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Table of Contents: Volume 10 Number 4 April 2016

ARTICLES

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Full Length Research Paper

Spatial dynamic of mobile dunes, soil crusting and Yobe's bank retreat in the Niger's Lake Chad basin part: Cases of Issari and Bagara

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The process of desertification is accelerated in the northern part of Lake Chad basin since the early 1970. Those processes linked to the recurrent drought and a heavy human pressure induced a great environmental damages. So this study based on diachronic cartography (1957, 1975 and 2007) aimed to describe and quantify the degradation dynamics in the contrasting Niger's Lake Chad basin part. Thus significant environmental changes have been observed in this area from 1957 to 2007. Indeed in the Manga, the natural commodities and fields were threatened by mobile dunes making blocking with sand: the mobile dunes spread from ~200 ha in 1975 to ~900 ha in 2007 while they had not watched in 1957. In the fluvio-deltaic area of Kadzell, the soil crusting and the Yobe River retreat remain the major damages. The crusting area has been multiplied by more than two while the lateral migration of the Yobe bank reached near of 3 m.yr^{-1}. This study highlights the key role of man in the process of degradation related to climate parameters

Key words: Lake Chad, degradation dynamics, soil crusting, dunes, human activities.

INTRODUCTION

The Lake Chad basin covers 2.5 million square kilometers and spreads on eight African countries. It concerns the life of 30 million peoples and the economic activities of the people around the lake rely on fishing, cattle breeding, agriculture and trade. Those activities remain traditional and largely dependent of climatic conditions. Indeed, since the early 1970, the processes of desertification were accelerated in the Niger and largely

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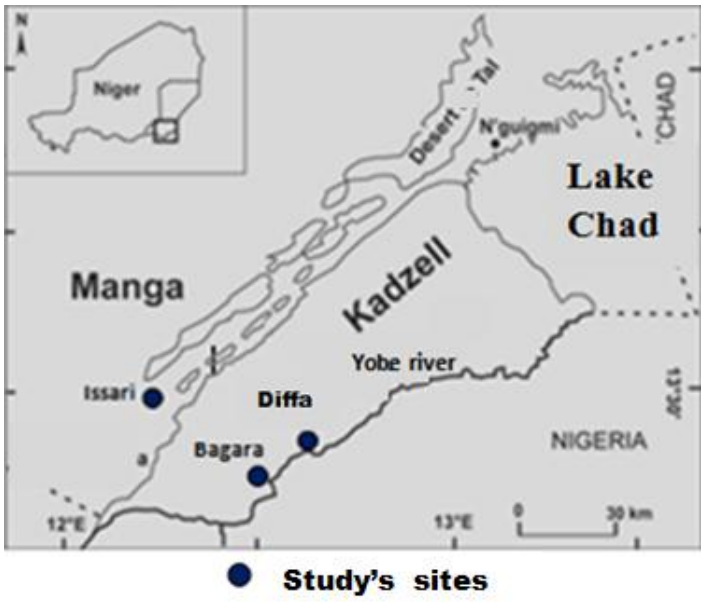

Figure 1. Localization of study's sites.

in the Sahel by a heavy human pressure and by recurrent drought which had induced the deaf of millions trees (Gado, 1992; Casenave and Valentin, 1992; Cornet, 2002; Tidjani, 2008; Lebel and Ali, 2009). The rapid population growth, largely observed in the Sahel, has increased food and firewood needs (Bielders et al., 2002, 2004; Tidjani, 2008; Boubé et al., 2011). This induced a progressive plant cover degradation linked to the extension of agricultural area and heavy breeding height (Moussa Issaka, 2014).

Besides the land degradation in the Sahel depends of geomorphology units and different degree of vulnerability to degradation was contingent to the lithology, vegetation cover and the vicinity of town (Couteron, 1997; Cissokho, 2011; Abdourhamane Touré, 2011; Moussa Issaka et al., 2014). In the Niger part, the geomorphology of the Lake Chad Basin is dominated by sandy plateaus (Manga), fluvio-deltaic area (Kadzell) and the Yobe River. Despite this contrast, the studies have been focused essentially on the Manga where mobile dunes make blocking with sand of pasturage, fields and other socio-economic commodity (Mainguet et al., 1979; Tidjani, 2008). The comprehension of the degradation dynamics in large contrasting basins like the Niger part of the Lake Chad basin is needed. This study aims to describe and quantify the environmental degradation dynamic in the various geomorphological units: Manga for dune dynamics, Kadzell for soil crusting and the Yobe River for collapse of banks.

MATERIALS AND METHODS

Study area

The study area comprises the Niger's Lake Chad basin part. The climate of the zone is sahelo-saharian with a mean annual rainfall ranging from 250 to 350 mm. The Manga site (Issari: 13°42-13°35N, 12°13-12°21E) is dominated by shrub savanna and arborous savanna developed on sandy plateaus made of an ancient erg flattened by (ancient) runoff and (current) wind erosion (Durand, 1993). These plateaus slightly slope to the southeast towards the Kadzell (Durand, 1993).

Kadzell site is located in a fluvio-deltaic area (Bagara: 13°16-13°22N, 12°37-12°42E) and it is occupied by savanna developed in the Niger part of the Yobe alluvial plain (temporary tributary of the Lake Chad). It is made predominantly of an ancient erg flattened by winds, spread by the Komadugu Yobe and mixed with clayey fluvial contributions. The plain is bounded on the NE by a sandy beach barrier that separates it to the Manga plateau (Figure 1). Besides, Bagara is situated near the bank of the Yobe River. Yobe is a semi-permanent river. Its flows generally occur from mid-July to stop in April for the period from 1962 to 1971, but stopped in March for the period starting from 1971 to 1985 and in February for the period from 1985 to 1993 (Moussa Issaka, 2014). In another way, October records near of 25% of the annual flow volume, September 22% and November 21% while the maximum daily flows recorded since the establishment of Bagara's station ranged from 25 $m^3.s^{-1}$ to 84 $m^3.s^{-1}$ (Moussa Issaka, 2014). This river spread the soil and imposed dynamic movement of the environment. This dynamic is analyzed at two meanders (B1, B2) around Bagara in relation with land use and climatic parameters.

Landscape unit dynamics

The strategy of the study is built on a diachronic cartography of landscape units between 1950 and 2007 in two sites Issari and Bagara (Figure 1). Thus aerial photographs of 1957 and 1975 completed with Landsat TM satellite images from 1975 and 2000, and Google Earth image of 2007 were used to produce land use maps for the periods 1957, 1975 and 2007 and to monitor the Yobe River. Thus panchromatic aerial photographs are scanned at 1200dpi for 1957 photographs and 300dpi for 1975 photographs with a resolution of 1 and 5 m respectively. These resolutions are sufficient to detect environmental changes. Then, scanned photographs were georeferenced in the Mercator projection system

Table 1. Key of interpretation for aerial photographs (Source: CENATEL, 2007).

Form	Gray tone	Texture	Structure	Identification
Irregular	Moderately grey	Little bit smooth and granulated	Granulated and smooth	Savane arborée
Irregular	Enough dark gray	Very few fairly smooth and granulated	Granulated and smooth	Savannas
Irregular	Light gray	Very few granular	Homogeneous	Shrublands savannas
Regular	Enough clear gray	Smooth pretty to smooth	Homogeneous	Cultivated areas
Regular	Dark gray	Granulated and aligned in order	Very homogeneous	Plantation
Irregular	Very clear gray	Smooth	Homogeneous	Dune's and encrusted surfaces
Sinuous	Dark gray	Smooth	Homogeneous	Rivers
Irrégulière	Very clear gray	Granulated and group	Fairly homogeneous	Habitations

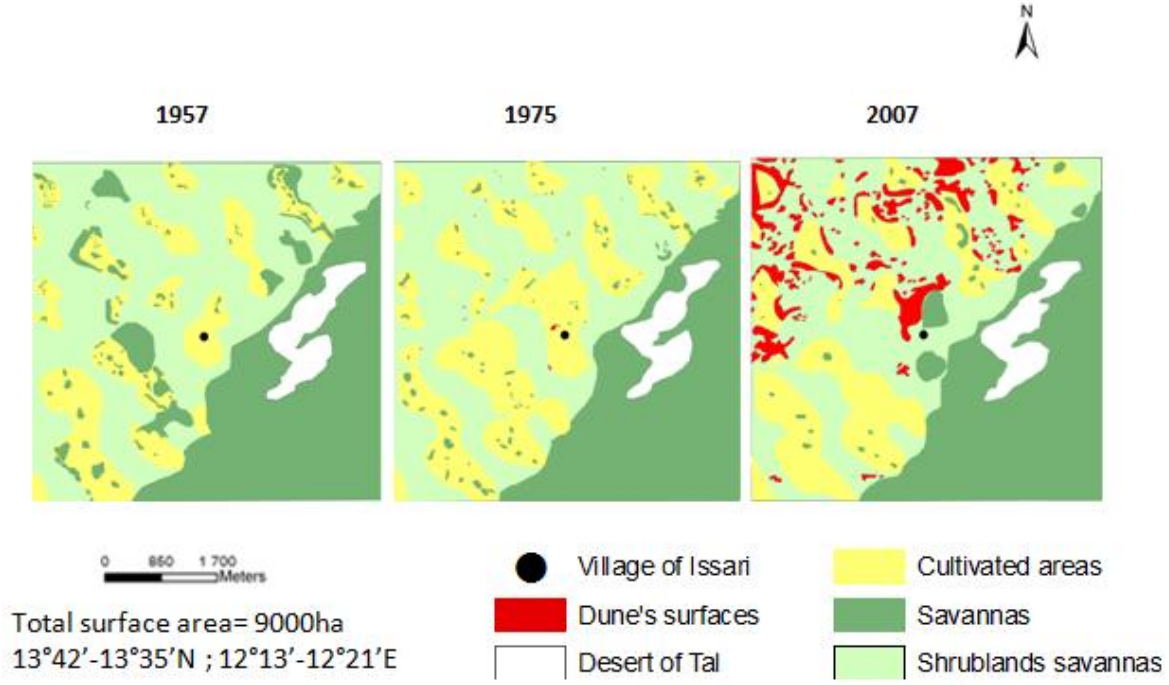

Figure 2. Land cover and land use of the site of Issari (Manga).

WGS_1984, UTM 33N by using the extension data analysis of Arc View processing software. Ten-minimal ground control points (GCPs) have been necessary to rectify each photo. The landscape unit mapping and classification is then done by using an aerial photographs key interpretation (Table 1). These keys consider agro-pastoral practices and landscape transformation in the Sahel (Diello, 2007). The results of the cartography have been checked during two ground-missions.

RESULTS AND DISCUSSION

Landscape unit dynamics

At Issari (Figures 2 and 3), the cultivated area have been increased from 3,555 ha (32% of the mapped area) in 1957 to 4,222 ha (38%) in 1975 before shifting down at 3222 ha (29%) in 2007, where in Bagara (Figures 4 and 5), the increasing of cultivated area is regular from 850 ha (11% of the mapped area) in 1957, to 5,850 ha (76%) in 1975 and 6,080 ha (79%) at 2007. In the zone, agriculture remains traditional, manual and it is usually done without fertilizers. In the context of food and firewood needs increasing linked to population growth, the consequence has been the extension of cultivated area. This cultivated area increasing has been reported in south- western Niger (Boubé et al., 2011; Abdourhamane Touré et al., 2010; Abdourhamane Touré, 2011) where 60,000 ha were subtracted annually in natural vegetation

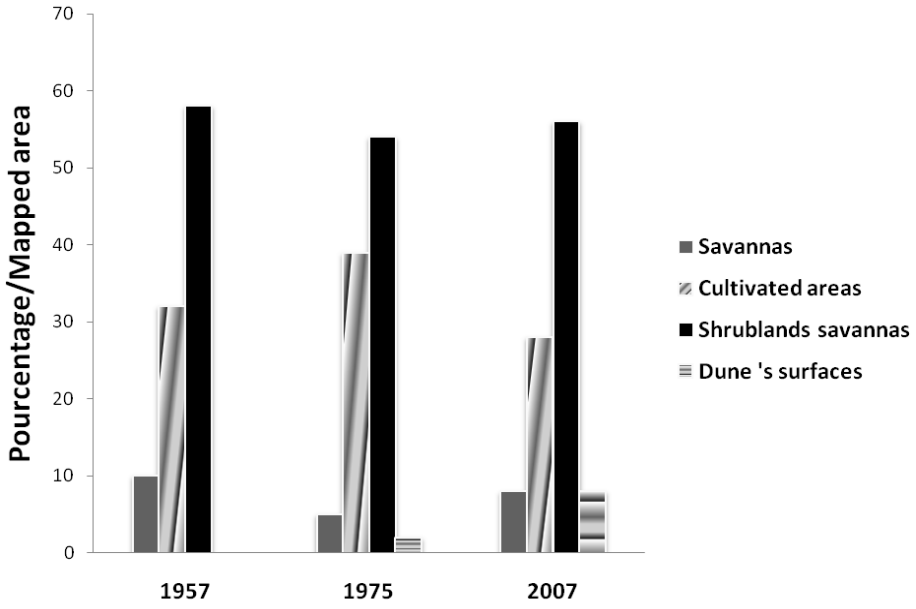

Figure 3. Land use dynamic at the site of Issari (Manga).

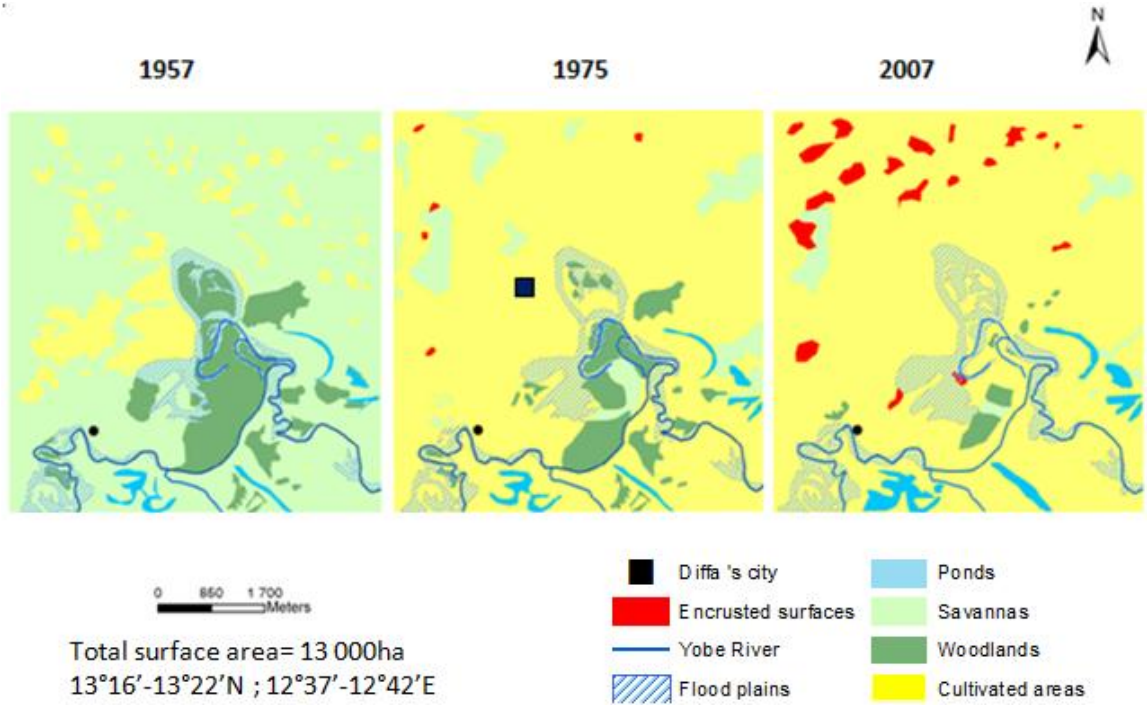

Figure 4. Land cover and land use at the site of Bagara (Kadzell).

for agriculture and uncontrolled deforestation (Ichaou, 1996). In the Burkina Faso, Diello (2007), observed the same trend and even under the Sudanese climate of Benin where the rainfall exceeds twice that of the central Sahel, Amoussou (2010) reported the increasing of the agricultural area.

At Issari, the declining in cultivated area between 1975 and 2007 occurred in favor of mobile dunes (Figure 2). These dunes appeared after 1957 occupied 222 ha (2% of the mapped area) in 1975 (Figures 2 and 3). The

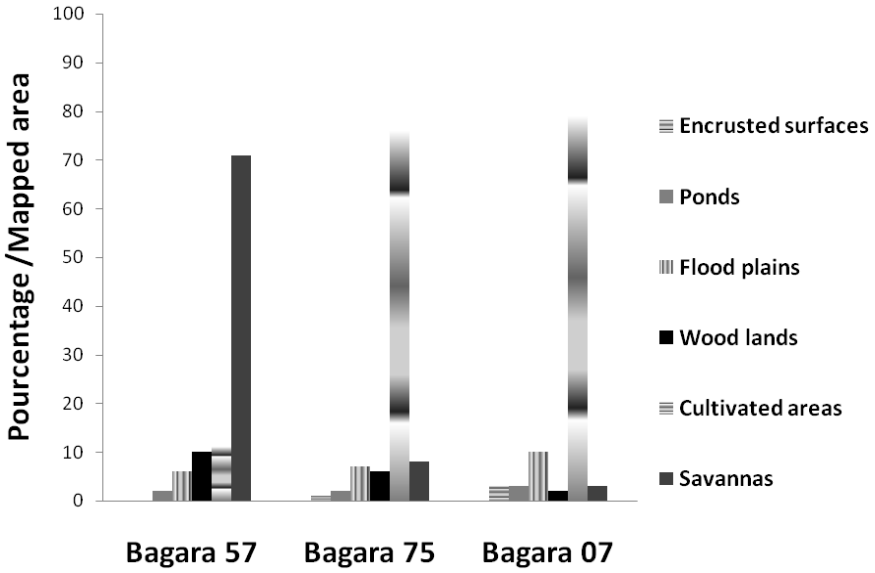

Figure 5. Land use dynamic at the site of Bagara (Kadzell).

mobile dunes occurrence was favored by the drought of the early 1970s and exacerbated by the deforestation and the cultivated area extension. The mobile dune appeared on the marginal soil of the sandy plateaus more sensitive to erosion when they have been cultivated (Cissokho, 2011) (Figure 2).

This increasing of dune's surface by human activities has been observed in the northern part of the Sahara in Algeria (Nedjraoui and Bedrani, 2008). From 1980 to 2005, in the southeastern Niger these dunes induced blocking with sand of more than 20% of the inter-dune basin which are the most productive soil in the area (Tidjani, 2008).

At Bagara, the appeared soil surface damage is erosion crust (Valentin and Bresson, 1992). These encrusted surfaces had the same dynamics as that of the dunes of Issari. Their expansion ranging from 76 ha to 230 ha respectively in 1957 and 2007 (Figures 4 and 5) is linked to the extension of cultivated area on marginal soil.

Indeed, in the southwestern Niger, the intensive cultivation of marginal soil which has less biomass productivity leads to less soil protected and great erosion rate followed by erosion crust extension (Abdourhamane Touré et al., 2010). Besides, the cultivation accelerated significantly nutrient's losses, reduces the physical and chemical soil fertility (Bielders et al., 2002). Also the pastoral charge (0.40 heads.ha^{-1}) in 2009 (Moussa Issaka, 2014) is high than the balance charge in semi-arid to arid zone estimated at 0.25 head.ha^{-1} (Boukhobza 1982). Bagara is then overgrazed. Thus this overgrazing participated in the disappearance of the vegetation cover and increased the vulnerability of soil to erosion. Thus, in the Kadzell, the ultimate degradation is crusting unlike blocking with sand observed in Manga (Figures 2 and 4). This difference of damage is essentially due to the geomorphology: Kadzell is an alluvial plain where the Manga is dominated by sandy plateaus. Nevertheless, the occurrence of the two damages highlights the important role of human pressure.

Yobe river's bank dynamic

The dynamics of the Yobe minor bed have been observed cartographically. Between 1957 and 1975, the lateral moving of Yobe minor bed was not very noticeable. On the contrary, between 1975 and 2007 the minor Yobe bed has evolved significantly. This evolution has been measured for two meanders (B1 and B2) bordering Bagara (Figure 6). It was very important from 1975 to 2007. At the B1 meander, the retreat of banks reached 120 m eastwards towards Bagara while for the B2 meander it was 92 m westwards backwards Bagara. The movement of the bed is accompanied by high sinuosity of the watercourse. The B1 meander wavelength ($\lambda B1_{1975}$) was 396 m in 1975 while it is 349 m in 2007 ($\lambda B1_{2007}$). For the B2, the same dynamic of bringing closer of the meander's banks was observed. B2 wavelength is increased from 1 083 m in 1975 ($\lambda B21975$) to 934 m in 2007 ($\lambda B22007$). The years 1957 to 1969 were mostly wet period, before the beginning of the drought in the early 1970's. But, the dynamics of the minor Yobe bed remaided stable between 1957 and 1975. The stability of the Yobe River's bank would have certainly been linked to the presence of savannas along its banks (Figure 4). Indeed, vegetation prevents embankment erosion. This has been particularly obvious in western Niger along the Boubon's kori (Mamadou,

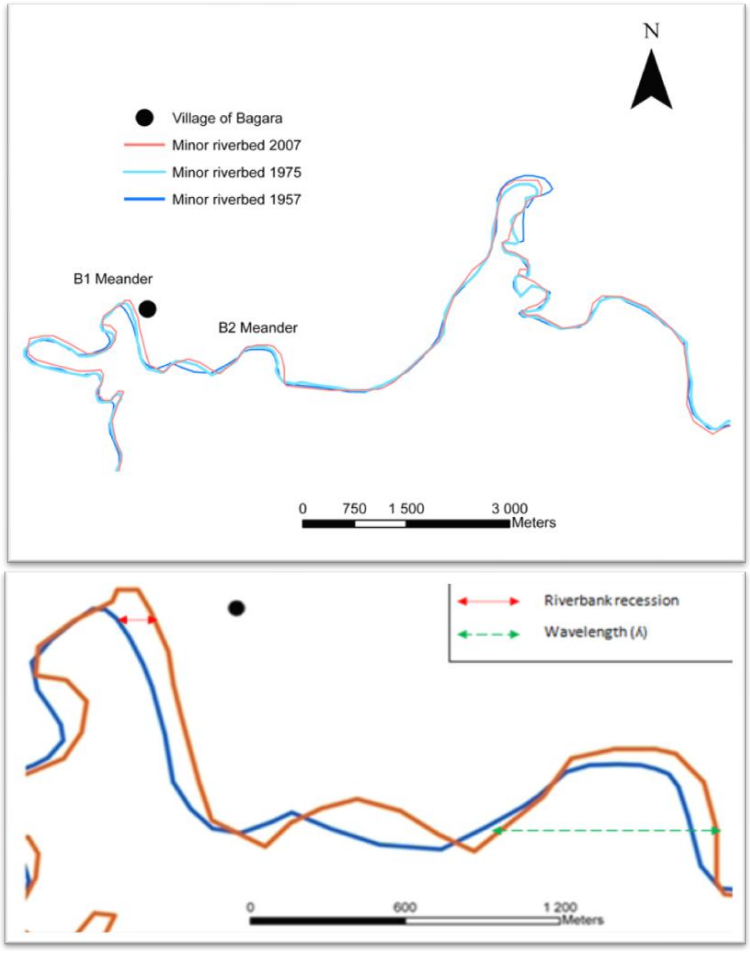

Figure 6. Polylines representing the minor riverbed of the Yobe river.

2012). This exoreic tributary feeding the Niger River has seen its eastern bank stabilized by hedges planted in 1985, while its west bank, without hedges, is subjected to a lateral erosion of more than 2 m per year. Between 1975 and 2007, the migration of the minor Yobe bed was most pronounced exceeding 3 m per year. This occurred in the context of a rainfall crisis (Descroix et al., 2009a, b) and reducing Yobe flow (Moussa Issaka, 2014). It is expected that such conditions should reduce river bed erosion. However, the banks of the Yobe are under strong anthropogenic influence. Between 1975 and 2007, woodlands and savannas protecting its banks have lost 75% (~600 ha) of their total area. Thus the speed of the Yobe riverbank migration is therefore probably linked to the intense clearing of its banks and the widespread of deforestation of its watershed by the exploitation of natural habitats (savannas and forests).

Conclusion

This analysis based on using of aerial photographs and satellite images allowed a description and a quantification of the degradation in the various geomorphological units of the Niger's Lake Chad Basin part. The environment has changed significantly between 1957 and 2007. It appears that the Manga environment is threatened by blocking with sand. Dune surfaces increased from 222 ha in 1975 to 888 ha in 2007. The alluvial plain (Kadzell) is threatened by soil crusting and Yobe River's bank retreat. Indeed, the encrusted area increased from 76ha in 1975 to 230 ha in 2007. The only river in the Niger's Lake Chad Basin part is under the collapse of the banks' threat and its migration. The displacement exceeds near of 3 m/yr at the two meanders (B1 and B2) analyzed between 1975 and 2007.

Conflict of Interests

The authors have not declared any conflict of interests.

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REFERENCES

Abdourhamane Touré A (2011). Wind erosion on cultivated sandy environment in Niger: current and recent dynamics in conjunction with human pressure and climate change. PhD Thesis. University of Bourgogne, France. P 234.

Abdourhamane Touré A, Guillon R, Garba Z, Rajot JL, Petit C, Bichet V, Durand A, Sebag D (2010). Sahelian landscape evolution during the last six decades in the vicinity Niamey: from the bush Crusting disappearing to the soil. Pangea 47:35-40.

Amoussou E (2010). Variability of rainfall and hydro-sedimentary dynamics of complex watershed. Mono - river-lagoon - Ahémé Couffo (West Africa). PhD thesis. University of Bourgogne, France. P 313.

Bielders CL, Rajot JL, Amadou M (2002). Transport of nutrients and soil by wind in bush fallow land and cultivated fields traditionally managed in the Sahel. Geoderma 109:19-39.

Bielders CL, Rajot JR, Karlheinz M (2004). Wind erosion in the Niger Sahel: Influence of current agricultural practices and methods of struggle. Secheresse 15:19-32.

Boubé M, Ambouta JM, Saley Z, Ali M, Mahamane S, Zamah AM, Brice S (2011). State of habitat degradation of the giraffe (*Giraffa camelopardalis peralta* Linnaeus, 1958) in Niger. Secheresse 22:57-64.

Boukhobza M (1982). The Algerian agro -pastoralism, from colonial tribal order disorder. O.P.U, Algiers. P 458.

Casenave A, Valentin C (1992). A runoff capability classification system based on area features criteria in semi- arid areas of West Africa. J. Hydrol. 130:231-249.

Cissokho R (2011). Development of a vulnerability index to wind erosion from sattelitales image in the Groundnut Basin of Senegal Case Thies. Thesis. Montreal University. P 251.

Cornet A (2002). Desertification at the intersection of the environment: a problem for us. World Summit on Sustainable Development, which stakes? What contribution of scientists? Johannesburg. pp. 93-130.

Couteron P (1997). Contractions of vegetation and drought. Example northwest of Burkina Faso. In: JM of Herbs, Ambouta JMK , Peltier R, eds. Operation and Management of contracted forest ecosystems Sahel. Montrouge (France).

Descroix L, Mahé G, Lebel T, Favreau G, Galle S, Gautier E, Olivry JC, Albergel J, Amogu O, Cappelaere B, Dessouassi R, Diedhiou A, Le Breton E, Mamadou I, Sighomnou D (2009a). Spatio-Temporal variability of hydrological regimes around the boundaries Sahelian and Sudanian Between Areas of West Africa: A synthesis. J. Hydrol. 375(1-2):90-102.

Descroix L, Mamadou Moussa MA, Bashir A, Moussa I, Le Breton E (2009b). Status and proposed soils remediation on the Tondi Kiboro BV an experimental basis. International Symposium of Port-au-Prince (Haiti).

Diello P (2007). Interrelation Climate -Man- Environment in the Burkinabé Sahel: Impact on surface conditions and hydrological modeling . Geo- Hydro Science and Environment. University of Montpellier II. P 395.

Durand A (1993). Sedimentary record of climate dynamics at the upper Quaternary in the central Sahel (Niger and Chad). Thesis. University of Dijon. P 562.

Gado BA (1992). Traditional Concepts of droughts, famines and epidemics in the Sahel. Secheresse 3(4):243-250.

Ichaou A (1996). Ecological research applied to the management of forest ecosystems contracted trays Western Niger. Niamey. Orstom / Energy Project II. P 37.

Lebel T, Ali B (2009). Recent trends in the Central and Western Sahel rainfall diet (1990-2007). J. Hydrol. 375:52-64.

Mainguet M, Canon- Cossus L, Chemin MC (1979). Deterioration in the central regions of the Republic of Niger. Trav. Inst. Geogr. Reims. pp. 61-73.

Mamadou I (2012). Accelerated dynamics koris the Niamey region and its impact on the silting of the Niger River. Thesis. University Abdou Moumouni of Niamey and Paris I. P 290.

Moussa Issaka A (2014). Dynamics of erosion and landscape in the Niger part of the Lake Chad Basin. Thesis. University of Abdou Moumouni, Niger. P 180.

Moussa Issaka A, Somé Yélézouomin Stéphane C, Garba Z, Abdourhamane Touré A, Yacouba H (2014). Erosion Response to Landscape Unit Changes in Eastern Niger: The Case of Bagara and Issari. Br. J. Appl. Sci. Technol. 4(21):2970-2984.

Nedjraoui D, Bedrani S (2008). Desertification in Algerian steppes: causes, impacts and control activities. Vertigo. Vol.8 No.1. Accessed March 5, 2013. URL: http://vertigo.revues.org/5375.

Tidjani AD (2008). Wind erosion in the Damagram East (southeastern Niger) parameterization , quantification and control methods. Thesis. Catholic University of Louvain. P 171.

Valentin C, Bresson LM (1992). Morphology, genesis and classification of surface crusts inloamy and sandy soils. Geoderma 55:225-245.

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Full Length Research Paper

Development of built environment and its implication on flood risk in Gombe Metropolis, Nigeria

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The increasing frequency of flood events in urban areas and its devastating impact on lives, properties, resources and the environment as a whole has posed a serious concern to environmental scientist the world over. There are many different perspectives regarding factors responsible for flood risk in urban areas, which range from hydrological extremes to man-induced factors. This paper examines the impact of built environment on the increasing flood occurrences in Gombe Metropolis in Nigeria. Data was essentially collected through questionnaire survey and analyzed using statistical model so as to discover the main factors causing flood in the metropolis. A multi-stage sampling technique was applied for data collection, where Gombe Metropolis was categorized into eleven residential quarters and a total of two hundred and fifty one questionnaires were administered to chief householders in the respective residential quarters in the metropolis, and finally multi- linear regression analysis was conducted, where flood risk is conveyed as a function of some selected urban development variables and used to examine the relationships and impact of these variables on causing flooding and the increasing flood risk via a statistical model. The result shows that rapid growth of built-up environment with poor implementation of building control measures is the main factor for flood risk in Gombe Metropolis. However, construction of built-up areas on floodplains as well as inadequate space between building structures as recommended by the town planning laws, has also contributed immensely to the increasing flood risk in Gombe Metropolis.

Key words: Flood risk, built environment, Gombe Metropolis, hydrological extremes, vulnerability.

INTRODUCTION

It is estimated that more than half of African population may probably live in urban areas by the year 2030, and Nigerian urban population is already rapidly proliferating at a rate of six percent annually (Balzerek, 2001). As a result, urban centers especially in Nigeria have witnessed an intensive physical development in terms of building constructions to accommodate the increasing urban population (Falade, 2003). Furthermore, the recent rise of flood occurrences in cities across Nigeria has been a great source of concern and challenge to people and

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governments especially Gombe Metropolis. Gombe Metropolis is typically one of the fast growing cities in Nigeria. Gombe metropolis has witnessed a significant growth immediately after its inception as the capital city of Gombe State in 1996. The city grew in total population from 169,894 in 1996 to 219,946 in 2000 and reaching 321.467, 400,000 in 2006 and 2010, respectively (National Population Commission, 2006; Mbaya, 2013). This demographic mobility triggered a rapid development of built-up and the increasing building density in the old settlement and the outward expansion of the marginal lands in virtually all directions of the metropolis. Since then, flood occurrence has become a seasonal event impacting lives, properties and the environment as a whole. Therefore, urban growth and the increasing development of built environment without adequate spatial planning has become a major concern worldwide especially with the rising trend in flood risk in urban areas.

Flood risk is one of the most recent environmental hazards affecting human settlements and causing a lot of mayhem to lives, properties, resources and the environment as a whole, and the world over. A risk is a probability of a loss that depends on two basics elements: hazard exposure and vulnerability. Indeed, if any of these elements increase or decrease, the risks also increase or decrease accordingly (World Meteorological Organization and Global Water Partnership, 2008). Hence, risk is a cross-cutting combination of vulnerability and hazard and a disaster cannot occur if only hazard exists with no vulnerability, or if there are vulnerable people but no hazard. In short, risk is the probability of hazard and the related consequence on the elements at risk. That is why, flood risk is defined as a probability of flood occurrence and the potential adverse consequences (Barredo and Engeleng, 2010).

There is a probability that flood events may increase in the future as a result of climate change, steady increase of human population, as well as increasing growth of built-up environment (United Nations International Strategy for Disaster Reduction, 2004). However, there are many different perspectives that can be proffered as reasons for the increasing flood events globally. For instance, floods occur as a result of extreme hydro-meteorological events causing inundation of usually dry places. Nevertheless, Pielke (2000) argued that the there is weak correlation between hydrological factors and the damaging floods in urban areas. Hooijer et al. (2004) asserts that urban flood risks increase not only due to climate change but also as a result of continued encroachment of people and their cultural built environment in areas of risk of flooding. Moreover, the damaging flood occurs from a combined force of both the physical and the social processes. This is because, the variable related to exposure normally include proximity to source of threat. Hence, the progressive land use change and growth of built environment on unsuitable urban places or areas liable to flood may play a significant role in the increasing flood frequency in urban areas. For this reasons, urban growth is one of the determinants of urban flood risk especially where developments of buildings are not accompanied by complementary spatial planning and poor development control measures, flooding became inevitable (Adewumi, 2013).

In addition, urban growth is by far the most forceful cultural change that causes peak flow discharge, changes in total run-off and capable of reducing infiltration capacity (Leopold, 1968). Thus, it is related to the percentage of an area overlaid with built-up structures on the earlier pervious surfaces. Thus, the increasing impervious surface has the potential of increasing flood risk in urban areas (Leopold, 1968). Therefore, urbanization increases the volume and rate of surface run-off by attenuation of the natural drainage system and the modification of runoff leading to quick creation of high volume of runoff in a short period of time and potentially leading to a dramatic increase in food peaks (Pielke, 2000).

Thus, this paper aimed to examine the process of urban growth and its implication on flood frequency in Gombe Metropolis and the objective of the study was to examine how urban growth increases flood frequency and also determined whether constructions of built-up on downstream areas increases flood risk in Gombe Metropolis.

Study area

The study area is Gombe Metropolis, a commercial, administrative town and the capital of Gombe State. The metropolis is approximately located at latitude 10° 0^{l} and 10° 20^{l} and 11° 1 ^{l} and 10° 19^{l} (Gombe State Ministry of Land and Survey, 2003).

Gombe Metropolis is located within the sub-Sudan wet and dry climate zone where the raining season is from November to March and the dry season is from April to October.It shares common boundaries with Kwami Local Government on the north and Akko Local Government Area to the south east and south west. The total population of Gombe Metropolis was 266,844 in 2006 and increased to almost double (400,000) in 2010 (National Population Commission, 2006, Mbaya, 2013).

The metropolis is a diverse multi-religious and multi-cultural consisting of mainly Muslims and Christians with different ethnic groups of Fulani, Hausa, Tera, Tangale, Bolawa, Waja, Igbo, Yoruba, and Kanuri tribes. Overall, the literacy level is considerable good with virtually all residents having at least the basic education but majority earning less than eighteen thousand minimum wage in a month.

The oldest core part of the metropolis is the most densely populated area with 260 persons per square hectare and coincidentally the most densely part of the

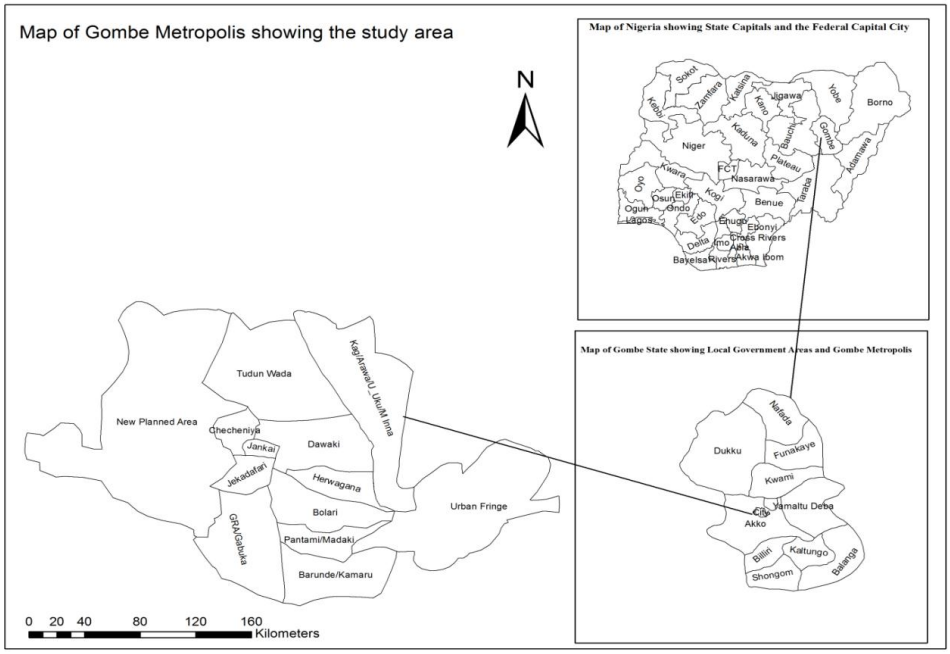

Figure 1. Map of Nigeria, Gombe State and the study area (Gombe Metropolis) (Source: Gombe State Ministry of Land and Survey, 2003).

metropolis in terms of buildings. Topographically, the highest part of the metropolis can be found on the west with an elevation of 489 m (Federal Low cost Quarters), while the lowest can be found in the extreme east with an elevation of 423 meters (Barunde) above sea level. Many gullies, rivers and streams in the metropolis have their sources from the foot of Akko escarpment and virtually all flow to the east (Figure 1).

Gombe Metropolis has evinced a rapid growth of built-up environment in progress on undeveloped ground in almost all parts of the metropolis, causing excessive building densities. The core town is becoming more compacted by spontaneous construction works more especially in the central metropolis that include: Jekadafari, Jankai, Dawaki, TudunWada, Pantami, Bolari/Madaki and Herwagana. These areas have increased in building densities, while in the urban fringes, there is a wide spread of development of new areas, such as in NPA, MUAK, Barunde. The urban growth around the urban fringe with poor development planning is causing a spontaneous development and poor spatial order. The shortage of housing and the desperate efforts of private developers have led to the emergence of the unplanned residential sectors, especially on places considered unsuitable for development (Gombe State Ministry of Land and Survey, 2003). These places are mostly common in the oldest part of the town and the urban fringes

METHODOLOGY

The scope of the research is the entire Gombe Metropolis with a total population of 312,467 (Mbaya, 2013). The research was conducted in stages where the metropolis was categorized into eleven residential areas comprising of Government Residential Areas (GRA), Pantami, Barunde, Checheniya, federal low cost quarters, Arawa, Kagarawal/Unguwa Uku, Dawaki, Madaki, Jekadafari, Herwagana, Jankai and Tudun Wada. The target population consists of a total of 1,929 chief householders within these residential section affected by the previous floods in Gombe Metropolis. Hence, thirteen percent (253) were randomly selected, where a total number of twenty three questionnaires were administered to each residential quarter to acquire necessary information relevant to the research. A Likert scale of three point scales and linear measurement were constructed to measure the variables, where structured close ended questions were coded and administered to the respondents with alternatives to choose based on their subjective views on a certain matter and a total of 251 questionnaires were returned and analyzed. Finally, standard regression method (multiple regression) was conducted using a computer and Statistical Package for Social Science (SPSS) to estimate flood risk from a set of urban development variables comprising of rapid development of built-up, proximity to floodplains and space between building.

RESULTS AND DISCUSSION

The Gombe State Urban Planning and Development Board (GSUPDB) are responsible for development control and implementation of physical development plans. Land use planning involves establishment of specific regulatory constraints to avoid or limit development of housing structures as key tool for planning strategy in urban management especially flood risk in urban areas (Wheat et al., 2009). The rapid urban growth in Gombe Metropolis ought to be guided towards

Table 1. Responses for space building of the households.

Residential quarters	Responses on space between buildings	
	1.7 m and below	Above1.7 m
Jekadafari	35	65
Jankai	78	22
Dawaki	65	35
Barunde	56	44
Tudun Wada	52	48
Pantami	74	26
Bolari/Madaki	69	36
NPA	83	17
MUAK	78	22
Checheniya	83	17
Herwagana	50	50
Total	66	43

Source: Field Survey, 2015.

a spatial order and development; this is due to reasons that the development control code stipulated that building should be constructed in conformity with the approved building plans. But unfortunately, the rapid increasing numbers of built-up areas in Gombe metropolis are not constructed in accordance with the town planning laws and regulations, which causes a serious setback for urban development in the metropolis and the consequential seasonal flooding.

The reason for such a spontaneous development of urban structures in the metropolis may also not be unrelated to erection of buildings by individuals without getting the approval of building plan by the appropriate authority. The building code stipulated that no building or construction of any structure shall commence except with building plan approval accompanied by the relevant building plan or construction plan (Gombe State Ministry of Land and Survey, 2003). However, this is contrary to what is seen where close to sixty percent of the metropolitan inhabitants have constructed their building structures without getting the building plan approval by Gombe State Planning and Urban Development Board.

Further sign for poor implementation of building codes is the constructions of built-up areas without leaving the stipulated space between buildings. The functional purpose to keep distance or space between buildings is essentially meant to allow passage of water in the event of heavy rainfall and lack of such provision for un-obstruction flow can lead to creation of a quick swirl and sudden high surge of runoff situation that can cause flooding. The recommended standard space between buildings in Gombe Metropolis is at least 1.7 m (5 ft) and maximum of 3 m (10 ft) (Gombe State Urban Planning and Development Board Law, 2012). The space between buildings in Gombe Metropolis is inadequate because a substantial part of the built-up areas (66%) have less than 1.7 m space between their buildings and the next opposite buildings, while only 34% leave a space of 1.7 m and above as depicted in Table 1. This could serve as one of the factors for accumulation of run- off water within a short period of time inundating the metropolis.

Further, the disadvantage of poor spatial planning is the construction of buildings in unsuitable location like floodplains, because, elevation is one of the most important factors in determining flood liability of areas, such as close to a rivers, streams or gullies. Variables related to exposure, normally include proximity to hazardous areas because people encroach urban floodplains reducing floodplain's capacity to attenuate the impact of flood, such an encroachment expose urban built-up areas to flood vulnerability and rapid increase of the flood risk potential (Wheat, 209).

According to Gombe Urban Development Laws, approval for building construction can only be granted where the sites and buildings are not in close proximity to any natural features like streams, rivers, gullies, that may render or expose the location to unsafe and vulnerable to flood risk (Gombe State Urban Planning and Development Board Law, 2012). A significant number of buildings in the metropolis are located in proximity to natural water channels (streams, rivers and gullies). For instance, these places include: Jankai, Barunde, Tudun Wada, Pantami, Bolari/Madaki, Checheniya, and Herwagana. On the whole on average, about 70% of the built-up areas in Gombe Metropolis are located on one way or the other within floodplains.

Factors predicting flood risk in Gombe Metropolis

The model conveyed flood risk (dependent variable) as a function of rapid built-up development, proximity to

Table 2. Flood risk: Model summary.

Variable	Flood risk		
	B (Slope)	Std. Error	βeta
Constant	-0.006	010	
Space between buildings	-0.079*	0.059	-102
Rapid built up development	0.384*	0.066	0.443
Proximity to floodplains	0.303*	0.048	0.380

N=251, β=unstandardized regression coefficient in parentheses, Beta =standardized regression coefficient, R =0 .710
R^2 = 0.504, Adjusted R^2 = 0.483, *P. value is statistically significant at 0.5 level (Source: Field Survey, 2015).

floodplains and the space between buildings (predictive variables).

The estimated regression coefficient for rapid development of building structures is 0.420 as indicated in Table 2. The implication of the coefficient can be interpreted as: each additional increase in constructing buildings causes flood risk increment on an average by 0.420 and this is statistically significant at 0.05 level of importance. The proximity to flood plains variable is also statistically significant at o.05 and by implication increasing the closeness of built-up environment to gully, river and stream, increases flood risk on an average of 0.322.

The coefficient for space between building variable also has a negative coefficient (-0.074) in the model and is also significant at 0.05 level. This explains each additional increase of distance between individual building structures which reduces flood risk on the average by 0.074 point.

The 'β' (unstandardized) coefficient relies heavily on the units of measurement for the dependent and the independent variables. However, it is rather difficult to compare coefficient of the two different variables measured in two different ways. Hence, 'βeta' (standardized) coefficient is used to bring all into a single common unit. The standardized coefficients explain how many standard deviations affect the changes in the dependent variable due to an increase in the standard deviation of the independent variables (Cramer, 1994). Therefore, an increase of one standard deviation in rapid development of built up structures gives an increase of 0.488 standard deviations in flood risk. By comparison of the standardized coefficients among different variables, we can have an idea of those variables that are more or less important in predicting the dependent variable (flood risk). The model in Table 2 shows that rapid development of built-up structures has the highest coefficient (0.488). Hence, it is the most important variable causing flooding and flood risk in Gombe Metropolis, followed by proximity to floodplains (.405). The least important variable causing flooding is space between building structures with the least coefficient of -0.096.

The R^2 measured how well the model predicts the dependent variable by the independent variable (Singh, 2007). The R^2 is 0.480 in the model, this means that rapid development of built up structures, proximity to floodplains and space between building, altogether, explained 48% of variation in flood risk and flood occurrences in Gombe Metropolis.

Conclusion

According to the result, it is vividly clear that generally in Gombe Metropolis, there is rapid growth of built environment in progress and this rapid urban growth has affected town planning and has posed problem to urban development board to properly discharge building control measures. Hence, spontaneous developments have taken place, where a significant number of buildings were constructed without considering the stipulated space limit or no space between buildings (as required for easy passage of run-off water). Furthermore, buildings were constructed on unsuitable locations such as in a close proximity to gullies, rivers and streams. The flood risk model estimated rapid development of built-up environment with poor implementation of building control measures as the most important factor for flood risk in Gombe Metropolis. However, construction of buildings on areas predisposed to flood as well as leaving inadequate space between buildings has significantly contributed to the increasing flood risk in Gombe Metropolis.

Policy implication

Based on the findings of the research, the following are applicable to policy makers in the state for sustainable flood mitigation in the metropolis:

The current building control measure is not effectively implemented to the expected level of controlling the rapid building development activities in the metropolis. Therefore, the results of the research indicate that there is a general lack of commitment from the acting urban planning and development agencies in ensuring a strict

enforcement of the implementation of the building regulations such as inadequate space between buildings, and erecting buildings on floodplains. Hence, spatial zoning can be proposed for flood risk vulnerable areas to regulate, prevent and restrict future building development.

The rapid development of built up environment with poor implementation of town and urban planning laws and regulations, the increasing flood frequency and its prevailing impacts necessitate the need for a comprehensive sustainable flood risk management measures for Gombe Metropolis. And finally, some sections of the residential areas that are very dense in terms of built-up should convert part of the built environment into open spaces in order to reduce the sealing effect of the built environment. These residential quarters include: Jekadafari, Barunde, Pantami, Bolari/Madaki, Herwagana, mostly located at the central town with the exception of Barunde.

Conflict of interests

The author has not declared any conflict of interests.

REFERENCES

Adewumi AS (2013). Analysis of land use/land cover pattern along the River Benue channel in Adamawa State, Nigeria. Acad. J. Interdiscip. Stud. 2(5):30-38.

Balzerek H (2001). Applicability of IKONOS-Satellite Scenes Monitoring, Classification and Evaluation of Urbanisation Processes in Africa. Case Study of Gombe/Nigeria. In Regensburger Geographische Arbeiten (2001). Proceedings of the International Symposium on Urban Remote Sensing, Regensburg (Germany: Electronic Publication Information Centre). pp. S15-18.

Barredo JI, Engeleng G (2010). Land use scenario modeling for flood risk mitigation. Sustainability 2(5):1327-1344.

Falade JB (2003). The urban and regional process, the old and the new paradigm: a paper presented at the (2003) Continuing Development Programme (MCPDP) of the Nigeria Institute of Town Planners (NITD) held in Calabar, Asaba and Kaduna.

Gombe State Ministry of Land and Survey (2003). Gombe Master Plan: Gombe State, Savannah Landev Konsult Nigeria. Ltd.

Gombe State Urban Planning and Development Board (2012). Gombe State urban planning and development board (amendment) law. GSUPDB Head Office, Gombe.

Hooijer A, Klijn F, Pedroli BM, Van Os AG (2004). Towards Sustainable Flood Risk Management in the Rhine and Meuse River Basins: synopsis of the findings of IRMA- SPONG. River Res. Appl. 20:343-357.

Leopold LB (1968). Hydrology for Land Planning: a guide book on hydrologic effect of urban land use geological survey circular 554. Washington: US Geological Survey.

Mbaya LA (2013). A Study of Inter-relationship among Gully Variables in Gombe town, Gombe State,Nigeria. Woodpecker J. Geograph. Reg. Plan. 1(1):001-006.

National Population Commission (2006). Census results: National Population Commissions State Office, Gombe, Nigeria.

Pielke Jr. RA (2000). Flood Impacts on Society, damaging floods as a framework for assessment, in: floods, edited by: Parker, D. J., Routledge hazards and disasters series, pp. 133-155.

United Nations International Strategy for Disaster Reduction (2004). Living with risk: a global review of disaster reduction initiatives. New York, USA: United Nations.

World Meteorological Organization and Global Watere Partnership (2008). Urban flood risk management: a tool for integrated flood management, world metrological organization (WMO) water partnership (GWP), associated programme on flood management, Geneva Switzerland.

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Environmental conditions in displaced communities of Khartoum State, Sudan

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Inadequate environmental sanitation has been recognized as a public health hazard worldwide. Nearly one quarter of all deaths and of the total disease burden and slightly more than one-third for children can be attributed to the changes and degradation of the environment. This study examined the environmental conditions of the displaced communities in Khartoum State, Sudan. A community-based descriptive, cross-sectional survey design was used for a population of 726,989 inhabitants of the Displaced communities in Khartoum State. Multi-stage cluster sampling was used in selecting 662 households in these communities and a structured questionnaire was used for data collection. Data were analyzed using frequencies, percentages, Chi-square test and multiple logistic regressions. Results showed that protected dug wells and tap water were the major sources of water supply in the study area, usually transferred to the house by cart and almost all was not treated. The major source of toilet facilities was traditional pit latrine and more than one-fifth of the populations share common latrines. More than one-third of the families had animals inside their housing. Almost half of the families were disposing their rubbish in collection areas far from housing followed by burning of rubbish, which had been used by more than one-third of them. More than one-fifth of the households' preschool children (21.3%) had diarrhea. A result of multiple logistic regressions showed that, time of hand washing (when to wash hand) was independently predictive for diarrhea among the households' preschool children (B = 0.005, Wald test = 6.758, p=0.009). It can therefore, be concluded that the environmental conditions including access to improved sources of water and hygienic latrines in these communities were accepted, although there were still some negative environmental practices, which can affect the safety of water and promote diseases spread. Bad hygienic practice was prevalent and led to high rates of diarrhea among the households' children. Therefore, to improve the environmental conditions in these communities, authorities should establish and enforce a more healthy environmental conditions approach and health promotion activities to improve the hygienic practice.

Key words: Displaced communities, Khartoum State, environmental conditions, hygienic practice and diarrhea.

INTRODUCTION

The environment is defined as: "All that which is external to the human". The environment can be divided into physical, biological, social, cultural, etc., any or all of which can influence health status of populations" (Prüss-

Üstün, 2006).

According to this definition, the environment would include anything that is not genetic, although it could be argued that even genes are influenced by the environment in the short or long-term (Prüss-Üstün, 2006).

The aim of this study was to examine the environmental conditions that affect the well-being of people, which include clean and safe water supply, efficient and safe human waste disposal and clean and safe housing and surroundings, of displaced communities and hygiene practice in Khartoum State, Sudan. By understanding the situation in these IDPs, this will help the government to develop specific plans to solve the targeted problems of environmental conditions and to create an evidence-based intervention program in order to improve the health situation of the population in the displaced communities of Khartoum State.

In 2012, 89% of the world's population had some form of improved water supply; while 64% had access to basic sanitation facilities (World Health Organization (WHO)/Global Health Observatory (GHO), 2015). An improved drinking-water source is defined as one that, by nature of its construction or through active intervention, is protected from outside contamination, in particular from contamination with fecal matter (WHO/UNICEF Joint Monitoring Programme, 2006). According to the WHO/GHO, improved drinking-water sources include piped water to the house or yard, public taps or standpipes, boreholes, protected dug wells, protected springs and rainwater collection (terms, WHO/UNICEF Joint Monitoring Report, 2012). An improved sanitation facility is defined as one that hygienically separates human excreta from human contact (WHO/UNICEF Joint Monitoring Programme, 2006). According to the WHO GHO, improved sanitation facilities include flush or pour-flush toilets connected to a piped sewer system, septic tanks or pit latrines, and composting toilets.

The environment influences our health in many ways; through exposures to the environmental risk factors and through related changes in our behavior in response to these factors (Prüss-Üstün, 2006). The evidence shows that environmental risk factors play a role in more than 80% of the diseases regularly reported by the WHO (Prüss-Üstün, 2006). Globally, nearly one quarter of all deaths and of the total disease burden and slightly more than one-third for children, can be attributed to the changes and degradation of the environment (Prüss-Üstün, 2006). Inadequate sanitation, hygiene or access to water increases the incidence of diarrheal diseases (World Health Organization (WHO)/Global Health Observatory (GHO), 2015). The highest proportion of deaths and Disability Adjusted Life Years (DALYs), as well as the highest absolute numbers, occur in countries with high mortality patterns, such as Africa and parts of South-East Asia (WHO/UNICEF Joint Monitoring Programme, 2006). “Most diarrheal deaths in the world (88%) were caused by unsafe water, sanitation or hygiene” as stated by WHO GHO (2015). “In addition to diarrhea, an important share of the following diseases could be prevented if adequate water quality and quantity, sanitation facilities, hygiene practices, as well as water resource management interventions were implemented: malnutrition, intestinal nematode infections, Lymphatic filariasis, Trachoma, Schistosomiasis, Malaria and other infectious diseases” as stated by WHO GHO (2015). Altogether, improvements related to drinking water, sanitation, hygiene, and water resource management could result in the reduction of almost 10% of the total burden of disease worldwide (Prüss-Üstün et al., 2008).

Sudan has been virtually in a state of civil war since its independence in 1956. The conflict has generated the largest internal displacement crisis in the world, and over two million people have died as a direct result of war. More than four million people are internally displaced, about half of whom have fled to the north and mostly settled around the capital Khartoum. Quantifying IDP populations in Sudan is complicated by traditional nomadic migration patterns as well as by people moving to access emergency assistance. The country is also prone to natural and man-made disasters, and famines have killed tens of thousands of Sudanese during the past 15-years (Norwegian Refugee Council/Global IDP Project, 2004). In Khartoum State, the government is implementing the process of permanent re-planning of some camps and IDPs must move to new settlements. According to the report of the international agencies, including International Non-Governmental Organizations (INGOs), Donors, and the UN, who have been following the situation of the IDPs in Khartoum State for the past years, there are complaints by IDPs on water shortages and a lack of access to sanitary facilities. INGOs operational in the area have observed that IDPs use open fields for defecation. In Wad el Bashier and Omdurman es Salaam IDPs, only five out of nine water yards are operating which has reduced access to water and raised costs, according to the Wad el Bashier Development Association, some areas have increased their water costs by as much as 50% (International Agencies in Sudan, 2004). The aim of any Water Sanitation Hygiene (WASH) programme is to promote

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good personal and environmental hygiene in order to protect health (UK Department for International Development, 2013). Ensuring the optimal use of all water supply and sanitation facilities and practicing safe hygiene will result in the greatest impact on public health. Hygiene promotion is vital to a successful WASH intervention. The focus on hygiene promotion is general and specific. In general terms, hygiene promotion is integral to all of the sections and is reflected in the indicators for water supply, excreta disposal, vector control, solid waste management, and drainage (UK Department for International Development, 2013).

MATERIALS AND METHODS

This study was conducted in the displaced communities of Khartoum State, Sudan. There are six displaced communities in Khartoum State; all are included in this study, which have 726989 people residing there. These communities comprise six displaced communities sites, namely, Wad Albashir–Omdurman, Alsalam-Omdurman, Jabel Awlia (Banteyou and Dar-Alsalam), Mayo (Angola and Mandela), Soba Alaradi, and Albaraka Al-Haj Yousif. A cross-sectional design was adopted in this study. The Khartoum State's six IDP communities were considered as the main sampling domains. A multistage sampling technique was used for this survey. The sample size was calculated using OpenEpi, entitled "OpenEpi for a Proportion for Cluster Surveys Version 04.06.08". Single proportion formula was at 95% confidence interval (CI) level Z = 1.96, Population size (N) = 131919, 14 households, an expected prevalence of 50% "the prevalence rate of the key indicator (when selecting P = 0.5, this will yield the maximum sample size, since the overall prevalence rate (P) of diarrhea was not known for the study area)" (WHO, 2006), 0.1 marginal error, and the design effect (for cluster surveys-DEFF) was = 1.5. The sample size was 575 households and the total sample size was completed to 662 households included in this study. Then, the sample size was divided into 30 clusters (Lot Quality Assurance Sampling (LQAS) Community Survey) and so the number of households per cluster was 22.

Furthermore, a structured questionnaire was used for data collection by well-trained data collectors (Annex 1). This questionnaire comprised demographics aspects of the respondents' families and assessed the environmental conditions of the study area. To enhance the validity of this instrument, all items of the questionnaire were framed in simplified language that was easy to understand. After the displaced communities' heads granted permission, the researcher with the help of community representatives from these communities administered the questionnaire. The sampled population covered the women at the households and their families including children younger than 6 years. The women were chosen as respondents, because of their availability at households most of the day in comparison to men. On the other hand, the women were more capable of answering the questions related to the households' environmental conditions, and answering other questions of the survey especially when asking about diarrhea among their children. The resulting data were entered into the Statistical Package for Social Sciences (SPSS) Version 15 for data analysis. Frequencies and percentages were computed for all variables, univariate associations between categorical variables were examined using chi-square test and multivariate analysis association was examined using multiple logistic regressions. A multivariate logistic regression analysis was run to study the independent association of variables (types of toilet facilities, use of toilet for defecation, regularity of hand washing and time of hand washing (when to wash hand)) with diarrhea among children. Statistical significance was tested at the 0.05 level of significance.

RESULTS

All households' respondents (662 households) agreed to administer the questionnaire. Table 1 shows the distribution of demographic characteristic of the respondents. More than half (428) women (64.7%) fall in the age group 26 to 45 years and few of them fall in the marginal age groups. Most of the respondents' ethnic groups fall under "others" tribe group, which include different small ethnic groups, almost one-third (203) of them were Nuba (30.7%) and few of them (31) were Arab (4.7%). Almost three-quarters of the households' families (489) fall in the family size group of 5 to 10 persons per family (73.9%) and nearly equal percentages was distributed between other two groups >10 persons per family (13.6%) and <5 persons per family (12.5%). More than half of the households' families (357) fall in the income group of 500 to <1000 Sudanese Bounds per month (53.9%) and only few of them (25) had an income more than 1500 Sudanese Bounds per month (3.8%). There was high percentage of illiteracy or no formal education among women (278) and men (272) in the households (42 and 41.1%, respectively) and few of them had university education (2.6 and 6.5%, respectively). More than three-quarters of the men in the households (551) were unskilled workers (83.2%) and only 4.7% of them were professional workers. More than three-quarters of the women in the households (543) were housewives or unemployed (82%) and 1.5% of them were professional workers.

The results in Table 2 show that almost half of the households (327) were recipients from piped water supply network (49.4%) and the other half (332) received water from protected dug well (50.2%). Most of the households' families transfer water to the house by cart (79%). Almost all families (657) were not purifying water before use (99.2%). A negligible percentage of them used boiling and filtration for purifying treatment (0.8 and 0.2%, respectively). Most of the households (469) had traditional pit latrine (usually consist of a single pit covered by a slab with a drop hole and a superstructure) inside their housing (70.8%) and 21% of them share latrine with other families. About two third of the families (446) were cooking in the kitchen (67.4%), the remaining had no kitchen and were cooking either inside their living room or at yard (14.8 and 14.7%, respectively). More than one-third (256) of the families had animals inside their houses (38.7%), 14.2% of them, had chickens and/or pigeons in their houses.

The results in Table 3 show that more than three-quarters of the pre-school children (539) had been

Table 1. Shows frequency and percentage distribution of the respondents by their sociodemographic characteristics in Khartoum State displaced communities, 2013. (N = 662).

Sociodemographic characteristics	Frequency	Percent
Women age		
< 15 years	1	0.2
15 - 25 years	223	33.7
26-45 years	428	64.7
> 45 years	10	1.5
Total	662	100.0
Ethnic group		
Arab	31	4.7
Fallata	31	4.7
Fur	109	16.5
Nuba	203	30.7
Others	288	43.5
Total	662	100.0
Family size		
< 5	83	12.5
>10	90	13.6
5-10	489	73.9
Total	662	100.0
Family income		
>1500 SDG	25	3.8
1000-1500 SDG	65	9.8
<500 SDG	215	32.5
500- < 1000 SDG	357	53.9
Total	662	100.0
Husband' education		
University	43	6.5
Secondary	101	15.3
Primary	246	37.2
No formal education or illiterate	272	41.1
Total	662	100.0
Women education		
University	17	2.6
Secondary	92	13.9
Primary	275	41.5
No formal education or illiterate	278	42.0
Total	662	100.0
Husband' occupation		
Unemployed	21	3.2
Professional	31	4.7
Skilled worker	59	8.9
Unskilled worker	551	83.2
Total	662	100.0

Table 1. Contd.

Women occupation		
Skilled worker	9	1.4
Professional	10	1.5
Unskilled worker	100	15.1
Housewife or unemployed	543	82.0
Total	662	100.0

Table 2. Frequency and percentage distribution of the respondents by housing characteristics in Khartoum State displaced communities, 2013. (N = 662).

Housing characteristics	Frequency	Percent
Water supply source		
Water supply network	327	49.4
Protected dug well	332	50.2
Others	3	0.5
Total	662	100.0
Method of water transfer		
Piped network	108	16.3
From the pump	22	3.3
Cart	523	79.0
Others	9	1.5
Total	662	100.0
Water purification		
Yes	5	0.8
No	657	99.2
Total	662	100.0
Method of water purification		
Poiling	4	0.6
Filtration	1	0.2
Not applicable	657	99.2
Total	662	100.0
Type toilet facilities		
Traditional split latrine	469	70.8
Share latrine	139	21.0
General latrine	27	4.1
Improve latrine with cement slab	15	2.3
Open defecation	11	1.7
Not applicable	1	0.2
Total	662	100.0
Place of cooking		
Kitchen	446	67.4
At room	98	14.8
At yard	97	14.7
Other	21	3.2

Table 2. Contd.

Total	662	100.0
Animals at the home		
Yes	256	38.7
No	406	61.3
Total	662	100.0
Type of domestic animals		
Chickens/pigeons	117	17.7
Goats/Sheep	53	8
Donkeys/Horses	18	2.7
Others	72	10.9
Not applicable	402	60.7
Total	662	100.0

Table 3. Frequency and percentage distribution of the respondents by practice of personal hygiene and life style factors in Khartoum State displaced communities, 2013 (N = 662).

Personal hygiene and life style factors	Frequency	Percent
Rubbish disposal method		
Garbage collection car	55	8.3
Burning	241	36.4
Collections areas far from home	322	48.6
Burning and in the collection area far from home	33	5.0
Others	11	1.7
Total	662	100.0
Use of toilet for defecation by the preschool children		
Yes	312	47.1
No	350	52.9
Total	662	100.0
Practice of hand washing by the preschool children		
Regular	539	81.4
Irregular	104	15.7
No hand wash	19	2.9
Total	662	100.0
Time of hand washing used by the preschool children (when do they wash hands?)		
Before eating	19	2.9
After eating	10	1.5
After toilet use	18	2.7
After waste disposal	4	0.6
Not applicable	35	5.3
Before and after eating	229	34.6
Before and after eating and after use of toilet	347	52.4
Total	662	100.0
What the preschool children use for hand washing		
Only water	263	39.7
Soap and water	366	55.3

Table 3. Contd.

Water and ramad	3	0.5
Others	1	0.2
Not applicable	29	4.4
Total	662	100.0
The practice of walking barefoot by the preschool children		
Yes	479	72.4
No	183	27.6
Total	662	100.0
Vegetable washing and cleaning (peeling) before eating		
Yes	639	96.5
No	23	3.5
Total	662	100.0

washing their hands regularly (81.4%) and only 2.9% of them were not washing hands at all. More than half of the pre-school children (347) used to wash their hands before and after eating and after using the toilet (52.4%). More than half of the pre-school children (366) were using water and soap for hand washing (55.3%) followed by 39.7% of them who were using only water to wash their hands. Almost three-quarters (479) of the pre-school children were walking barefoot (72%), which was a bad hygienic practice. Almost half of the families (322) were disposing of their wastes in collection areas far from their home (48.6%) followed by burning of rubbish method, which had been used by 36.4% of them. More than half of the preschool children (350) were not using toilets (52.9%) and were practicing open defecation. Almost all of the families (639) were washing and cleaning (peeling) the vegetables before eating them (96.5%).

The obtained results based on the women and men educational qualification show significant association between the men education and the practice of water treatment (p=0.015). The results showed that there was no significant association between the family income (p=0.088), the women education (p=0.748), men occupation (p=0.798) and women occupation (p=0.776) with the practiced of water treatment. On the other hand, the results showed significant association between the men education (p=0.001), the women education (p=0.011) and men occupation (p<0.001) with the type of toilet facilities in the house. There was no significant association between the women occupation (p=0.508) with the sanitation and type of toilet facilities. Moreover, the results showed significant association between the men and women education (p=0.001 and p<0.001, respectively) and women occupation (p<0.001) with the waste disposal method. Results showed that there was no significant association between the men occupation (p=0.755) with the waste disposal method. Results showed significant association between the men and women occupation (p=0.043 and p<0.001, respectively) with the regularity of hand washing. Results showed that there was no significant association between the men education (p=0.198), the women education (p=0.062), and women occupation (p=0.776) with the regularity of hand washing.

Considerable percentages of the households' preschool children (21.3%) had been complaining from diarrhea (stated by their mothers) in the last week prior to the data elevation as shown in Figure 1. Variables assessed for association with outcome variable during the univariate analysis were further re-entered into final multivariate model using logistic regression analysis. In the multivariate analysis, time of hand washing (when to wash hand) was independently predictive for diarrhea among the preschool children of the respondents (B = 0.005, Wald test = 6.758, p=0.009) (Table 4).

DISCUSSION

This study assessed the environmental conditions in displaced communities of Khartoum State, Sudan and found that most of the Displaced population had one of two main source of water supply. The first source of water supply was piped water supply network (50.2%) and the second one was protected dug wells (49.4%). These two sources of water were considered as improved sources of drinking water according to the WHO, which define an improved drinking water source as a source that, by nature of its construction, adequately protects the water from outside contamination, in particular from fecal matter (WHO/UNICEF Joint Monitoring Report, 2012). Despite of the high percentage

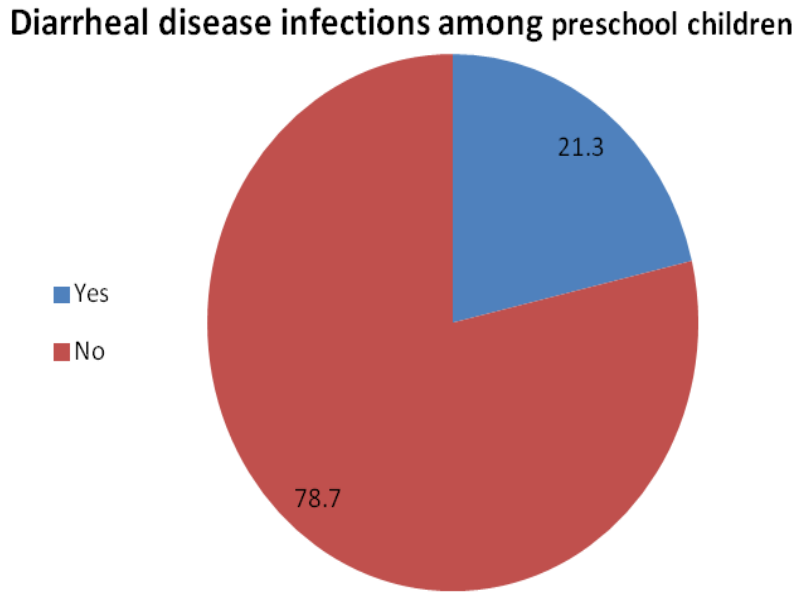

Figure 1. Percentage distribution of diarrheal diseases among respondents' preschool children (1-5 years) in the last week in Khartoum State Displaced communities, 2013.

Table 4. Multiple logistic regression results of the association between housing characteristics and practice of personal hygiene with diarrhea among the respondents' preschool children.

Variable	B	SE	Wald statistic	df	Sig.	Exp (B)
Types of toilet facilities	-0.174	0.102	2.922	1	0.087	0.840
Use of toilet for defecation	-0.266	0.202	1.733	1	0.188	0.767
Regularity of hand washing	-0.184	0.204	0.809	1	0.368	0.832
Time of hand washing	0.005	0.002	6.758	1	0.009*	1.005
Constant	1.891	0.446	17.988	1	0.000	6.629

*Significant at 0.05.

of the improved source of drinking water in the study area, this study revealed that most of the populations were transferring water to their houses by cart (79%) and almost all of them were not purifying water before use for drinking (99.2%). These factors might affect the safety of drinking water in the study area. These results were better than the previous interagency assessment report findings, which were studied by different NGOs in the same IDPs in 2004. Their assessment showed that the water was sourced either directly at water points or purchased from donkey carts (84%). The assessment also reported that the children were the ones primarily responsible for fetching water, and that there was often conflict at the water sources (International Agencies in Sudan, 2004). Our findings also showed better situation when compared with the two household surveys carried out to assess the water and sanitation situation in refugee camps, one in West Africa (Ghana) in 2005 and one in East Africa (Kenya) in 2006, showed that only 6% of the estimated water needs had been covered (Cronin et al., 2008).

Most of the displaced populations (70.8%) have a traditional pit latrine type of toilet. A considerable percentage (21%) shared latrine with other families, 4.1% have been using public latrines, 1.7% having none and defecate openly, and only 2.3% of the populations having improved latrine with cement slab inside their houses as shown in Table 2. Our survey showed better results than the NGOs interagency assessment report in 2004, which found that there were few latrines available; the people either defecated in open areas, in neighbors' latrines, or in public latrines and the latrine coverage was concerning

with 30% of households in all areas reporting no access (to either their own latrine, neighbors' or public) (International Agencies in Sudan, 2004). Our findings showed better situation when compared with the two household surveys carried out in refugee camps in Ghana and Kenya, which showed that only 2% of the estimated sanitation needs had been provided (Cronin et al., 2008). A comparatively good situation in our study area was gotten compared to the aforementioned studies, but more attention is needed for the 26.8% of the populations who share the latrine with other families, who use public latrines and those who have no latrines. The effect of improved water sources and sanitation will be reflected positively in health and nutritional status of the population, this was found in a study in Bangladesh (World Vision, 2011) and many other studies conducted in the developing countries. On the other hand, unsafe water may additionally affect the nutritional status of the population through diarrheal diseases (World Vision, 2011). More than one-third (38.7%) of the populations in our study had animals inside their houses, 45.7% of them have chickens and/or pigeons type of animals. Although this can help to improve the economic situation of the families, it can affect the hygiene and cleanness of the houses, attracting flies and might carry pathogens. What are houseflies attracted to? (http://animals.mom.me/houseflies-attracted-to-5559.html). Almost half of the displaced populations (48.6%) had been getting rid of their waste in the waste collections areas far from their housing, followed by the burning of rubbish method, which had been used by 36.4% of them. Only a small percent of the households (8.3%) used a garbage car collection method. It becomes obvious that the IDPs settlements in Khartoum State need more capacity to improve garbage and waste collection, collected in a healthy-respected way; it will improve the environment situation and the health status of the community. More than three-quarters of the households' preschool children (81.4%) were washing their hands regularly in these communities and a few of them (2.9%) were not washing their hands at all. This was surprising to us because of the high percentage of illiteracy among women and men in these communities. More than half of the preschool children (55.3%) were using water and soap for hands washing followed by 39.7% of them who were using only water to wash hands. In addition to that, this study found that almost all of the households with preschool children (96.5%) were washing and cleaning (peeling) their vegetables before eating them. Despite the low education percentages and high poverty rates among the displaced populations, still good results were observed concerning personal hygiene practice and life style factors. This could be due to spread of mass media and availability of NGOs health services in these settlements, which concentrate more on these issues.

Concerning the associations between the water supply, sanitation facilities and practicing safe hygiene among the families based on some of their sociodemographic characteristics (educational qualifications and occupations of the women and men), it was noticed that the men education significantly affected the practice of water treatment rather than the women education. On the other hand, it was noticed that the men and women education also positively affected the sanitation and type of toilet facilities in their house and the waste disposal method. The men occupation significantly affected the sanitation form and type of toilet facilities in the house rather than the women occupation. On the other hand, the women occupation significantly affected the method of waste disposal rather than men occupation. Moreover, the men and women occupation positively affected the regularity of hand washing of their preschool children. There was high percent of diarrhea among children in the study area, which might be affected by the environmental conditions. However, in this study, it was found out that the time of hand washing (when to wash hand) was independently predictive for diarrhea among the preschool children of the respondents.

Conclusion

This study examined the environmental conditions in a Sudanese community and found that most of the residents in this community, which comprised six displaced communities sites, had access to improved sources of water and sanitation, in addition to a high standards of personal hygiene practice and life style factors, despite low education percentages and a high poverty rates among the displaced population. It can therefore be concluded that the environmental conditions in these communities were accepted, although there were still some negative environmental practices such as use of carts to transfer water to the houses and not purifying water before use for drinking, breeding animals inside the houses, dumping of waste openly and sharing of latrine with other families and the public.

Based on the findings, the following recommendations were made in order to enhance the environmental conditions in the study area and even in the Khartoum State and the country at large: The government at all levels should continually review and revise existing policies with respect to urban planning, developing healthy standards, infrastructure and environmental regulations in order to make them more attainable and compatible with local conditions. Legislations should be enforced concerning indiscriminate getting rid of waste and burning in the study area. The local authorities should endeavor to provide more rubbish containers and place them at strategic positions and the defaulters should be made to face the full wrath of the law. Health

promotion should be increased by the local authority on the need to avoid open defecation and to build hygienic latrine inside the houses, purifying drinking water and breeding animals inside the houses. Health education should be carried out according to the needs of the inhabitants to adopt the habit of regular hand washing after using toilets and for food preparation or taking meals.

Conflict of Interests

The author have not declared any conflict of interests.

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REFERENCES

Cronin AA, Shrestha D, Cornier N, Abdalla F, Ezard N, Aramburu C (2008). A review of water and sanitation provision in refugee camps in association with selected health and nutrition indicators – the need for integrated service provision. J. Water and Health 06.1

Database of the Norwegian Refugee Council a Compilation of the information available in the Global IDP (2004). Profile Of Internal Displacement: Sudan, Norwegian Refugee Council/Global IDP Project, Chemin Moïse Duboule, Geneva - Switzerland, 59(1209):8

Definitions and Methods (2016): Refining the definitions: an ongoing process and the ladder concept. WHO/UNICEF Joint Monitoring Programme (JMP) for Water Supply and Sanitation, (Internet communication, 13th of January 2016 data at http://www.wssinfo.org/definitions-methods/).

International agencies in Sudan (2004), Khartoum State Interagency Rapid Assessment Report, Executive Summary and key findings, Khartoum, pp. 20-23.

Prüss-Üstün A, Bos R, Gore F, Bartram J (2008). Safer water, better health: costs, benefits and sustainability of interventions to protect and promote health. World Health Organization, Geneva.

Prüss-Üstün A (2006). Preventing disease through healthy environments, towards an estimate of the environmental burden of disease. World Health Organization, Geneva,

UK Department for International Development (2013). Water, Sanitation and Hygiene: Evidence paper. London: The Department;

Water, Sanitation and Health Key terms, WHO/UNICEF Joint Monitoring report 2012 (internet communication available at (http://www.who.int/water_sanitation_health/monitoring/jmp2012/key_terms/en/)).

Water, sanitation and hygiene. World Health Organization, Global Health Observatory (GHO) (2015). (Internet communication, 2 September 2015 data at http://www.who.int/gho/phe/water_sanitation/en/).

WHAT ARE HOUSEFLIES ATTRACTED TO? (Internet communication available at http://animals.mom.me/houseflies-attracted-to-5559.html).

WHO the regional health system observatory; health system profile, (2006).

World Vision (2011). Water, Sanitation, and Hygiene: Sector Case Statement. The organization.

ANNEXES

Annex 1. Questionnaire.

S/N	Parameter	Coding
	Region name Data collector team No (a, b) Cluster No Questionnaire date: Data collector name: Respondent name (Optional): Serial Number:	Camp name.....Squire No... Day...Month... Year.....
1	Women age	1=Less than 15 years 2=15-25 years 3=26-45 years 4=Greater than 45 years
2	Ethnicity	1=Arabs 2=Four 3=Nuba 4=Fallatah 5=Other (specify.....)
3	No of family members:	.....Individuals
4	Household's monthly income (in Sudanese pound):	..... Sudanese pound
5	Educational level of the Women	1=Illiterate/ None formal education 2=Primary/Basic 3=Secondary 4=University/Postgraduate
6	Educational level of the Husband	1=Illiterate/None formal education 2=Primary/Basic 3=Secondary 4=University/Postgraduate
7	Women occupation	1=Housewife 2=Unskilled worker 3=Skilled labor 4=Professional worker
8	Father's occupation	1=Unemployed 2=Unskilled worker 3=Skilled labor 4=Professional worker
9	Source of drinking water	1=River or canals 2=Water supply network 3=Protected Well 4=Other (specify).....
10	If the answer is a water supply network or well what are the means of water transport?	1=Pipes network. 2=Directly from the pump

Annex 1. Questionnaire. Contd.

		3=From the cart. 4=Other (specify)..... 9=Not applicable
11	Water Purification	1=Yes 2=No
12	If the answer is yes, what are the means of water Purification?	1=Poiling 2=Filtration 3=Other (specify)..... 9=Not applicable
13	Type of toilet facilities	1=Split latrine 2=Share latrine with other families 3=Public latrine 4=Improve latrine with cement slab 5=Open defecation 6= Not applicable
14	Place of cooking	1=At the Kitchen 2=At room 3=At yard 4=Other (specify)...
15	Do you have animals at the home?	1=Yes 2=No
16	Type of domestic animals	1=Chickens/pigeons 2=Goats/Sheep 3=Donkeys/Horses 4=Other (specify)... 5=Not applicable
17	Rubbish disposal method	1=Garbage collection car 2=Burning 3=Collections areas far from home 4=Burning and in the collection area far from home 5=Others specify.....
18	Use of toilet for defecation by the preschool children	1= Yes 2= No
19	Practice of hand washing by the preschool children	1=Regular 2=Irregular 3=No hand wash
20	At what time you wash your child's hands?	.....
21	What used for hands washing?	.....
22	Walking barefoot habit most of time per day	1= Yes 2= No
23	Vegetable washing and cleaning (peeling) before eating	1= Yes 2= No
24	Did your preschool children (1-5 years) suffer from diarrhea in the last week	1= Yes 2= No

At the end of the questionnaire thank the women and take her/her husband telephone number to return back for any inquiry: Telephone number.....

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Full Length Research Paper

Temporal relationship between climate variability, *Prosopis juliflora* invasion and livestock numbers in the drylands of Magadi, Kenya

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A study was conducted to determine the association of climate variability, *Prosopis juliflora* spread, and other vegetation trends with livestock population dynamics in Kajiado County, Kenya. Monthly rainfall, mean monthly temperatures, cattle, sheep and goats populations from January 2000 to December 2014, were analyzed to determine time series trends. Normalized Difference Vegetation Index (NDVI) data derived from moderate resolution imaging spectroradiometer (MODIS) 250 m satellite imageries for 2000 to 2014 were used to determine the temporal dynamics of *P. juliflora* invasion in the study area. Both temperature and rainfall trends showed marked variability over the period under study. The mean monthly temperatures during the long dry season increased erratically from 33°C in 2000 to 37°C in 2014. Moreover, the rainfall during the wettest season was 600 mm in 2000 and 250 mm in 2014. During the study period, divergence from the long term mean rainfall (450 mm) decreased from 585 to 403 mm. At the same time cattle population decreased, sheep and goats populations remained static. *P. juliflora* invasion correlated positively (r=0.2; P<0.05) with mean monthly temperature and negatively (r=-0.4; P<0.05) with rainfall and other vegetation cover in drier parts, but not in the higher altitude and wetter parts of the study area. It also correlated negatively with cattle populations (r=-0.4; P<0.05). In the 1980's, bushlands and woodlands constituted 95 and 5% of the land cover, while in 2008, herbaceous vegetation, shrublands, and open trees together with bare areas constituted 50, 30, and 22%, respectively; out of which 70% had been taken over by *Prosopis* in 2014. This study demonstrated that even though the trends showed that cattle population decreased as climate variability and *Prosopis* invasion increased, there was no significant correlation among the attributes, over the period under study.

Key words: Climate, drylands, livestock, *Prosopis juliflora,* variability vegetation, trends, mesquite.

INTRODUCTION

After introduction to Africa in the 1820s and in Kenya in the 1970's and 1980's (Wahome et al., 2008; Choge and Pasiecznik, 2006), *Prosopis juliflora* (Sw.) DC (hereafter simply *Prosopis*) and also known as mesquite has been aggressively invading grazing and farm lands (Tewari et al., 2000; Pasiecznik et al., 2001; Andersson, 2005). Shiferaw et al. (2004) reported that *Prosopis* is equipped with a number of biological characteristics that can

facilitate its rapid invasion of new areas. Germination is a crucial stage in the life cycle of plants: temperature and drought stress have a dominant role, while higher levels of nutrients increased translocation of sugars to the radicle, improving water uptake capacity through increased osmolarity (El-Sharkawi et al., 1997; Nakano et al., 2004; Leparmarai et al., 2015). Efforts to eradicate *Prosopis* have not succeeded anywhere in the world. Due to its hardiness and versatility, it grows fast in such areas as dry degraded grasslands and wastelands with scanty and erratic rainfall, shifting sand dunes, eroded hills and river beds and saline terrains, and spreads, where virtually no other trees survive (Silva, 1986).

Increased climatic variability trends in the drylands of Africa, associated with frequent and intense droughts, increased proportions of degraded lands that disrupted livelihoods of pastoralists (UNEP/CBD, 2010). Thus, climate change is costly and predictions are that both it and its cost will escalate (Nanyingi et al., 2012). The key costs emanate from livestock deaths and displacement and suffering of human populations (GOK-PDNA, 2012). Despite such costly interventions as free provision of livestock feed and supplements, the dryland communities still suffer enormous livelihood loss (GOK-PDNA, 2012). Climate variability and population increase in the pastoral areas have contributed to the degradation of grazing lands (Kazmi et al., 2010) that has led to changes in vegetation cover and *Prosopis* invasion further aggravating the livelihood challenge. Reports that exist fail to address specific plant species habits towards climate variability (Galvin et al., 2004; IPCC, 2007; Resilience Alliance, 2010; Tennigkeit and Wilkes, 2008; WISP Policy Note No. 04, 2007).

Spread of *Prosopis* was observed since 1994 in Olkiramatian location of Magadi, Kajiado County. The spread was noted to have some effects on indigenous vegetation species and livestock populations (Maundu et al., 2009; Kaur et al., 2012; Getachew et al., 2012; Rettberg et al., 2012). The objective of this study was to evaluate the relationship between *Prosopis* spread patterns, climate variability, vegetation cover trends and livestock population dynamics in the drylands.

MATERIALS AND METHODS

Study area

The study was conducted in Olkiramatian location of Magadi division - Kajiado County. The area is located in South West of Kenya, bordering Tanzania to the south and Narok County to the west. It is situated at altitude of600 m within latitude/longitude 1°40'S, 36°E, 2°S, 36°15'E (Figure 1), under the inner lowland and lower midland agro-ecological zones (Jatzold and Schmidt, 1978). It has a bimodal rainfall pattern with a an annual total of 460 mm and a mean of 50 mm, mean temperatures of 32°C. The soil texture is very clay, clay and loam, with occasional sand. The clay types are montmorillonitic, kaolinitic and interstratified clay (Kenya Soil Survey, 1997). The landforms are composed of plains, plateaus, low gradient foot slopes, medium gradient hills and occasional high gradient hills (Gregorio and Latham, 2002). The slopes range from flat and wet slopes, gently undulating, rolling and steep slopes. The vegetation is sparse, open bushland, with increasing presence of *Prosopis* (Gregorio and Latham, 2002).

The Olkiramatian plains in Olkiramatian sublocation, recieves 400 mm of rainfall annually, average temperatures of 35°C and a vegetation cover of mainly shrubs and bare land with *Prosopis* being the the main shrub in the area. The Ngurumani hill slopes in Ngurumani sublocation receive 600 mm of rainfall annually with mean temperatures of 28°C and vegetation dominated by bushland, *Prosopis* and irrigated crop fields.

Data types and sources

Rainfall and temperature data were collected and collated from Makindu and Narok meteorological stations climate data recorded over 30 years (1982-2012); National drought management authority (NDMA) - Kajiado county climate data for 7 years (2007-2013); Magadi soda ash company climate data for 50 years (1964-2013); Kajiado Maasai rural center (Isinya) climate data for 23 years (1981-2014). Olkiramatian climate data (local weather station manned by South rift association of land owners (SORALO) for 5 inconsistent years (2008-2014). The Olkiramatian climate data was used to validate the meteorological stations of Narok and Makindu, Kajiado county (NDMA) climate data Magadi soda ash company climate data and the Kajiado Maasai rural center (Isinya) climate data.

Vegetation and *Prosopis* productivity data, derived from the Terra MODIS (NASA:https://lpdaac.usgs.gov/products/modis_products_table/mod13q1) series vegetation indices Normalized Difference Vegetation Index (NDVI) satellite data (Reeves et al., 2002; Robinson et al., 2008) was used. NDVI data was downloaded from the ENDELEO website (http://endeleo.vgt.vito.be/), unzipped and reprojected in ArcGIS (ArcGIS: http://www.esri.com/software/arcgis/arcgis-for-desktop). Magadi division and Olkiramatian location vegetation extends were extracted using ArcGIS tools. The vegetation data - NDVI with spatial resolution of 250 m for the period of 14 years (2000 – 2014) and temporal resolution of 30 days (one month) from MODIS satellite images was analysed for vegetation and *Prosopis* trends. Land use, land cover and soil data, field GPS data, and GIS databases from Regional Mapping Center - Kasarani, International Livestock Research Institute (ILRI), Department of Remote Sensing and Resource Surveys (DRSRS), Food and Agriculture Organization (FAO) and Kenya Soil Survey Institutions dealing with spatial data were also used in determining vegetation and *Prosopis* patterns. Participatory mapping of *Prosopis* clusters was done withhelp of local key informants who composed of three elderly men, one woman and one young man.

Livestock population data were obtained from the annual livestock population collected and collated from Kenya National Bureau of Statistics (2010), Kajiado County livestock offices, Magadi division livestock offices and DRSRS in Nairobi for the period

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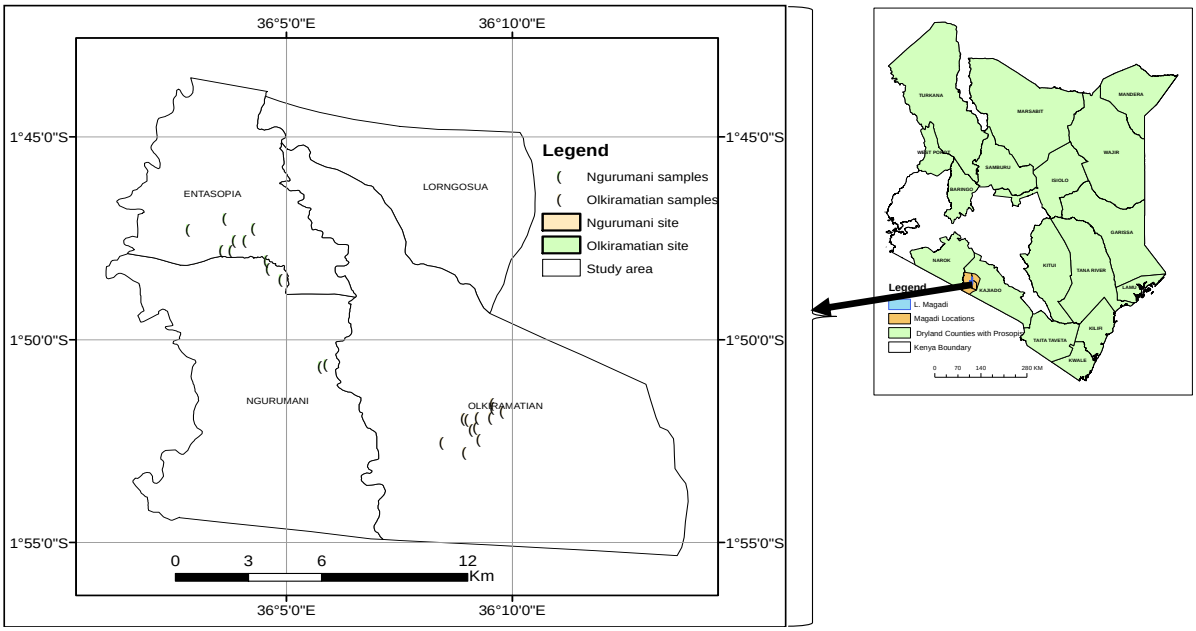

Figure 1. Study area in Magadi of Kajiado County, Kenya.

1980-2013.

GIS and remote sensing methods for estimating vegetation biomass

MODIS satellite derived NDVI images (Jenkerson et al., 2010) were used to establish the spread patterns of *Prosopis*. The NDVI was used to identify the vegetation types which were photosynthetically active during the drought periods. These vegetation types were most likely *Prosopis* plants. Land cover, soil data, GPS data, and GIS databases were used to identify areas with the suitability characteristics for *Prosopis* to thrive.

$$NDVI = (NIR - Red) / (NIR + Red) \quad (1)$$

where NIR (near infra read) and Red are the visible bands of the electromagnetic wavelength (Reeves et al., 2002).

NDVI has been used to indicate the level of photosynthetic activity in a green plant (Grace et al., 2006). It is expressed in values in the range of -1 to +1. Healthy vegetation absorbs most of the visible light that hits it and reflects a large portion of the near-infrared light. Unhealthy or sparse vegetation reflects more visible light and less near-infrared light (Grace et al., 2006). It is an indicator of vegetation health status (greenness).

High NDVI values (greater than 0.7) obtained during the dry periods of the year (January to March and June to September) were used to isolate *Prosopis*, which remains green during the dry periods when all other vegetation types have dried up or shed leaves due the dry environmental conditions. Values lower than 0.1 typically correspond to areas with little or no vegetation (rocks, ice, and desert). Moderate values (around 0.2 and 0.3) correspond to shrub and grasslands and high values (0.5 and above) typically correspond to dense vegetation like rainforests (Rahman and Dedieu, 1994; Huete et al., 2002).

The preference of Prosopis to saline soils and flood plains was also used to identify Prosopis stands in the satellite images. The preference of Prosopis to riverine areas; sparse and dense vegetation areas, woodlands and grasslands was further used to help in delineating Prosopis occupied areas.

To establish the disappearance of other plant species, MODIS NDVI images, land use, land cover and soil data, GPS data, participatory mapping of Prosopis clusters using community opinion leaders and GIS databases were used. Comparison of climate data trends, Prosopis, other vegetation cover and livestock population was done using Excel spreadsheets to establish relationships. This was done using previously developed techniques (Monteith, 1972; Tucker, 1979; Sellers 1985; Roy and Ravan,1996; Gregorio and Latham, 2002; Running, 1986; Jeyaseelan, 2003).Ground GPS data was collected and used to calibrate and validate the presence of of *P. juliflora* in the different levels of *Prosopis* invasions of the two landscapes of Olkiramatian plains and Ngurumani hillslopes. The two landscapes of the study area were identified purposefully. Each landscape contained three (3) sites containing sparse (less than 30%) *Prosopis* density, moderate *Prosopis* density of 50 to 70% *Prosopis* and high *Prosopis* density (dense) of greater than 70% *Prosopis.* These were identified with the help of the knowledgeable local informants using participatory mapping and topomaps. GPS points were taken in each site with the help of research assistants. They were used for spatial data overlay analysis, ground truthing and verification using GIS tools.

Data analysis

Climate data (average temperature and total rainfall), livestock population data and vegetation and *Prosopis* productivity datasets for the period 2000 to 2014 were plotted against time to establish trends over the study period.

Correlations analyses were done to determine the longitudinal relationships between trends in rainfall and temperature and livestock population, *Prosopis* and other vegetation cover. Strength and direction of the relationships were tested, while descriptives (standard deviation, mean, range and coefficient of variation (C.V.)) were determined for all variable relationships.

Multiple correlations were done for the monthly and dry season

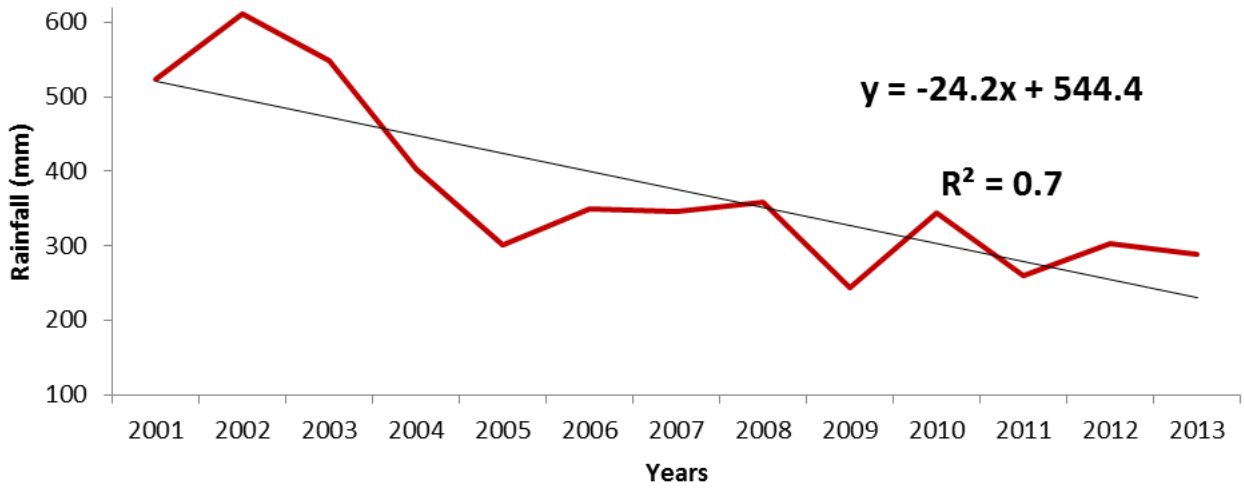

Figure 2. Annual rainfall (mm), trends in Magadi, Kajiado (2001 to 2013) (Magadi Soda Company Meteorological Department, 2014).

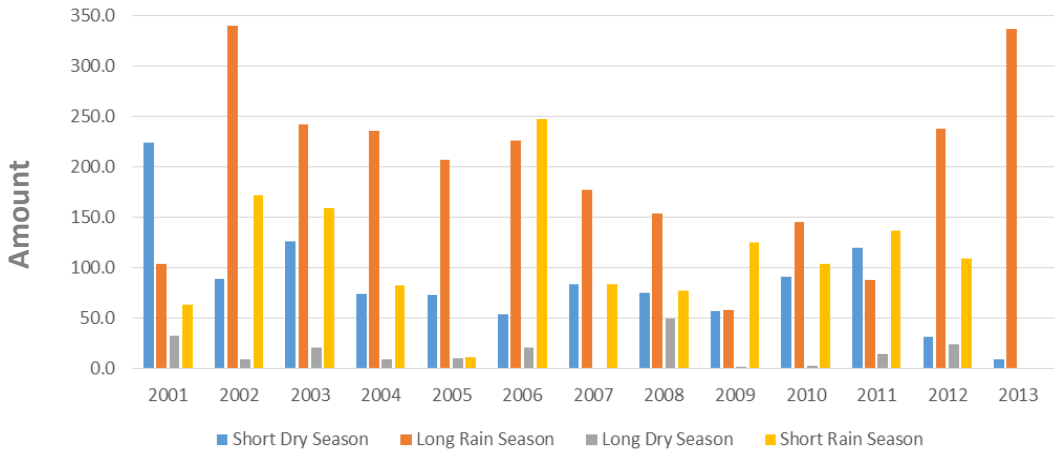

Figure 3. Total seasonal rainfall amounts (mm) in Magadi, Kajiado (2001 to 2013).

time series of the vegetation and *Prosopis* productivity (NDVI) data for the period 2000 to 2014; climate data (monthly rainfall totals and mean temperatures) and livestock populations.

RESULTS AND DISCUSSION

Rainfall and temperature variability in the study area

Long term annual rainfall amounts for Magadi division were plotted against time and a trend developed. It showed that the rainfall amounts were varying and have been on the decline over time and the small R^2 of 0.30 showed there was high rainfall variability (Figure 2).

Seasonal rainfall trends within seasons and within years in Magadi were analysed (Figure 3). The seasons were January to February (short dry season), March to May (long rain season), June to September (long dry season) and October to December was the short rain season (Agnew et al., 2000). This showed that rainfall variability occurs within the season, from season to season, and even from year to year. A declining trend in the rainfall amounts was observed over the period under study - period of 13 years (Figure 2 and 3). The R^2 values of 0.7 showed there was high rainfall variability duting the study period and very low quantities during the short dry season. This has direct implications on the vegetation, livestock and livelihood dynamics.

The results were similar to research done in Eastern Kenya in which it was found that rainfall distribution was very important and rainfall variability was the main limiting factor in biomass production as it causes variation in biomass formation. Infact, the yield of maize stabilized

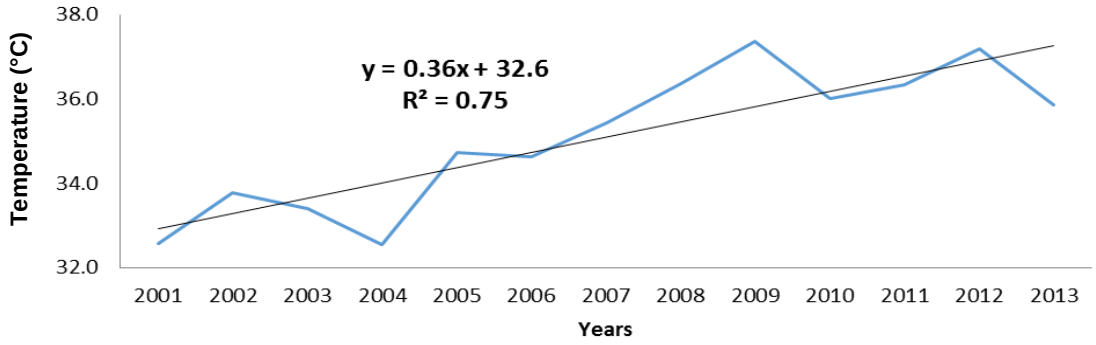

Figure 4. Annual average temperatures in Magadi, Kajiado (2001-2013).

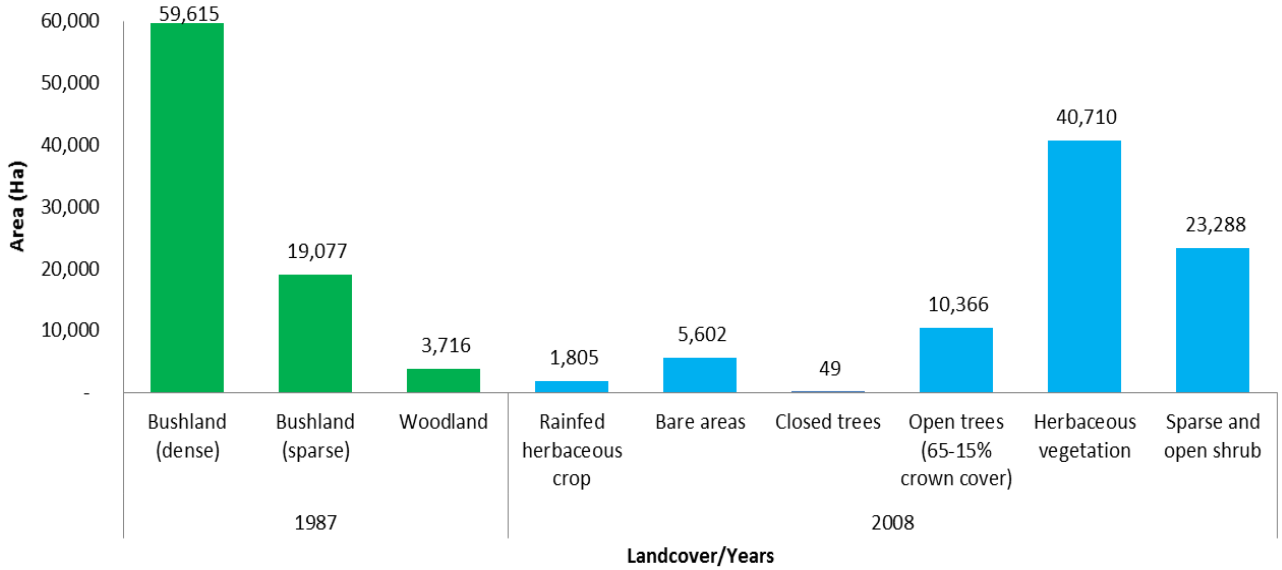

Figure 5. Vegetation cover change over the 20 year period (1987-2008) (Analysis based on FAO Africover Databases)

with even rainfall distribution and increased with increasing rainfall amounts (Kinama et al., 2007).

Droughts are the major climatic conditions which affect vegetation and livelihoods in the ASALs. It was in the dry periods when the effects of water shortages are most apparent. Among the effects was the low vegetation quality and quantity (GOK-PDNA, 2012).

A plot of the annual average temperatures for the period 2001 to 2013 against time (Figure 4) revealed an increase in average temperatures over the study period. A positive relationship between temperature and time (R^2=0.75) is an indication of a strong association between temperature and time. Possible effects for the rise of temperatures are the depressed vegetation growth for less drought tolerant plants, dominance of the aridity tolerant plants such as *Prosopis* and high water losses through evapotranspiration (Kinama et al., 2005). Elsewhere, other studies in the ASALs showed that soil evaporation can take upto 50% of seasonal total rainfall (Kinama et al., 2005). Temperature rises have increased over the years and contributed to global warming.

Land cover changes and in Olkiramatian location

A shift from woodlands and bushlands in the 1980s to shrublands, herbaceous cover and bare lands in the 2000s was evident in land cover change analysis in Olkiramatian location (Figure 5). This could be attributed partly to the declining rainfall amounts, the raise in temperatures and increased human activity (land use). The shrublands, herbaceous cover and bare lands land cover of the 2000's has been taken over by *Prosopis* in 2014 by upto 70% of the landcover (Figure 6).

P. juliflora trends in the floodplains and hillslopes

During the dry seasons, most of the indigenous (native) plants productivity is depressed. *Prosopis* was introduced in Olkiramatian between 1989 and 1994 and it is able to

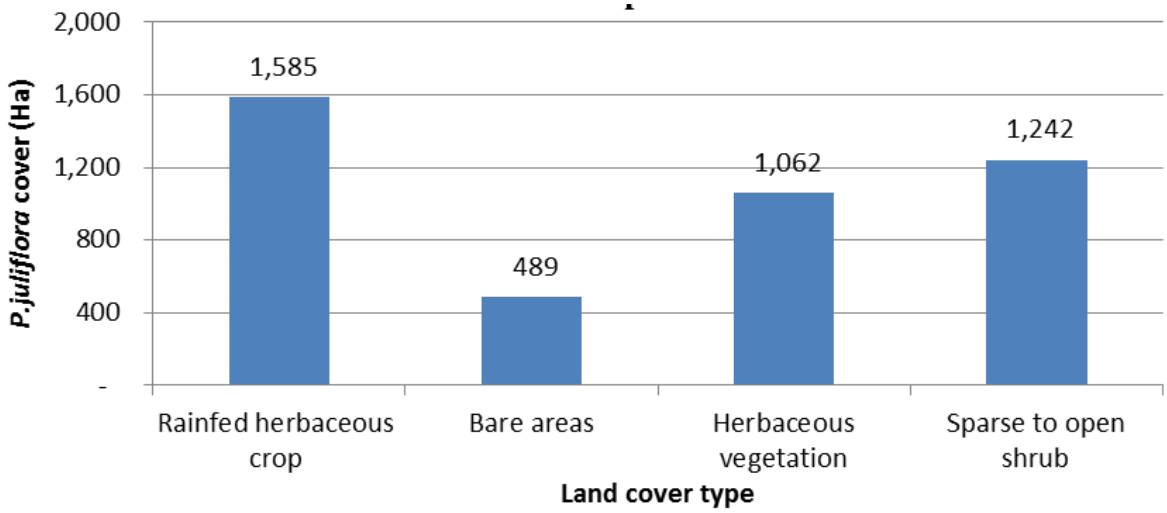

Figure 6. Area (Ha) invaded by *Prosopis* in 2014 (Analysis based on FAO Africover databases, 2008).

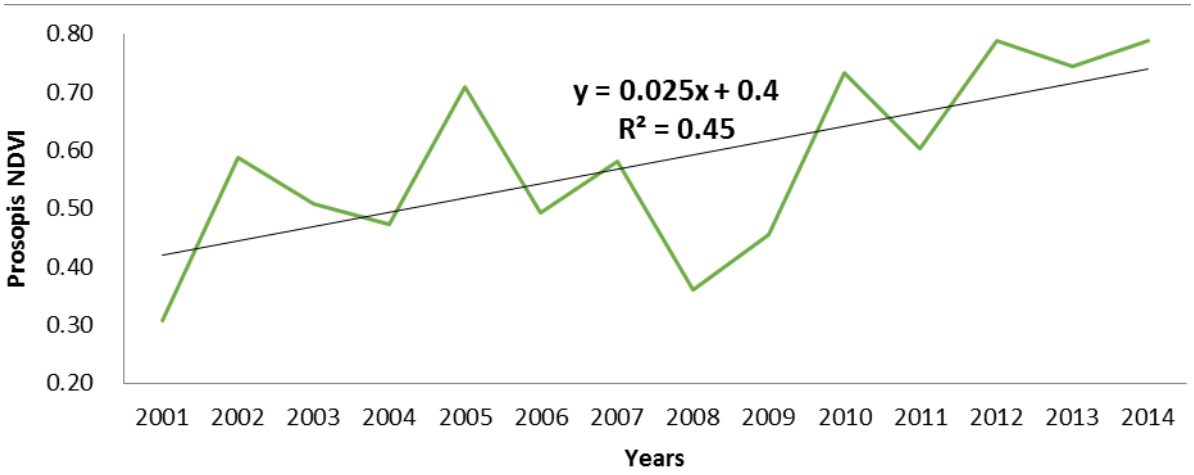

Figure 7. Prosopis productivity (NDVI) trends in Olkiramatian (2001-2014) (Author's analysis based on MODIS 250 m data).

tolerate very difficult environments including very arid (hot and dry) areas, very poor soils, saline soils, sandy soils and highly degraded areas (Muturi et al., 2010). It is always green when most of the other vegetation types have either dried up or shed their leaves to cope with drought. The *Prosopis* clusters digitized from the participatory mapping of *Prosopis* locations and the GPS points of the randomly selected field 30×30 m *Prosopis* plots were used to extract *Prosopis* NDVI values from the general vegetation NDVI values in the MODIS 250 m images, using ArcGIS software. *Prosopis* NDVI values were extracted for both the short and long dry seasons. NDVI values declined for the periods between 2006 and 2009, then a steady increase in the NDVI upto 2014 (Figure 7) in Olkiramatian. This could be attributed to the depressed and highly variable rainfall (Figures 2 and 3) when there was a severe drought in this area. After 2009, the NDVI started to grow at a faster rate. Overall, there was modest increase (R^2=0.45) in *Prosopis* productivity during the period under study.

This observation could be further explained by the tolerant behavour of the *Prosopis* to aridity and saline soils (Yoda et al., 2012). Following its introduction in the early 90s', *Prosopis* was not competitive enough to suppress the other vegetation types until the 2006 to 2009 droughts. After 2009, *Prosopis* was more dominant and competitive owing to its superior adaptive capacity to arid conditions (Pasiecznik et al., 2004). The annual rainfall amounts were declining during the entire monitoring period from 585 to 403 mm (Figure 2).

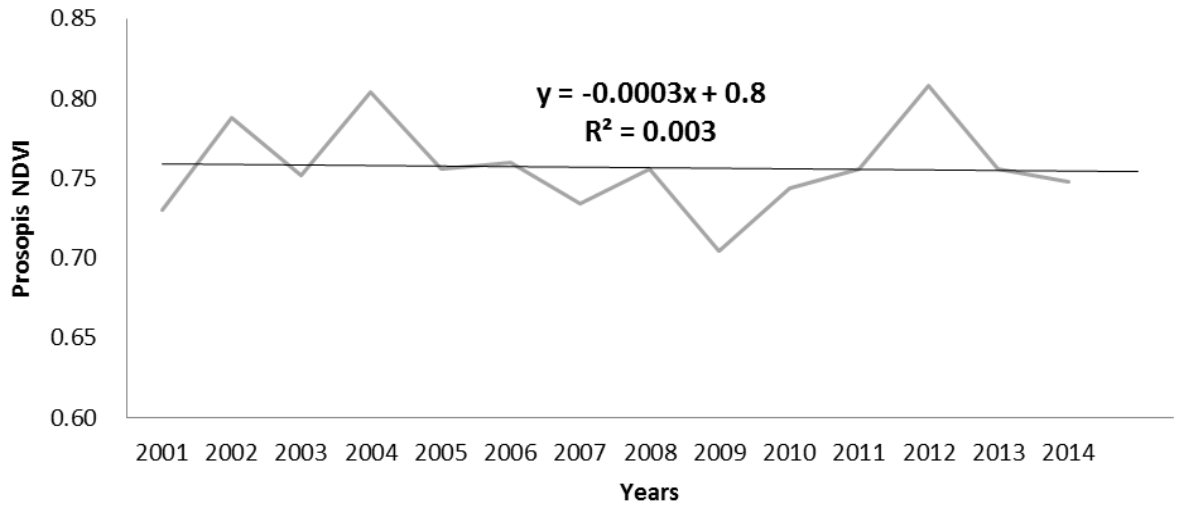

Figure 8. Prosopis productivity (NDVI) trends in Ngurumani (2001-2014) (Author's analysis based on MODIS 250 m data).

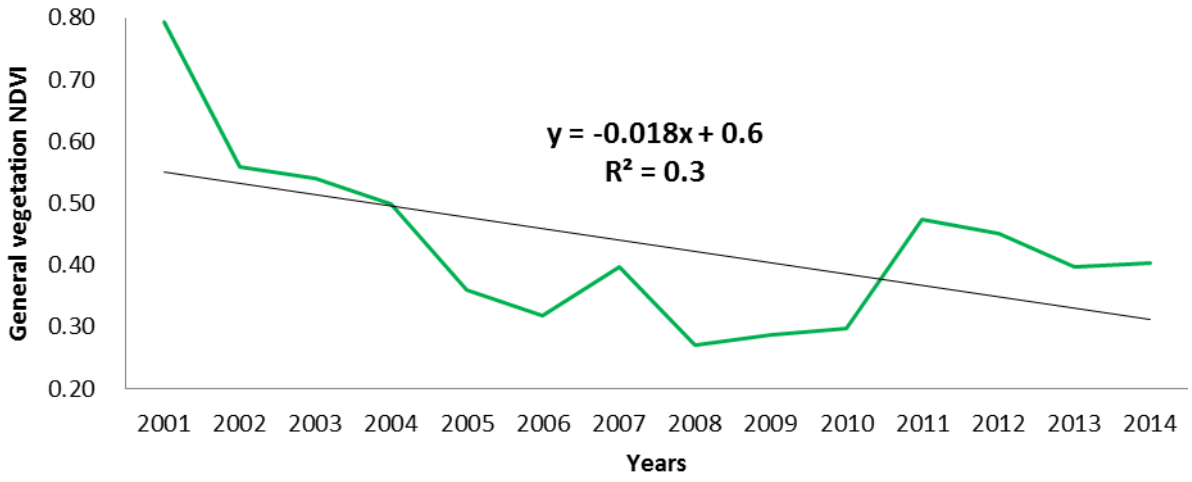

Figure 9. General vegetation NDVI trends in Olkiramatian plains (2001-2014) (Author's analysis based on MODIS 250 m data).

The low value (R^2=0.003) suggested that there was less fluctuation of *Prosopis* trends but there was high values in *Prosopis* NDVI in Ngurumani (Figure 8). Ngurumani hill slopes, the traditional dry season grazing area of the local Maasai community, receives moderately higher rainfall amounts than the Olkiramatian plains (Agnew et al., 2000). It has numerous natural springs flowing throughout the year and in the late 1990s, 'much of its woodlands and bushlands were opened up for irrigated agriculture (Agnew et al., 2000). The combination of the opened spaces, saline soils, Ewaso Ngiro riverine ecosystem and the severe droughts of the late 2000s' encouraged *Prosopis* colonization. Although *Prosopis* was colonizing the area at a faster rate, it had not reached the stage where it could competitively suppress the other vegetation types. This was due to the availability of relatively adequate water sources to enable other plants to compete favorably. The high NDVI values (greater than 0.75, Figure 8) was an indication that there were favorable conditions for *Prosopis* to thrive, notably good supply of water.

Other vegetation trends

NDVI values for the other vegetation for the period 2000 to 2014 were plotted against time (years) – (Figures 9 and 10) in the floodplains of Olkiramatian sublocation and the hillslopes of the Ngurumani and Entasopia sublocations in Magadi Subcounty.

The NDVI values in the Olkiramatian plains declined in that period (Figure 9), while there was little change (less

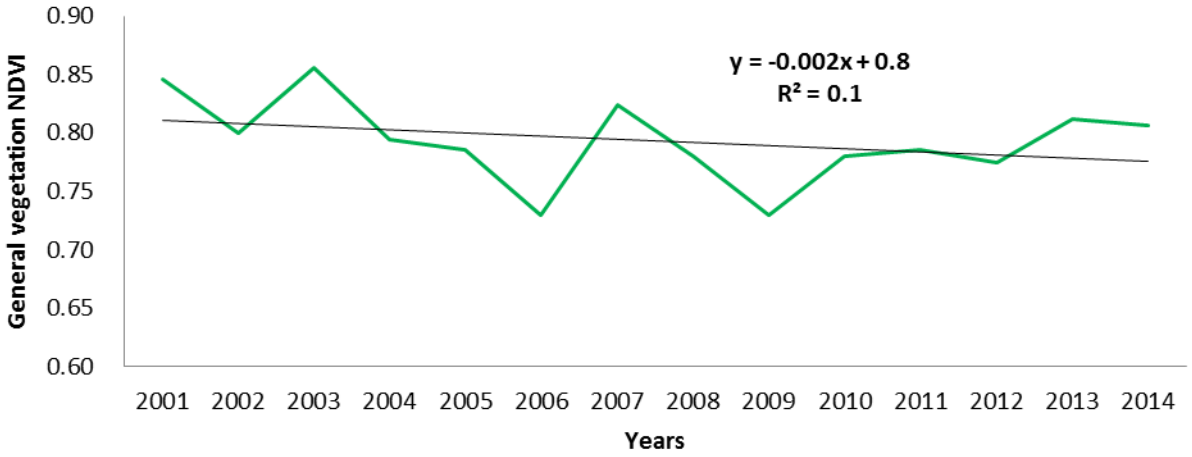

Figure 10. General vegetation NDVI trends in Ngurumani hill slopes (2001-2014) (Author's analysis based on MODIS 250 m data).

fluctuations) to the NDVI values for the Ngurumani hillslopes (Figure 10) for the same period. This could be attributed to the lower rainfall amounts in the Olkiramatian plains (Figure 2) and the higher rainfall amounts and the numerous natural springs in the Ngurumani hill slopes (Agnew et al., 2000). It could also be as a result of the competitive advantage of the drought resistance plants e.g. *Prosopis* in the water stressed plains as opposed to the hillslopes.

There was an observed decline in the NDVI values upto the period between 2006 and 2009, then a steady increase in the NDVI upto 2014 (Figure 9). This could be attributed to the depressed rainfall upto 2009 when there was a severe drought in Olkiramatian. After 2009, the NDVI grew at a slower rate. The overall NDVI trends of the general vegetation are in the decline, in line with the depressed rainfall amounts. In Ngurumani, other vegetation NDVI trends have little fluctuations due to the higher moisture levels in Ngurumani (Figure 10). This mirrors the landcover change trends, where the cover changed from woodlands and bushlands in early 1980's to open trees, herbaceous vegetation, shrublandas and bear lands in 2000's (Figure 8).

Vegetation plays a keep role in regulating the atmospheric dynamics and also ensures the survival of both the humans and animals. Monitoring vegetation productivity is important in assessing threats to environment and to ensure feed and food sustainability to humans and animals. Ali et al. (2013) estimated vegetation productivity using normalized difference vegetation index (NDVI). It is an indicator of photosynthetic activity in a living plant. It has been used as an indicator (proxy) for vegetation vigour and vitality (Reeves et al., 2002).

Droughts are the major climatic conditions which affect vegetation and livelihoods in the ASALs. It is in the dry periods in Magadi when the effects of water and forage shortages are most apparent. Among the effects is the low vegetation quality and quantity. Vegetation productivity during the dry seasons is one of the most limiting factors to pastoral livelihood sustainability in the ASALs (Kazmi et al., 2010). Dry season vegetation and *Prosopis* productivity was established due to the significance of the dry seasons to the pastoral communities and the green *Prosopis* all year round (Kazmi et al., 2010). It has a direct consequence to pastoral livestock production systems. It is therefore important to understand the vegetation dynamics during these critical periods (Patel et al., 2012) as it informs decision making for interventions (FAO, 2007). It is also during the dry seasons when *Prosopis* has superior competitive capacities for survival in these areas (Kazmi et al., 2010). It is the period when it is easy to isolate *Prosopis* from the other plants due to its greenness when all the other plants have either shed leaves or dried up.

Vegetation productivity during the dry seasons is one of the most limiting factors to pastoral livelihood sustainability in the ASALs (Agnew et al., 2000). It has a direct consequence to pastoral livestock production systems. It is therefore important to understand the vegetation dynamics during these critical periods as it informs decision making for interventions.

Comparisons of *Prosopis* and other vegetation productivity trends

There were few fluctuations, similar trends and higher values in the NDVI values in the Ngurumani *Prosopis* and other vegetation in both the short and long dry seasons (Figures 11 and 12). This was because of the higher water endowment in Ngurumani hill slopes for most of the time during the year.

In the Olkiramatian *Prosopis*, the situation was different.

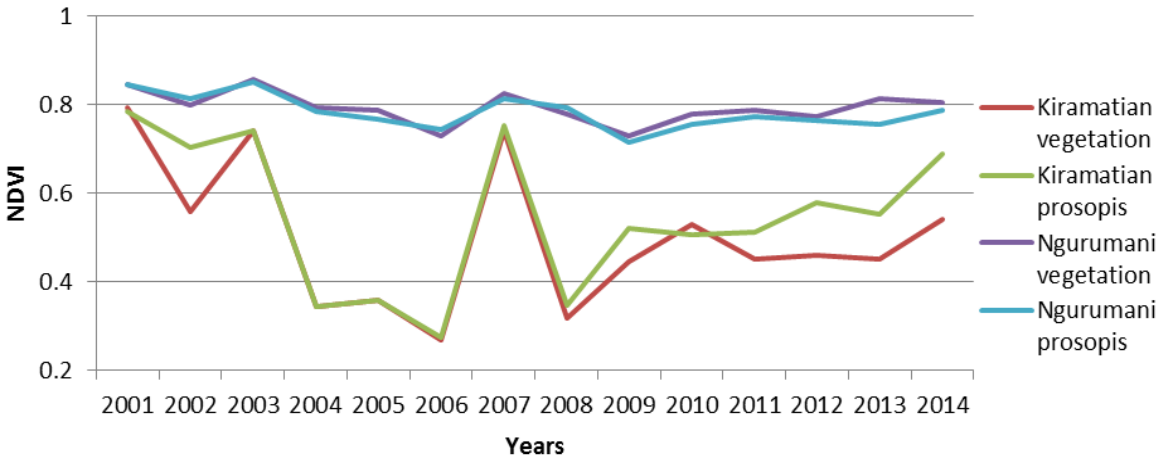

Figure 11. NDVI comparisons during the short dry season (2001-2014) (Analysis based on MODIS 250 m data from Endeleo website (http://endeleo.vgt.vito.be/)).

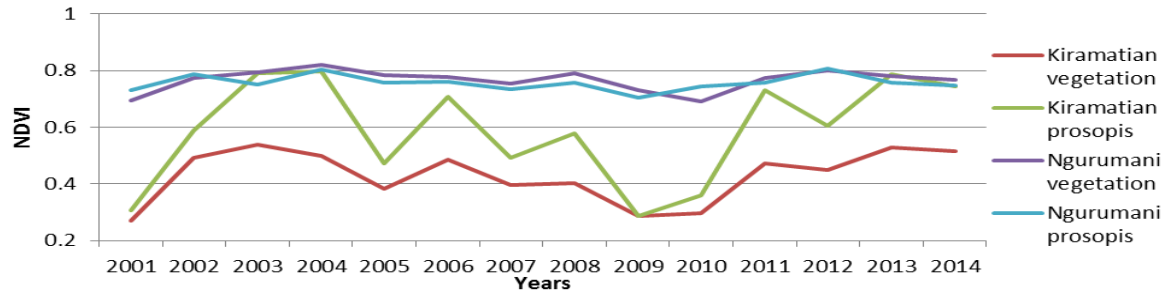

Figure 12. NDVI comparisons during the long dry season (2001-2014) (Analysis based on MODIS 250 m data from Endeleo website (http://endeleo.vgt.vito.be/))

The superior competitive advantage of *Prosopis* was evident in the steady increase of NDVI values from year 2008 in both the short and long dry seasons, after a period of similar pattern to that of the other vegetation types (Figures 11 and 12). However, the *Prosopis* NDVI increase in Olkiramatian was most prominent during long dry period, when it was consistently higher than that of the other vegetation and it marched the trends in the water endowed Ngurumani *Prosopis* in 2003 and 2004 (Figure 12). Reasons for these patterns could be due to *Prosopis* superior competitive coping capacities during the dry seasons (de Bie et al., 2011).

Livestock population trends in Magadi

There was little change (R^2=0.1) in the population trends of goats and sheep (shoats) from 2001 to 2013 (Figure 13). However, there was significant change (decrease) in the cattle numbers (R^2=0.6) during the same period and the population numbers were decreasing (Figure 13). This could be explained partly by the disappearance of the grasslands (GOK- PDNA 2012) and the appearance of the *Prosopis,* among other shrubs, replacing the former grasslands. Goats and sheep are generally browsers, feeding mainly on shrubs. The shoats were also known to browse on *Prosopis* (Koech et al., 2010). Cattle mainly feed on grasses, which was on the decline. The opening up and alienation of the Ngurumani dry season grazing areas for irrigated agriculture (Agnew et al., 2000) has also contributed to the decrease of the cattle population.

Relationships between rainfall, temperature, *Prosopis*, other vegetation and livestock trends

Correlation analysis was done to determine the relationship between climate variability, *Prosopis* spread, vegetation change and livestock population dynamics and it was found that the correlations were significant at the 0.05 confidence level (Table 1). Correlation coefficients for *Prosopis* spread against rainfall were -0.4 in Olkiramatian and coefficients for *Prosopis* spread against temperature were 0.3 in Ngurumani and Correlation coefficient for *Prosopis* spread against cattle

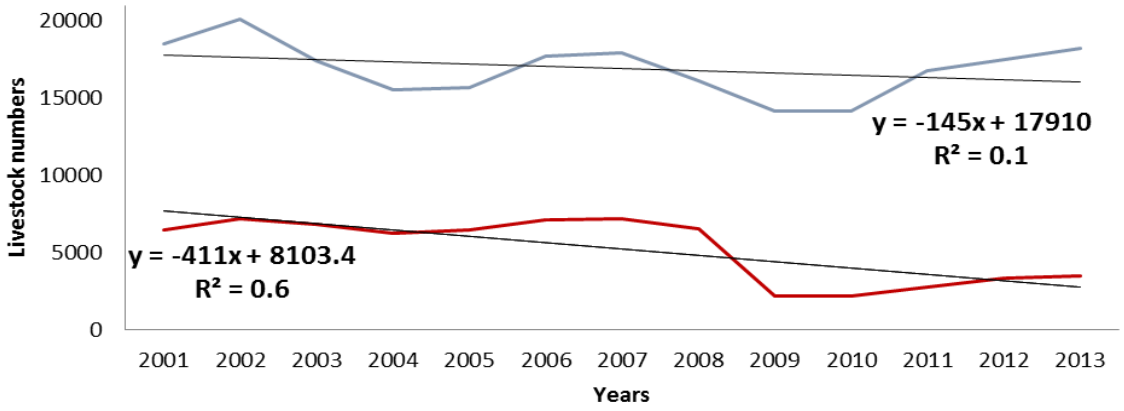

Figure 13. Livestock population trends in Olkiramatian location (2001-2013) (Agadi Division Livestock Office, 2014).

Table 1. Correlations between rainfall, temperature, *Prosopis*, other vegetation and livestock populations.

Correlation	Rainfall totals	Average Temperature	Kiramatian vegetation	Kiramatian *Prosopis*	Ngurumani vegetation	Ngurumani *Prosopis*	Cattle	Shoats
Rainfall totals	1	-0.169* 0.039 151	0.360** 0.000 151	-0.367** 0.000 151	0.385** .000 151	0.227** 0.005 151	0.093 0.256 151	0.158 0.052 151
Average temperature	-	1	-0.219** 0.007 151	0.228** 0.005 151	-0.375** 0.000 151	-0.343** 0.000 151	-0.523** 0.000 151	-0.319** 0.000 151
Kiramatian vegetation	-	-	1	0.992** 0.000 151	0.620** 0.000 151	0.602** 0.000 151	0.073 0.376 151	0.244** 0.003 151
Kiramatian *Prosopis*	-	-	-	1	0.611** 0.000 151	0.597** 0.000 151	-0.364 0.400 151	0.241** 0.003 151
Ngurumani vegetation	-	-	-	-	1	0.734** 0.000 151	0.251** 0.002 151	0.314** 0.000 151
Ngurumani *Prosopis*	-	-	-	-	-	1	0.337** 0.000 151	0.330** 0.000 151
Cattle	-	-	-	-	-	-	1	0.559** 0.000 151
Shoats	-	-	-	-	-	-	-	1

*Correlation is significant at the 0.05 level (2-tailed). **Correlation is significant at the 0.01 level (2-tailed).

was -0.4 (Table 1). Although the correlation coefficients were low for *Prosopis*, these values could be higher if the period of study was divided into two (from 2001 to 2008 and 2009 to 2004). In the first period (from 2001 to 2008), *Prosopis* biomass was declining and the second period (2009 to 2004) *Prosopis* biomass was on the increase.

CONCLUSION AND RECOMMENDATIONS

The study revealed decreasing and variable rainfall amounts and patterns; and an increase in mean annual temperatures in the study area. The vegetation cover was noted to decline especially during the long dry seasons when livestock feed supply was limited and *Prosopis* cover was increasing during the same period. The cattle populations were also on the decline over the 13 year study period while the sheep and goats populations remained largely unchanged.

These trends could be attributed partly to climate variability. With climatic variability expected to continue, it was recommended that viable *Prosopis* utilization options be explored to take advantage of its adaptability to climate variability. Options for the control of the aggreesive spread of *Prosopis* need to be explored. Among the viable options include control through utilization as animal feeds, human food and source of carbn credits, fuel and high quality hard wood timber (Zimmermann et al., 1991; Choge and Pasiecznik, 2006; Wahome et al., 2008).

Conflict of Interests

The authors have not declared any conflict of interests.

REFERENCES

Agnew ADQ, Mwendia CM, Oloo GO, Roderick S, Stevenson P (2000). Landscape monitoring of semi-arid rangelands in the Kenyan Rift Valley East African. Wild Life Society. Afr. J. Ecol. 38:277-285.

Ali A, de Bie CAJ, Skidmore AK, Scarrott RG, Hamad AA, Venus V, Lymberakis P (2013). Mapping land cover gradients through analysis of hyper - temporal NDVI imagery. In: Int. J. Appl. Earth Observ. Geoinfo. (JAG) 23:301-312.

Andersson S (2005). Spread of the introduced tree species *Prosopis juliflora* (Sw.) DC in the Lake Baringo area, Kenya. SLU, Umea, Sweden, 31 p.

ArcGIS software website: http://www.esri.com/software/arcgis/arcgis-for-desktop

Choge S, Pasiecznik NM (2006). The challenges of eradicating Prosopis in Kenya. Policy brief. HDRA, Coventry, UK. 2pp. Climate Change, Adaptation and Pastoralism: available on the WISP website: www.iucn.org/wisp/wisp-publications

de Bie CAJM, Khan MR, Smakhtin VU, Venus V, Weir MJC, Smaling EMA (2011). Analysis of multi-temporal SPOT NDVI images for small-scale landuse mapping. Int. J. Rem. Sens. 32(21):6673-6693.

El-Sharkawi HM, Farghali KA, Sayed SA (1997).Trifactorial interactive effects of nutrients, water potential and temperature on carbohydrate allocation to the embryonic axis of desert plant seeds. J. Arid Environ. 35:655-664.

ENDELEO Website: Monthly NDVI of the years 2000 - 2014 for Kajiado. Retrieved April 11, 2014 from http://endeleo.vgt.vito.be/.

FAO (2007). Climate variability and change: Adaptation to drought in Bangladesh ftp://ftp.fao.org/docrep/fao/010/a1247e/a1247e02.pdf

Galvin K, Thornton P, Boone R, Sunderland J (2004). Climate variability and impacts on east African livestock herders: The Maasai of Ngorongoro Conservation Area, Tanzania. Afr. J. Range Forage Sci. 21(3):183-189.

Getachew S, Demissew S, Woldemariam T (2012). Allelopathic effects of the invasive *Prosopis juliflora* (Sw.) DC. On selected native plant species in Middle Awash, Southern Afar Rift of Ethiopia. Manage. Biol. Invas. 3(2):105-114.

GOK-PDNA (2012). Kenya Post-Disaster Needs Assessment 2008-2011 Drought.

Grace J, San José J, Meir P, Miranda HS, Montes RA (2006). Productivity and carbon fluxes of tropical savannas. J. Biogeogr. 33:387-400.

Gregorio A, Latham J (2002). Land use, land cover and soil and soil sciences – Vol. I – FAO Africover Land cover and soil classification and mapping project.

ICRAF (1992). A selection of useful trees and shrubs for Kenya: Notes on their identification, propagation and management for use by farming and pastoral communities. ICRAF.

IPCC Synthesis Report (2007). An Assessment of the Intergovernmental Panel on Climate Change.

Jatzold S (1978). Food and Agriculture Organization (FAO) Chapter 2.

Jenkerson CB, Maiersperger T, Schmidt G (2010). eMODIS: A user-friendly data source: U.S. Geological Survey Open-File Report 1055:10.

Jeyaseelan AT (2003). Droughts floods assessment and monitoring using remote sensing and GIS. In: P.S.R. M.V.K. Siva Kumar, K. Harmsen, S.K. Saha (Editor), Satellite Remote Sensing and GIS Applications in Agricultural Meteorology, Dehra Dun, India.

Kaur R, González WL, Llambi LD, Soriano PJ, Callaway, RM, Rout ME, Gallaher TJ, Inderjit (2012). Community impacts of *Prosopis juliflora* invasion: Biogeographic and congeneric comparisons. PLOS One 7:1-13.

Kazmi SJ, Shaikh S, Zamir U, Zafar H, Rasool A, Tariq F, Afzal A, Arif T (2010). Ecological and Socio-economic Evaluation of the Use of *Prosopis juliflora* for Bio-char Production in Pakistan, Drynet.

Kenya National Bureau of Statistics (2010). 2009 Kenya Population and Housing Census.

Kenya Soil Survey (1997). Soil physical and chemical properties of Kenyan soils by Kenya Soil Survey (KSS) in 1982 and revised in 1997.

Kinama J, Stigter C, Ong C, Nganga J, Gichuki F (2005). Contour hedgerows and grass strips for erosion and runoff control in semi-arid Kenya. Arid Land Research and Management.

Kinama J, Stigter C, Ong C, Nganga J, Gichuki F (2007). Alley cropping (contour hedgerow intercropping) maize or cowpea/senna for increased dry matter production in the semi-arid areas of eastern Kenya. Proceedings of African Crop Science Society (ACSS) in Melkia – Egypt.

Koech OK, Kinuthia RN, Wahome RG, Choge SK (2010). Effects of *Prosopis juliflora* Seedpod Meal Supplement on Weight Gain of Weaner Galla Goats in Kenya. Res. J. Anim. Sci. 4(2):58-62.

Leparmarai P, Alvarez M, Heller G, Becker M (2015). The role of endozoochory on the recovery and germination of *Prosopis juliflora* seeds. Arid Lands 7(5):000-000 (in press).

Maundu P, Kibet S, Morimoto Y, Imbumi M, Adeka R (2009). Impact of *Prosopis juliflora* on Kenya's semi-arid and arid ecosystems and local livelihoods. Biodiversity 10:33-50.

Monteith JL (1972). Solar radiation and productivity in tropical ecosystems. J. Appl. Ecol. pp. 747-766.

Muturi GM, Mohren GMJ, Kimani JN (2010). Prediction of prosopis species invasion in Kenya using geographical information system techniques. Afr. J. Ecol. 48:628-636.

Nakano H, Nakajima E, Hiradate S, Fujii Y, Yamada K, Shigemori H, Hasegawa K (2004). Growth inhibitory alcaloids from mesquite

(*Prosopis juliflora* (Sw.) DC,) leaves. Phytochemistry 65:587-591.
Nanyingi M, Kiama SG, Thumbi SM, Muchemi GM (2012). Climate Change Vulnerability, Adaptation and Mitigation of Livestock Systems in Kenya.
NASA MODIS vegetation productivity website (http://modis.gsfc.nasa.gov/): Data set characteristics.
Pasiecznik NM, Harris PJC, Smith SJ (2004). Identifying Tropical Prosopis Species: A Field Guide.HDRA, Coventry, UK. 30 p.
Pasiecznik NM, Felker P, Harris PJC, Harsh LN, Cruz G, Tewari JC, Cadoret K, Maldonado LJ (2001). The *Prosopis juliflora* – *Prosopis pallida* Complex: A Monograph. HDRA, Coventry, UK. 162 p.
Patel NR, Parida BR, Venus V, Saha SK, Dadhwal VK (2012). Analysis of agricultural drought using vegetation temperature condition index (VTCI) from Terra / MODIS satellite data. In: Environ. Monit. Assess. 184(12):7153-7163.
Reeves MC, Jerome C, Running S (2002). Mapping weekly rangeland vegetation productivity using MODIS data. In First Virtual Global Conference on Organic Beef Cattle Production - Brazil.
Resilience Alliance (2010). Assessing resilience in social-ecological systems: Workbook for practitioners.Version 2.0. Online: http://www.resalliance.org/3871.php
Rettberg S, Müller-Mahn D (2012). Human-environment interactions: the invasion of Prosopis juliflora in the drylands of Northeast Ethiopia. In Changing deserts, edited by Mol, L. andT. Sternberg (eds.). Whitehorse, Cambridge, UK, 2012.
Robinson TP, van Klinken RD, Metternicht G (2008). Spatial and temporal rates and patterns of mesquite (*Prosopis* species) invasion in Western Australia. J. Arid Environ. 72:175-188.
Roy P, Ravan S (1996). Biomass estimation using satellite remote sensing data - An investigation on possible approaches for natural forest; J. Biosci. 21(4):535-561.
Running SW (1986). Global primary production from terrestrial vegetation: Estimates integrating satellite remote sensing and computer simulation technology. Sci. Total Environ. 56:233-242.
Shiferaw H, Teketay D, Nemomissa S, Assefa F (2004). Some biological characteristics that foster the invasion of *Prosopis juliflora* (Sw.) D.C. at Middle Awash Rift Valley Area, north-eastern Ethiopia. J. Arid Environ. 58:134-153.
Silva AS (1986). Utilization of flour from *Prosopis juliflora* pods as a substitute for wheat flour in rations for egg-laying hens: The Current State of Knowledge on *Prosopis juliflora*. International Conference on *Prosopis* – Brazil.
Tennigkeit T, Wilkes A (2008). Carbon finance in rangelands: An Assessment of Potential in Communal Rangelands.
Tewari J, Harris P, Harsh L, Cadoret K, Pasiecznik NM (2000). Managing *Prosopis juliflora* (Vilayati Babul): A Technical Manual.CAZRI, Jodhpur, India and HDRA, Coventry, UK. 94 p. (English and Hindi).
Tucker CJ (1979). Red and Photographic Infrared Linear Combinations for Monitoring Vegetation. Rem. Sens. Environ. 8(2):127-150.
UNEP/CBD (2010). Compilation of Experiences in the Field of Climate Change Mitigation and Adaptation, Soil Management and Pastoralism in Dry and Sub-Humid Lands.
Wahome RG, Choge SK, Pasiecznik NM (2008). A global overview of the actual use of *Prosopis* pods as an animal feed and their potential value in Kenya. Linking industry to the *Prosopis* pod resource. Soi Safari Lodge, Baringo, Kenya, ILRI, Nairobi, Kenya pp. 12-13.
WISP (2007). Pastoralists as Shrewd Managers of Risk and Resilience in the Horn of Africa.World Initiative for Sustainable Pastoralism (WISP) Policy Note 04.
Yoda K, Elbasit MA, Hoshino B, Nawata H, Yasuda H (2012). Root system development of *Prosopis* seedlings under different soil moisture conditions. J. Arid Land Stud. 22:13-16.
Zimmermann HG (1991). Biological control of mesquite, *Prosopis* spp. (Fabaceae), in South Africa. Agriculture, Ecosyst. Environ. 37:175-186.

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