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ORIGINAL RESEARCH

Petro-Landscapes: Urban Expansion and Energy Consumption in Mbanza Kongo City, Northern Angola

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Abstract

Angola is a resource-rich country, which experienced a major urban concentration of the population owing to a long civil war followed by an oil-related economic boom. The majority of the population, however, remains without access to basic services such as potable water, sanitation or electricity. Despite the economic and social exclusion of the majority of the citizens, how does its oil wealth translate into the energy consumption patterns of poor urban households in the capital city of one of its oil-rich provinces? Research conducted in around 300 households of Mbanza Kongo city of Zaire province—whose livelihoods relied on odd jobs and/or peri-urban agriculture—showed that contrary to much received wisdom most of the poor urbanites do not use either fuelwood or charcoal as their main source of energy, and thus do not contribute to deforestation or forest degradation. Unexpectedly, a major impetus for deforestation is house construction. Attention must be paid to diverse drivers of deforestation and greenhouse gas emissions. The major expansion of urban areas is an important factor; here we mapped one World Heritage city in Angola through remote sensing.

Keywords Deforestation · Fuelwood · Household energy consumption · Urban landscape changes. Angola

Introduction

Mbanza Kongo – formerly known as São Salvador – is one of the oldest urban centres of Central Africa (Thornton 2000), famous as the capital of the kingdom of Kongo. Presently the capital of the Zaire province in northern Angola, it is considered one of the most important sites in the cultural heritage of Central and Southern Africa, and was designated a UNESCO World Heritage Site in 2017. Despite abundant literature on the historical importance of the city (see Máximo 2016 for a review), major transformations in daily livelihoods and infrastructures arising from war and such post-war conditions as the return of refugees remain mostly unstudied.

One of the major reservations regarding Mbanza Kongo's nomination as a World Heritage site identified by UNESCO specialists (Dr Biluka Nsakala Nsenga, personal communication, August 2016) was the lack of urban planning and limited infrastructure development (sewage, piped water, and even streets and paths) outside the core city centre. The energy consumption patterns of poor urban inhabitants are largely unstudied. Our research is designed to rectify this. We first provide a description of the study area, followed by our methodology for data collection and remote sensing analysis, for which we utilized a "people and pixels approach" (Liverman *et al.* 1998) to the study of human-environment interactions. We then discuss the energy consumption patterns for cooking and lighting of poor agricultural households — thus the ones more likely to use biomass as a source of energy as they can collect it for free — in relation to urban expansion, monitored over the last 18 years (1998–2016) using remote sensing data. Following Ribot (1999) and Lambin *et al.* (2001), we argue for the need to go beyond crisis narratives and associated myths, and to study contextually the role that wood extraction by poor households for fuelwood and charcoal use in tropical cities plays in deforestation. Finally, we provide some policy recommendations.

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Background

After almost four decades of anti-colonial and civil wars, Angola achieved peace in 2002. Due to a major increase in

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oil extraction and the rising international price, the country soon became one of the world's fastest-growing economies (e.g., Soares de Oliveira 2011, 2014; Pearce *et al.* 2018), albeit entirely dependent on oil and diamonds revenue (e.g., Gaibazzi 2017: 971), notwithstanding favourable agro-ecological potential (Castanheira Diniz 2006). Consequently, the sudden decline in oil prices in mid-2014 (Croese 2017: 84) left Angola an aid-dependent country (e.g., Pearce *et al.* 2018). Pre-war Angola was a leading African exporter of agricultural products (e.g., Sogge 1994; Neto 2005: 172, 173; Soares de Oliveira 2014: 28). According to the FAO (2017) only around 10% of the arable land is currently under cultivation and about 37.4% of the population is classified as rural (INE 2016).

To enhance his political legitimacy, the previous president directed a part of the Angola's oil and diamond wealth towards road infrastructure reconstruction (e.g., Croese 2017), but limited investments were made in agriculture, education, health, sanitation, grid electricity, and drinking water provision (Soares de Oliveira 2011 and 2014: 62; see also Croese 2017). The country is ranked 147 out of 186 by The Human Development Index of 2018 (UNDP 2018). Pearce *et al.* (2018: 146) state: "Angolan society remains marked by significant exclusions and skewed patterns of wealth distribution." Pacheco (2014: 94) goes further to say that the development strategy implemented by the government is restricted to "islands that leave the majority of the population excluded." As for the oil-producing regions of Cabinda and Zaire, Reed (2009) documents how the majority of inhabitants are not only excluded from the profits but are also suffering from the environmental externalities of on-shore and off-shore oil extraction.

In Sub-Saharan Africa, 81% of the population use woody biomass energy for domestic and economic activities (Bildirici and Özaksoy 2016: 288), especially the poor (Bone *et al.* 2017). According to some authors, the large majority of this population depends upon the use of fuelwood in rural areas (e.g., Adkins *et al.* 2012) and of charcoal in urban and peri-urban spaces (e.g., Ribot 1999; IEA 2006: 20; Vollmer *et al.* 2017). In Angola socioeconomic exclusion means that most households in the country are still dependent on traditional biomass to meet their cooking, lighting, and heating needs, and have no access to grid-electricity (e.g., IEA 2006; Cornelio 2009; UNEP 2013). Nonetheless, according to Bildirici and Özaksoy (2016: 292) Angolans perceive wood fuel energy as an "inferior good."

As in many other tropical countries (e.g., Geist and Lambin 2002; Bone *et al.* 2017), Angola's growing urbanization and the political economy of energy production and consumption are drivers of deforestation around urban centres. During the wars, large parts of the countryside were afforested (e.g., IEA 2006: 141), similarly to what happened in other African countries (Temudo and Silva 2011; Temudo 2012). More recently, charcoal production, driven by growing populations and expanding urbanization, is leading to major deforestation around the main cities (IEA 2006: 141; Cornelio 2009; Cabral *et al.* 2010). In most sub-Saharan African cities, charcoal is a major source of energy for cooking (Ribot 1999; Vollmer *et al.* 2017). It does not produce smoke, it is light and easy to transport and store, it is much less expensive than gas or electricity, and it lights much better than fuelwood during the rainy season (Vollmer *et al.* 2017). Charcoal production is also an important source of income for poor households (Vollmer *et al.* 2017). However, charcoal production is inefficient and causes more deforestation than the use of fuelwood (Godfrey *et al* 2010). Nevertheless, as Ribot (1999) highlighted, the urban demand for fuelwood does not always give rise to permanent deforestation, and growing urban expansion does not necessarily result in a wood fuel crisis.

Study Area

Mbanza Kongo city is located in the Zaire province of Northern Angola (Fig. 1), a region dominated by savanna scrublands and some dense humid forests, mostly along rivers, creeks and gullies. Many anthropogenic forests comprised of native species and mango, cola, safou, avocado, citrus, and guava trees can also be found in ancestral villages abandoned due to forced resettlement by colonial administration (Castanheira Diniz 2006: 63, 74–77). The climate is tropical savanna (Aw, in the Köppen–Geiger climate classification system) and the mean annual rainfall is around 1300 mm, distributed in two periods separated by a short dry season (Castanheira Diniz 2006: 63).

The Bakongo are one of the three main ethnic groups in Angola, and they constitute the large majority of the population in Zaire province, including Mbanza Kongo city. The population of Mbanza Kongo city and of the Zaire Province has fluctuated widely during recent history mainly for political reasons. The anti-colonial war began in 1963, and over the next 13 years, the entire population − with the exception of soldiers and of few inhabitants of Mbanza Kongo and some other cities – took refuge in southern Democratic Republic of Congo, DRC (Brinkman 2008; Mateus and Mateus 2011). Angolan refugees in DRC amounted to more than 100,000 people in June 1961 and over half a million in 1972 (Wheeler and Pélissier 1971: 187).[1]

Since the end of the civil war in 2002 there has been a major increase in the urban population caused by the return

[1] The end of the anti-colonial war in 1974 and the declaration of independence in 1975 did not trigger a massive immediate return, as a civil war started between former anti-colonial movements *Movimento Popular de Libertação de Angola*-MPLA (which seized power) and *União Nacional para a Independência Total de Angola*-UNITA (e.g., van der Waals 2011; Spall 2014).

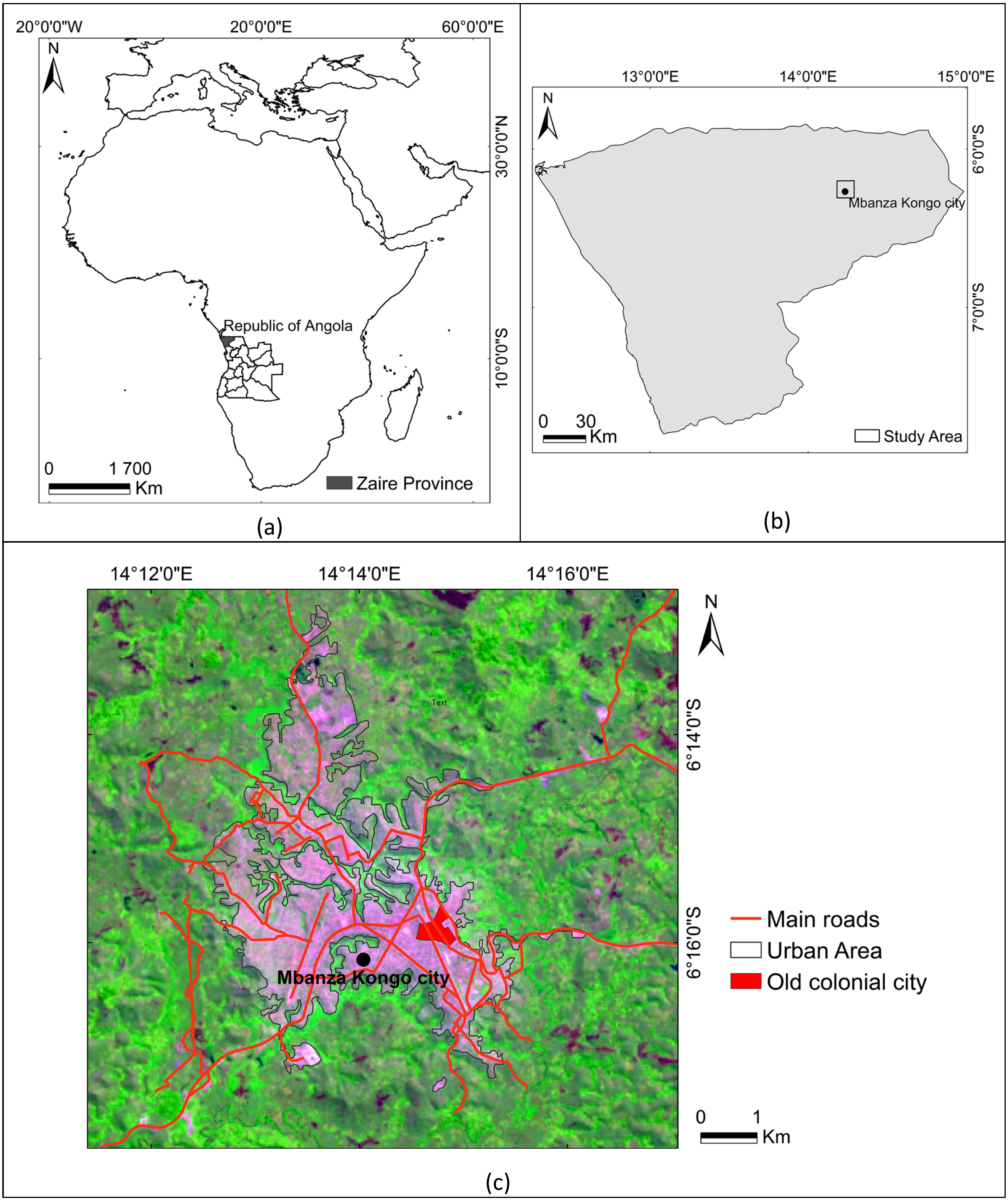

Fig. 1 (**a**) Location of the Zaire Province in the Republic of Angola and in the African continent, (**b**) Location of the study area in the Zaire province, (**c**) Landsat OLI (RGB 754) color composite corresponding to the study area

of refugees from the DRC and rural out-migration (Temudo and Talhinhas 2018). The General Census of Population and Housing conducted in May 2014 reports that the Zaire Province has around 2.3% of Angola's population, of which 73.9% live in urban areas with a population density of 15 inhabitants per square kilometre (INE 2016). The most recent

Fig. 2 Landscape view of a city district outside the city centre (in the foreground). Land slides and the destruction of houses are common during the rainy season

estimate of the population of Mbanza Kongo is 26,577 inhabitants.[2] Despite its rapid growth, the city's infrastructure, apart from its former colonial centre which has paved roads, concrete buildings, piped water, and grid-electricity, reflects an urban-rural continuum between the *bairros* (city districts) and the villages along the main roads (Fig. 2).

After 2002, Mbanza Kongo was connected to Luanda, the capital city, and to Luvo (bordering the DRC) by paved roads. However, land routes to most cities of the Zaire province (Soyo, Mandimba, Noki, and Kuimba) are still under construction and public transport is poor and infrequent. The state has made some efforts to build houses for civil servants, although they are generally provided as a reward to MPLA loyalists (Croese 2017).

Methods

The first author collected empirical data on household energy consumption during nine months of fieldwork (June, July, and August of 2014, 2015 and 2016) using mixed methods (Creswell and Plano Clark 2011) in order to understand the livelihood strategies adopted by poor post-war urban households. In light of the difficulties inherent in applying a randomized sampling procedure in the highly dispersed settlement of Mbanza Kongo and the lack of census data, she contacted the leaders of the main churches (Catholic, Protestant, Pentecostal, and Prophetic) in each quarter of the city to present her research plan (Gerring 2007). Over three months in 2014, 300 urban residents whose agricultural fields lay in the peri-urban area (at between one- and three-hours walking distance) agreed to be interviewed. Since almost every Bakongo belongs to a church (Sarró 2017) and the majority practice agriculture, this sample provided a broad picture of poor urban households. Structured interviews focused on household demographics, main, and secondary occupations, date of the last return from neighbouring DRC, housing tenure status, and sources of energy for cooking and lighting. Qualitative research was conducted in 2015 and 2016 and included informal conversations, interviews with key informants, direct observation, visits to fields and forests, interviews with rural sellers of wood, market wholesalers of charcoal and of grilled meat snacks, and with farmers in many villages around Mbanza Kongo. All interviews were conducted directly by the first author in either French or Portuguese, or in Kikongo (and sometimes in Lingala) with the help of a translator. Unless otherwise stated, all data results are from field research.

The expanded urban area of Mbanza Kongo was analysed by the second author using Landsat Thematic Mapper (TM) and Operational Land Imager (OLI) data for 1998, 2008, and 2016.

Dates of the images were selected according to cloud cover, quality, and date of acquisition, favouring proximity to historical dates and dry season when data were available. All images were downloaded from the United States Geological Survey.[3] Each year included only one single image covering the study area. Several Landsat band combinations were analysed to find the one that best highlighted the urban area. A clear visual depiction was obtained through the combination of Landsat TM bands 7, 4, 3 for 1998 and 2008 and Landsat OLI bands 7, 5, 4 for 2016. Using these combinations and in order to assure an accurate quantification, the urban area corresponding to Mbanza Kongo city was manually digitized on-screen for each year in the Geographic Information System ArcGIS 10.5.0.6491 (ESRI 2016). The accurate delimitation of the urban area in the 2008 image was not compromised by the presence of cloud and its shadow since it was located inside the urban area. In addition, a simplified legend of eight land-cover classes (Forest, Savanna, Grassland, Agriculture/Bare soil, Burnt, Water, Urban, and Clouds) was defined, taking into account field knowledge and the available ancillary information (published articles, written descriptions of vegetation, and old vegetation maps). Each Landsat image was used to generate three land-cover maps for each land-cover class through

[2] https://www.britannica.com/place/Mbanza-Congo, last accessed 07/08/2018

[3] https://earthexplorer.usgs.gov/

a supervised classification technique based on the maximum likelihood classifier (Lillesand *et al* 2015). Given the difficulty in separating Urban and Agriculture/Bare soil classes due to their spectral similarity, the respective urban area of Mbanza Kongo delimited on-screen and converted to raster format was overlapped on each final land cover map. All clouds and cloud shadows in the Landsat images of each year were manually digitized on-screen and a common mask was built and applied to each classified map. The accuracy of the land cover map for 2016 was assessed based on a formal comparison between the image classification and a reference dataset composed of data collected, by visual interpretation, over a random origin systematic grid overlaid on high-resolution images from Google Earth (GE) with dates between 2016 and 2018. The validation grid containing 1000 points was based upon the minimum bounding box containing the satellite image, but all the points located at the *no data* region were removed. The sampled land cover points showing date differences between the classification map and the GE high-resolution images were simultaneously verified in terms of the spectral response observed in the Landsat images (Cabral *et al.* 2010). The accuracy of the maps produced for the remaining dates was not assessed, considering that neither ground validation data nor GE images near or of the same date were available. Nonetheless, according to Cabral *et al.* (2010), if the entire historic image data set was subject to consistent processing, it can be assumed that the validation accuracy of the most recent map will be enough to support the validity of the historical map data set. Two measures of accuracy agreement were calculated for 2016, namely, overall accuracy and Cohen Kappa coefficient (Li *et al.* 2013). The image classification shows good results with an overall accuracy and Kappa coefficient values of 93% and 87%, respectively. To identify the main land cover types occupied by urban expansion, the delimited polygons of the urban area of Mbanza Kongo were overlapped with the respective land cover map of the previous year.

Results

Urban Expansion and Households' Sources of Energy for Cooking and Lighting

Until independence, the core city center of Mbanza Kongo had an area of approximately 23,48 ha. The return of refugees at the end of the anti-colonial war in 1974 and their concentration in urban areas due to the civil war are reflected in a clear expansion of the city's area to 614,54 ha (Fig. 3). The end of the civil war (2002) did not immediately trigger a major increase of the urban area, which had reached 743,66 ha by 2008, but further expansion occurred after 2009 due to increased rural out-migration and the expulsion of most of the remaining Angolan refugees from the DRC (Fig. 3). This expansion mainly occurred at the expense of the savanna, and more recently of small areas of forest, grassland, and/or agriculture/bare soil. However, according to interviewees, urban population growth parallels an increase of biomass energy consumption, mostly for the manufacture of mud bricks for house building (Fig. 4), bakeries, restaurants, and small street meat barbecues. Indeed, the manufacture of the mud bricks for a single house requires burning around three mature trees (about 3 m height and a trunk of 40–60 cm of diameter), and the output of bakeries and street snacks is increasing exponentially. More recently, many trees (mostly of mango and safou) planted in urban and peri-urban house gardens on steep slopes have been cut and used for brick manufacture leading to increased soil erosion and land slides (Fig. 2).

The study households were divided into three groups based on the gender division of household and farm leadership (Table 1): 1) male-headed married households (although also a few single, divorced, or widowed men) in which the husband spends the same or more days than the wife working in the field (38.3%); 2) households headed by single, divorced, or widowed women who also manage the farm (30%)[4]; 3) married households in which the husband is employed outside agriculture and the wife manages the farm (31.7%).

On average, households had six members of which three could be considered dependent, as, irrespective of age, they did not contribute to family subsistence. Female-headed households were smaller and faced more labor (Table 1) and economic constraints.

The majority of all households (57.3%) used kerosene stoves for cooking (Table 2), especially those in which the main activity of the head of the household was not agriculture (Table 3). Reflecting their comparatively worse economic condition, female-headed households used less kerosene as their main energy source, while households headed by men employed outside agriculture showed the highest use of kerosene and the lowest use of fuelwood (Table 2). Fuelwood was the main (and sole) source of energy for 23% of households although it is also used as a secondary source combined with kerosene (11.7%), charcoal (5%), and even gas (1%). More female-headed households use fuelwood as

[4] These households were usually the poorest, with the highest proportion of dependent members.

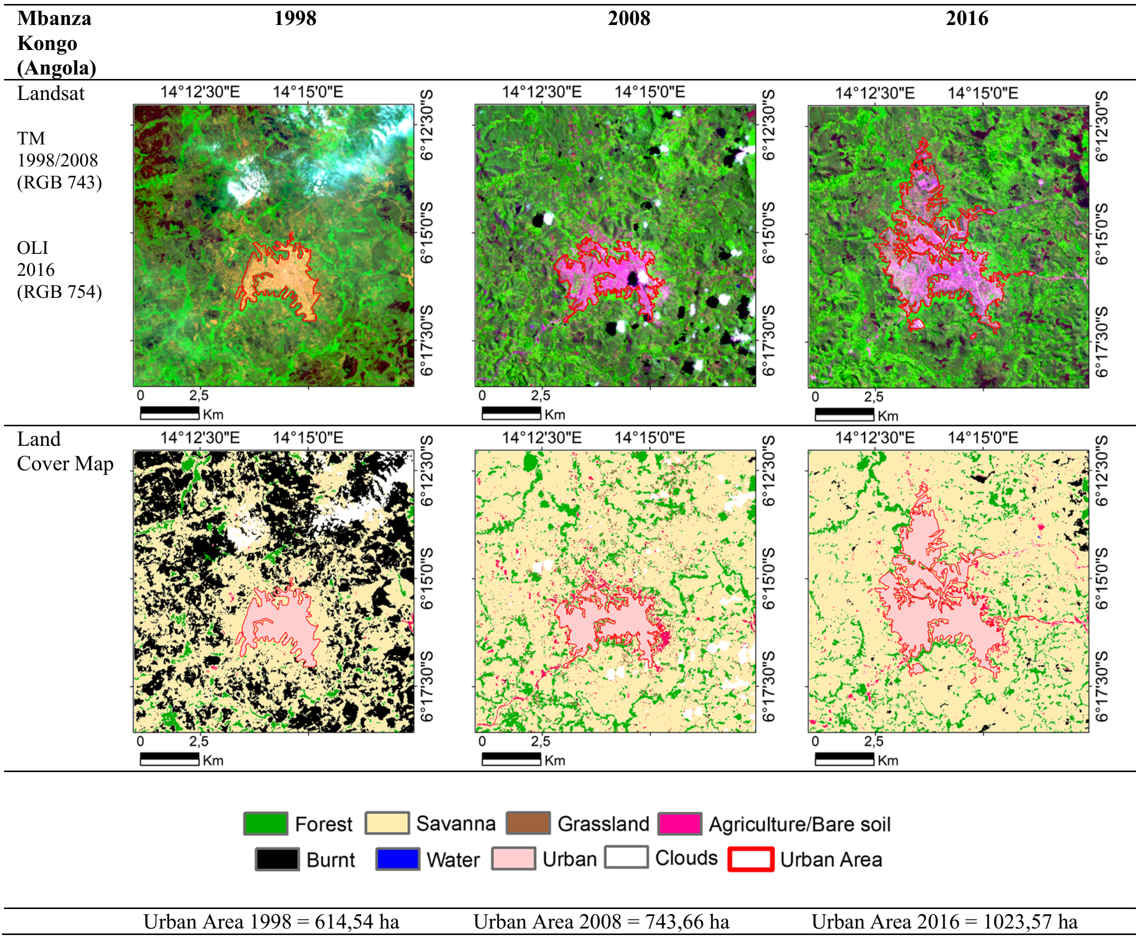

Fig. 3 Landsat TM (RGB 743) and OLI (RGB 754) color composites corresponding to the study area, represented in Fig. 1, together with the respective land cover maps and the urban area quantification

their main/sole source of energy for cooking (28.4%), followed by male-headed households and farm (25.2%); only 14.4% of the households in which the man had a job outside agriculture used fuelwood as the sole source of energy. Fuelwood was the only source of energy used for the extended boiling of

Fig. 4 Medium size mud brick oven and some fuelwood

Table 1 Demographic characteristics per household type

Household type	Number of family members (average)	Number of dependents (average)	Dependency Ratio (average)
Male-headed family and farm (38.3%)	6.18	2.82	0.456
Female-headed family and farm (30,0%)	5.37	2.94	0.547
Male household head, female farm head (31.7%)	6.69	3.48	0.520
Total (100%)	6.08	3.05	0.502

Table 2 Sources of energy for cooking by household type

Household type	Man is head of family and farm ($n = 115$)	Woman is head of family and farm ($n = 95$)	Man is head of family and woman is head of farm ($n = 90$)	Total ($n = 300$)
Main source of energy for cooking				
Gas	6.1% (7)	6.3% (6)	10% (9)	7.3% (22)
Kerosene	57.4% (66)	51.6% (49)	63.3% (57)	57.3% (172)
Charcoal	11.3% (13)	13.7% (13)	12.2% (11)	12.3% (37)
Wood	25.2% (29)	28.4% (27)	14.4% (13)	23% (69)
Main and secondary sources of energy for cooking				
Gas and kerosene	2.6% (3)	1.1% (1)	2.2% (2)	2% (6)
Gas and charcoal	0.9% (1)	1.1% (1)	2.2% (2)	1.3% (4)
Gas and wood	0% (0)	1.1% (1)	2.2% (2)	1% (3)
Gas only	2.6% (3)	2.1% (2)	3.3% (3)	2.7% (8)
Kerosene and charcoal	7% (8)	7.4% (7)	6.7% (6)	7% (21)
Kerosene and wood	12.2% (14)	10.5% (10)	12.2% (11)	11.7% (35)
Kerosene only	37.4% (43)	34.7% (33)	45.6% (41)	39% (117)
Charcoal and wood	7.8% (9)	2.1% (2)	4.4% (4)	5% (15)
Charcoal only	3.5% (4)	11.6% (11)	7.8% (7)	7.3% (22)

cassava flour snacks, a major source of income for households in which men were head of family and farm and helped carry either the wood or the snacks prepared in the distant farms to the city. The households in which the head was not a farmer — thus providing a regular influx of cash — used less biomass energy for cooking (16% of wood and 9.9% of charcoal) and more gas (Table 3). Charcoal was not used as the main source of energy for cooking by many households (12.3%), and by even fewer as the sole source energy (7.3%). Unexpectedly, 50% of female-headed households (11 out of 22) used only charcoal. Interviewees stated that charcoal was mostly used either for certain dishes (e.g., grilled fish) and/or in the preparation of snacks (fried flour cakes with sugar) for sale on the street. Lastly, gas stoves were used by a minority of households as their main (7.3%) or sole (2.7%) source of energy for cooking. No major differences among household types were observed. Farm residues or dung/manure were not mentioned by any informant as sources of energy and no improved cook stoves were used.

Older household heads did not indicate a preference for any specific source of energy, while the younger ones used mostly kerosene (Table 4). It is interesting to note that informants aged 50–65 years old reported higher use of wood. The analysis of the relationship between the date of return from DRC and the main source of energy used for cooking (Table 5) shows that

Table 3 Main sources of energy for cooking by main activity of the household head

Main activity of family head	Agricultural ($n = 219$)	non-Agricultural ($n = 81$)
Main source of energy for cooking		
Gas	6.4% (14)	9.9% (8)
Kerosene	54.8% (120)	64.2% (52)
Charcoal	13.2% (29)	9.9% (8)
Wood	25.6% (56)	16% (13)
Main and secondary sources of energy for cooking		
Gas and kerosene	1.4% (3)	3.7% (3)
Gas and charcoal	0.9% (2)	2.5% (2)
Gas and wood	0.9% (2)	1.2% (1)
Gas only	3.2% (7)	2.5% (2)
Kerosene and charcoal	7.3% (16)	7.4% (6)
Kerosene and wood	12.3% (27)	9.9% (8)
Kerosene only	35.2% (77)	46.9% (38)
Charcoal and wood	5.9% (13)	2.5% (2)
Charcoal only	7.3% (16)	7.4% (6)
Wood only	25.6% (56)	16% (13)

Table 4 Main source of energy for cooking according to age grade of the family head

Age grade of farm head	≤35 years ($n = 46$)	36–50 ($n = 103$)	50–65 ($n = 133$)	>65 ($n = 18$)
Gas	2.2% (1)	7.8% (8)	6.8% (9)	22.2% (4)
Kerosene	69.6% (32)	60.2% (62)	54.9% (73)	27.8% (5)
Charcoal	13% (6)	11.7% (12)	10.5% (14)	27.8% (5)
Wood	15.2% (7)	20.4% (21)	27.8% (37)	22.2% (4)

Table 6 Sources of energy for cooking by housing tenure status

Housing tenure	Own ($n = 193$)	rent/borrowed ($n = 107$)
Kerosene	63.2% (122)	45.8% (49)
Gás	8.8% (17)	4.7% (5)
Charcoal	11.9% (23)	13.1% (14)
Wood	15.5% (30)	364% (39)

even recent arrivals still struggling to establish a living used mostly kerosene; however, they did not use the two more expensive energy sources (gas and charcoal) and almost half used only fuelwood. Similarly, poorer households who were still renting or borrowing a house used much more fuelwood (Tables 6).

Fifty of the 300 interviewed households were engaged in fuelwood harvesting and trade (Table 7), the majority headed by men (21) and women (21) whose main livelihood was agriculture. However, the majority of interviewees associated this activity with the civil war. Many argued, "We do not have that kind of poverty anymore," while others mentioned that they were not requesting their young siblings to help them in agricultural work (or even to bring agricultural products and fuelwood home) because children had suffered a lot during the war helping them to collect fuelwood to sell. Nonetheless, fuelwood trade was seen mostly as an occasional source of money when the household members were able to bring home more wood than they needed.

Analysis of the main sources of energy for lighting shows that the majority of households use kerosene lamps (Table 8). However, most households in which men were heads of family and women were heads of farm use grid electricity. Dry cell battery lamps (flashlights) are seldom used, and use of candles was not mentioned. Households in which the head is employed outside agriculture showed a relatively higher use of grid electricity (Table 9).

The evolving economic conditions through the domestic cycle were clearly reflected by the fact that households headed by men or women aged between 35 and 65 years used the most electricity (Table 10). Similarly, those that returned earlier from DRC and those who own their house also showed higher electricity use (Tables 11 and 12).

Table 5 Main source of energy for cooking according to date of return from DRC

Return from DRC	1975–2001 ($n = 191$)	2002–2008 ($n = 75$)	2009–2016 ($n = 34$)
Main source of energy for cooking			
Kerosene	53.9% (103)	54.7% (41)	52.9% (18)
Gas	10.5% (20)	2.7% (2)	0% (0)
Charcoal	12.0% (23)	18.7% (14)	0% (0)
Wood	18.3% (35)	24% (18)	47.1% (16)
Main and secondary sources of energy for cooking			
Gas and kerosene	3.1% (6)	0% (0)	0% (0)
Gas and charcoal	1.6% (3)	1.3% (1)	0% (0)
Gas and wood	1.6% (3)	0% (0)	0% (0)
Gas only	4.2% (8)	1.3% (1)	0% (0)
Kerosene and charcoal	8.4% (16)	6.7% (5)	2.9% (1)
Kerosene and wood	12.0% (23)	10.7% (8)	11.8% (4)
Kerosene only	38.7% (74)	37.3% (28)	38.2% (13)
Charcoal and wood	4.7% (9)	8% (6)	0% (0)
Charcoal only	7.3% (14)	10.7% (8)	0% (0)
Wood only	18.3% (35)	24% (18)	47.1% (16)

Table 7 Households engaged in fuelwood harvesting and selling

Household type	Man is head of family and farm	Woman is head of family and farm	Man is head of family and woman is head of farm	Total
Sell fuelwood ($n = 50$)	18,3% (21)	22,1% (21)	8,9% (8)	16,7% (50)
Do not sell fuelwood ($n = 250$)	81,7% (94)	77,9% (74)	91,1% (82)	83,3% (250)

Table 8 Main source of energy for lighting by household type

Household type	Man is head of family and farm	Woman is head of family and farm	Man is head of family and woman is head of farm	Total
Electricity	40% (46)	41.1% (39)	51.1% (46)	43.7% (131)
Kerosene	55.7% (64)	57.9% (55)	44.4% (40)	53.3% (159)
Flashlight	4.3% (5)	0% (0)	4.4% (4)	3.0% (9)

Table 9 Source of energy for lighting by main activity of household head

Main activity of family head	Agricultural	Non-Agricultural
Electricity	39,7% (87)	54,3% (44)
Kerosene	56,6% (124)	43,2% (35)
Flashlight	3,7% (8)	2,5% (2)

Table 10 Main source of energy for lighting by age grade of the head of the household

Age grade of farm head	≤35 years	36–50	50–65	>65
Electricity	47,8% (22)	38,8% (40)	45,1% (60)	50% (9)
Kerosene	45,7% (21)	58,3% (60)	52,6% (70)	44,4% (8)
Flashlight	6,5% (3)	1,9% (2)	3% (4)	5,6% (1)

Table 11 Source of energy for lighting by date of return from DRC

Return from DRC	1975–2001	2002–2008	2009–2016
Electricity	52.2% (106)	33.3% (21)	11.8% (4)
Kerosene	45.8% (93)	61.9% (39)	79.4% (27)
Flashlight	2.0% (4)	4.8% (3)	8.8% (3)

Table 12 Source of energy for lighting by housing tenure status

Housing tenure	Own ($n = 193$)	Rent/Borrow (n = 107)
Electricity	51.3% (99)	29.9% (32)
Kerosene	45.6% (88)	66.4% (71)
Flashlight	3.1% (6)	3.7% (4)

Discussion and Policy Recommendations

Liverman *et al.* (1998) have noted that remote sensing technology and data (pixels) allow us to improve our understanding of social processes and human-environment interactions. Our research revealed that the expansion of the urban area of Mbanza Kongo did not involve deforestation, as settlement was in what was previously savanna. Additionally, unlike most African cities (Ribot 1999; IEA 2006: 141; Cornelio 2009; Cabral *et al.* 2010; Ndayambaje and Mohren 2011; Bildirici and Özaksoy 2016) neither charcoal nor fuelwood are main sources of energy for cooking. The main cause of forest degradation was, thus, neither population increase nor poverty per se, but a change in house-building techniques. Our research, then, contributes to the growing body of literature identifying unexpected causes of deforestation and their drivers' interactions in each specific case (e.g., Ribot 1999; Lambin *et al.* 2001). Also similar to other studies (e.g, Masera and Saatkamp 2000), our research shows that we must go beyond linear fuel-switching models and situate household preferences within each particular historical, ecological, socioeconomic, and cultural context.

Poor households' fuel preferences were multiple and fuel-mix choices revealed the relative importance of many factors, such as fuel, cash, and labor availability, engagement in food processing for sale, age and gender composition of the agricultural labor force, saving strategies, income diversification activities, and cultural perceptions. The main source of energy for cooking mentioned by interviewees was kerosene and, differing from what would have been expected, wood and especially charcoal were used by a much lower number of urbanites practicing agriculture. A number of factors contribute to this: firstly, the price of kerosene in such an oil-rich country is low and the sale of surplus agricultural products makes it affordable even for the poor; secondly, as previously noted, most people connect fuelwood harvesting and use with extreme poverty during the wars; thirdly, with the expansion of the city, agricultural fields became more distant from their dwellings, and many had to spend more than two hours a day walking to them making it hard to transport either wood or charcoal produced after slashing and burning a field. The use of fuelwood instead of buying kerosene could be a strategy to save money, but is not often so used. The use of charcoal, as noted, is more connected with the preparation of specific dishes and with the frying of snacks for street selling.

In general interviewees have little access to grid-electricity, which is restricted to those both located in more central city districts and with regular cash income sources. The large majority use kerosene lamps as the main source of lighting, and the use of solar lamps (or even knowledge about their existence) was not reported by any interviewee.

In an oil-rich region, petroleum availability, price, ease of use, and perceived connection with higher socioeconomic status, may make it a more attractive fuel than biomass for the poor. However, poor urbanites are a heterogeneous category in relation to their energy consumption choices. Among those generally categorized as poor, we find clear differences in livelihood conditions and a diversity of preferences, needs, and constraints defining specific fuel-mix choices. Although we did not conduct research among the wealthier urbanites of Mbanza Kongo, the qualitative data collected in restaurants, bakeries, and markets leads us to conclude that this group largely contributed (though mainly indirectly) to biomass fuel use. Their houses, however, were built with cement bricks and beams, not contributing to deforestation or forest degradation.

At a more general level, our results also indicate that oil-wealth can be a factor hampering households' sustainable energy transition, namely in relation to the use of solar energy for lighting. As Agoramoorthy and Hsu (2009) highlighted in another context, the use of petroleum-based products contributes to air pollution, global climate change, and the exhaustion of non-renewable resources, making urgent the adoption of clean energy sources. Angola's current president and government seem ready to start taking drastic measures to reverse the abuses of the previous oligarchy that enriched itself while leaving most of the population in poverty (Soares de Oliveira 2014). This, together with the fact that Mbanza Kongo is now a UNESCO World Heritage Site, opens new possibilities for the creation of a fairer and sustainable society. This might include the creation of incentives for the introduction of renewable energy technologies (e.g., improved cook stoves and solar photovoltaic lanterns that are now popular in many African countries), the cultivation of fast-growing multi-purpose trees (to reduce deforestation, carbon emissions, soil erosion, and landslides, and to increase soil fertility and carbon stocks), and the development of environmentally-friendly house-building techniques, all contributing to climate change mitigation.

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Compliance with Ethical Standards

Conflict of Interest The authors declare that they have no conflict of interest.

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