*	-0.860**	0.687*	-0.832**	0.958**	0.801*	1.000

Table 4: Correlation coefficients (r) between measured parameters in Omu-Aran soils

	pH	Ni	Cd	Cr	Pb	Zn	Co	Cu	Mn
pH	1.000								
Ni	0.500	1.000							
Cd	0.866**	0.866**	1.000						
Cr	-0.397	0.596*	0.115	1.000					
Pb	0.500	0.990**	0.866**	0.596*	1.000				
Zn	0.044	0.887**	0.538*	0.899**	0.887**	1.000			
Co	0.619*	0.989**	0.929**	0.475	0.989**	0.812*	1.000		
Cu	0.866**	0.000	0.500	-0.803*	0.000	-0.461	0.143	1.000	
Mn	0.116	0.918**	0.597*	0.866**	0.918**	0.997**	0.852**	-0.396	1.000

Table 5: Correlation coefficients (r) between measured parameters in Ogbondoroko soils

	pH	Ni	Cd	Cr	Zn	Co	Cu	Mn
pH	1.000							
Ni	-0.952**	1.000						
Cd	-0.877**	0.982**	1.000					
Cr	-0.877**	0.982**	0.998**	1.000				
Zn	-0.931**	0.998**	0.992**	0.992**	1.000			
Co	-0.911**	0.993**	0.997**	0.997**	0.999**	1.000		
Cu	-0.877**	0.982**	0.999**	0.998**	0.992**	0.997**	1.000	
Mn	-0.893**	0.988**	0.999**	0.999**	0.996**	0.999**	0.999**	1.000

** Correlation is significant at the 0.05 level*

*** Correlation is significant at the 0.01 level*

CONCLUSION

The agricultural soils in Idofian, Oro, Omu-Aran and Ogbondoroko were assessed for heavy metals concentration. The result showed that the most dominant among the assessed metals was Mn and the metal with the least concentration value was Cd. Though there is variation in the concentration of the metals across the location, the values are within the permissible limit for agricultural soils. This showed that the concentration of the heavy metals in all the areas are not of high risk for now and the soils are still good for agricultural purposes. The results of correlation analysis indicated strong relationship among the heavy metals and soil pH. Considerable high value of some of the metals indicated probable anthropogenic sources of pollution.

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Inter-annual variability in the Surface Water Resource of Komadugu Yobe Basin, Nigeria

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Abstract

The Komadugu Yobe Basin is situated in the Sudan-Sahel zone of northeast Nigeria and southeast Niger, and it is a sub-catchment of the larger Lake Chad Basin. The population in the basin is increasing major water management problems in the basin is the fragmented, inequitable and uncoordinated management of surface water resources resulting in reduced flow to Lake Chad. The problem is compounded by paucity of hydrological data, climate variability and climate change as well as population dynamics. The inadequacy of hydrological data has also hindered either intra-basin or inter-basin transfer. The surface water resources of the upper reach of KYB was assessed using the Geospatial Streamflow Model and satellite derived rainfall and, potential evapotranspiration data; and remotely sensed soil and vegetation data as input The estimated mean annual yield (1981-2015) of the Tiga sub-basin was 865 Mm^3, while the observed flow during the pre-construction of Tiga dam was 1000 Mm^3. The estimated specific yield in the Hadejia sub-basin was 0.12 Mm^3/km^2, while that of the Jama'are sub-basin is 0.18 Mm^3/km^2. The coefficient of variation of annual flow varied from 0.167 in Tiga, to 0.15 in Challawa in Hadejia sub-basin, and 0.11 in Jama'are sub-basin of KYB. The variation in yield is in contrast to the population distribution. Thus, there should be a much greater emphasis on water resources management and a shift of emphasis from supply to demand management of water resources.

Introduction

The Komadugu Yobe Basin (KYB) is a sub–catchment of the larger Chad Basin, covering an area of 148,000 km^2, 57% of which lies in north eastern Nigeria and the rest in south eastern Niger. It represents approximately 35% of the conventional basin of Lake Chad. The Nigerian sector of KYB accounts for 95% of the basin's total contribution to the lake (Fig. 1). The geological formation of the upstream part of the catchment consists of mainly impermeable basement complex rocks which dip away to the east where it is covered with the permeable sands, gravels and clays of the Chad Formation. Alluvial sediments are present overlying the Chad Formation close to the rivers. Much of the catchment is relatively flat with the only significant hills (the Jos Plateau) rising in the south-west from where the headwaters of the Jama'are River and to a lesser extent the Kano River begin. Soils tend to be sandy and relatively deep with the exception of shallower soils dominating the headwaters of the Jama'are. The majority of the basin falls within Sudan Savannah Ecological Zone which has a natural vegetation cover dominated by shrubs and dense grasses with a minor tree component. However much of the natural cover has been affected and is continuing to be affected by man, and large areas are used for various forms of rainfed agriculture or pasture. Natural woodland only dominates in the south-western parts of the basin.

The main rivers of the basin are the Hadejia and Jama'are Rivers that meet in the Hadejia-Nguru Wetlands to become the Yobe River that drains to Lake Chad. The hydrology of the internationally significant Hadejia-Nguru Wetlands where the two river systems meet is consequently very complex and has been the subject of numerous studies (Goes and Zabudum, 1998; IUCN, 1999). Seasonal flooding plays an essential role in maintaining the ecological system of the wetlands and enables both flood and recession farming to be conducted in the wetland region and along the lower reaches of the rivers.

Supply of water to the river system is dominated by the contribution from the headwater regions underlain by the basement complex rock. Network of river gauging stations were installed in the 1960s and 1970s to monitor the flows (Afremedev, 1999). The river systems also support the Hadejia-Nguru Wetlands (HNWs), which is Nigeria's premier Ramsar site that is of immense local, national and international economic and ecological importance. The HNWs harbour over 370 species of birds, 33% of which are migratory as well as about 100 species of fish. There are also some endemic plant species of agronomic importance which are threatened with extinction and which have attracted strong conservation interest. These include a local variety of rice cultivated between Gashua and Geidam stretch (IUCN, 1999). Inequitable and uncoordinated management of surface water resources within the basin are major water management problems in the basin. The Yobe River has been estimated to contribute only about 2% of the total flow into Lake Chad (KYBP, 2006).

The Climate of the region is governed primarily by the interaction of two major air masses, the Tropical Maritime (TM) and the Tropical Continental (TC), which meet along the Inter-Tropical Convergence Zone (ITCZ). Warm and moist TM air moves inland in a general southwest to northeast direction from the Gulf of Guinea. Warm and dry TC air moves southwest from the desert and rises over the TM air, which assumes a wedge shape increasing in thickness towards the southwest. The ITCZ contact with the ground arrives from the southwest in April or May and passes back over the basin in September or October. During these transitional months the wedge of humid air is too thin for convective rain but line squalls are common providing intense, localized rainfall of short duration. The mean annual rainfall, occurring between May and October, varies from over 1,000 mm in the south-western plateau region to about 500 mm in and around the Nguru wetlands and to a minimum of less than 300 mm near Lake Chad in the far north-east of the catchment. The highly seasonal nature of the rainfall is a result of the annual migration of the Inter-Tropical Convergence Zone. Notable trends within the annual rainfall series have been a feature over the last 50 years, with periods of significantly below average rainfall occurring in both the early 1970s and particularly the 1980s. The corresponding pan evaporation rates are 3,400-3,600 mm per year near the Kano-Kari highway and about 3,800 mm in the Nguru-Gashua area. Annual potential evaporation tends to vary between 1,800 mm and 2,400 mm across the basin, though lower rates are recorded at Jos on the raised plateau (IUCN/NIWRMC, 2011).

The total population of the basin in 2005 was over 20.8 million representing almost 60% of the Lake Chad Basin's population and consisting of predominantly male farmers, fishermen and nomadic pastoralists below 60 years of age (GIWA, 2004). The network of river systems and wetlands that constitute the KYB support a wide range of ecological processes and economic activities, including recession agriculture, pastoralism, forest regeneration, fish breeding and production, trading, drought-fall-back security, and tourism potential. Based on these activities, several centres of development, trading and administration have emerged along river courses and on floodplains in the basin, constituting very high population concentrations in a characteristically sparsely populated dryland region. Currently, the livelihood of the over 10 million people in the basin, both in Nigeria and Niger, depend almost exclusively on these activities. The Hadejia-Jama'are-Komadugu-Yobe River system is the life-wire of these communities (KYBP, 2006). The basin is an area of relatively dense population concentration in a dryland region, with the population critically and increasingly dependent on scarce water resources. Thus, there is a need to assess the inter-annual variation in the surface water resource of the headwater. This will promote the shift from demand management to supply management in the basin.

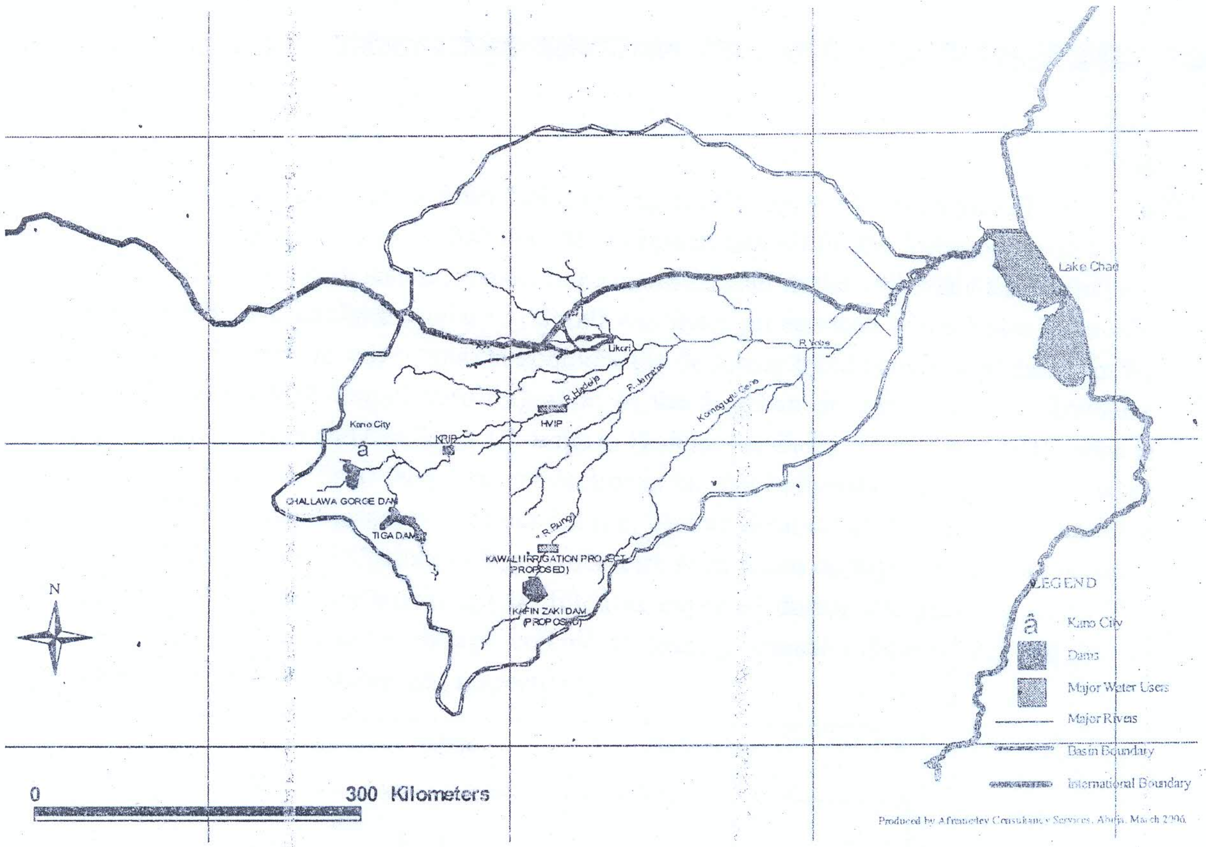

Fig. 1: Location of Komadugu Yobe Basin

Methodology

Daily streamflow data at four stations (Tiga, Challawa and Kafin Zaki) were simulated using Geospatial Stream Flow Model (GeoSFM) model. The model is a semi-distributed, physically based, catchment-scale, hydrologic modelling system developed by scientists at the United States Geological Survey Centre for Earth Resources Observation and Science (USGS/EROS), with the cooperation of the United States Agency for International Development, Office of Foreign Disaster Assistance (Artan *et al.*, 2007; Asante et al., 2007). The model runs within a GIS environment (ESRI ArcView) for data input, preparation, and visualization of simulation outputs. The rainfall data used for daily simulations in the model was the gridded satellite daily rainfall data available: the Climate Hazards Group InfraRed Precipitation with Stations (CHIRPS) data archive available from 1981 to 2015 at 0.05° resolution (Funk *et al.*, 2014). The daily potential evapotranspiration (PET) was based on the data produced by the Famine Early Warning Systems Network (FEWSNET). The input data include soil characteristics, topography (Shuttle Radar Topography Mission (SRTM) data with a vertical accuracy specification of +/- 5 meters, and available in resolutions of 3 arc-second (90m) data around Nigeria from the USGS website was downloaded), land use and land cover data and rainfall data. Soil Characteristics, including soil type, texture and hydraulic conductivity (Ks) values were determined (Zobler 1986, Webb *et al.* 1991). Calibration of the model was based on discharge record at Tiga and Challawa stations. Model calibration was conducted using the historical flow record before construction of Tiga dam (1974). Flows were simulated based on CHIRPS dataset, DEM and soil characteristics. The standardized streamflow index at 3-month and 6-month time steps were calculated using Mckee *et al.* (1993) approach.

Results and Discussion

Annual rainfall at Hadejia sub-basin varies from 700 mm and 1,200 mm, while mean annual rainfall in Jama'are sub-basin varies from 800 mm to 1,200 mm. Mean annual rainfall for the Yobe sub-basin varies between 250 mm and 600 mm. There was a persistent decline in rainfall in the 1980s and the rainfall did not recover until mid-1990. The declining trend in rainfall was more pronounced in the Yobe River sub-basin than the Hadejia and Jama'are sub-basins. In addition, the declining trend commenced earlier in the sub-basin which is attributed to the southward migration of the Sahelian drought. Figure 2 shows the standardized rainfall index of Tiga and Challawa sub-units in Hadejia sub-basin, as well as rainfall index in Jama'are sub-basin. The figure confirms the persistent decline in rainfall in the basin since the 1980s when major water resources development projects were carried out. The implication of the declining rainfall in the basin is that inflow into Tiga and Challawa Gorge reservoirs were based on high rainfall that occurred in the pre-1980s. Thus, the reservoirs would not be filled as expected during the planning stage. This observation is confirmed by the ratio of storage volume to average annual inflow of 2.5 and 1.6 for Challawa Gorge Reservoir and Tiga Reservoir, respectively.

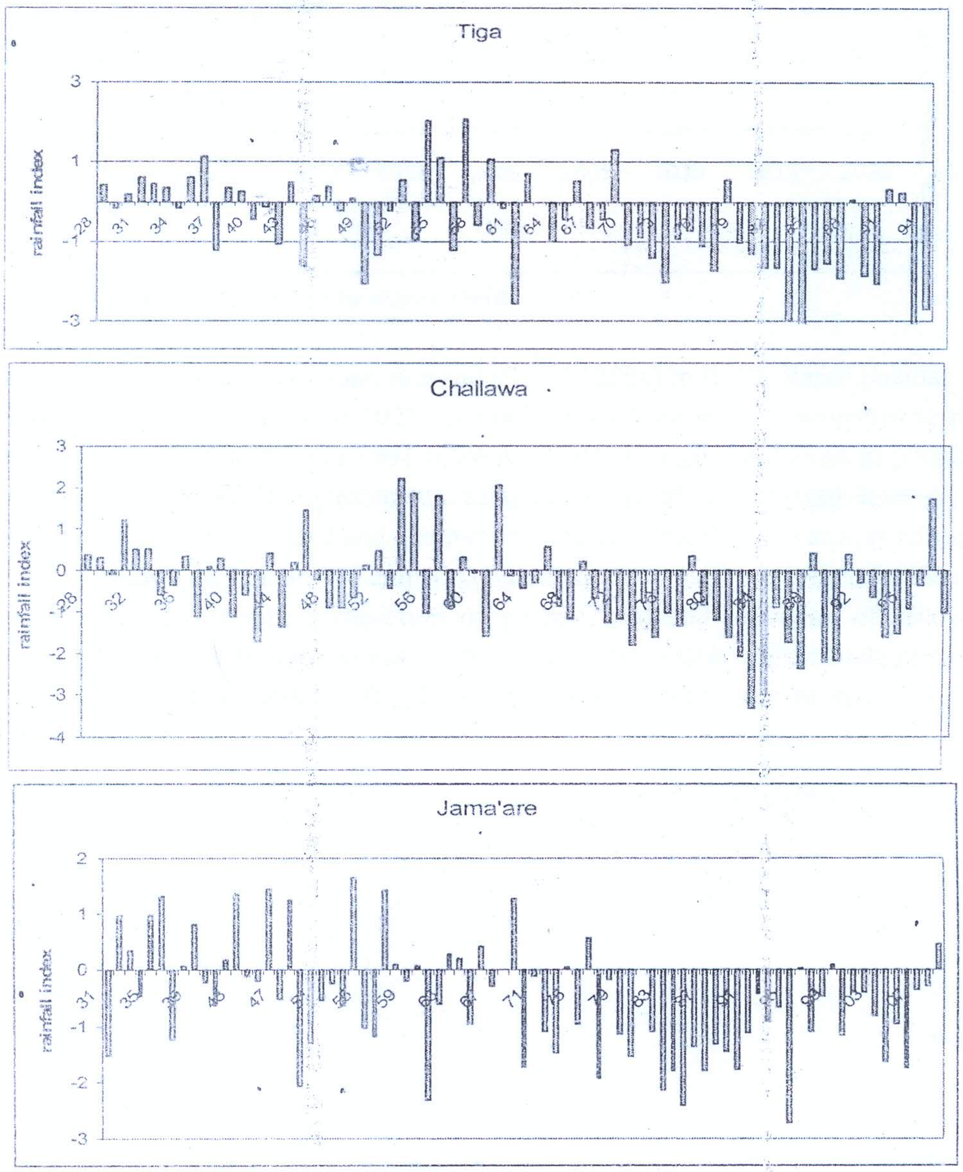

Fig. 2: Normalised rainfall index of the basin

Figure 3 shows the variation in annual yield at Tiga, Challawa and Kafin Zaki. The annual yield between 1981 and 2015 at Tiga varied between 589 Mm3 and 1120 Mm^3, with a mean of 865 Mm^3. The estimated mean during the period is lower than observed flow (1000 Mm^3) during the pre-construction stage of Tiga dam (Diyam Consultants, 1996). The specific yield at Tiga was 0.12 Mm^3/km^2. This confirms the reported low yield in the region from the 1980s. The specific yield in the Jamaare sub-basin was 0.18 Mm^3/km^2. The standardized streamflow index for Tiga, Challawa and Kafin Zaki is presented in Fig. 4. The proportion of times that drought occurred is 47% for Tiga, 53% for Challawa and 46% for Kafin Zaki. The observed drought could be mild (68% to 75%) or moderate (17% - 20%).

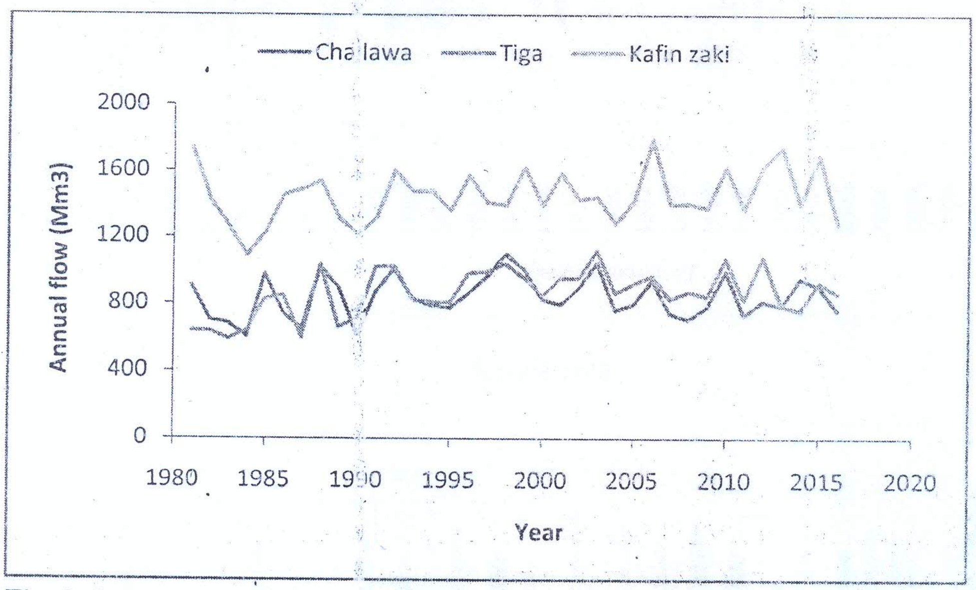

Fig. 3: Inter-annual variation in water yield

Figure 5 shows the estimated water demand (KYBP, 2006) in KYB. Rapid population growth in the basin is a major problem. By the year 2025 the population of the basin is projected to rise to over 25 million from the figure of 15 million in 1991 (GIWA, 2004). This and migration in pursuit of livelihood by the pastoralists, fishermen and environmental refugees as a result of increased desertification, have intensified the competitions for scarce land and qualitative water resources in the basin, resulting in frequent conflicts. Similarly, the growing human and animal populations are in part responsible for the cultivation of marginal land, increased deforestation, depletion of grazing land and reduction of fallow period, which have seriously degraded the land in the basin. Immediate actions that will facilitate proper targeting of the poor and design of effective measures for poverty reduction are necessary to make progress towards improved living conditions.

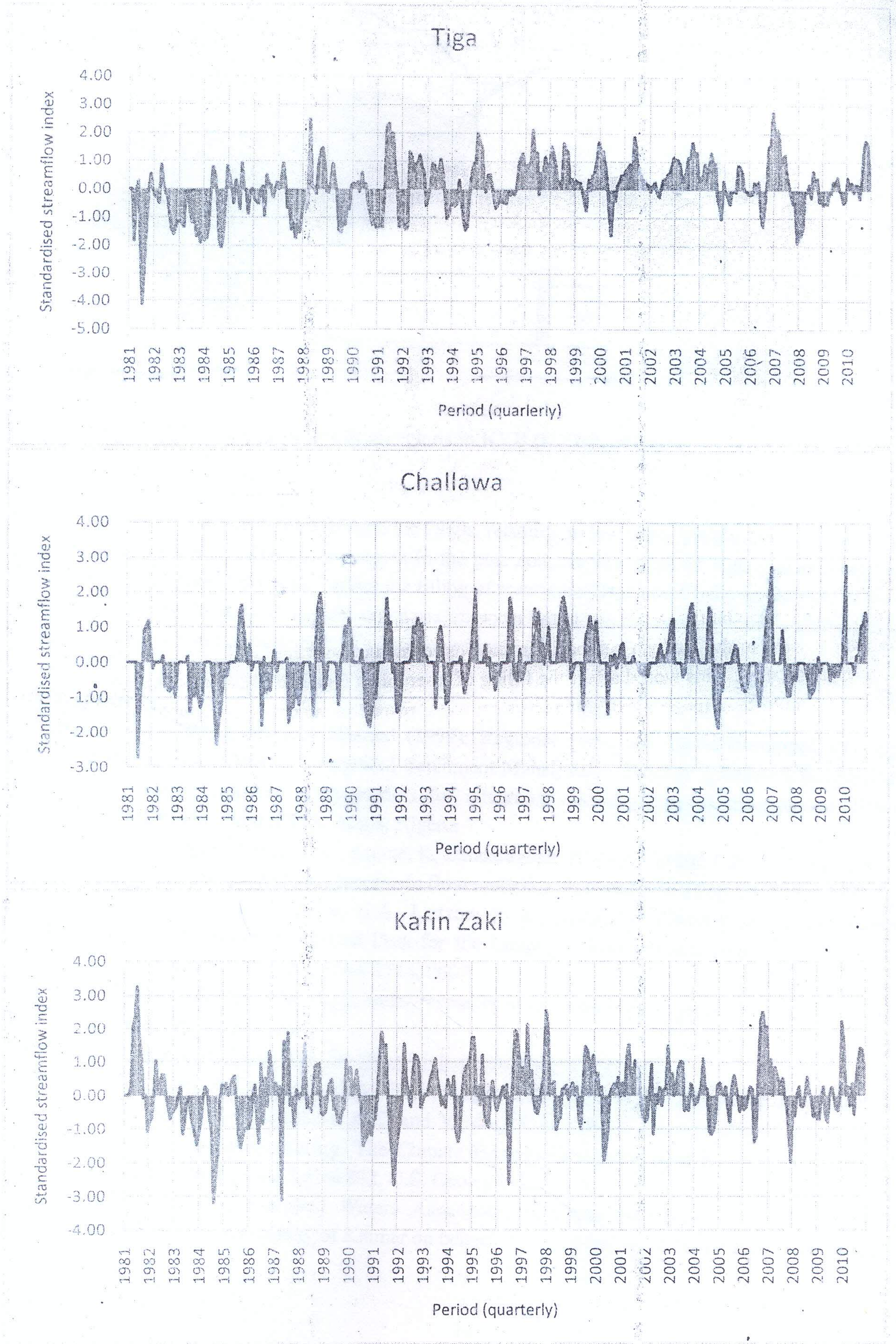

Fig. 4: Standardised streamflow index – 3-month step

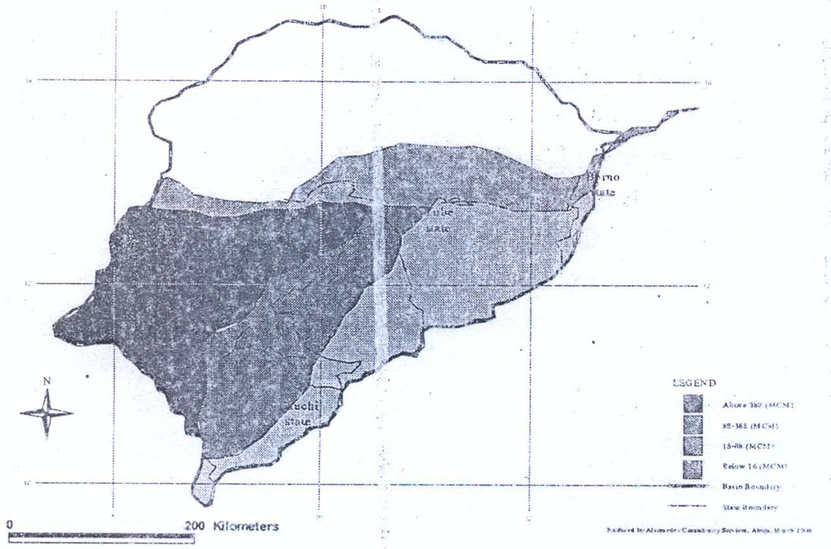

Fig. 5: Major water users and political regions in KYB (KYBP, 2006)

Conclusions

There is persistent decline in rainfall from the 1980s, resulting in low water yield in rivers in the KYB. The mean annual yield in the Hadejia sub-basin in the post construction stage of Tiga dam is lower than the pre-construction stage. This would affect the filling of reservoirs (Tiga and Challawa George) in the basin. Thus, there should be a much greater emphasis on water resources management and a shift of emphasis from supply to demand management of water resources.

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