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ORIGINAL RESEARCH ARTICLE

DECLINE IN AGRICULTURAL ACTIVITY AROUND LAKE CHAD: ANY PROSPECT FOR RESTORATION? A REVIEW

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ABSTRACT

Lake Chad that has been an economic hub for centuries has in the last few decades witnessed continued degradation threatening food security and livelihood of the population who depend on the lake for a living. The impact of depletion of the lake is being felt by an estimated 30 million people from the four riparian states, namely: Cameroon, Chad, Niger and Nigeria. This paper focuses on the causes of low agricultural activity around Lake Chad with particular emphasis on crop production. The paper also highlights the prospects for reviving agricultural activity through implementation of innovative soil management techniques. Analysis of the literature revealed that in addition to devastating effects of violent armed conflict on livelihood conditions in this region, frequent drought, dwindling rainfalls, degraded soils and sparser vegetation cover are among the factors responsible for the low agricultural activity in this region where a large proportion of the population relies on rainfed agriculture. The review revealed that organic farming practices that support biodiversity has the potential for besides improving soil health and reduce pest pressure, also improve crop yields and protect the environment. Furthermore, the use of biofertilizers to reduce the dependence on conventional inorganic fertilizers by farmers offers the means of mitigating the declining soil mineral nutrient reserves in this region. It is envisaged that restoring the lake to its near original state coupled with improving the productivity of the fragile soils will go a long way in addressing the challenges of food insecurity, a major factor stabilizing factor in the area

1.0 Introduction

The Lake Chad Basin is one of the largest inland drainage basins in Africa. The Borno and Yobe States of Nigeria are located within the basin and cover an area of about 116,000 km^2 (Bunu, 1999). The basin which covers about 8 percent of the surface area of the African continent is being shared between the countries of Chad, Cameroon, Niger and Nigeria (Figure 1). The lake has been a source of livelihood to about 30 million people, most of whom are farmers, fishermen and livestock breeders (Adamu, 2005). It is widely believed that the lake shrunk to about 10% of its original size over the last few decades thus heavily impacting the Basin's economic activities and food security. The shrinkage of the Lake has been driven by both global and local causes: climate change and the ever increasing competing demands on the Lake and its surrounding land have accelerated its shrinkage over the past years. Human impacts such as damming of rivers, increased irrigation, and reduced rainfall are among the obvious reasons for water shortages in the lake.

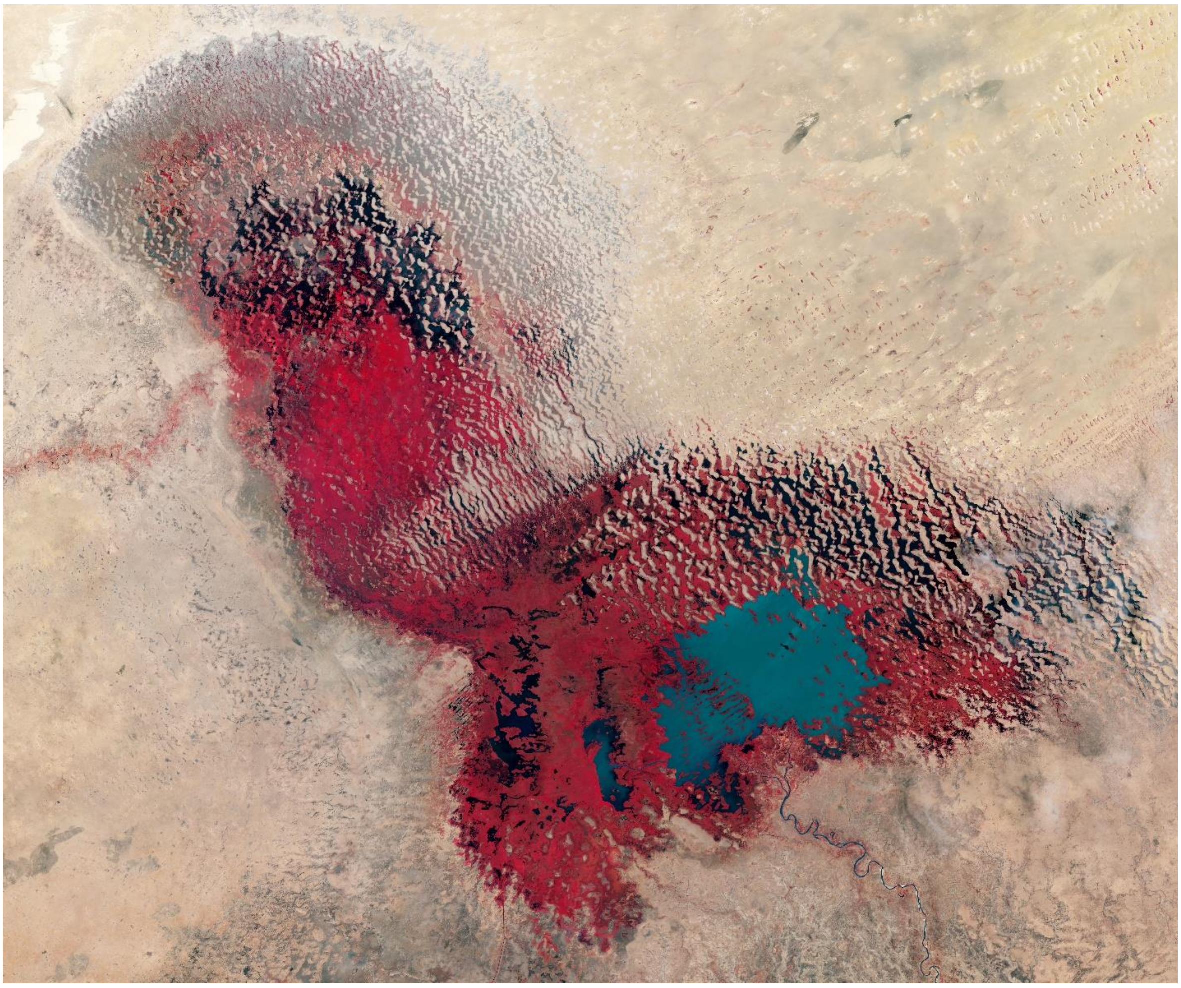

Figure 1: Satellite image of Lake Chad in 2017 with the actual lake in blue and vegetation in red

Source: https://www.earthobservatory.nasa.gov/images/91291/the-ups-and-downs-of-lake-chad accessed on 8th March, 2021

The ensuing water shortage has impacted negatively on the basin's economic activities including the fisheries, agriculture, animal husbandry sand wetland economic services. Studies have shown that prospects of natural recharge through precipitation are limited by excessively high temperatures causing most of the precipitation to evaporate as soon as it falls. The depletion of Lake Chad poses a pressing challenge to the flood recession agriculture widely practiced around the lake and the adjoining riverine wetlands. Flood recession farming is an important water consumer and the source of livelihoods for the overwhelming majority of the population consisting mainly of traditional smallholders, producing mainly staple foods for household consumption. Studies have shown that much as much as half of existing as well as potentially productive agricultural land in developing countries is being lost through the processes of land degradation and abandonment (Cleaver and Schreiber, 1994; Barbier, 1997). It is widely acknowledged among both soil specialists and policy-makers that soil degradation in Sub Saharan Africa (SSA) is expanding at an alarming rate, accompanied by the lowest agriculture and livestock yields of any region in the world (FAO, 2015) and that, unless the process of degradation is controlled, many parts of the continent will suffer increasingly from food insecurity (Lal, 1990; UNEP, 1982). However, of all the threats to soils and related ecosystem functions in SSA, the most critical are soil erosion, loss of soil organic matter, soil nutrient depletion and loss of soil biodiversity (FAO, 2015). In the Sudan and Sahel regions of Nigeria in particular, the over-dependence on the natural resources for survival has exerted uncontrolled pressure on the land (Samaila, 2005). Overgrazing and inappropriate cultivation practices are the principal causes of soil degradation in most part of Nigeria irrespective of ecological differences (Olderman *et al.,* 1991). Due to serious degradation of soil and water resources in and around the lake, interest has been developing in recent years for seeking ways to improve the productivity and livelihoods of the small-scale farmers in Lake Chad Basin. This paper examines the declining trends in agricultural productivity around the basin and makes recommendations on strategies for improving productivity of smallholder production systems around the lake.

2. Ecological Settings in Lake Chad Basin

The hydrology of the Lake Chad basin is dominated by the Logone-Chari Rivers, the Komadugu-Yobe, the Yedseram and the El-beid Rivers (Ngounon-Ngatcha, 2009). The Logone-Chari Rivers account for more than 90% of the volume of water supplied to the lake each year. The Komadugu-Yobe and Yedseram Rivers discharge less than 10% of the northern pool of the Lake Chad (Olivery *et al.,* 1996; Iliya and Bura, 2012). The rainfall distribution over the area is determined by the position of the meteorological equator and its two associated structures, the Inter Tropical Front (ITF) and Inter Tropical Convergence Zone (ITCZ) (Thambaypillay, 1991). This zone is defined as the southern border of the Sahara desert, characterized by low and unreliable annual rainfall, usually between 200 and 600 mm/year, along a positive gradient southward and occurring mainly between June and October (Visser and Sterk, 2007). Rainfall patterns are erratic and unpredictable, and crops can suffer from moisture deficits and drought even during normal rainfall periods (Parr *et al.,* 1990). The zone is characterized by sparse vegetation cover with the species consisting of thorny shrubs interspersed between annual and perennial grasses at the north which changes to taller vegetation with more trees towards the south (Herrmann *et al.,* 2005). The northern half of the basin is desert, containing the Tenere desert, Erg of Bilma and Djurab Desert. South of that is the Sahel zone, characterized by dry and thorny shrub savanna. Majority of the soils in the Lake Chad as elsewhere in the Sahel are sandy with the dominant soil types being Entisols and Alfisols (Kang, 1985), low in organic matter, nutrient and water reserves available for plant growth (Chiroma *et al.,* 2010b; Bationo *et al.,* 2014). These soils are believed to have formed from wind-sorted desert sands that accumulated over long periods of time when the Sahara desert encroached several kilometers south of its present limits (CPN, 1997). Aridity has enhanced the deposition of sand by wind developing into sandy loams, friable and easy to cultivate (Iloeje, 1982). Vertisols with high productive potentials are also found in this zone (CPN, 1997). Selected characteristics of the major soil types found in this zone are presented in Tables 1 and 2.

Table 1: Physical properties of the surface (0-20 cm) of a vertisol around Lake Chad.

Auger no.	Particle size distribution (%) Sand	Silt	Clay	*Soil texture class	% Dispersible silt + clay	Bulk density (g/cm^3)	Penetration resistance (kPa)	Moisture content (%)	Hydraulic conductivity (cm/h)
A1	38.9	15.0	51.1	C	83.2	1.66	620	0.188	
A2	34.1	17.8	48.1	C	63.2	1.47	551	0.305	
A3	53.9	30.0	16.1	SL	42.2	1.21	448	0.516	0.044
A4	33.9	17.5	48.6	C	58.1	1.39	498	0.502	
A5	53.9	10.0	36.1	C	58.2	1.36	476	0.512	
A6	28.9	22.5	48.6	C	65.8	1.56	613	0.276	
Mean	40.6	18.8	41.4	C	61.7	1.44	534	0.383	

*C = Clay; L = Loam; SL = Sandy loam.

Source: Chiroma *et al.* (2010a).

Table 2: Chemical properties of the surface (0-20 cm) soils around Lake Chad.

Auger no	pH	EC (dS/m)	Exchangeable cations me/100g Ca^{2+}	Mg^{2+}	K^+	Na^+	Total	CEC (me/100g)	Base saturation %	ESP	OM (%)	N (%)	P (mg/kg)
A1	7.2	0.50	15.6	16.8	0.94	0.34	33.7	34.0	99.1	1.00	2.80	0.31	22.5
A2	7.4	0.80	14.8	11.6	1.23	0.35	28.0	28.3	98.9	1.24	2.08	0.29	15.0
A3	8.9	0.14	54.4	19.2	0.77	15.3	89.4	89.7	99.7	17.1	0.58	0.10	2.8
A4	7.8	0.33	51.7	20.6	0.87	1.21	74.4	74.8	99.5	1.62	0.60	0.15	4.0
A5	7.6	0.34	19.4	18.1	1.10	0.78	39.4	39.8	99.0	1.96	1.57	0.27	11.0
A6	8.2	10.3	22.7	23.1	0.90	5.00	51.7	52.1	99.2	9.60	1.34	0.08	6.0
Mean	7.9	2.07	29.8	18.2	0.97	3.83	52.8	53.1	99.4	5.42	1.50	0.20	10.2

Source: Chiroma *et al.* (2010b).

Table 3: Crop production figures for South Chad Irrigation Project

Year	Area cropped to rice (ha)	Yield (tons)	Area cropped to wheat (ha)	Yield (tons)	Area cropped to sorghum (ha)	Yield (tons)	Area cropped to cotton (ha)	Yield (tons)	Area cropped to maize (ha)	Yield (tons)	Area cropped to cowpea (ha)	Yield (tons)	Area cropped to vegetables (ha)	Yield (tons)
1979/80	526	23,929	730	14,525										
1980/81	792	19,357	1,152	12,160							58	111		
1981/82	493	8,525	2,240	27,367	140	5								
1982/83	672	8,757	4,945	103,101									100	3,000
1983/84			7,000	145,492	1,000	1,500					7,500	15,000	600	12,000
1984/85					2,750	2,850	50	50	3,400	3,400	10,000	25,000	800	16,000
1985/86														
1986/87														
1987/88														
1988/89			6,000	80,100										
1989/90			5,200	72,350										
1990/91														
1991/92			5,000	42,692										
1992/93			4,991	25,817										
1993/94														
1994/95	20	400	4,500	13,334										
1995/96	45	1,000												
1996/97	136	51	2,221	13,358										
1997/98	152	485	759	1,938										
1998/99	40	992												
1999/00	100	3,099	200	1,139										
2000/01	155	3,131												
2001/02	712	6,644	6,049	3,867										
2002/03	453	4,688	436	2,683										
2003/04	125	401												
2004/05	116													
2005/06	120	55												

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3. Agriculture around Lake Chad

The vast majority of the people representing about 80-90% of the population in the Lake Chad basin rely mainly on agriculture for their livelihood and food security. Crop production and agro-pastoralism are the main economic activities in areas with rainfall of about 600 mm whiles in areas with rainfall of about 400 mm, rearing of livestock is the main economic activity (Mortimore and Turner, 2005). The farming communities in the upstream (uplands) practice rainfed agriculture in the months of June to October to grow mainly millet, sorghum, cowpea and groundnut on the sandy soils poor in nutrient and water retention capacity. Communities in the downstream and fortune seekers coming from drought stricken areas in the region practice flood recession agriculture to grow diverse types of cereal crops including maize, rice, wheat and vegetables. The majority of the population being small holder farmers relies on the traditional methods of farming characterized by zero or little usage of external inputs such as improved seeds, fertilizers and other agro-chemical necessary for sustained productivity. In recent years, farmers practicing the rainfed crop cultivation are faced with numerous challenges such as low soil productivity, low and variable rainfall brought about by climate change, environmental concerns and global market changes, which have had major local impacts on their production system organization, dynamics and viability. An empirical assessment of sub-Saharan Africa's soil fertility confirms that the region faces a significant decline in soil fertility, which could worsen food security if no appropriate action is taken. Jama and Pizarro (2008) argued that increased productivity and food security can be achieved in Africa if the appropriate investments are made in key interventions: soil fertility improvement, improved seeds, water management, market access, extension services, access to credit, and improvements in weather forecasting. Whereas the extent and rate of soil degradation in SSA is still under debate as there are no reliable data to substantiate such claims, nevertheless, there is growing evidence that certain soils are losing their ability to provide food and essential ecosystem services (Tully *et al.,* 2015). This could be true particularly in the case of soils around the Lake Chad. Field observations revealed that farmers often reallocate their fields from upland areas as an adaptation to declining rainfall and soil fertility. Alternatively, some farmers resort to cultivating more land than their family labour can support in a desperate attempt to stabilize crop yields (Chiroma *et al.,* 1996). Often times, such farmers abandoned their fields to weeds owing to labour shortage during critical periods of the season. Agricultural extensification is gaining popularity in many farming communities in the Sahel as part of adaptation mechanism in the face of ever growing challenges posed by climate change. Extensification in many dryland areas do not always result in increased yields per unit land area. For example, pearl millet production increased in Niger and Mali due to extensification, but yields remains unchanged for about 30 years (FAO, 2007).

Although farmers in this zone have in recent years perceived a steady decline in crop yields due to decline in rainfall and soil quality, it is practically impossible to assess the contributions of these environmental factors to the yield decline in the absence of reliable data on crop yields from famer managed fields. Small holder farmers in developing countries often lack the culture of record keeping making comparative analysis difficult. The narrative from institutionally managed fields like the one by the Chad Basin Development Authority (CBDA) is not encouraging either. The CBDA established a gigantic irrigation scheme known as South Chad Irrigation Project (SCIP) in the Lake Chad Basin with the mandate of growing crops like rice, wheat, maize and sorghum. The scheme at its inception in 1979 was able to cultivate a total of 525.6 ha of rice and 730 ha of wheat yielding about of 23,929 and 14,525 tonnes of paddy rice and wheat, respectively (Tables 3). As shown in the table, the scheme recorded relative success in the years between 1979/80 and 1983/84 and beyond this period the scheme suffered some setbacks as a result of unsustainable government policies towards agriculture, the changing climate and poor funding among other constraints. This dismal performance by institutionally managed fields further confirms the enormity of the twin challenges posed by climate change and decline in soil quality.

4. Innovative Technologies for Improving Soil Quality

Marginal, infertile soils occupy most of the adjoining uplands around the Lake Chad Basin. These soils are besides being coarse textured, low in organic master content and nutrients, occur in a harsh environment characterized by low water availability and supra optimal soil and ambient air temperatures. These soils can be made productive if the soil degradation processes are offset by appropriate soil conservation/reclamation practices. Commercially available fertilizers containing NPK (Nitrogen, Phosphorus and Potassium) are globally known to be the "best" method in agriculture due to its economic benefits, especially for farmers and entrepreneurs who would like to increase crop yields at the lowest cost possible (Javier, 2018). However, chemical fertilizers are expensive, non-eco-friendly, cause eutrophication, reduce organic matter and micro-biotic activity in soil and are hazardous to health (Sahoo, *et al.,* 2017). From an ecological perspective, the use of artificial fertilizers proves to disrupt the nutrient ratio in soils and lead to the competition of plants in croplands. This can be considered as one of the main cause of competitive exclusion among vegetation. Furthermore, repeated application may cause toxic buildup of chemicals in soils and may alter the soil pH which can harm beneficial microbial ecosystems (Javier, 2018). Therefore, the use of biofertilizers is desirable as they are natural, biodegradable, organic and more cost-effective than chemical fertilizers. Biofertilizers consist of plant remains, organic matter and some special class of micro-organisms.

Regular additions of organic materials such as animal manures and crop residues to soils can reduce erosion and nutrient runoff losses, improve soil structure, increase water-holding capacity, lower soil temperatures and provide a source of plant nutrients. Organic farming practices such as crop rotation and polycultures that support biodiversity, are known to besides improving soil health and reduce pest pressure, also improve crop yields and protect the environment (Ponisio, 2014). Interestingly, both these practices mimic nature by creating ecologically diverse systems that draw strength from natural interactions between species. The study by Ponisio, (2014) show that although organic crop yields are about 19% lower under organic farming than conventional systems, certain management practices such as planting multiple different crops at the same time (polyculture) and planting a sequence of crops (crop rotation) on an organic farm cut the difference in yield by about half.

Overall, the significant role of biofertilizers in plant growth productivity and protection against some stresses makes them a vital and powerful tool for organic and sustainable agriculture (Sahoo, *et al.,* 2017). The application of microbial inoculants (biofertilizers) is a promising technology for future sustainable farming systems in view of rapidly decreasing phosphorus stocks and the need to more efficiently use available nitrogen (N). Various microbial taxa are currently used as biofertilizers, based on their capacity to access nutrients from fertilizers and soil stocks, to fix atmospheric nitrogen, to improve water uptake or to act as biocontrol agents (Schütz *et al.,* 2018). Efforts to mitigate the declining mineral nutrient reserves are currently major topics of research but the perturbance of the global biogeochemical cycles, mainly driven by the use of mineral fertilizers, remains a serious problem (Kahiluoto *et al.,* 2014). Several studies have demonstrated the potential of biofertilizers in fixing nitrogen (N), help to access nutrients such as phosphorus (P) and N from organic fertilizers and soil stocks, improve drought tolerance, improve plant health or increase salt tolerance (Vessey, 2003; Arora, 2013). Examples of microbial inoculants tested in these and other studies include Arbuscular mycorrhizal fungi- AMF (Lekberg and Koide (2005); Berruti *et al.,* (2016); Schütz *et al.,* 2018), Plant growth-promoting rhizobacteria-PGPR (Rubin *et al.,* 2017). The results of these and other studies have often been inconsistent due mainly to reasons such as soil conditions, strain identity, or host genotype. Schütz *et al.,* (2018), however, opined that what is missing is a comprehensive quantitative analysis over all biofertilizers and across all target crops and climatic conditions at global scale. These authors recently analyzed the potential of Arbuscular mycorrhizal fungi as biofertilizers under multi-climatic environments and concluded that averaged across all biofertilizer categories, yield was increased the most in dry climates (+20.0 ± 1.7%), followed by tropical climates (+14.9 ± 1.2%), oceanic climates (+10.0 ± 3.7%), and continental climates (+8.5 ± 2.4%). The authors however, cautioned that in interpreting these results it is important to keep in mind that 45% of the comparisons in dry climate were conducted in the presence of irrigation.

5. Conclusions

Based on the analysis of current situations in the Lake Chad, there is evidence that resources in and around the basin are under enormous pressure arising mainly from the influx of people in search of opportunities. The increased competing demands on the Lake and its surrounding land have accelerated its shrinkage and the subsequent deterioration of soil resources around the lake. It is envisaged that improving the productivity of the fragile soils will go a long way in addressing the challenges of food and energy insecurity, a major stabilizing factor in the area. Organic farming practices that support biodiversity, are known to besides improving soil health and reduce pest pressure, also improve crop yields and protect the environment. Furthermore, the use of biofertilizers to reduce the dependence on conventional inorganic fertilizers by farmers offers the means of mitigating the declining soil mineral nutrient reserves in this region.

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