Journal of Agriculture and Rural Development in the Tropics and Subtropics
Vol. 123 No. 1 (2022) 75–85

https://doi.org/10.17170/kobra-202203085848 ISSN: 2363-6033 (online); 1612-9830 (print) – website: www.jarts.info

The 'fine balance' of West African savannah parklands: biomass generation versus firewood consumption

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Abstract

In sub-Saharan Africa, the long-awaited fuelwood gap, resulting of the unbalance between a declining supply of firewood and the increasing demand of households, remains a latent social-ecological challenge. As its quantitative basis remains elusive, we have assessed agroforestry parklands, assumedly main providers of firewood, and firewood consumption in Dassari, Benin and Dano, Burkina Faso, both in the West African savannah. Data collected included botanical inventories, tree biomass estimations, householders' firewood collection habits and consumption. Our findings show a drifting in preference for firewood-provider species, either by resource exhaustion or as preventive strategy. Tree biomass stock is a misleading proxy of firewood availability, by the increased use of other species, and the bias in calculations caused by non-used larger species. Firewood gathering has expanded towards communal lands and even natural reserves and its trade is emerging, what aside the ecological harm, started to weaken regulatory institutions and the internal social networks. Although the estimated firewood per capita consumption rounds 1 kg day^{-1} (inferior to precedent estimations), the signs of forest degradation persist. Commercial uses, like local breweries, pose the main challenge, as their demands are disproportional, up to one third of the whole; their demand of larger pieces that leads to more detrimental chopping, and contributes to emerging firewood markets fed by pieces of doubtful origin.

Keywords: agroforestry, dry savannah, fuelwood, balance, offer, demand

1 Introduction

Parklands are the characteristic vegetation type and production system in the West African Sudan Savannah: scattered, even-sized, multipurpose trees that cover farm- or fallow-lands and interact with crop species and/or livestock. The tree species either grow naturally or are planted for the economic and/or ecological benefits they provide (Nair, 1993; Boffa, 1999, 2000; Maranz & Wiesman, 2003; Nikiema, 2005). Their diversity, density, regrowth or regeneration are determined by the long-term selection and management practiced by locals, reflecting their interests, cultural significance, and benefits the trees are expected to provide (Boffa, 1999, 2000; Boffa *et al*, 2000; Lovett & Haq, 2000; Maranz & Wiesman, 2003). Hence, trees in parklands are significant contributors of wood for furniture, construction and fuel, but also of non-timber forest products (NTFPs) such as food, medicine, fodder, and oils (Boffa *et al*., 2000; Slingerland, 2000; Mertz *et al*., 2001; Nikiema, 2005). Furthermore, trees in parklands provide ecosystem services, help to temper micro-climate, improve soil fertility and make groundwater available, as well as increase the yields of some understory crops which improves farmers' financial income (Boffa, 1999; Sanou *et al*., 2012; Coulibaly *et al*., 2014). However the growing pressure by an increasing demand for their products and byproducts, e.g., fuelwood, is causing the degradation of parklands and even overall deforestation (Ouédraogo *et al*., 2015).

In West Africa the main drivers of deforestation are the agricultural expansion and the demand for fuelwood and fodder (Slingerland, 2000; Houessou *et al*., 2013). Among

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Published online: 15 March 2022 – Received: 12 March 2021 – Accepted: 31 January 2022

these, fuelwood exploitation appears to be the most worrying, since fuelwood is often the source of cooking energy for households and even commercial uses, such as bakeries, restaurants and local beer breweries, especially in the Sudan Savannah region (Orekan, 2008; Akouehou *et al*., 2011). For instance 200 000 households in Cotonou and Porto-Novo consume up to 11.2 million of cubic meters of fuelwood per year, and in Cotonou alone the annual consumption surpasses 1 ton per capita (Akouehou *et al*., 2011). At a 4 % population growth this consumption rates are expected to surpass the country's production potential by 2027. In Ouagadougou, the annual firewood consumption is estimated at 304 000 ton per year (Arevalo, 2016). In the main cities of Niger, i.e., Niamey, Zinder, Maradi and Tillaberi, more than 90 % of households use firewood for cooking, and the per-capita consumption oscillates around 0.6 kg day^{-1}, and tend to increase in the rural areas (Lawali & Mahamane, 1999).

This fine balance between the generation and consumption of fuelwood, although already announced in the 80's as a forthcoming 'woodfuel gap' (Eckholm, 1975; Anderson & Fishwick, 1984), is still poorly addressed, in great extent because quantitative analyses are sparse and its social and environmental impacts limitedly explored. In this framework, this study aims a) to quantify the fuelwood production in agroforestry parklands, and b) to estimate the local firewood consumption in two rural catchments of the West African Sudan Savannah; we expect that by contrasting these two data streams to be able to offer reality-grounded insights on the subject.

2 Materials and methods

2.1 Research sites

This study was carried out in two sites in West Africa, i.e., Dano in Burkina Faso and Dassari in Benin. Both sites conform the common sampling frame (recurrent areas of data collection), of the West African Science Service Center on Climate Change and Adapted Land Use (WASCAL; https://wascal.org/). Although the unit is essentially geographic (hydrological catchment), the overlap with administrative boundaries was considered for the gathering of socioeconomic data.

Benin's human development index is 0.485 and Burkina Faso's 0.402, what make them ranking 167 and 185 respectively, out of 188 countries (UNDP, 2016). In both countries, infrastructure and services provision are poor, getting worse in the country side. Population growth rates are around 3 % and children mortality is in the order of 5.5 %. By 2015, rural population was about 65 % in Benin and 70 % in Burkina Faso (CIA, 2018).

Dassari and Dano are located in the Sudan Savannah region, where agroforestry parklands are the dominant land use. Streams and ponds are scarce and often ephemeral during the rainy season from May to September (Savadogo, 2007). Livelihoods depend mostly on subsistence rain-fed agriculture with low use of external inputs and low levels of mechanisation. Farming provides food and income, through small-scale sale of cash crops. The principal cash crops are rice and cotton, the latter an international commodity, whose trade is monopolized by government programs. Staple foods are millet, sorghum, maize and yam, beans like groundnut and cowpea, and various vegetables and spices. Other economic activities are livestock rearing, forestry and fishing (Callo-Concha *et al*., 2013; Callo-Concha, 2018).

Dano department, is the capital city of the Ioba province located in southwestern Burkina Faso. The department covers 669 km^2 and counts 22 rural villages and one urban, administrative and economic centre: Dano city, which has a population of around 47 000 inhabitants (INSD, 2006). The rainfall regime is bimodal, mean annual rainfall is 926 mm of which only 20 mm falls in the dry season. The mean annual temperature is 29.5°C with lowest and highest average temperatures ranging from 20.1 to 38.4°C (World Bank, 2016).

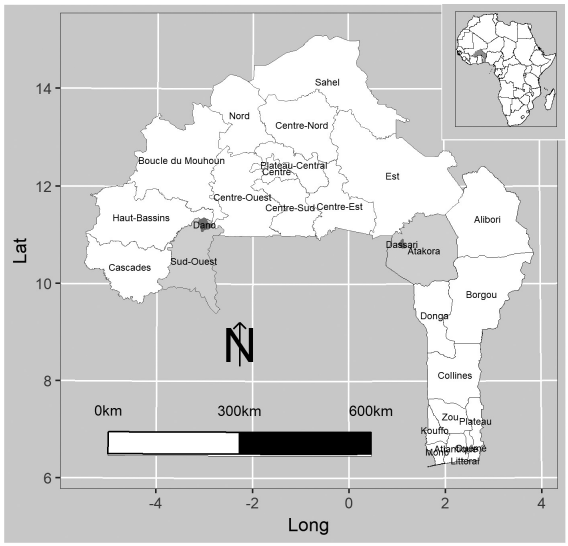

Fig. 1: *Location of the study sites in Burkina-Faso and Benin.*

Dassari arrondissement belongs to the municipality of Materi in the Atacora department, northwestern Benin. It comprises 17 scattered villages developed around housing centers, markets and roads. In 2006 the population of Dassari was 28 000 (INSAE, 2013). Rainfall surpasses 1 000 mm distributed in a bimodal regime, the annual mean temperature is 28.7 °C, with an average minimum of 22 °C and the maxima can surpass 40 °C (World Bank, 2016) (Fig. 1).

2.2 Methodology

Field data were collected between 2014 and 2015. Collected data built up upon existing household databases from Dassari and Dano (Callo-Concha, 2018). Mixed methods were applied for the two data streams: parklands inventory and biomass stocks estimation; and household firewood gathering and consumption.

(i) Botanical inventory of parklands and tree biomass measurements: Each parkland plot corresponded to a surveyed household (n=108 for Dano, and n= 98 for Dassari). Parkland plots were delimited and geo-localised and tree species over 5 cm diameter at breast height (DBH) identified. For Dassari only, in a sampling plot of known area, the biomass of existing trees was calculated applying Chave *et al*. (2014):

$$\mathrm{AGB_{est}} = 0.0673 \times (\rho D^2 H)^{0.976} \quad (1)$$

Where, AGB_{est} = Estimated aboveground biomass; ρ = Tree species wood density; D = Tree diameter at breast height; and H = Tree height.

The summed biomass of trees per plot was converted into values per ha, and then upscaled to the catchment level. For that a random forest classification algorithm was applied to TerraSAR-X® and RapidEye® satellite images, to differentiate forested land-uses for the years 2013 and 2014 (Forkuor *et al*., 2014). The map from Forkuor was used but the agricultural classes were lumped into parklands.

(ii) Household firewood gathering and consumption: Species relevance and estimated consumption were assessed via household survey (n = 118 for Dano, and n = 137 for Dassari) and semi-structured interviews with key informants. These were done with the support of female assistants (as firewood gathering is considered a female task). Firewood was the only source of energy considered, as exploratory results suggested the use of other sources to be minimal in both sites.

(iii) Firewood consumption was measured in the same households/compounds, by weighting a pre-defined firewood pile before and after daily cooking, the process was repeated for several days and the values were averaged. The measurements were fit to the nearest 0.1 kg and divided by the number of household members to obtain the consumption per capita. Only for Dano, and by their regional importance, a similar procedure was applied to calculate the firewood consumption of cabarets (breweries and dispensers of dolo, a traditionally consumed sorghum-based beer). Inhabitants were asked for the number and location of cabarets in their village, since these are centres of social life. From that, a quota sampling was taken (n = 6). The average firewood consumption values were extrapolated to the catchment level according to the number of cabarets in it. Firewood measurements were made during the rainy season in both sites, which were later compared. Exceptionally, in Dassari, firewood measurements were also carried out in the dry season, to analyse the seasonal variation. Firewood consumption values were upscaled to the Dassari arrondissement and the Dano town levels and later to the catchment level, based on national population census data (INSAE, 2013, INSD, 2006).

Analyses included discourse and text analyses to process interview responses of key informants and secondary literature. Statistical methods to analyse the survey data, which included descriptive statistics to assess the frequency of existing woody species, the preferred species for firewood, the size of agroforestry parklands, and the firewood provenance and consumption; an independent t-test for the seasonal differences in firewood consumption; and the probability distribution of per capita firewood consumption. Statistical analyses were done using SPSS 23 (IBM, 2015) and R (R Core Team, 2018).

3 Results

3.1 Agroforestry parklands, dominant species and biomass stocks

In Dano and Dassari almost all farming plots are agroforestry parklands, where crops grow in between and under the trees. Trees tend to be economically and culturally valuable; thus, the ones found in parklands around Dano are preferably used for wood, food and fodder, i.e., *Azadirachta indica*, *Vitellaria paradoxa* and *Faidherbia albida*, that made 24 %, 22 % and 17 % of the sample respectively, in lower degree, *Lannea microcarpa* and *Tectona grandis* with 6 % each, and less frequently *Mangifera indica*, *Moringa oleifera*, *Parkia biglobosa* and *Acacia senegal*. In Dassari, *Vitellaria paradoxa*, *Hyphaene thebaica* and *Azadirachta indica* reached 11 %, 8.2 % and 7.1 % correspondingly, and less frequently, *Combretum* spp., *Borassus akeassii* and *Eucalyptus* spp. In Dassari, the number of species is considerably higher (35 vs. 22), and their distribution is more skewed. The dominant species differ greatly between sites; among the ones regularly cited as omnipresent in parklands, e.g., *Azadirachta indica*, *Vitellaria paradoxa*, *Parkia biglobosa*, *Faidherbia albida* and *Acacia senegal* (Gijsbers *et al*., 1994; Nikiema, 2005), only the former is prevailing in both sites, while the others are present in lower numbers. Interestingly, palm species such as *Hyphaene thebaica* and *Borassus akeassii* were frequently found (Fig. 2). Concerning the species preferences for firewood, in Dassari, *Anogeissus leiocarpa* (10 %), *Pericopsis laxiflora*, *Azadirachta*

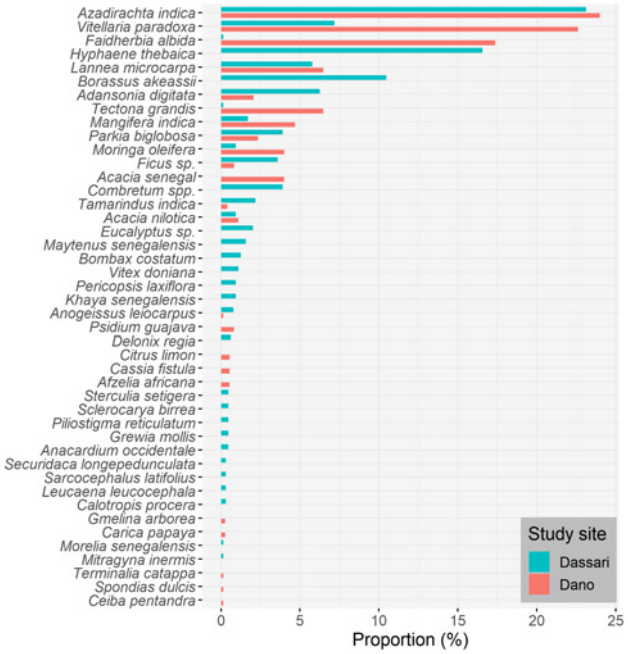

Fig. 2: *Relative frequencies of dominant woody species in parklands of Dano and Dassari.*

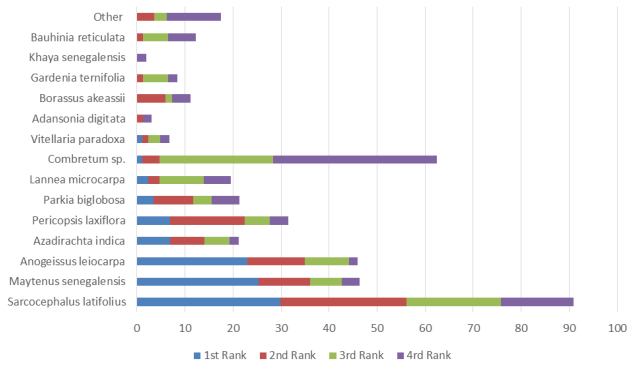

Fig. 3: *Ranking of species by the quality of the firewood in Dassari.*

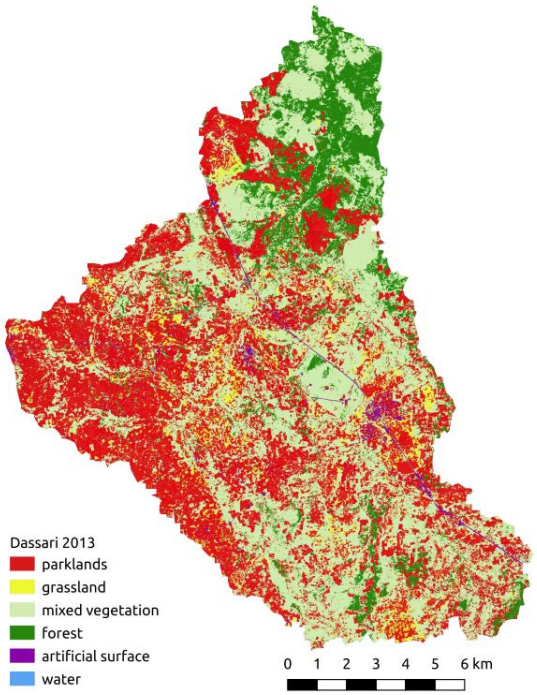

Fig. 4: *Parklands coverage in Dassari catchment (authors elaboration).*

indica, and *Parkia biglobosa* (each about 7 %), were the species most used for firewood. However, when asked about the quality of the firewood, *Sarcocephalus latifolius* (30 %), *Maytenus senegalensis* (25 %), and *Anogeissus leiocarpa* (23 %) headed the list. When the preference list was enlarged to include a second, third, etc. species, *Pericopsis laxiflora* and *Lannea microcarpa* came into play, but mainly *Combretum* spp., a tree genus abundant in the region and of high regeneration potential (Nikiema, 2005, Kokou *et al.*, 2009; Aleza *et al.*, 2015). Notable is that, *Maytenus senegalensis*, *Pericopsis laxiflora* and *Sarcocephalus latifolius* also grow as shrubs, either scattered in parklands or in bush relicts, where they are subject of branching and pruning, common firewood gathering practices. Actually, 42 % of the species used for firewood were shrubs while 45 % trees, what may suggest the use of other firewood sources (Fig. 3). In Dassari, we estimated the parklands coverage at about 8000 ha, equivalent to 40 % of the overall area of the catchment (c.a. 195 km²). However, parkland density is uneven, higher along the more populated western side and lower in the north-eastern flank, where the Pendjari National Park is located and a protection regime is implemented. It is known that farmers control the densities of trees and understory crops to prevent competition, but also to regulate the exploitation of byproducts (Coulibaly *et al.*, 2014), as seems to be the case of firewood, where the more scattered the trees are their usage for firewood is lower (Fig. 4). Furthermore, we estimated the tree biomass in random parkland plots (n=86). The mean size of a plot was 1.2 ha and the average aboveground tree biomass stocks 129 t ha^{-1} with quite a high standard deviation of 108.8 t ha^{-1}, implying a great amplitude between the minimum and maximum values (Fig. 5).

3.2 *Householder firewood use and gathering habits*

Firewood is the major source of fuel in Dano and Dassari. Crop residues, like cereal straws, are prioritized for animal feed, and animal dung and charcoal, barely used, likely by cultural or economic constraints.

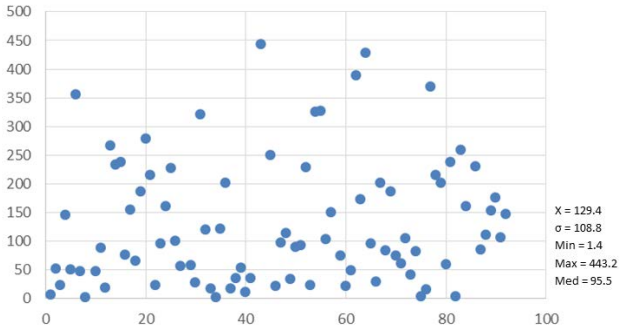

Fig. 5: *Tree biomass stocks ($t\,ha^{-1}$) per plot in Dassari parklands ($n = 86$).*

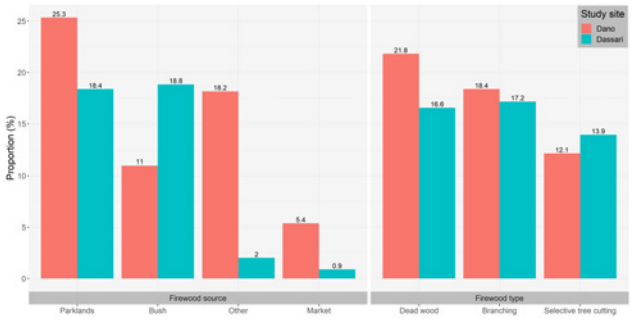

Fig. 6: *Use of firewood in Dassari, Benin and Dano, Burkina Faso a) Main sources of firewood; b) Firewood gathering techniques.*

Firewood gathering is carried out regularly by all households. It relays mainly on women and children. Male gatherers were estimated only at 10 %. In Dassari, 50 % of children do it habitually, which may imply an early gender-based labour division. The amount of gathered firewood in a household is considered as a proxy of the industriousness of the housewife, hence, firewood is organised in piles and placed in visible spots, becoming a reason of pride and superiority on the ones who owe smaller piles. The distance to collect firewood is in average 11 km and each collector carried between 10 and 30 kg each time.

Concerning the sources, firewood is mainly collected from parklands, bushlands (small forest patches), and to a lower degree also bought (Fig. 6a). The preferred firewood sources depended on the purpose of the collected firewood and the property rights on the sites. In Dano, for instance, there are four types of fields: (i) the field of the husband, (ii) the family fallow, (iii) the community fallow and (iv) 'other' lands, e.g., lands of neighbouring communities, or reserves. For domestic uses, the collection follows that prioritization. For commercial purposes, like dolo brewing, firewood collection targets family and community lands less, and increases in 'other' lands. The purchase of firewood for commercial purposes is also increased since thicker branches and stems are required.

The collection of firewood occurred via dead wood gathering, cutting of branches, and (partial or complete) tree chopping. In Dano, sometimes dolo brewers buy a complete tree to satisfy the high demand of energy that the activity requires (Land chief of Bankandi, interview 5.9.2015). In Dassari, the use of the three techniques is rather balanced (Fig. 6b). We found an association between the collection types and the origin and nearness of the firewood, i.e., trees near the homesteads are rarely touched, branching is preferred on family lands, and larger pieces are mostly collected from far away. Evidently, these practices were conceived to minimize the harm on the stocks and sustain a long-termed consumption. However, the increased pressure for firewood shows its effects, as branching is getting more invasive and more entire trees are cut (Fig. 7).

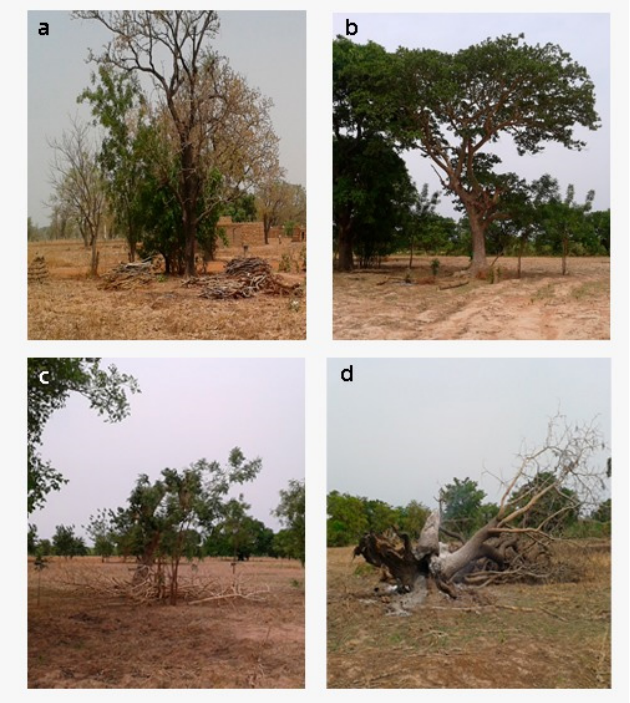

Fig. 7: *Firewood extraction in savannah parklands. a) Gathering and collection of small pieces; b) cut of larger branches; c) severe cut of major branches; and d) felling a whole tree (Photos by D. Callo-Concha).*

3.3 Firewood consumption

3.3.1 Households cooking and others

Traditionally, rural houses are clustered in compounds that aggregate several homesteads sharing a central yard, where cooking is often performed and firewood stored. Mostly, cooking consists in the steaming of *Tô* (a polenta-like dough made from millet, sorghum or corn, which is the main staple

food), whose preparation takes between one and two hours, and is therefore made daily or every second day. The accompanying sauce is made fresh for each meal. The frequency of cooking was uneven, in Dano 79 % of households prepared two meals a day, while 18 % did it once, and only 3 % thrice. Frequency was related to the size of the family and to the availability of firewood. More than 90 % of householders reduce the number of meals or their type (foods that require less cooking time) in response to firewood scarcity. In less extent, firewood consumption is also required for heating water for personal hygiene or to process commercial products at small scale, such as *shea* butter (*Vitellaria paradoxa*), *soumbala* spices (*Parkia biglobosa*) or cooked leaves. The 'three stones' cook stove is broadly used (Amous, 2000), but sometimes energy-efficient stoves are found, especially in cabarets (Fig. 8). The average amount of fire-

Fig. 8: *Firewood usage. a) Multipurpose yard; b) Three stone cooking stove; c) Firewood pile in a backyard; d) set of stoves for Dolo brewing (Photos: a,c,d by D. Callo-Concha; b by L. Krings).*

wood consumed per household differs by site: households in Dano use one third less firewood than in Dassari (8 vs. 12 kg day^{-1}), and proportionally its variance is higher too. In both sites, upper quartiles are slightly larger and show few outliers, affirming the existence of households of about three times above-average consumption (Fig. 9). Roughly, the daily per capita consumption of firewood is alike in both sites: 1.11 kg day^{-1} in Dano and 1.03 kg day^{-1} in Dassari. But the trends differ, adjusting the per capita consumption to a normal probability distribution (quantile-quantile plot), a better fitting with the Dano households data appears, and a more asymmetric one (thicker tails) in Dassari. The overlapping of lefts tails (lower consumption) is higher, and as consumption increases they diverge, as well as the outliers' expansion. This indicates that higher firewood consumption is not necessarily related to household energy demand, but more likely to household specific features, e.g., family size or other energy uses (Fig. 10). When these values are up-

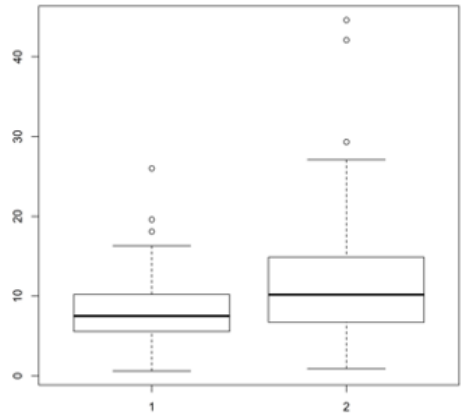

Fig. 9: *Daily household firewood consumption (in kg) during the rainy season in Dano (1) and Dassari (2).*

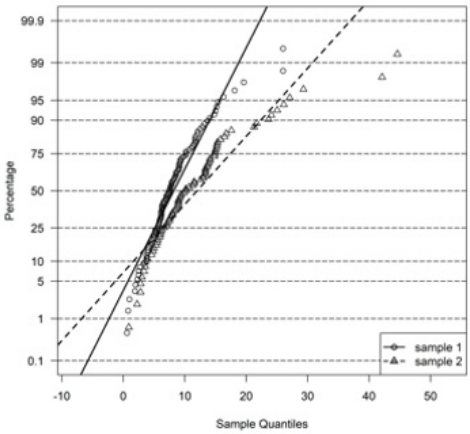

Fig. 10: *Probability distribution of the per-capita firewood consumption in Dano (circles) and Dassari (triangles) during the rainy season*

scaled to the sampling sites, Dano reaches an overall firewood consumption of 20.5 ton day^{-1}, summing up to 7 441 ton year^{-1}; and Dassari 28.8 ton day^{-1} and 10 526 ton year^{-1}. These values correspond to the rainy season, when the consumption of firewood increases due to higher water content and the proportional lower calorific power of firewood. In Dassari, by comparing the consumptions between rainy and dry seasons, the extent of this variation was estimated in about one fifth, falling from 1.03 to 0.81 kg day^{-1} per capita ($p < 0.05$).

Householders, however, were not aware of the amount of their own firewood consumption. Asked about it in Dassari, they overestimated it in the dry season by about 150 % (2.02 instead of 0.81 kg day^{-1}), and in the rainy season by 50 % (1.56 instead of 1.03 kg day^{-1}) (p=0.01). Similarly, their awareness on the impact of consumption on future firewood

availability was variable: while 64.8 % of householders in Dano and 93.2 % in Dassari acknowledged the risk of future resource scarcity, 35.2 % of farmers in Dano and 6.8 % in Dassari perceived their consumption levels as harmless.

3.3.2 The Dolo *cabarets*

Dolo is a traditional fermented beer made of sorghum or millet widely consumed in Burkina Faso, and whose preparation is input and labour demanding, especially in firewood (Ouédraogo & Point, 2015), reason why we conducted an in-depth study in Dano.

In Dano, cabarets were found in all villages, 73 operated daily and 40 once a week. A quota sampling of six (6) cabarets, returned a firewood consumption varying between 145.5 and 246 kg day^{-1}, and an average of 170 ton day^{-1} and 4 884 ton year^{-1}. This corresponds to 65 % of the amount of firewood that households required for cooking, estimated in 7 441 ton year^{-1}. This large demand and the nature of the dolo brewing (long boiling time-spans) triggered the emergence of firewood markets, especially for larger pieces. The origin of the marketed fuelwood is blurry, it might come from private parklands, communal forest patches, or even reserves.

4 Discussion

4.1 Firewood species in parklands

Our findings reveal some digression from precedent reports: the number of parkland canopy species is high, although may vary considerably by location: 35 and 22 in Dassari and Dano, respectively. The assumedly predominant species, i.e., *Vitellaria paradoxa*, *Parkia biglobosa* and *Faidherbia albida*, e.g. Boffa (1999) and Nikiema (2005) are not that prominent, maybe due to overexploitation, or rapid vegetation succession following intensified exploitation. Another possibility would be that locals are exploring and using other species for different uses. In this line, when asked on the species used for firewood, local householders responded that the species currently used are the ones of less quality, which include non-woody species like shrubs and palms, e.g., *Maytenus senegalensis*, *Pericopsis laxiflora*, *Sarcocephalus latifolius*, *Hyphaene thebaica* and *Borassus akeassii*. This situation confirms the pressure on species traditionally used for firewood and the adaptation of other species used as firewood. Observations from other areas in Benin and Burkina Faso showed also that firewood gathering decreased the diversity of species in general and increased the use of other species previously ignored (Paré *et al*., 2010; Houehanou *et al*., 2013). Moreover, and coincidentally with our findings, *Pericopsis laxiflora* and *Borassus akeassii*, were identified among these species (Sieglstetter *et al*., 2011), as well as several species of the genus *Combretum* spp. (Jurisch *et al*., 2012).

Our assessment of tree biomass stocks in parklands is in line with this view of selected lodging. However, the estimated stocks appear considerably high: 129 ton ha^{-1} in average. This may be biased, due to the applied allometric equations, based on indirect proxies like the DBH that tend to overestimate biomass stocks, as well as the abundance of thick-stemmed individual trees, like Baobab (*Adansonia digitata*) and Neem (*Azadirachta indica*). Still, such biomass stock ranges and sources of variation have been broadly reported previously (Lewis *et al*., 2009; Ribeiro *et al*., 2013; Dayamba *et al*., 2016; Qasim *et al*., 2016) .

4.2 Firewood collection

Although there are other sources of energy, firewood gathering remains the most important. It involves great investments of labour, mainly by women, and as firewood scarcity increases, gatherers are forced to extend their daily radius of collection and amounts collected. Such phenomena are widely documented in other parts of Africa like Malawi, Tanzania, Uganda and Kenya, where the gender divide spills over girls as young as five years old, and the daily gathering time and carried volumes can reach up to 240 min and 30 kg, respectively (Tabuti *et al*., 2003; Biran *et al*., 2004; Njenga *et al*., 2017). This has also social implications, e.g., breaking social norms, by collecting firewood from communal lands or buying larger pieces of doubtful origin, mostly for profit activities. In this case, the ecological damages like hindered tree regeneration and resources exhaustion, prevail on social and institutional aspects. Communal lands, previously forest sanctuaries, are shrinking or disappearing, which impacts on traditional religious and ritual activities.

The institutions in charge of controlling these activities are weak, as their mandate and decisions are constantly challenged and disobeyed, which progressively evolves into inaction and deteriorates social cohesion. Female wood gatherers are e.g., forced to violate rules and act clandestinely. A similar situation has been observed in the Lake Malawi National Park, where institutions in charge of protecting forests, start to weaken and eventually become useless due to the growing pressure from firewood gatherers (Abbot & Mace, 1999) Male land owners however, are entitled to planting trees, but are not fully aware of the increasing resource scarcity, due to the gender specific labour division. Thus, they invest less effort on tree planting and indirectly allow the decay of stocks. Relatedly, the trade of firewood merits special attention as its sources are unknown. Currently, it is not possible to associate it to the decline of

local resources, but it is probable that it contributes to the damage of neighbouring forests and maybe to not far-away reserves like, Bontioli in Burkina Faso or Pendjari in Benin.

4.3 Firewood consumption

Food cooking and dolo brewing are the two major firewood-demanding activities in rural areas. However, a distinction has to be made. In Dano, dolo preparation appears to be quite important as it relates to about one third of the whole firewood consumption, while in Dassari its share is much less prominent. Here, the defining argument is religious. Although in both sites various beliefs are widespread, Islam predominates in Dassari and is expressed in a taboo on alcohol consumption. The situation where commercial activities demand higher volumes of firewood in comparison to households, is also occurring in other African countries. For instance, in the Bulamogi county, Uganda, the demand for firewood is dominated by small-scale industries: bricks firing (55 %) and spirits' distilling (26 %) (Tabuti *et al*., 2003).

Assuming that firewood per capita consumption is a sound proxy, we observed the notable seasonal variations in fuelwood consumption. Consumption in the dry season is about 20 % lower than in the rainy season, likely due to the higher calorific efficiency of drier biomass. The unawareness of the households' own firewood consumption, and the only moderate recognition on the resulting resource and forest degradation need to be addressed. All these points also call for direct accounting methods. This is evidenced by comparing our findings of around 1 kg firewood day^{-1} per person, with direct estimations of per capita consumptions of 1,4, in Malawi, 1,3 in Kenya and 1,5 kg day^{-1} in Uganda (Biran *et al*. 2004; Egeru *et al*., 2014), with interview-based estimations of 3 kg day^{-1} in Benin (Akouehou *et al*., 2011).

5 Conclusions

This research aimed to assess the 'firewood gap' for our study sites, but above-described challenges prevented us to fully achieve that goal. Still, we gained some new insights. As the firewood demand keeps growing, the increasing pressure on the environment is becoming more evident. The uses and composition of savannah parklands are changing, e.g., traditionally-used species are preserved, new ones emerge (e.g., palms), and a third group remains untouched, maybe either by taboos or uselessness. Any prospective policy on firewood should rely on precise measurements of stocks and consumption, and for the former dendrometry is an unrealistic approach. With regard to consumption, our findings underline that direct weighting should be applied, instead of estimations by users. Finally, firewood scarcity is provoking societal challenges in traditional regulatory institutions and therefore in peoples' social interactions. The irruption of market forces may increase even further the ecological harm, by commodifying firewood in setting of resource scarcity.

So far, afforestation, reforestation and restoration initiatives are mostly inexistent, and the time-lapse required to rebuild current stocks, fades. Technological aids, such as improved cookstoves are scantly promoted and got a mild acceptance: there is anecdotal evidence of their use in dolo breweries (also framed in a pro-profit rationale). However, in the mid- and long-term, demographic growth remains as the defining argument.

Acknowledgements

This research was carried out within the mandate and scope of activities of the West African Science Service Center on Climate Change and Adapted Land Use (WASCAL), financed by the German Federal Ministry of Research and Education. We are thankful to the anonymous reviewers who helped to improve greatly the manuscript.

Conflict of interest

The authors declare no affiliation or involvement in any organisation or entity with any type of financial or non-financial interest in the subject matter discussed in this manuscript.

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