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Remarkable increase in tree density and fuelwood production in the croplands of northern Nigeria

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ABSTRACT

This paper examines trends in woody vegetation and tree species composition in the Sudan zone of West Africa, using the Kano region of northern Nigeria as a case study. The study compares data on tree density, fuelwood production and tree species composition from fieldwork conducted in 1981 and 2016, as well as on several dates of aerial and satellite images since the 1960s. Recent satellite-based reports of greening in arid West Africa as a response to recovery from droughts in the 1970s and 1980s, are examined to explain the observed trends. Tree densities in the goods and services hinterland of Kano city have at least doubled since the drought period, and no decline, rather a slight increase was observed during the drought decades. This contradicts reports of woody vegetation trends from the more arid and less densely populated Sahel zone, which generally observed decline during the drought years and current recovery to pre-drought levels. The remarkable increase in tree numbers in Kano region is accompanied by increasing fuelwood production as suggested by greater concentration by farmers on tree species highly valued for fuel, at the expense of other traditional species. The main driver of such trends is thought to be rapid population growth in the context of a remaining dependence on wood as fuel by both urban and rural populations in Nigeria. Climate is thought to play only a minor role in explaining the trends. These observations confirm trends in fuelwood production observed in Kano region more than three decades previously, and indicate a somewhat Boserupian response to Malthusian-type pressures on available resources. Nevertheless, a return to rainfall levels of the drought decades combined with climate change predictions of increasing temperatures in dryland Africa, may have serious consequences for rural households if energy sources are not diversified.

1. Introduction

The Fifth Assessment Report (AR5) of the International Panel on Climate Change (IPCC) predicts that temperatures in dryland Africa will rise faster than the global average during the 21 st century (IPCC, 2014). Predicted changes in the rainfall regime suggest up to 20% decline in the length of growing season across the arid Sudan and Sahel zones of West Africa (Thornton et al., 2006). In this region where rainfall is already highly variable on both annual and decadal timescales, peoples' livelihoods are still closely tied to biomass production. Therefore such predictions need to be considered in the context of social and economic trends. At national level, these trends cannot be divorced from government policies which, whether intended or incidental, often have repercussions at village level. The Kano Close Settled Zone of northern Nigeria (Mortimore and Wilson, 1965) surrounds Nigeria's second largest city, Kano. Kano is the largest city in savanna Africa, and has some of the highest rural population densities in the world. The number of persons per km^2 almost doubled from 169 in 1991 (Tiffen, 2001) to 308 in 2006 (National Population Commission, 2006). Kano city itself grew rapidly from the late 1950s, with annual growth rates rising to approximately 6% from 2% in earlier decades. The city's population grew from 0.13 million in 1952, saw a tenfold increase over the next 40 years to 1.36 million in 1991 and then more than doubled to 2.83 million over the next 15 years up to 2006. Since 47% of the population of Kano region was below 15 years of age in 2006, there is potential for further rapid growth. Indeed, by 2050 Nigeria's population is expected to be 2.5 times its current size, reaching 440 million, and to account for 10% of all births in the world (UNICEF, 2014).

In spite of Nigeria's position as the world's 6th largest oil producer, wood remains by far the most common energy source for cooking and heating, even in major cities. Nigeria's northwestern states with 37% of the national population receive only 6% of Nigeria's fossil fuel supply (Naibbi and Healey, 2013), thus urban areas experience frequent

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blackouts and electricity supply is rare in rural areas. Due to the unreliability or absence of electricity in Kano, and fluctuating price of kerosene, 95% of energy used for cooking is from wood (National Bureau of Statistics, 2011).

Wood fuel in Kano has traditionally been derived from trees grown and maintained by farmers in the farmed parklands surrounding the city. Rural households derive a large variety of other basic necessities and additional income from farmland trees, which provide food, fodder, medicines, fibre and building materials (Boffa, 1999; Timberlake et al., 2010). Thus the current scenario of high and still increasing population growth combined with predictions of higher temperatures and decreased rainfall, may pose a major challenge to food security in coming decades.

Many studies have examined the relationship between biomass and climate in arid West Africa over the last three decades since satellite images were available, and certain trends are now recognised. Following many reports of rapid human-induced desertification which was being reported as recently as 2007 (UNEP, 2007), satellite observations suggest a greening trend originating in the 1980s decade, and continuing to present. This greening is seen as a response to increasing rainfall after severe droughts in the 1970s and 1980s (Anyamba and Tucker, 2005; Brandt et al. (2014a, 2014b); Capecchi et al., 2008; Hiernaux et al., 2009; Mishra et al., 2015; Olsson et al., 2005; Tappan et al., 2004), rather than to human land use pressures. But how this satellite-observed greening based on the NDVI is related to ground conditions and to local household economies has not been rigorously examined. Furthermore, it is acknowledged that the NDVI's ability to represent biomass is more representative of the green herbaceous layer than the mainly non-green biomass of woody vegetation, and the short-approximately 3-decade record of satellite images is shorter than the lifespan of many trees (Gonzalez et al., 2012).

A few more recent studies have specifically examined trends in woody vegetation (Brandt et al., 2014a; Gonzalez et al., 2012; Hänke et al., 2016; Hiernaux et al., 2009) using time-series of images combining archived aerial photographs and recent high resolution satellite images. Such higher resolution datasets have enabled the estimation of tree cover and density. As with satellite-based NDVI, trends in tree cover and tree density appear to be aligned with climatic trends. Gonzalez et al. (2012), working in three Sahelian villages in Senegal and Mauritania found an overall long term decline in tree cover in the second half of the twentieth century, and Audu (2013) gives similar warnings for northern Nigeria, although no recent survey has been done there. Brandt et al. (2014a) and Hänke et al. (2016), report similar declines in Sahelian tree cover in the later twentieth century. However, while Brandt et al. (2014a) note that tree densities are still far below the levels of the 1960s, Hänke et al. (2016) and Brandt et al. (2017) observe recovery back to 1960s levels by 2006 and 2015, respectively.

Recognising that tree densities alone may not fully represent social-ecological interactions, several studies have also considered trends in tree species composition, comparing recent field inventory with past field inventory (Herrmann and Tappan, 2013) or with informant recollection (Brandt et al., 2014a; Gonzalez et al., 2012; Hänke et al., 2016; Tappan et al., 2004; Vincke et al., 2010). Overall, a decline and shift in species diversity related to increasing aridity is reported, entailing a trend to fewer, and more drought-tolerant species at the expense of those with more southerly distributions.

By far the majority of studies of biomass trends in West Africa have been in Sahelian countries, where mean annual rainfall is 75–600 mm and grazing of perennial grasses and woody shrubs is the main land use activity. Few studies are available for the moister and more densely populated Sudan zone. In a review of remotely sensed vegetation dynamics in West Africa (Karlson and Ostwald, 2016; Knauer et al., 2014), only three of over 100 studies were of Africa's most populous country, Nigeria, where over 40% of land area lies within the Sudan zone (Fig. 1). Moreover, it is likely that climate-controlled biomass impacts on local economies will be country-specific due to differing government policies, particularly those relating to energy distribution and energy subsidies (Cline-Cole and Maconachie, 2016). Previous investigations of tree densities in the Kano Close Settled Zone of northern Nigeria (Mortimore and Wilson, 1965) indicated an approximate 23% increase in tree densities surrounding the city between 1972 and 1981, and slight decline in the outer hinterland (Nichol, 1989; Cline-Cole et al., 1990). However, these data were collected in the early 1980s before the full effects of the 1970s to 80 s drought on tree stocks, and when population was less than half that of today. More recent reports from farm questionnaires have indicated declining tree stocks around Kano (Maconachie and Binns, 2006; Maconachie et al., 2009).

The main objective of the current study is to examine trends in woody vegetation abundance and composition in the Sudan zone of West Africa, using the farmed parklands surrounding Kano, northern Nigeria as a case study. Kano's status as the largest city in savanna Africa, with probably the highest rural population densities, provides a model for understanding social-ecological interactions under a scenario of climate change and population pressure. The study is based on historical data from archived aerial photographs and satellite images, as well as field data collected in the early 1980s and 2016.

2. Materials and methods

2.1. Study area

The research was conducted in three study areas surrounding Kano city (Fig. 1), which is situated at 12 °N in the northern Sudan Zone of West Africa. Kano's mean annual rainfall of 750 mm, supports a natural vegetation of tree savanna, with flat-topped trees browsed by savanna fauna and livestock, when grass is unavailable during the October to April dry season.

Rainfall is highly variable both inter-annually and on a decadal timescale (Fig. 2). Severe drought in the 1970s and 80s was experienced throughout West Africa, but rainfall in Kano appears to have recovered to 1960s levels. The Kano Close Settled Zone (Mortimore and Wilson, 1965) describes the densely populated agricultural region influenced by the proximity of Kano and serving as its hinterland in terms of interdependency of products, trade goods and services. Over 80% of the land is cultivated in the April to September rainy season, with main subsistence crops of Guinea corn, Millet and Sorghum. Vegetables are grown along valleys and on irrigation schemes. The 'parkland' landscape is defined by the large variety of trees propagated and maintained on farmland, which are used for a very wide variety of purposes including medicinal use, food, fibre, construction and as fuelwood (Boffa, 1999; Timberlake et al., 2010). Traditionally, goods were brought to Kano markets by donkey, limiting the fuelwood hinterland to around 50 km, but replacement by pickup trucks over the last two decades has expanded this to over 100 km. Questionnaires to farmers in the Kano Close Settled Zone (Maconachie et al., 2009; Maconachie and Binns, 2006; Machonachie, 2013) indicate that farmers perceive declining tree cover on farmlands, as well as reductions in tree species diversity in recent decades.

Three study areas (Fig. 1, Table 1) were selected within Kano's hinterland as follows. Study area 1, Kano West extends westwards from Kano city covering 100 km^2, and Study area 2, Kano East is situated in the region of the Jakara river, 30 km northeast of Kano city and covers 110 km^2. These two study areas represent the long-established Kano Close Settled Zone of intensive agriculture and high rural population within a day's walking or donkey distance to the city market. They were selected based on their geographical differences, with mainly red, well-drained sandy loam soils in Kano West, compared to Kano East dominated by the Jakara river lowlands draining into the Hadejia river and ultimately, Lake Chad. Soils in Kano East are heavier, yellow-red to grey in colour, with more clay. Study area 3, Daura, covering 200 km^2, was selected farther north bordering the more arid Sahel Zone, where only approximately 60–70% of land is cultivated, compared with over 90%