(https://www.sciencedirect.com/science/journal/13899341)

ISSN: 1389-9341

Forest Policy and Economics

Editor-in-Chief: Lukas Giessen, PhD (https://www.journals.elsevier.com:443/forest-policy-and-economics/editorial-board/lukas-giessen-phd)

› View Editorial Board (https://www.journals.elsevier.com:443/forest-policy-and-economics/editorial-board)

› **CiteScore: 5.7** ⓘ **Impact Factor: 3.139** ⓘ

Submit Your Paper (https://www.editorialmanager.com/FORPOL/default.aspx)

Supports Open Access (https://www.elsevier.com/journals/forest-policy-and-economics/1389-9341/open-access-options)

View Articles (https://www.sciencedirect.com/science/journal/13899341)

Guide for Authors

Abstracting/ Indexing (http://www.elsevier.com/journals/forest-policy-and-economics/1389-9341/abstracting-indexing)

Journal Metrics

> CiteScore: **5.7** ⓘ

Impact Factor: **3.139** ⓘ

5-Year Impact Factor: **3.085** ⓘ

Source Normalized Impact per Paper (SNIP): **1.482** ⓘ

SCImago Journal Rank (SJR): **1.127** ⓘ

> View More on Journal Insights

(https://sdgresources.relx.com/)

Help expand a public dataset of research that support the SDGs. (https://www.elsevier.com/connect/help-expand-a-public-dataset-of-research-that-support-the-un-sdgs)

Your Research Data

> Share your research data (https://www.elsevier.com/authors/author-resources/research-data)

> Data in Brief co-submission (https://www.journals.elsevier.com/data-in-brief/about-data-in-brief/data-in-brief-co-submission)

> MethodsX co-submission (https://www.journals.elsevier.com/methodsx/about-methodsx/methodsx-co-submission)

Related Links

> Author Stats ⓘ

> Researcher Academy

> Author Resources (https://www.elsevier.com/authors/author-resources)

> Try out personalized alert features

Forest Policy and Economics 116 (2020) 102192

Contents lists available at ScienceDirect

Forest Policy and Economics

journal homepage: www.elsevier.com/locate/forpol

Fuelwood consumption and supply strategies in mangrove forests - Insights from RAMSAR sites in Benin

Jean Adanguidi[a], Elie Antoine Padonou[b,c], Afio Zannou[c], Sidol B.E. Houngbo[c], Idelphonse O. Saliou[c], Symphorien Agbahoungba[c,*]

[a] Food and Agriculture Organization of the United Nations, Cotonou, Benin
[b] School of Tropical Forestry, National University of Agriculture, BP 43 Ketou, Benin
[c] Faculty of Agronomic Sciences, University of Abomey-Calavi, Laboratory of Applied Ecology, 01 BP 526 Cotonou, Benin

ARTICLE INFO

Keywords:
Mangroves
Wood energy
Consumption
RAMSAR
Benin

ABSTRACT

In West Africa, fuelwood is the main source of energy in rural areas. The growing needs for wood energy cause the degradation of forests, including mangroves in Benin. This study assessed the wood energy needs in the mangrove areas of RAMSAR sites 1017 and 1018 in Benin. Surveys were conducted with 614 stakeholders (firewood housekeepers, collectors and sellers, manufacturers and sellers of charcoal, and food sellers). The annual wood consumption, annual wood consumption per capita, annual wood need per capita, and the projection of future wood needs per year and over 10 years were estimated using appropriate formulas. The results showed that, on average, 8.21 m3 of firewood and 23.19 kg of charcoal were consumed per capita per year. Annual firewood and charcoal needs were 12.83 m3 and 36.25 kg per capita, respectively. A gap of around 36% remains to be filled to meet wood energy needs at RAMSAR sites 1017 and 1018 in Benin. The wood needs are projected to be 18.859806 hm3 for firewood and 53,271.485 tons for charcoal in 2027. Sustainable strategies including the use of domestic gas and solar energy should therefore be developed to meet these wood energy needs and to save mangrove ecosystems.

1. Introduction

Conservation of natural resources and satisfying the needs of local populations constitutes a major challenge for most governments in developing countries (Wali et al., 2017). In Benin, 75% of domestic energy is provided by firewood and 14% by charcoal (PANER, 2015). The fulfilment of these needs in terms of wood energy represents a threat for forestry ecosystems, particularly in the context that access to other sources of energy (e.g., butane gas, solar energy, biogas, etc.) is limited (PANER, 2015). For instance, only 2.37% of households have access to butane gas; and whilst approximately 448 kW of solar energy is currently being used to support rural solar electrification systems such as health care units and telecommunication in Benin (REEEP, 2012). The current level of solar energy consumption is far below the potential level (6.2 kWh/m^2) (REEEP, 2012). The total consumption of energy in 2012 was evaluated at 3924 million tons equivalent-petrol for a population estimated at 10,000,000 habitants in 2012 (DPE, 2015). Substitution of wood energy by butane gas and other energy sources in Benin by 2030 through promoting access to small-sized cooking equipment for 275,000 new households is the main goal of Benin's government (PAG, 2016). Other approaches planned by the government of Benin are to promote the use of energy-efficient charcoal stoves by 25% of the population by year 2030 and facilitate access to modern domestic energy sources (biogas, solar stoves, butane gas) for at least 40% of the population (PANER, 2015). However, before 2030, most of the population living in and around the country's natural ecosystems will still be cutting down trees to fulfill their needs in terms of wood energy required for cooking.

Mangroves are among those ecosystems that provide wood energy to the surrounding populations. They refer to a tidally influenced wetland ecosystem within the intertidal zone of tropical and subtropical latitudes (Duke and Schmitt, 2016) and are important for the survival of the surrounding populations. Mangroves are also designated as 'marine tidal forest', which includes trees, shrubs, palms, epiphytes and ferns (Edwards and Tomlinson, 2007). The success of fishing in many tropical coastal areas depends on the health of mangroves because they serve as spawning grounds and nurseries for most fish species (Adite et al., 2013). Mangroves occupy only 1% of the tropical forest area but their primary productivity in terms of carbon fixation and storage is very high, with rates equivalent to those found in tropical rainforests

* Corresponding author.
E-mail address: agbasympho@gmail.com (S. Agbahoungba).

https://doi.org/10.1016/j.forpol.2020.102192
Received 5 February 2020; Received in revised form 26 April 2020; Accepted 28 April 2020
1389-9341/

(Alongi, 2012). Mangroves capture atmospheric carbon and transform it into biomass with great efficiency (Walcker, 2015). They also provide other services such as coastal protection against storms, floods and erosion.

In Benin, mangrove ecosystems are found at RAMSAR sites 1017 and 1018 and are areas of national as well as international importance from policy and management perspectives. Recently, however, these mangroves have been adversely affected by both natural and man-made factors, as presented by Khan et al. (2020), including their overexploitation for wood. The Food and Agriculture Organization of the United Nations (FAO) estimated that 35% of the world's mangroves disappeared between 1980 and 2000, and this record then steadily worsened between 2005 and 2010 (Dahdouh-Guebas, 2011). Benin's mangroves area decreased from 13,306.05 ha in 1995 to 9452.52 ha in 2015, representing a reduction of 29% in 20 years (Sinsin et al., 2018) and an annual average rate of reduction of 3.1% above the global degradation rate of 2.1% (Valiela et al., 2001). The degradation of mangroves is mainly due to the cutting of wood for domestic wood energy and for salt production (Saenger and Bellan, 1995). This alarming situation confronting Benin and international organizations is a fundamental challenge of sustainable conservation – protecting the ecosystem (in this case, the mangroves) whilst satisfying the needs of the local population (in this case, the supply of wood energy against a background of limited access to modern energy sources such as domestic gas and solar energy). To meet this challenge, it is necessary to estimate the needs of the population in terms of wood energy, which will then serve as a reference for sustainable strategies to meet these needs from the mangroves as well as the implementation of an appropriate planting strategy. In this context, the aim of this study was to evaluate the current level of wood energy consumption, the satisfaction levels of local populations, and the future needs in terms of wood energy in the mangrove areas of RAMSAR sites 1017 and 1018 towards appropriate management and conservation strategies for the mangroves of Benin.

2. Materials and methods

2.1. Study area

RAMSAR sites 1017 and 1018 are located in the littoral zone of southern Benin between the longitudes of 1°37′45″–2°42′35″E and latitudes of 6°12′37″–7°1′N. The ecosystems at these sites are coastal plain ecosystems, earthen plateau ecosystems, clay depression ecosystems and mangrove ecosystems. This study was conducted on the mangrove ecosystems of RAMSAR sites 1017 and 1018 (Fig. 1).

In the study area, at least 70% of the population use wood energy to supply their energy needs (Akouehou, 2009). The stakeholders involved in the use of wood energy are households, food sellers (restaurants), firewood collectors and sellers, and charcoal manufacturers and sellers. In the bigger of the two RAMSAR sites (1018) (Cotonou and Porto-Novo), a total of 1,217,990.562 tons of wood energy was consumed in 2008 (Akouehou, 2009). The quantity of wood energy sold in Cotonou and Porto-Novo in 2008 was 767,012,430.1 tons (Akouehou, 2009).

2.2. Data collection

A total of 12 experimental villages were selected in RAMSAR sites 1017 and 1018 based on the presence of mangroves. A stratified sampling scheme was used to select the number of participants. The range of people considered included stakeholders involved in the use of wood energy. A total of 30 household heads were selected randomly in each village because of the high number of households, while systematic sampling was used for the other stakeholders because of their relative scarcity. In total, a sample size of 643 respondents was achieved, including 360 household heads, 119 food sellers, 110 firewood collectors and sellers, and 54 charcoal manufacturers and sellers. Surveys were conducted with questionnaires for each stakeholder category to collect data on their wood energy needs. At the household level, data were collected on the energy sources used for cooking (firewood, charcoal, oil and gas stoves), the wood species used, the quantities used, the frequency of use (number of days for the use of fuelwood per week), the supply sites, and the level of satisfaction with respect to fuelwood needs. The firewood collectors and sellers and the charcoal manufacturers and sellers provided information on the species used, the quantities collected per species, the sources of supply, the sales markets, the potential buyers of the wood and their thresholds of satisfaction with respect to their wood needs, and the availability of wood energy plantations as well as the constraints upon them. Regarding food sellers, data were collected on the different energy sources used, the wood species used, the quantities purchased, the suppliers, the places of supply or purchase markets, and the level of satisfaction with respect to people's needs. The quantities of wood energy used were collected in numbers of steres and then converted into m^3, on the basis that 1 stere is equivalent to 1 m^3. The wood fuel supply strategy plan of the city of Cotonou (AERAMR, 2009) and the maps of RAMSAR sites 1017 and 1018 served to obtain the forest areas of the RAMSAR sites' supply basins and to assess the available woody stock as well as the annual wood production.

2.3. Data analysis

Formulas proposed by Daïnou et al. (2008) were adapted to estimate the annual wood consumption, annual wood consumption per capita, the annual wood need per capita, and the projection of future wood needs per year and over 10 years. The annual wood consumption (C_a) was estimated based on the volume of wood used in m^3 per day (V_b), the number of days the wood was used per week (f), and the number of weeks in a year (52), using the formula:

$$C_a = V_b \times f \times 52 \quad (1)$$

Annual wood consumption per capita (C_{ah}) was obtained by dividing the annual wood consumption (C_a) by the size of households. The annual wood need per capita was determined by dividing the annual wood consumption per capita (C_{ah}) by the level of satisfaction with respect to wood needs (s) using the formula:

$$B_{ah} = \frac{C_{ah}}{s} \quad (2)$$

The projection of future wood needs per year and over 10 years was computed by considering the annual wood need per capita (B_{ah}), the total population, and the annual population growth rate of the two RAMSAR sites. The total population and the annual growth rate of the population were obtained from the 4th General Census of Population and Housing (INSAE, 2016).

The total wood need during the year n was:

$$B_n = B_{ah} \times P_o(1 + \alpha)^n \quad (3)$$

where P_o is the population in the reference year and α is the annual growth rate of the population.

The concentration index (C_x) and Hirschman–Herfindahl index (C_H) were used to analyze the wood species on which consumption was concentrated (Bailly and Carrère, 2015). C_x measures the cumulative frequency of the consumption of each wood species in the overall consumption. It reveals the relative importance of the most consumed wood species. C_H was calculated as the sum of the squares of the consumption of all wood species. It allowed comparison of the pressure levels exerted on the wood species in the mangrove areas of the two RAMSAR sites:

$$C_H = \sum_{i=1}^{n} m_i^2 \quad (4)$$

where m_i is the consumption of the wood species i.

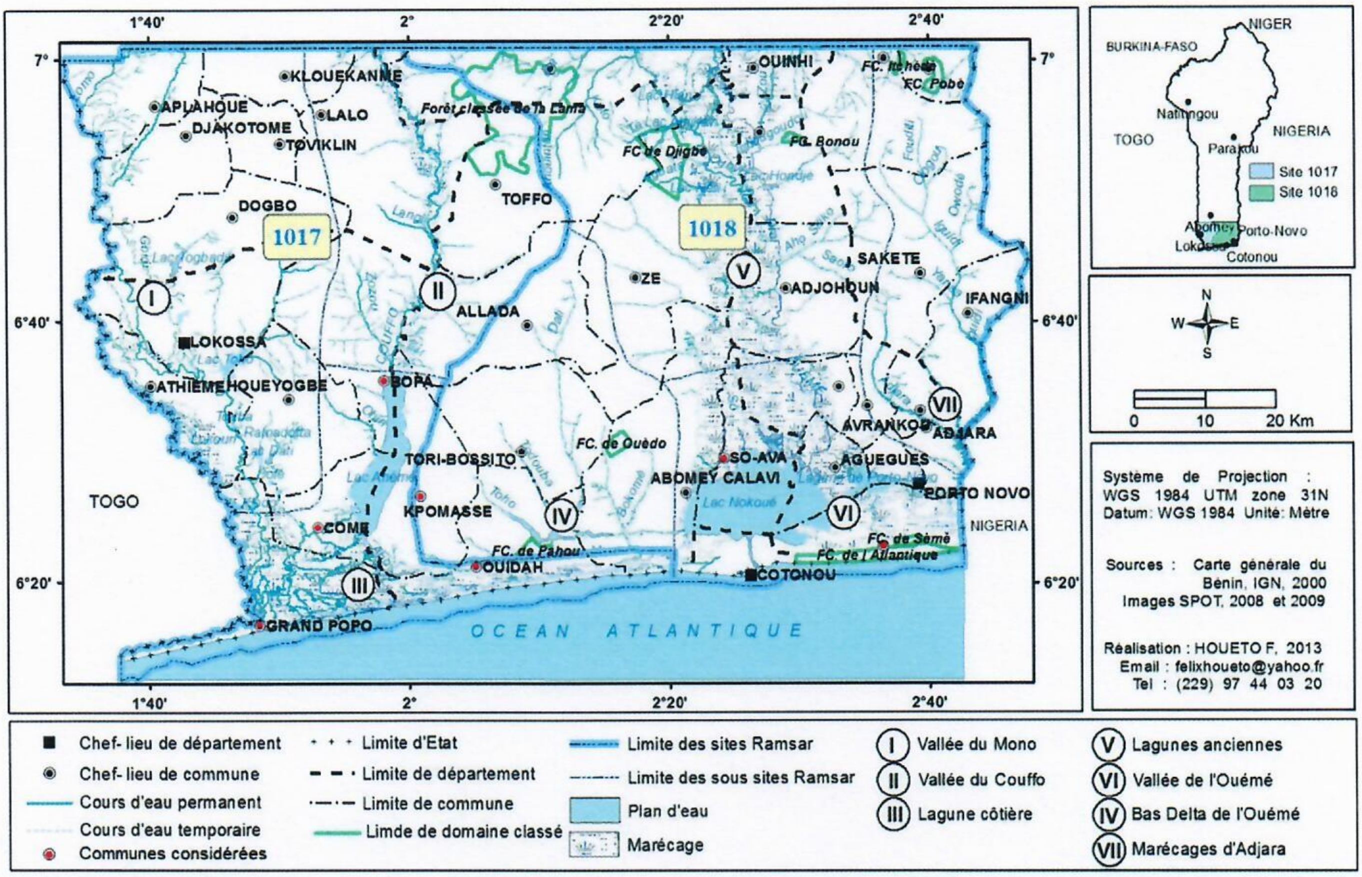

Fig. 1. Map of the geographical location of the municipalities covered by RAMSAR sites 1017 and 1018.

3. Results

3.1. Annual consumption of wood energy

Most households (95.57%) used firewood as their energy source. Thus, firewood remains the main source of energy used at both sites 1017 (95.98%) and 1018 (94.39%). Charcoal was the second most common form of energy used, with consumption by 54.46% of households at site 1017 and 49.53% at site 1018. Stoves and gas were used by only a few households at both sites – 3.63% for stoves and 1.79% for gas.

The annual volume of firewood consumed per capita was 8.21 m^3 (8.49 m^3 at site 1017 and 7.62 m^3 at site 1018). The annual average quantity of charcoal consumed per capita was 18.71 kg (31.49 kg at site 1017 and 5.92 kg at site 1018).

Firewood was also the main source of energy used by food sellers. Specifically, it was used by 94.59% of food sellers surveyed at site 1017 and 100% at site 1018. Meanwhile, 39.2% and 28.9% of food sellers used charcoal at site 1017 and 1018, respectively. Some of them (2.70%) used stoves for cooking. Food sellers consumed an average of 161.98 m^3 of firewood and 13.34 kg of charcoal per year. At the site level, they consumed 133.92/208.13 m^3 of firewood and 17.37/6.71 kg of charcoal per year at site 1017/1018.

On average, 513.96 m^3 of firewood was collected and sold per year, with 369 m^3 of firewood sold per year at site 1017 and 742.38 m^3 per year at site 1018. The species collected at site 1017, in order of importance, were: *Mitragyna inermis* (Willd) Kuntze; *Acacia auriculiformis* Benth; *Elaeis guineensis* Jacq.; and *Holarrhena floribunda* (G. Don) T. Durand & Schinz (Fig. 2). These species represented 62.33% of the total amount of firewood collected at site 1017. The species constituting more than 50% of the total supply amount for firewood sellers were *Bridelia ferruginea* Benth., *A. auriculiformis*, *H. floribunda* and *Tectona grandis* Lf. at site 1017; and *Psidium guajava L.*, *M. inermis*, *Mangifera indica* L. and *B. ferruginea* at site 1018.

Analysis of C_H showed that the pressure exerted by firewood sellers on these species was higher at site 1018 (1754.89) than at site 1017 (1403.2).

The surveys of manufacturers and charcoal sellers revealed that, on average, 1031.13 m^3 of wood was transformed into charcoal per year at site 1017. The average amount of charcoal produced was 1453.92 kg per year. The average amount of charcoal supplied by charcoal sellers was 313.56 kg per year at site 1017 and 218.4 kg per year at site 1018. The most valuable species for charcoal production were *Azadirachta indica* A. Juss., *A. auriculiformis*, *Albizia zygia* (DC.) J. F. Macbr. and *Mangifera indica* L. (Fig. 3). These species represented about 60% of the total amount of wood used for charcoal production.

3.2. Level of satisfaction with respect to fuelwood needs

At the household level, the average consumption of fuelwood represented 63.98% of the current needs. A gap of 36% remains to be filled at both sites. For food sellers, current needs regarding wood energy were satisfied at 61%, with 60.14% at site 1017 and 61.56% at site 1018 (Fig. 4). The collectors and firewood sellers had a gap of about 45% of their current needs unsatisfied. Sellers were more satisfied than collectors. Less than 50% of the current needs of collectors were covered, while the level of satisfaction of firewood sellers was 60% and 62% at site 1017 and 1018, respectively.

The level of satisfaction of charcoal sellers was 69.44% at site 1017 and 62.73% at site 1018. The wood needs of charcoal manufacturers were satisfied at 35% across both sites.

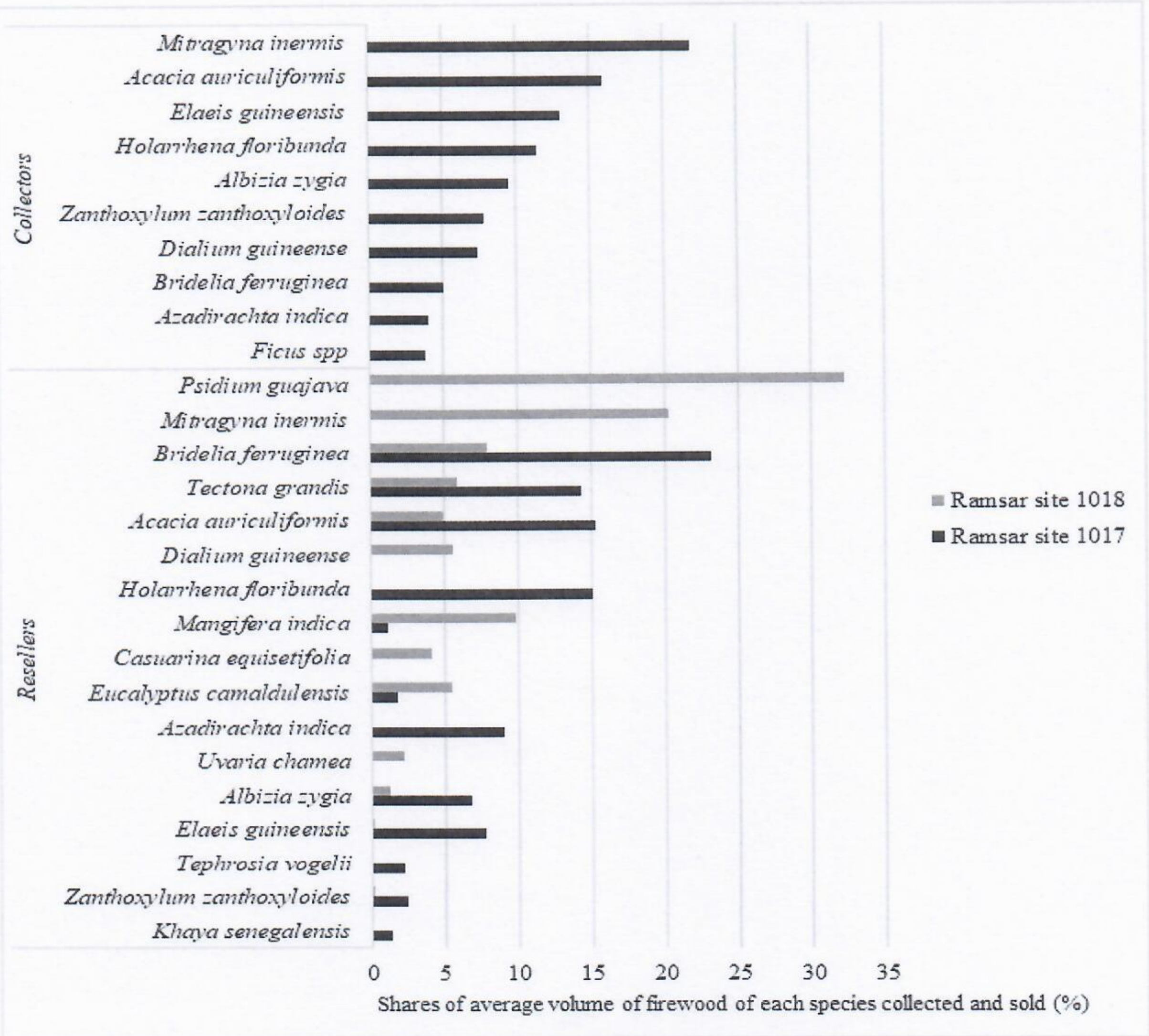

Fig. 2. Fractions of the average volume of wood of each species of wood collected and sold.

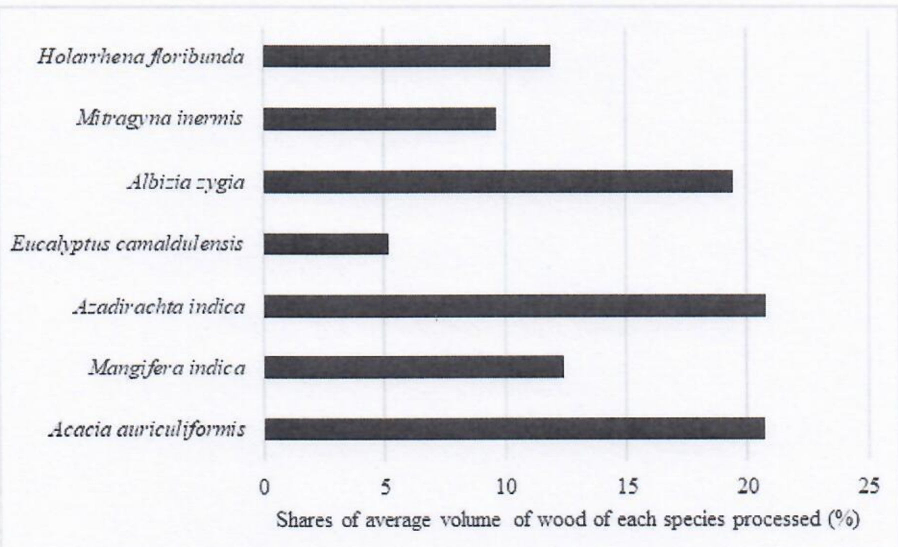

Fig. 3. Fractions of the average wood volume of each wood species processed by the charcoal manufacturers.

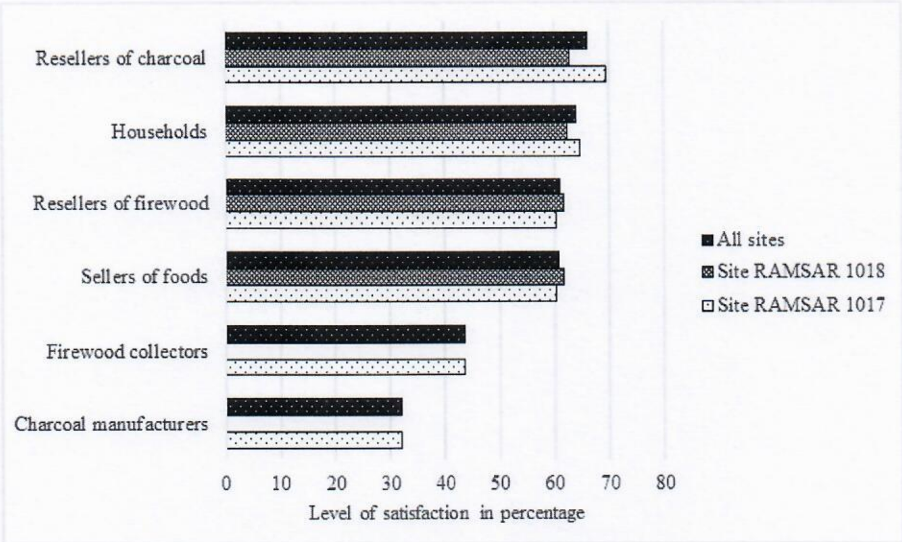

Fig. 4. Level of satisfaction with respect to current wood energy needs by stakeholder category.

3.3. *Future needs of fuelwood*

The annual fuelwood needs were 12.83 m^3 per capita at both sites. At site 1017, the need was estimated at 13.11 m^3, while it was 12.22 m^3 at site 1018. The total firewood need in 2017 was 6.667010 hm^3 at site 1017 and 6.703486 hm^3 at site 1018. By 2027, this volume is projected to be 13.099012 hm^3 at site 1017 and 15.217164 hm^3 at site 1018 (Fig. 5).

The annual charcoal need per capita for both sites was estimated at 36.25 kg (48.63 kg at site 1017 and 9.49 kg at site 1018). The total charcoal need in 2017 was 13,488.758 tons at site 1017 and 34,009.424 tons at site 1018. By 2027, this is expected to increase to 28,499.999 tons at site 1017 and 80,184.484 tons at site 1018 (Fig. 6).

3.4. *Fuelwood supplies*

Surveys indicated that fuelwood supplies at RAMSAR site 1017 were inside the site and sometimes outside from Cotonou city (Republic of Benin) and from the Republic of Togo. At site 1018, the fuelwood supplies were from the cities of Cotonou and Abomey-Calavi in the Republic of Benin. Some households adopted private plantations, with 35.2% of households owning at least one plantation (38.8% at site 1017 and 31.5% at site 1018). The main limitation for plantations was the unavailability of land in mangrove areas. The species planted at site 1017 were *A. auriculiformis* (22.99%), *E. camaldulensis* (6.90%), *C. nucifera* (3.16%), *T. grandis* (1.72%), *E. guineensis* (0.57%) and *Casuarina equisetifolia* (0.29%). At site 1018, *A. auriculiformis* and *E. camaldulensis* were the most planted species.

4. Discussion

Wood is still the most important source of renewable energy, providing about 6% of the global primary energy supply (FAO, 2017). More than two billion people depend on wood energy for cooking and/or heating, particularly in households in developing countries. It represents the only domestically available and affordable source of energy. Private households' cooking and heating with fuelwood represents one third of the global renewable energy consumption, making wood the most decentralized energy in the world (FAO, 2017). In the present study, firewood was found to be the main source of energy at both RAMSAR sites, followed by charcoal, and the current needs of the surveyed populations with respect to fuelwood in the mangrove areas of RAMSAR sites 1017 and 1018 are high and not fully covered. This is consistent with the findings of FAO (2017), in which fuelwood and

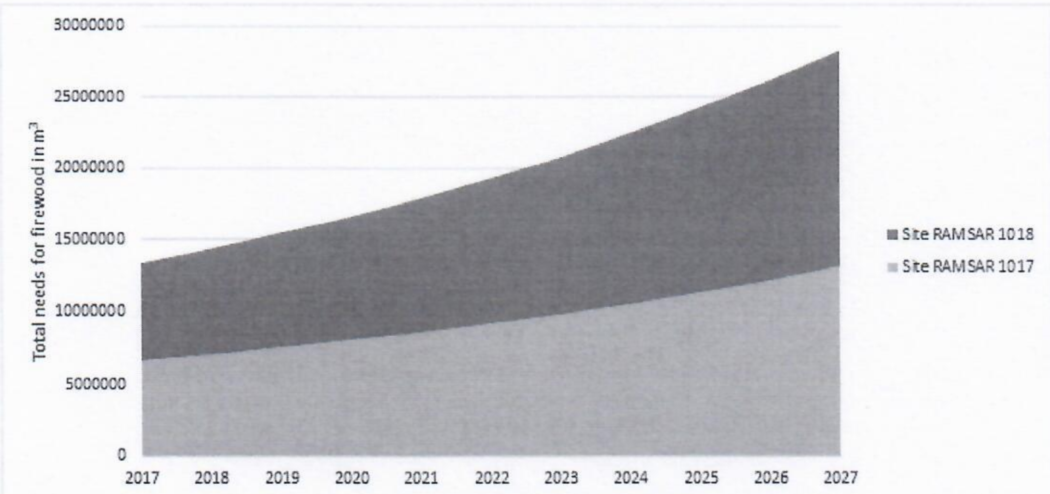

Fig. 5. Projection of future firewood needs in the mangrove areas of RAMSAR sites 1017 and 1018.

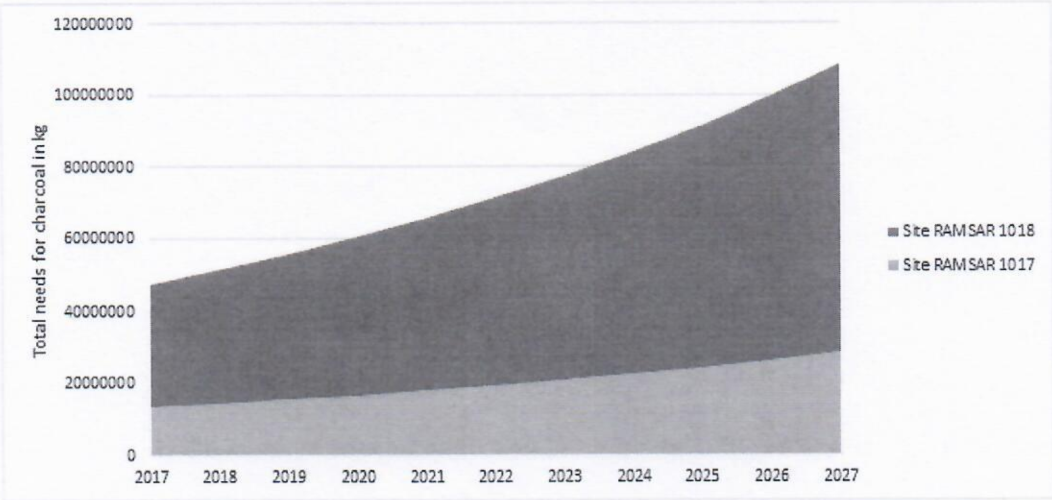

Fig. 6. Projection of future charcoal needs in the mangrove areas of RAMSAR sites 1017 and 1018.

charcoal production were reported to be the predominant use of woody biomass in developing countries. The reasons for this vary considerably, including cultural preferences and availability, as well as economic factors (López-Angarita et al., 2016). This study has revealed that firewood is more accessible compared to charcoal since it costs less and can be obtained by collecting or cutting trees in nearby villages. However, charcoal is utilized more by the population during rainy periods in the study areas, while in other regions large quantities of fuelwood are consumed in the production of charcoal, which is used as a household fuel and also has many commercial and industrial applications, as reported by FAO (2010). The estimated average consumption of wood energy represented less than 70% of current population needs. Most of the species used as fuelwood are extracted from plantations, fields or natural forests, including mangroves. Despite the prohibition of mangroves exploitation by the Beninese Government, some people continue to cut mangrove species to meet their fuelwood needs, and the reasons behind that are that the wood of mangrove species burns for longer compared to other species and are most suitable for the production of salt. Similar results were reported by Liingilie et al. (2015) in Tazania, where mangroves forest trees serve as firewood for salt production, which has led to the reduction of and damage to both the mangrove forests and mangrove ecosystem (Zakari-Allou et al., 2016; Zannou et al., 2017; Sinsin et al., 2018). The over-exploitation of mangrove forests may create an impeding layer, elevate local salinity, and increase the soil temperature as a result of the formation of hard pans that prevent infiltration or the mixing of water, according to Liingilie et al. (2015). In this study, some interviewees added that the use of mangroves as fuelwood to smoke fishes and shrimps improves the appearance of the smoked products – a factor of competitiveness in the market for these products. This perception is consistent with the findings of Daïnou et al. (2008), who reported that the most preferred forest species of populations are indeed mangrove species because they provide improved appearance of the smoked products. To avoid deforestation and mitigate climate change, there is a need to implement alternative forms of income generation and forest rehabilitation activities for the protection, conservation and utilization of mangrove resources. Improvement of the mangrove forest condition will help to optimize the associated benefits and sustainable management of forest resources (Aye et al., 2019). Further research should be conducted on alternative species that meet the preferences and requirements of the populations concerned.

A gap of more than 30% remains to be filled in terms of the total satisfaction with respect to fuelwood needs. This non-satisfaction gap causes pressures on the mangroves, despite their protection. The installation of private plantations and enrichment of the mangroves could help to fill the gap. In this regard, the contribution of the government, NGOs and international organizations to address the satisfaction of stakeholders will positively impact the livelihoods of local populations (Rahman and Giessen, 2017; Khan et al., 2020). Many efforts have been made by the Beninese government, NGOs and international institutes to restore the mangroves of RAMSAR site 1017. For instance, in 2016, the different stakeholders at site 1017 were trained in the production of mangroves species (FAO, 2016). However, most of these efforts are not producing the expected results because of a lack of coordination. Therefore, the installation of trained stakeholders in the production of mangroves and private plantations at both sites could provide significant results.

The present study has revealed that most of the fuelwood sold at RAMSAR sites 1017 and 1018 comes from Cotonou city, which is mainly supplied by the center and the north of Benin (Akouehou, 2009). However, the gap (−834,390.570 tons in 2008) between the availability of and the for wood in Cotonou and its supply zones is very high (Akouehou, 2009). Thus, promoting the installation of plantations in the zones surrounding Cotonou, in the center and the north of Benin could fill the gap in wood supply and reduce pressure on the natural forests. In the mangrove areas of sites 1017 and 1018, some households have adopted private plantations, and these have been widely recognized for their potential to alleviate pressure on natural forests including mangroves (Akouehou, 2009). However, this strategy is limited by the unavailability of land in the study areas. In addition, most of the species used in the plantations do not always meet the population's needs. In some areas of mangrove sites, people live on islands that do not have enough available land for both food crops and tree plantations (Yo et al., 2018). Therefore, the forest species most preferred by the riparian population for firewood could be selected by the forest managers for plantation and the mangroves enrichment program.

The projection of future needs over 10 years showed that the needs in 2027 will be higher. Thus, the managers of RAMSAR sites 1017 and 1018 are encouraged to promote the introduction of firewood species (*Mitragyna inermis*, *Acacia auriculiformis*, *Elaeis guineensis*, *Holarrhena floribunda*, *Bridelia ferruginea* Benth., *Tectona grandis*, *Psidium guajava*, *Mangifera indica*), in the agroforestry system of the local population to improve their availability, or promote domestic gas and solar energy to reduce the huge pressure on forest resources.

5. Conclusions and policy implications

Current fuelwood needs for the populations living in mangrove areas of RAMSAR sites 1017 and 1018 are high and are not fully covered. The estimated average consumption of wood energy represents less than 70% of the current needs of the population. A gap of more than 36% remains to be filled to achieve total satisfaction regarding fuelwood needs. This non-satisfaction gap causes pressures on the mangroves, despite their protection. Moreover, projection of future needs over 10 years (i.e., in the year 2027) shows that the needs will be higher. It is therefore necessary to implement wood energy supply strategies at the two RAMSAR sites based on the preferences of the population and integrating adjacent areas of land for plantations of firewood and the supply areas of Cotonou city. A national policy is also recommended that expands the use of government-subsidized domestic gas and solar energy to reduce the huge pressure on forest resources that have become increasingly scarce.

Authors' contributions

Jean Adanguidi: Conceptualization and manuscript drafting.

Elie Antoine Padonou: Conceptualization, data collection and manuscript drafting.

Afio Zannou: Conceptualization, data analysis and manuscript drafting.

Sidol B.E. Houngbo: Data collection and analysis.

Idelphonse O. Saliou: Data collection and analysis.

Symphorien Agbahoungba: Manuscript drafting.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Acknowledgements

The authors thank the Coordination board of the project Technical Cooperation Program (TCP/BEN/3502) of the Food and Agriculture Organization of the United Nations (FAO) of Benin that supported this research.

References

Adite, A., ImorouToko, I., Gbankoto, A., 2013. Fish assemblages in the degraded mangrove ecosystems of the Coastal Zone, Benin, West Africa: implications for ecosystem restoration and resources conservation. J. Environ. Prot. (Irvine,. Calif) 04, 1461–1475. https://doi.org/10.4236/jep.2013.412168.

Akouehou, G.S., 2009. Approvisionnement en bois-énergie des grands centres urbains de Porto-Novo et de Cotonou au Bénin, une menace pour les mesures d'adoption aux changements climatiques. Ministère de l'Environnement de l'Habitat et de l'Urbanisme, Bénin, pp. 21. https://www.sifee.org/static/uploaded/Files/ressources/actes-des-colloques/yaounde/session-3-2/3_AKOUEHOU_TXT.pdf.

Alongi, D.M., 2012. Carbon sequestration in mangrove forests. Carbon Manag. 3, 313–322. https://doi.org/10.4155/cmt.12.20.

Association pour Etudes et Réalisations des Aménagements en Milieu Rural (AERAMR), 2009. Schéma directeur d'approvisionnement en bois-énergie de la ville de Cotonou. In: Projet Bois de Feu - Phase II, Direction Générale des Forêts et des Ressources Naturelles. Ministère de l'Environnement et de la Protection de la Nature, Bénin, pp. 88. http://koha.uac.bj/cgi-bin/koha/opac-detail.pl?biblionumber=47365&query_desc=su%2Ccomplete-subfield%3ASch%C3%A9ma%20directeur.

Aye, W.N., Wen, Y., Marin, K., Thapa, S., Tun, A.W., 2019. Contribution of mangrove forest to the livelihood of local communities in Ayeyarwaddy region, Myanmar. Forests 10, 1–13. https://doi.org/10.3390/f10050414.

Bailly, P., Carrère, C., 2015. Statistiques descriptives. In: L'économie et les chiffres. Presses universitaires de Grenoble ISBN 978-2-7061-2214-9. https://www.pug.fr/produit/1216/9782706122156/statistiques-descriptives.

Dahdouh-Guebas, F., 2011. World atlas of mangroves: mark Spalding, Mami Kainuma and Lorna Collins (eds). Hum. Ecol. 39, 107–109. https://doi.org/10.1007/s10745-010-9366-7.

Daïnou, K., Vermeulen, C., Doucet, J.-L., 2008. Consommation de bois en zones humides du complexe ouest du Bénin : Besoins et gestion locale des formations ligneuses : Gestion de la ressource ligneuse. Bois forêts des Trop. 298, 13–24. https://revues.cirad.fr/index.php/BFT/article/view/20361.

Direction de la Promotion Economique (DPE), 2015. Deficit Energetique et Competitivite de l'Economie Beninoise. http://www.dgae.finances.bj.

Duke, N.C., Schmitt, K., 2016. Mangroves: Unusual forests at the Seas' edge. In: Pancel, L., Köhl, M. (Eds.), Tropical Forestry Handbook. Springer, Berlin, Heidelberg. https://doi.org/10.1007/978-3-642-54601-3_129.

Edwards, P.J., Tomlinson, P.B., 2007. The botany of mangroves. Kew Bull. 42, 956. https://doi.org/10.2307/4109956.

FAO, 2010. What woodfuels can do to mitigate climate change? FAO Forestry paper n°162. Rome. pp. 98. (ISSN 0258-6150). http://www.fao.org/3/i1756e/i1756e00.htm.

FAO, 2016. Production et plantation des mangroves sur le site Ramsar 1017: La FAO renforce les capacités des acteurs locaux. http://www.fao.org/benin/actualites/detail-events/fr/c/425979/.

FAO, 2017. Wood Energy. http://www.fao.org/forestry/energy/en/.

INSAE (Institut National de la Statistique et de l''Analyse Economique), 2016. Effectif de la population des villages et quartiers de villes du Bénin. RGPH 4, République du Bénin. https://www.insae-bj.org/images/docs/insae-statistiques/demographiques/population/Effectifs%20de%20la%20population%20des%20villages%20et%20quartiers%20de%20ville%20du%20benin/Cahier%20Village%20RGPH4%202013.pdf.

Khan, M.F.A., Rahman, M.S., Giessen, L., 2020. Mangrove forest policy and management: prevailing policy issues, actors' public claims and informal interests in the Sundarbans of Bangladesh. Ocean Coast. Manag. 186, 105090. https://doi.org/10.1016/j.ocecoaman.2019.105090.

Liingilie, A.S., Kilawe, C., Kimaro, A., Rubanza, C., Jonas, E., 2015. Effects of salt making on growth and stocking of mangrove forests of south western Indian Ocean coast in Tanzania. Mediterr. J. Biosci. 1, 27–31. http://www.medjbio.com.

López-Angarita, J., Roberts, C.M., Tilley, A., Hawkins, J.P., Cooke, R.G., 2016. Mangroves and people: lessons from a history of use and abuse in four Latin American countries. Forest. Eco. Manag. 368 (2016), 151–162. https://doi.org/10.1016/j.foreco.2016.03.020.

Plan d'Action National des Energies Renouvelables (PANER), 2015. Ministere de L'Energie, des Recherches Pétrolières et Minières, de l'eau et du Développement des Energies. https://www.se4all-africa.org/fileadmin/uploads/se4all/Documents/Country_PANER/CO%CC%82TE_D%E2%80%99IVOIRE_Plan_d_Actions_National_pour_les_Energies_Renouvelables.pdf.

Programme d'Action du Gouvernement 2016–2021, 2016. Un plan global de développement. Presidence de la République du Bénin, pp. 98. Revealingbenin.com/wp-content/uploads/2017/03/Le-Programme-dActions.pdf.

Rahman, M.S., Giessen, L., 2017. Formal and informal interests of donors to allocate aid: spending patterns of USAID, GIZ, and EU forest development policy in Bangladesh. World Dev. 94, 250–267.

Renewable Energy and Energy Efficiency Partnership (REEEP), 2012. Energy production and consumption profile in Benin. https://www.reeeporg.

Saenger, P., Bellan, M.F., 1995. The mangrove vegetation of the Atlantic Coast of Africa: a review. Université de Toulouse, Toulouse, France.

Sinsin, B., Assogbadjo, A.E., Tente, B., Yo, T., Adanguidi, J., Lougbegnon, T., Ahouansou, S., Sogbohossou, É., Padonou, E., Agbani, P., 2018. Inventaire floristique et faunique des écosystèmes de mangroves et des zones humides côtières du Bénin. FAO & Laboratoire d'Écologie Appliquée, Bénin ISBN 978-92-5-103148-7 (FAO-Bénin). http://www.fao.org/publications/card/fr/c/I8402FR/.

Valiela, I., Bowen, J.L., York, J.K., 2001. Mangrove forests: one of the World's threatened major tropical environments. BioScience 51 (10), 807–815. https://doi.org/10.1641/0006-3568(2001)051[0807:MFOOTW]2.0.CO;2.

Walcker, R., 2015. Dynamique spatiale des mangroves de Guyane entre 1950 et 2014 : forçage atmosphérique et conséquence pour le stock de carbone côtier. Thèse de doctorat. Université Paul Sabatier - Toulouse III, pp. 177. https://tel.archives-ouvertes.fr/tel-01412331.

Wali, A., Alvira, D., Tallman, P.S., Ravikumar, A., Macedo, M.O., 2017. A new approach to conservation: using community empowerment for sustainable well-being. Ecology and Society 22 (4), 6. https://doi.org/10.5751/ES-09598-22040.

Yo, T., Adanguidi, J., Zannou, A., Padonou, E., 2018. Évaluation des besoins en bois des populations au niveau des zones de mangroves des sites RAMSAR 1017 et 1018. In: Rapport d'étude. Organisation des Nations Unies pour l'Alimentation et l'Agriculture (FAO). Bénin, pp. 134. http://www.fao.org/documents/card/fr/c/I8541FR/.

Zakari-Allou, N., Zannou, A., Adébi, Y., Biaou, G., 2016. Perception de la dynamique des revenus et efficacité de la gestion des forêts de mangrove de la lagune côtière du Sud Bénin. Bull. Rech. Agro. Bén. 79, 20–25. http://www.slire.net/document/2364?locale=fr.

Zannou, A., Zakari-Allou, N., Biaou, G., 2017. Déterminants sociotechniques et économiques de la dégradation des forêts de mangrove dans la lagune côtière du Bénin. Ann. Sci. Agro. 21 (1), 77–88. https://www.ajol.info/index.php/asab/article/view/151393.