



The role of local deities and traditional beliefs in promoting the sustainable use of mangrove ecosystems

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ABSTRACT

Customary laws and traditional beliefs are progressively used in conservation and management of natural resources. However, their effectiveness has received limited attention. This case study from the Benin Republic (West Africa) examines how local deities and traditional beliefs can reduce manmade threats to mangroves. Data were collected from three categories of mangroves (sanctuary, sacralised, and non-deity mangroves) via direct observations, informal interviews ($n = 5$), in-depth interviews ($n = 10$), focus group discussions ($n = 3$) and household surveys ($n = 200$). We used twelve indicators including the quantity of resources collected, the use value and the perceived diversity of fish and plant species to characterize each category of mangroves. Eight of these twelve indicators showed significant variation among the categories of mangroves. Highly destructive uses were generally associated with non-deity mangroves, whereas moderately and less destructive uses were mostly associated with sacralised and sanctuary mangroves, respectively. Local deities can thus assist to limit unsustainable use of mangrove forests. Among the mangrove users, salt producers and residents with many children collect and commercialise more mangrove resources than others and should be continually involved in sensitization and community engagement to foster the sustainable use of mangroves.

1. Introduction

Mangroves grow in tropical, subtropical, and warm temperate latitudes along the intertidal land–sea interface, in bays, estuaries, lagoons and backwaters. Most of them are woody trees and shrubs, but some are non-woody (e.g., *Nypa palm*) or herbaceous (e.g., *Acrostichum* and *Acanthus*). These plants and their associated organisms form the ‘mangrove forest community’ or ‘mangal’. The mangal and its associated abiotic factors constitute the ‘mangrove ecosystem’ (Dahdouh-Guebas et al., 2021). Mangroves are considered as the most carbon-rich forests in the tropics and can sequester up to 1023 Mg carbon ha⁻¹ (Donato et al., 2011). They also play a major role in the worldwide supply of

fishery resources (Zu Ermgassen et al., 2021).

Due to human interference, the global cover of mangroves has declined by 30 to 50% over the past 50 years (Mukherjee et al., 2014). Cross-regional studies indicated that mangrove loss is country-specific and especially pronounced in areas of high coastal development. For instance, since 1990, human-caused actions have resulted in an average annual loss of 2.20%, 1.48%, 1.12% and 1.23% of mangroves in Panama, Ecuador, Colombia, and Costa Rica (López-Angarita et al., 2016). The situation is similar in Thailand and Indonesia where significant mangrove loss occurred during recent years. Indonesia, which has the world's highest mangrove coverage, lost 30% of its mangroves from 1980 to 2005 (Arifanti et al., 2022). Fortunately, their conservation has

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become more optimistic in recent years as degradation rates have decreased compared to 15 years ago (Duke et al., 2007; Friess et al., 2020).

To curb the rapid decline of mangroves, traditional beliefs and customary laws are being increasingly associated with legal policy to protect mangroves in many coastal countries (Bell-James et al., 2020). This is also the case in the Benin Republic, where local deities or endogenous divinities intervene in the conservation of mangroves (Zanvo et al., 2021). Depending on the local governance system, three categories of mangroves can be identified in Coastal Benin. They include deity mangroves (sacralised mangroves and sanctuary mangroves) and non-deity mangroves. Sacralised mangroves are areas, sections or stretches of mangroves demarcated in some villages and protected by a local deity called “Zangbêto” to slow down their destruction (Zanvo et al., 2021). Sanctuary mangroves, on the other hand, symbolise a cultural identity of local populations and have been established for ages by the forerunners of the current occupants of the coast. Regarding non-deity mangroves, they do not host divinities and are accessible to local communities without restrictions. Due to the strictness of the local deities used or worshiped, it is assumed that sacralised and sanctuary mangroves face less anthropogenic pressure than non-deity mangroves.

Although traditional beliefs are progressively applied in many countries, only limited scientific evidence exists on how they contribute to the conservation of mangrove resources (Rim-Rukeh et al., 2013). For instance, information on whether a specific category of mangrove is under low or high anthropogenic pressure is still lacking in Benin. Also, very few studies investigate the socioeconomic factors that influence the use of mangroves worldwide (Satyanarayana et al., 2013; Mallick et al., 2021). These data are, however, critical in guiding decision-making to promote the sustainable use of mangroves. As such, this study used Benin Republic as a case study to examine the role of cultural attributes, traditional beliefs and local deities in the promotion of the sustainable use of mangroves for informed decision making. The specific objectives of the study and the underlying hypotheses are as follows:

- (i) To evaluate the perceived diversity of plant and fish resources across the three categories of mangroves.

H_i: The perceived diversity of plant and fish species is higher in sacralised and sanctuary mangroves than in non-deity mangroves.

- (ii) To assess the resource utilisation patterns and the proportion of resource users in the identified categories of mangroves.

H_{ii}: The number of destructive uses is lower in sacralised and sanctuary mangroves than in non-deity mangroves.

- (iii) To quantify the plant and fish resources extracted every week in the identified categories of mangroves.

H_{iii}: The estimated quantity of fish and wood resources extracted from mangroves every week is lower in sacralised and sanctuary mangroves than in non-deity mangroves.

- (iv) To evaluate the commercial value of mangrove resources in the identified categories of mangroves.

H_{iv}: Plant and fish resources collected from sacralised and sanctuary mangroves are less commercialised than those collected from non-deity mangroves.

- (v) To identify the sociodemographic factors which determine the use and commercialisation of mangrove resources in the study communities.

H_v: The use and commercialisation of mangrove resources are determined

by some key sociodemographic characteristics including the household size, gender, and activities of mangrove users.

2. Theoretical framework

Local deities protect the fish species present in sacred forests (Shalli, 2017). The species richness represents therefore an important indicator to assess the effectiveness of local deities in the protection of mangroves. Species richness refers to the number of species in an ecosystem. It can be assessed either by sampling species directly from the field (Compaoré et al., 2022) or by using questionnaires (Southon et al., 2018). The latter, termed “perceived species richness”, captures the perceived number of plant and fish species present in a system (Southon et al., 2018). Resource utilisation patterns and the proportion of resource users are also essential in evaluating the extent to which traditional beliefs are effective in terms of sacred forest conservation. Resource utilisation patterns refer to the different categories of use in an ecosystem. Some categories of use can be highly destructive and lead to the degradation of the system whereas others can be less destructive and underpin the sustainability of the ecosystem (Cardoso et al., 2013). The use value (UV) is a commonly used indicator to quantify the utilisation patterns in ethnobiology (Camou-Guerrero et al., 2008). The quantity of resources collected, as well as their commercial value provide further insights on the importance of local deities and traditional beliefs in terms of sacred forest conservation (Camou-Guerrero et al., 2008). It is known that people desist from harvesting and selling resources from forests protected by deities to avoid misfortunes (Shalli, 2017; Djagoun et al., 2022).

Although deities can help in reducing pressures on mangroves, some key sociodemographic characteristics also determine the use of and the attitude towards mangroves, and understanding these is fundamental to sustainably manage the ecosystem. A good monitoring of these characteristics (through sensitization and awareness), and considering the traditional beliefs (deities, customary laws, etc.), can help in attaining the desired sustainable use of mangroves. Peoples’ activities represent one of the most documented factors which influence the use of mangroves (Mallick et al., 2021). Human activities that cause the degradation of mangroves include unsustainable fishing, wood extraction and agricultural development (Adotey et al., 2022; Cissell et al., 2018; Bhowmik et al., 2022). Age, the level of education, and household size also influence the extent to which people use mangroves. In Sri Lanka for instance, adult people between 30 and 70 years collect more mangrove resources than elderly people above 70 years (Satyanarayana et al., 2013). Also, people with higher education and broad global access to information are reportedly more concerned about mangrove conservation, because they have better knowledge on the services they provide (Itfan, 2023). Regarding the household size, it is reported that households with many children put more pressure on mangroves as they need more resources to survive, than those with few children (Stone et al., 2008). It is therefore essential to identify sociodemographic factors which determine the use of mangroves in a given context and monitor them, together with the application of traditional means of conservation to curb the ongoing degradation of mangroves (see Fig. 1).

3. Materials and methods

3.1. The study area

This study was conducted in Benin, particularly in the Ramsar site 1017 (Fig. 2). Many reasons explain the choice of Benin to conduct the study. Firstly, mangrove cover in Benin has drastically declined from 13,306 ha in 1995 to 9452 ha in 2015, representing a loss of 29% in 20 years (Sinsin et al., 2021). The primary reason for this is that coastal communities use mangrove wood for domestic purposes (Tekka et al., 2019). Since it is the most abundant plant resource, it is the one harvested the most frequently. Therefore, conservation-oriented studies are

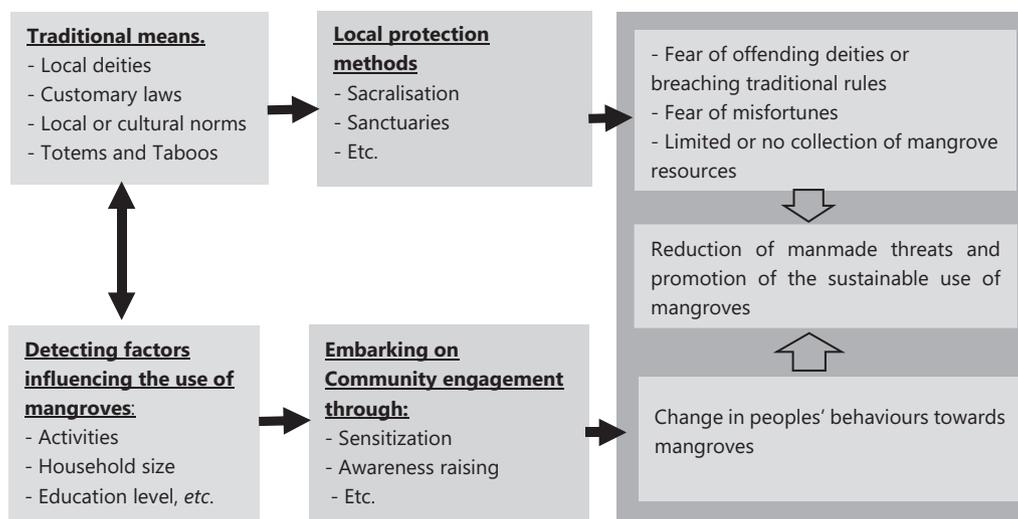


Fig. 1. Theoretical framework of the study: Traditional beliefs such as local deities, customary laws, etc. can be used to sacralise mangroves or create sanctuaries. Coupling this with the detection of socioeconomic factors which influence the use of mangroves for adequate sensitization and awareness raising can help in changing peoples' behaviour towards mangroves, provoking fear among users and limiting the collection of mangrove resources in order to promote the sustainable use of the ecosystem.

(Source: Authors' illustration)

critical to facilitating decision-making processes for mangrove restoration. Finally, the country is well known for its traditional beliefs, voodoo, and cultural practices which are highly applied for the local management of natural resources (Djagoun et al., 2022). All these conditions provide a good environment to test our hypotheses.

Three villages were selected in coastal Benin, including Adouanko (in the city of Abomey-Calavi), Houakpè-Daho (in the city of Ouidah) and Avlo (in the city of Grand-popo) (Fig. 2). A field reconnaissance survey revealed that only these three villages host all three categories of mangroves (sacralised, sanctuary and non-deity mangroves) in the study area. Though sacralised and sanctuary mangrove types are both sacred mangroves accommodating deities, they differ in several characteristics (Fig. 3a and c). Firstly, sacralised mangroves host only one deity, the “Zangbèto”, whereas sanctuary mangroves can house one or many deities, but not necessarily the “Zangbèto”. The type of deity significantly influences the use of mangroves in Benin. Secondly, while sacralised mangroves are more recent (starting in 2015), sanctuary mangroves were established ages ago by the forbears of the current coast occupants. Thirdly, sanctuary mangroves are home to year-round ceremonies and sacrifices where thousands of villagers gather regularly to offer sacrifice to their endogenous gods, whereas no ceremony or sacrifice takes place in sacralised mangroves. All three categories of mangroves were selected per village, summing up to nine mangrove sites in total. The study area lies in the sub-humid tropical climate zone and is characterized by two rainy seasons from April to July and from October to November (Tekla et al., 2019). The annual average temperature of the sites is about 30 °C, and the annual precipitation ranges from 820 to 1300 mm. The dominant ethnic groups include Fon, Plah and Pédah, while other ethnic groups such as Adja, Mina, Yoruba and Ouatchi are found in minority. The primary means of subsistence of the coastal dwellers in the selected communities are fishing, salt production and vegetable cultivation (Tekla et al., 2019).

3.2. Data collection

3.2.1. Approaches used for data collection

Data were collected from July to September 2022 using a concurrent mixed method (qualitative and quantitative) (Fig. 4). The qualitative phase included in-depth interviews ($n = 10$), focus group discussions ($n = 3$) and informal conversations ($n = 5$). Traditional leaders, priests and

dignitaries, heads of villages, NGO officials, chief fishermen and residents who have lived in the communities for at least fifteen years and who have a good knowledge about the animal and plant species found in mangroves were interviewed for the qualitative phase. They were selected using snowball sampling techniques (Sagoe et al., 2021). For the quantitative phase, a household survey was conducted in the selected villages using a random sampling technique (Mensah et al., 2017).

3.2.2. Sample size determination

Before starting the data collection, a pilot survey helped to determine the sample size for the quantitative phase. Fifty respondents per village were selected randomly to calculate the proportion p of people who know and use mangrove plant and animal resources. The sample size for each village was determined using the formula (Mensah et al., 2017)

$$n = \frac{1}{e^2} p(1-p) U_{1-\frac{\alpha}{2}}^2 \quad (1)$$

where n represents the total sample size, U is the value of the normal random variable ($U = 1.96$ for $\alpha = 0.05$), and e represents the margin error, held to be 9%. In total, 200 households were selected in the villages as follows: 52 households in Adouanko ($p=0.88$), 71 households in Houakpè-Daho ($p=0.82$) and 77 households in Avlo ($p=0.79$).

3.2.3. Assessing the perceived diversity of plant and fish species (Hypothesis 1)

The perceived number of fish and plant species were used as indicators to assess the diversity of plant and fish species (Southon et al., 2018). During the focus group discussions and the in-depth interviews, informants were first asked to cite in their local languages all fish and plant species found in each mangrove category per village. These were then encoded and used in a questionnaire for the quantitative phase. Respondents of the household survey were then asked to select from the encoded list those species they usually encounter in each mangrove category and to add to the list in case of omission of any species.

3.2.4. Assessing the mangrove utilisation patterns and the proportion of resource users of each mangrove category (Hypothesis 2)

Mangrove utilisation patterns and the proportion of users of each mangrove category were assessed using five indicators, including the use

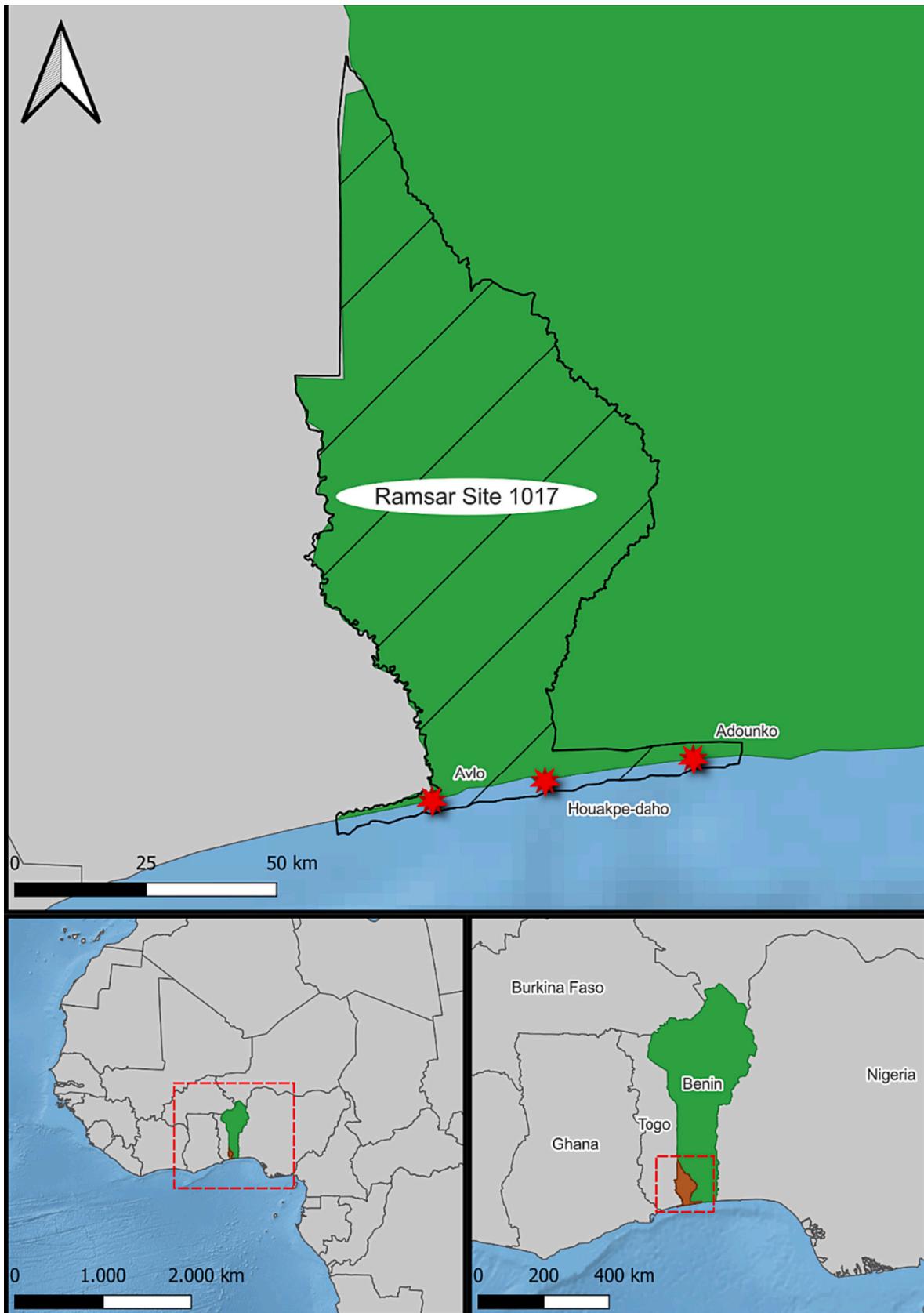


Fig. 2. Map of the study area showing the country, the situation of the Ramsar site and the specific sampling sites (stars) of the study.



Fig. 3. (a) Sacralised mangrove with the deity “Zangbéto”, (b) non-deity mangrove, (c) Sanctuary mangrove hosting the deity “Dan”, (d) Heaps of *Rhizophora racemosa* species collected as firewood from mangroves, (e) Basket used to estimate the quantity of fish collected from mangroves (f) The basket containing fish collected from mangroves, (g) Heaps of *Rhizophora racemosa* species collected as construction wood from mangroves. Source: Photos taken from the field (coastal Benin) by the first author between July and September 2022.

value (UV), the percentage of people who use each mangrove and the percentage of people engaged in highly, moderately, and less destructive uses (Camou-Guerrero et al., 2008; Cardoso et al., 2013). During the household survey, respondents were asked to cite and describe all the specific uses in each mangrove category. Based on the literature and best professional judgement, the specific uses from the field records were then grouped into three different types, including the highly destructive uses, the moderately destructive uses, and the less destructive uses. These refer respectively to the utilisation patterns which have the potential of causing large, moderate, or little to no degradation of mangroves.

3.2.5. Assessing the quantities of plant and fish resources collected from each mangrove category (Hypothesis 3)

To evaluate the quantity of resources extracted, three indicators were used including the quantity of firewood and construction wood collected, as well as the quantity of fish collected per week. During the

quantitative survey, respondents were asked to estimate the weekly quantity of fish, firewood, and construction wood they harvest from each mangrove category. As there is no standardized metric to quantify these resources, a 5 kg-basket commonly used along the coast to sell harvested fish served as a proxy (Fig. 3e). Therefore, harvest weights (in Kg) of fish were calculated by asking respondents to estimate how many baskets of fish they harvest per collection event and how often they collect the resource per week from each mangrove category. Similarly, firewood and construction wood are generally sold in heaps (Fig. 3d and g). So, the number of heaps of firewood and construction wood that respondents replied to extract from each mangrove category per collection event and per week served to convert those quantities into m^3 following Fonseca (2010).

3.2.6. Commercial value of mangrove resources and factors that determine their use (Hypotheses 4 and 5)

The commercial value of the collected resources was assessed with

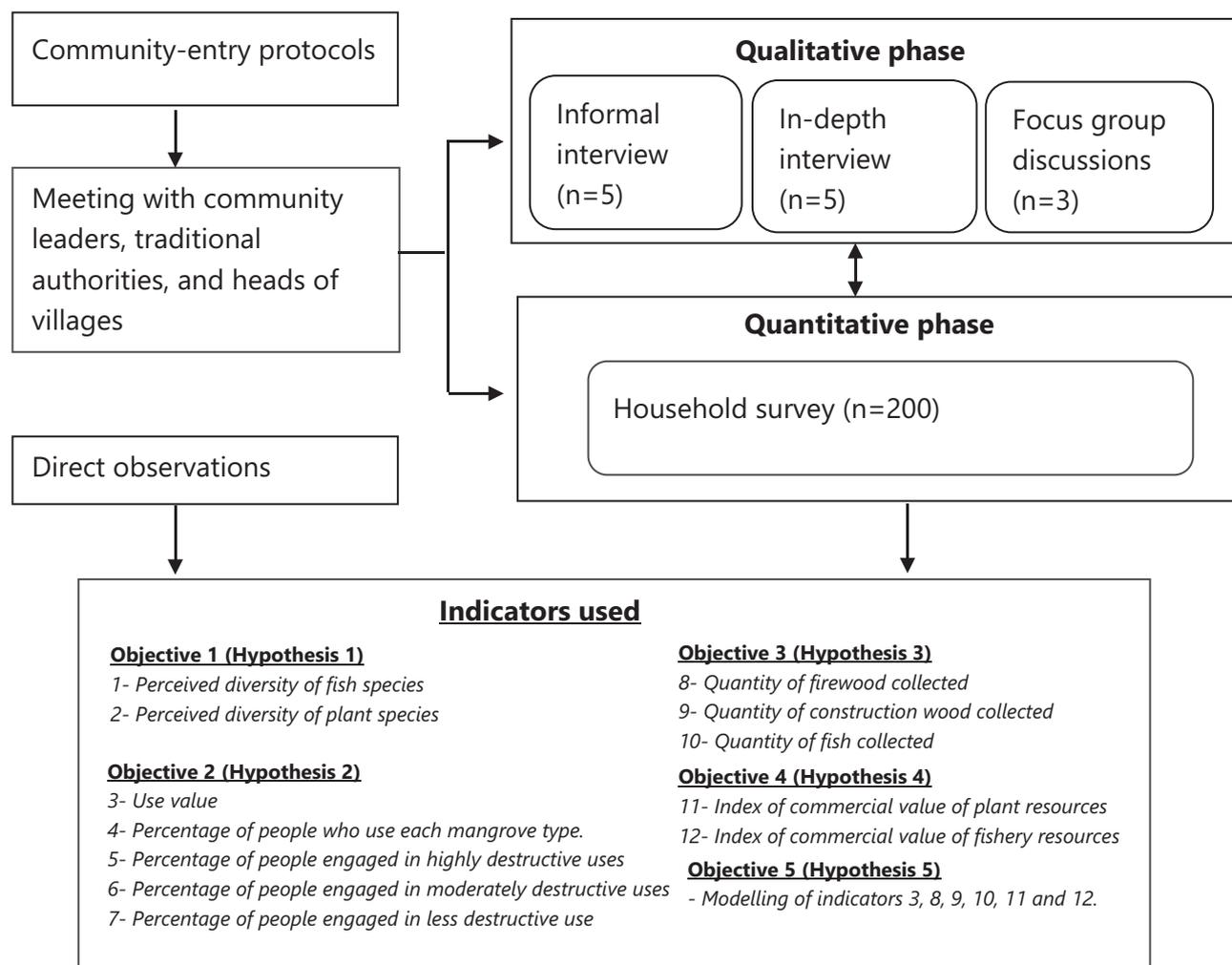


Fig. 4. Flowchart of the methodological approach showing the data collection methods and the indicators considered for the study (1 to 12). The selected indicators were used to measure objectives 1, 2, 3 and 4 and those which showed significance across the different mangrove categories were modelled in objective 5.

the help of two indicators, including the index of commercial value of fishery and plant resources (Balima et al., 2018; Favi et al., 2022). To compute these indicators, respondents had to indicate whether or not they sell the plant and/or fish resources that they collect (Yes or No question). To identify sociodemographic factors influencing the use and commercialisation of mangrove resources, key characteristics of respondents were recorded during the quantitative survey (see Table S1, supplementary file 1) and modelled together with the types of local governance (i.e., the categories of mangroves: sacralised, sanctuary and non-deity mangroves).

3.3. Data analysis

3.3.1. Perceived diversity of plant and fish species (Hypothesis 1)

Fish species recorded from the field were identified following Viahou et al. (2021) based on their local names and checked for consistency using FishBase (<https://www.fishbase.se/search.php>). Plant species were identified following Akoègninou et al. (2006). The number of fish and plant species reported per mangrove category and village was then counted, and the relative frequency of citation (RFC) of each species computed as a measure of its local occurrence, using the formula:

$$RFC = \frac{n}{N} \times 100 \quad (2)$$

where n is the number of times a species is mentioned, and N is the total number of species mentioned by all respondents. After computation,

Levene's test, Shapiro Wilk test and Durbin Waston test were applied on the perceived number of plant and fish species to check the homogeneity of variance, the normality, and the independence of residuals (ANOVA's assumptions) across the three categories of mangroves (see Table S2, supplementary file 1). Thereafter, their variation across the categories of mangroves was tested using analysis of variance test (ANOVA) (Glèlè Kakaï et al., 2006). When significant differences are detected, Student-Newman-Keuls (SNK) test was used to separate means in the package *agricolae*, in R version 4.2.2.

3.3.2. Utilisation patterns and the proportion of resource users of each mangrove category (Hypothesis 2)

With the specific uses recorded during the household survey, the use value (UV) was computed for each mangrove category following the formula by de Lucena et al. (2012):

$$UV = \frac{\sum_{i=1}^n U}{N} \quad (3)$$

Where U is the number of specific uses reported by each respondent for each category of mangrove, and N is the total number of respondents engaged for the study. Further, a simple correspondence analysis (CA) was applied to explore the association between the categories of mangroves and the specific uses.

The proportion of respondents using each mangrove category for their activities as well as the proportion of respondents engaged in highly, moderately, and less destructive uses were computed using the

formula:

$$P = \frac{t}{N} \times 100 \quad (4)$$

Where t is the number of respondents who use each category of mangrove or number of respondents engaged in each type of use, and N is the total number of respondents. ANOVA and SNK tests were run on the use value and the proportions of users to assess their variation across the categories of mangroves.

3.3.3. Quantities of plant and fish resources collected from each category of mangroves (Hypothesis 3)

The average quantities of firewood, construction wood and fish extracted from each category of mangrove per week were determined using an equation adapted from Adanguidi et al. (2020):

$$Q = \frac{\sum q_t}{N} \quad (5)$$

where q is the estimated quantity of the resource harvested per respondent per collection event, t is number of collection events per week, and N is the number of respondents. The calculated quantities of resources were further submitted to ANOVA and SNK tests to assess their variation across the categories of mangroves.

3.3.4. Commercial value of mangrove resources (Hypothesis 4)

The index of commercial value (ICV) used to assess the commercial value of mangrove plant and fish resources was calculated following Lozano et al. (2014):

$$ICV = \frac{n_p}{N} \quad (6)$$

where n_p is the number of respondents who sell the resources for each category of mangrove, and N is the total number of respondents. A resource is of a high commercial value if $ICV \geq 75\%$ (Lozano et al., 2014). A Kruskal-Wallis' test was used to check the variation of the ICV of fish resources across the categories of mangroves (because this indicator did not meet ANOVA's assumptions even after transformations, see Table S2, supplementary file 1), whereas ANOVA and SNK tests were applied for the ICV of plant resources.

3.3.5. Factors that determine the use of mangrove resources (Hypothesis 5)

A Chi-square test was first used to explore the independence (i.e., non-association) of the model predictors. Predictors used included the categories of mangroves (sanctuary, sacralised and non-deity mangroves) as well as sociodemographic characteristics such as respondents'

Table 1
Models used, depending on the nature of the data.

Data (Response variables)	Nature	Type of model used	References
Specific use	Count data	Multilevel models with poisson error distribution	Zuur et al. (2009)
ICV of plant resources	Binomial (Yes or No)	Multilevel models with binomial error distribution	Warton et al. (2016)
ICV of fish resources	Binomial (Yes or No)	Multilevel models with binomial error distribution	Warton et al. (2016)
Quantity of firewood collected	Continuous variable	General linear model	Nakagawa and Schielzeth (2013)
Quantity of construction wood collected	Continuous variable	General linear model	Nakagawa and Schielzeth (2013)
Quantity of fish collected	Continuous variable	General linear model	Nakagawa and Schielzeth (2013)

village, gender, age, ethnicity, education level, main activity, religion, engagement in alternative livelihoods and the number of children. Response variables were the specific uses, the ICV of plant and fish resources and the quantities of firewood, construction wood and fish collected. Table 1 summarizes the models used depending on the type of data. Three rounds of data analysis were performed. For the first round, only the variable "category of mangroves" (sanctuary, sacralised and non-deity mangroves) was used as predictor (Table 3). For the second round, the variable "category of mangroves" was supplemented by sociodemographic factors and used as predictors in the models (Table 3). For the third round, the combination "category of mangroves", sociodemographic factors, and villages were used as predictors. In this last round, village was considered as a random factor (Table 3).

4. Results

4.1. Perceived diversity of fish and plant resources across the categories of mangroves (Hypothesis 1)

The perceived number of fish and plant species recorded were similar irrespective of the village and the category of mangroves. On average, 18 fish species were reported for sanctuaries whereas 16 species were recorded for both, sacralised and non-deity mangroves (Table 2). For plants, 5 species on average were cited for sanctuaries and non-deity mangroves whereas 4 species were mentioned for sacralised mangroves (Table 2). The variation across the categories of mangroves for the total number of fish and plant species reported was not significant (ANOVA test, $p = 0.69$ for fish species and $p = 0.76$ for plant species) (Table 2). However, mangroves with deities were recognized to host big-sized fish which are of high commercial interest to fishers. In fact, 90% of the respondents acknowledged that big-sized fish inhabit sacralised and sanctuary mangroves, whereas small-sized species are common in non-deity mangroves. Table S3 (supplementary file 1) presents the entire list of the fish and plant species recorded from the field. The mostly cited fish species included *Chrysichthys auratus* (Geoffroy Saint-Hilaire, 1809) (RFC = 99%) *Clarias gariepinus* (Burchell, 1822) (RFC = 99%), *Synodontis schall* (Bloch & Schneider, 1801) (RFC = 98%), *Hepsetus odoe* (Bloch, 1794) (RFC = 97.5%) and *Caranx hippos* (Linnaeus, 1766) (RFC = 93.5%). The most common plant species reported were *Rhizophosa racemosa* (G. Mey) (RFC = 100%), *Avicennia germinans* L. (RFC = 100%), *Cyperus articulatus* L. (RFC = 80%), *Acrostichum aureum* Linn. (RFC = 75.3%), and *Drepanocarpus lunatus* (L.f.) G. Mey. (RFC = 70%).

4.2. Proportions of users and specific uses of each category of mangroves (Hypothesis 2)

On average, 24% of the respondents acknowledged that they collect resources from sanctuary mangroves for their wellbeing and livelihoods whereas 54% of them agreed that they collect resources from sacralised mangroves and 95% agreed that they collect resources from non-deity mangroves. The proportion of respondents who collect resources from each category of mangrove differed significantly across the categories of mangroves (ANOVA test, $p = 3.131e-05$), indicating that most people depend on non-deity mangroves for their activities but only few people depend on sanctuary and sacralised mangroves (Table 2).

In terms of utilisation patterns, a total of 21 specific uses were reported for the 3 categories of mangroves. Out of these, 8 were highly destructive (sugarcane growing, aquaculture, vegetable growing, fish harvesting, firewood and construction wood collection, *C. articulatus* collection and salt production), 8 were moderately destructive (shrimp, crab, and oyster collection, propagule harvesting, medicinal plant collection, dye, fodder, and water collection) and 5 were less destructive (ecotourism, baby outing, rainmaking, sacrifices, and purification).

The mean use value (UV) computed for the three categories of mangroves was 1.77 ± 0.15 for sanctuary mangroves, 1.60 ± 0.02 for

Table 2
Mean values of the indicators used across the different categories of mangroves and their comparison (ANOVA and SNK tests).

		Perceived diversity (Hypothesis 1)		Use patterns and proportions (Hypothesis 2)					Quantity of resources harvested (Hypothesis 3)			ICV (Hypothesis 4)	
		1.Perceived number of fish species	2.Perceived number of plant species	3.UV Index	4.Proportion People who use each category (%)	5.Proportion People engaged in highly destructive uses (%)	6.Proportion People engaged in moderately destructive uses (%)	7.Proportion People engaged in less destructive uses (%)	8.Estimated quantity of fish collected per week (Kg)	9.Estimated quantity of firewood collected per week (m ³)	10.Estimated quantity of construction wood collected per week (m ³)	11. ICV plant resources (%)	12. ICV fishery resources (%)
Sanctuary mangroves	Adouanko	15	4	1.53 ± 0.07	29	12.21	9.15	7.63	21.4 ± 7.09	13.69 ± 1.04	2.89 ± 2.35	13	69
	Houakpè-Daho	19	6	2.07 ± 0.06	20	4	9	7	6.80 ± 3.14	14.29 ± 0.72	2.81 ± 1.80	16	80
	Avlo	19	4	1.71 ± 0.05	23	7.66	7.66	7.66	10.36 ± 4.06	12.23 ± 2.10	0.29 ± 0.5	11	83
	Mean ± standard error	17.66 ± 1.32^a	4.66 ± 0.66^a	1.77 ± 0.15^b	24 ± 0.24^c	7.95 ± 0.14^b	8.60 ± 0.15^a	7.43 ± 0.14^b	12.85 ± 4.39^c	13.40 ± 0.61^c	1.99 ± 0.85^b	13 ± 0.01^c	77 ± 0.24^a
Sacralised mangroves	Adouanko	18	5	1.57 ± 0.07	65	6.77	20.31	37.91	75.11 ± 8.86	19.84 ± 1.61	4.27 ± 1.28	38	67
	Houakpè-Daho	15	2	1.59 ± 0.05	46	8.76	3.65	33.58	108.54 ± 6.89	18.09 ± 2.10	2.33 ± 0.37	21	87
	Avlo	15	5	1.66 ± 0.06	51	7.06	4.70	39.23	18 ± 5.70	16.02 ± 1.08	3.81 ± 0.70	23	87
	Mean ± standard error	16 ± 0.99^a	4 ± 0.99^a	1.60 ± 0.02^b	54 ± 0.28^b	7.53 ± 0.14^b	9.55 ± 0.28^a	36.90 ± 0.27^a	67.21 ± 26.43^b	17.98 ± 1.10^b	3.47 ± 0.85^b	27 ± 0.26^b	80 ± 0.23^a
Non-deity Mangroves	Adouanko	20	4	3.73 ± 0.16	100	89	6.80	4.18	125.59 ± 22.72	35.59 ± 6.17	10.82 ± 4.32	94	71
	Houakpè-Daho	13	7	3.54 ± 0.12	94	87.31	4.32	2.35	144.04 ± 32.34	28.83 ± 2.10	8.27 ± 3.18	95	77
	Avlo	15	4	3.55 ± 0.13	92	83.83	5.93	2.22	171 ± 31.56	35.98 ± 5.24	10.31 ± 3.50	96	89
	Mean ± standard error	16 ± 2.07^a	5 ± 0.99^a	3.6 ± 0.05^a	95 ± 0.12^a	86.71 ± 0.20^a	5.63 ± 0.12^a	2.91 ± 0.81^c	146.87 ± 13.18^a	33.46 ± 2.32^a	9.8 ± 0.77^a	95 ± 0.21^a	79 ± 0.26^a
	<i>p</i> -value	0.69	0.76	1.31e ^{-05*}	3 1.31e ^{-05*}	6.38e ^{-08*}	0.68	9.3e ^{-07*}	0.04*	0.01*	0.03*	4.68e ^{-06*}	0.87

ICV = Index of Commercial Value, UV index = Use value Index, * = $p < 0.05$. Means with different letters are significantly different (SNK test). Source of the data: Household survey ($n = 200$) in Benin from July to September 2022.

sacralised mangroves and 3.6 ± 0.05 for non-deity mangroves and differed significantly among the categories of mangroves (ANOVA test, $p = 1.31e-05$). The number of specific uses was significantly higher in non-deity mangroves than in sacralised and sanctuary mangroves (Table 2). An in-depth analysis of the users of each category of mangrove indicated that among the 24% of respondents agreeing to collect resources from sanctuary mangroves, 7.95% were engaged in highly destructive uses while 8.60% and 7.43% were engaged in moderately and less destructive uses, respectively. Among the 54% of respondents acknowledging to collect resources from sacralised mangroves, 7.53% and 9.55% were engaged in highly and moderately destructive uses, while 36.90% were engaged in less destructive uses. In contrast, among the 95% of respondents who agreed to collect resources from non-deity mangroves, the large majority (86.71%) was engaged in highly destructive uses, whereas 5.63% and only 2.91% were engaged in moderately and less destructive uses (Table 2). The proportions of respondents engaged in highly destructive uses (ANOVA test, $p = 6.38e-08$) and less destructive uses (ANOVA test, $p = 9.3e-07$) were dependent on the categories of mangroves, showing that in the study communities, non-deity mangroves are largely subject to destructive uses, whereas sanctuaries and sacralised mangroves are mostly subject to non-destructive uses. This is further confirmed by the correspondence analysis (CA), showing that sanctuaries are associated with rituals and traditional ceremonies such as sacrifices, purification, rainmaking, and baby outing, which are all less destructive, sacralised mangroves are mostly associated with water supply, dye and ecotourism which are moderately destructive and non-deity mangroves are mostly associated with firewood and construction wood extraction, fish collection, aquaculture, sugarcane growing and salt production which are all highly destructive (Fig. 5).

4.3. Quantity of plant and animal resources extracted from each category of mangroves (Hypothesis 3)

The quantity of fish collected from mangroves differed significantly across the categories of mangrove (ANOVA test, $p = 0.04$). Respondents harvested eleven times more fish from non-deity mangroves (146.87 Kg on average) than from sanctuary mangroves (12.85 Kg on average) and two times more fish than in sacralised mangroves (67.21 Kg on average) (Table 2). The quantities of firewood (ANOVA test, $p = 0.01$) and construction wood (ANOVA test, $p = 0.03$) collected from mangroves in the study communities also differed significantly among the categories of mangroves (Table 2). The quantity of firewood extracted from non-deity mangroves ($33.46m^3$ on average) was almost two and three times higher than the one collected from sacralised mangroves ($17.98m^3$ on average) and sanctuary mangroves ($13.40m^3$ on average) respectively (Table 2). The same trends were observed for the collection of construction wood. The quantity of construction wood collected from non-deity mangroves on a weekly basis was almost five times higher ($9.8m^3$ on average) than the one collected from sanctuary mangroves ($1.99m^3$ on average) and three times higher than the one collected from sacralised mangroves ($3.47m^3$ on average).

4.4. Commercialisation of mangrove resources across categories (Hypothesis 4)

Although the index of the commercial value of the fishery resources was not influenced by the categories of mangroves (Kruskal-Wallis's test, $p = 0.87$), the fish resources collected from the three categories of mangroves were of high commercial importance for respondents (on average ICV = 77% for sacralised mangroves, 80% for sanctuary mangroves and 79% for non-deity mangroves) (Table 2). This shows that

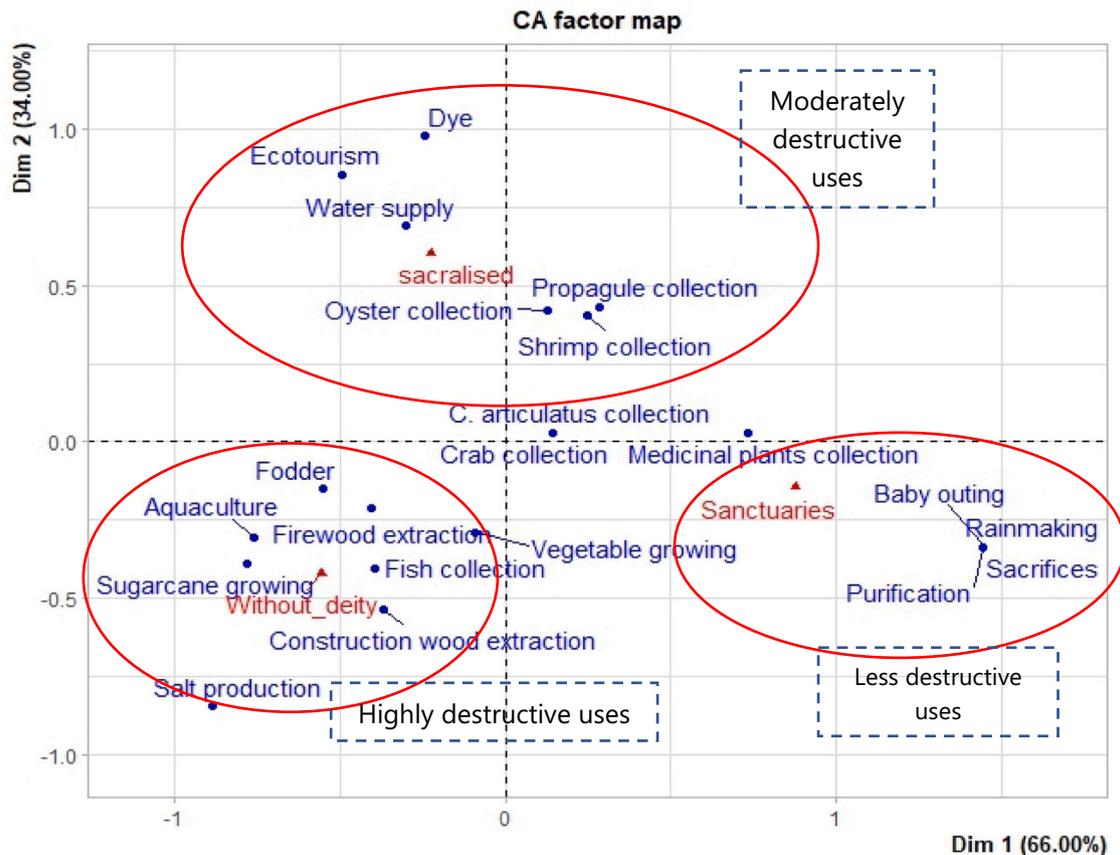


Fig. 5. Association between the use patterns and the different categories of mangroves (results of a simple correspondence analysis). Source: Household survey ($n = 200$) in Benin from July to September 2022.

Table 3
Results of the linear models (Hypothesis 5).

Variables	Round 1: only the variable "Category of mangroves" used predictor of the model						Round 2: Category of mangroves and sociodemographic characteristics used as predictors of the models						Round 3: Category of mangroves, sociodemographic characteristics and villages used as predictors of the models						
	Fish harvesting	Firewood Collection	Construction wood	Use value	Plant selling	Fish selling	Fish collection	Firewood Collection	Construction wood	Use value	Plant selling	Fish selling	Fish collection	Firewood Collection	Construction wood	Use value	Plant selling	Fish selling	
	Types of governance: mangroves without deities as reference						Types of governance: mangroves without deities as reference						Types of governance: mangroves without deities as reference						
Intercept	65.01***	71.05***	13.93	0.47**	-1.81***	15.5***	2.5	49.5**	15.7	0.01	-0.9	15.0	-18.3	182.3	18.9	0.007	-13.91	14.06	
Sacralised	-53.07**	-17.61	-6.19**	-0.10	-0.79**	-0.22	-53.0***	-17.6	-6.1***	0.1	0.8***	-0.2**	-52.1***	-17.0	-6.2**	0.1	-0.81**	-0.21	
Sanctuaries	-84.62**	-62.37***	-25.26***	-0.8**	-4.8***	-4.4***	-84.6***	-62.3*	-25.2***	-0.7***	-4.96**	-0.09***	-84.3***	62.9**	-25.2***	-0.7***	-4.90***	-0.09	
Gender (M as Reference)																			
F							5.7	4.1	-0.9	-0.02	0.09	-0.1	6.3	2.9	-1.0	-0.02	0.06	-0.12	
Children (Households with <5 children as reference)																			
5-10							4.7	3.8	2.9	0.02	0.1	0.4	5.7	4.4	2.9	0.01	0.16	0.22	
Sup 10							33.9*	33.7**	2.8	0.008	0.6	0.2	33.5*	34.1*	3.0	0.008	0.64*	0.42	
Activity (Farmers as reference)																			
Fishing							38.2*	-1.5	-2.4	-0.04	0.2	-0.2	32.7	-6.1	-2.6	-0.03	0.15	-0.20	
Salt production							34.6	-7.9	2.5	-0.02	0.2	-0.2	35.3	-11.8	-2.7	-0.01	0.21	-0.24	
Petty trading							40.0	-2.3	-6.6*	-0.07	0.3	-0.2	40.5	-5.6	-6.7*	-0.07	0.36	0.10	
Education (No formal education as reference)																			
Primary							-123.2	25.4	0.5	0.45	13.0	-13.6	21.9	-112.9	1.5	0.4	12.42	-12.7	
Secondary							-131.2	7.5	-1.4	0.47	12.9	-13.7	6.5	-122.8	-0.6	0.4	12.27	-12.8	
Alternative (No alternative livelihood as reference)																			
Yes							10.5	11.6	-0.2	0.04	-0.4	-0.38	10.6	11.0	-0.2	0.04	-0.46	-0.39	
Villages (Adoukou as reference)																			
Avlo													-4.7	-9.3	-4.7	0.01	-0.48	1.03***	
Houakpè-Daho													15.5	-14.7	-6.6*	0.05	-0.36	0.67***	

Level of significance: * = $p < 0.05$; ** = $p < 0.01$; *** = $p < 0.001$.

Data used: Quantity of fish, firewood and construction wood collected, use value and commercial value of fish and plant resources. Source of the data: Household survey ($n = 200$) in Benin from July to September 2022.

respondents sell their fish catch irrespective of the category of mangroves in which they are harvested. As for plant resources, their commercial value depends on the category of mangroves (ANOVA test, $p = 4.68e-06$). Indeed, plant resources collected from sanctuary and sacralised mangroves had low commercial value (on average, ICV = 13% for sanctuaries and 27% for sacralised mangroves), whereas those collected from non-deity mangroves showed high commercial value (on average ICV = 95%) (Table 2). This indicates that respondents sell plant resources collected from non-deity mangroves, but rarely sell those harvested from sacralised mangroves and sanctuaries, which are used for domestic purposes.

4.5. Factors affecting the use and the commercialisation of mangrove resources (Hypothesis 5)

The results of the Chi square test run to explore the independence of the predictors showed that variables such as gender, number of children, activity, education, engagement in alternative livelihoods, village, and the category of mangroves (*sanctuary mangroves, sacralised mangroves, and non-deity mangroves*) were not correlated (Chi square test, $p > 0.05$, see Table S4, supplementary file 1) and could thus be used for the models. Table 3 shows the factors that affect the use and the commercialisation of mangrove resources in the study communities. The first round of data analysis indicated that the predictor “category of mangroves” influenced all response variables. More explicitly, the values for harvesting and selling of fish and plant species as well as the specific uses of mangroves were higher in non-deity mangroves than in sacralised and sanctuaries mangroves (Table 3). The second and the third rounds of analysis showed that other than the variable “category of mangroves”, sociodemographic characteristics such as respondents’ activities, number of children and location (village) influence the collection and selling of mangrove resources (Table 3). In fact, respondents who have more than ten children collect more fish and firewood than those who have less than five children (Table 3). Also, salt producers collect more firewood than farmers (Table 3). Regarding the impact of location (villages), construction wood is less collected in Avlo than Adouanko (Table 3).

5. Discussion

5.1. Perceived fish and plant diversity and their variation across the categories of mangroves (Hypothesis 1)

Mangrove ecosystems are fragile, and their sustainability depends on how they are exploited or utilised (Hakim et al., 2017). This study hypothesised that the perceived fish and plant diversity is high in sacralised and sanctuary mangroves. Our data did not support this hypothesis, since the number of plant and fish species reported by respondents did not vary significantly among the categories of mangroves. One reason may be the high mobility of fish species that are able to move far distances within mangrove ecosystems, and hence between the three categories of mangroves. Mangrove ecosystems in the Ramsar site 1017, where the study was conducted, belong to the same water body, and are tightly connected. This probably explains the fact that almost the same fish species were reported for the three mangrove categories. Still, respondents reported a large variation in the fish size across the categories of mangroves. They indicated that fish caught in sacralised and sanctuary mangroves are far bigger than those collected from non-deity mangroves. Fish diversity in this study was assessed based on respondents’ perception. In fact, it can be considered as basic work to stimulate more detailed research to better understand the utilisation and functioning of sacralised and sanctuary mangroves. Respondents investigated have lived for a long time (>15 years) in the communities and proved to have keen knowledge about the flora and fauna. Thus, their indications on fish and plant species can be considered reliable and be used as proxy for more precise field data, which were not

available (Southon et al., 2018). Furthermore, villagers regularly visit sanctuary mangroves for rituals and ceremonies in the study communities. And even if fishing activities are banned, people still fish in sanctuary and sacralised mangroves sometimes to feed their families violating the customary laws of the communities. Thus, their knowledge on the fish and plant species found in all mangrove categories is considerable. However, further studies based on direct fish sampling are needed to confirm our results, since some species that are not of interest for respondents might have been overlooked.

Like the fish species, no difference of perceived number of plant species was found between the three mangroves categories. Also, Zanco et al. (2021) found no impact of anthropogenic activities or geographical location on the diversity of plant species in mangroves in Benin, but rather an effect on their density and structural parameters. Other authors have already pinpointed the limited plant diversity occurring in West African mangroves (Ashton and Macintosh, 2002; Nagelkerken et al., 2008).

5.2. Proportion of users, specific uses, quantity of resources collected and their variation across the categories of mangroves (Hypotheses 2 and 3)

To meet their daily needs, a high proportion of people collect resources from non-deity mangroves but only few do so from sacralised and sanctuary mangroves, supporting our hypothesis 2. Our findings are consistent with Aheto et al. (2016) and Djagoun et al. (2022) who reported that the presence of divinities and associated customary laws refrain many people from collecting resources from sacred forests to avoid misfortunes. Our study further showed that the use value is higher for non-deity mangroves than for sacralised and sanctuary mangroves. This difference can probably be explained by the presence of the deities and a strong association between specific uses and the categories of mangroves is well illustrated by the correspondence analysis. For instance, sanctuary and sacralised mangroves were highly associated with less and moderately destructive uses, respectively. Non-deity mangroves on the other hand were mostly used in a highly destructive manner which, if not controlled, can exacerbate the degradation of the ecosystem, and compromise its functioning (Datola et al., 2022).

Like the proportions of users and the specific uses, the quantities of fish, firewood and construction wood collected were also larger in non-deity mangroves than sacralised and sanctuary mangroves, supporting our hypothesis 3 and illustrating to what extent resources of non-deity mangroves are under pressure in the study communities. As stated above, the presence of divinities in sacralised and sanctuary mangroves compels coastal residents to limit the exploitation of these resources. Apart from the legal regulations protecting mangroves in Benin, customary laws and indigenous rules have been established to manage sanctuary and sacralised mangroves. In the selected communities, it is strictly prohibited to extract plant resources from both sanctuary and sacralised mangroves. Informants explained that people who exploit these mangroves violate the legal and traditional arrangements and would be sanctioned if caught in the act. For instance, the cutting of mangrove trees in the sanctuary mangrove of Houakpè-Daho leads systematically to death, because the forest represents a pristine convent for the deity who founded their village. Thus, people never collect plant resources from this forest, although it is close to their settlements. The presence of deities and their associated totems, taboos, rules, and regulations play, therefore, a major role in reducing the quantities of fish, firewood, and construction wood harvested and subsequently promote sustainability of these mangrove categories. Also in Tanzania, sacred mangroves are believed to host ancestral spirits in the form of big fish (Shalli, 2017). Tree cutting, wood collection, fish harvesting, and all sorts of pollution is prohibited, and people who violate these bans can suffer different degrees of misfortunes, ranging from sickness to death.

5.3. Commercial value of the resources collected and their variation across the categories of mangroves (Hypothesis 4)

Mangrove resources in Benin are collected for domestic or commercial purposes (Tekka et al., 2019). We showed that the fish resources harvested from mangroves, irrespective of the category, are of high commercial value (ICV \geq 75%) and mainly sold. Many authors have already reported that fishing for commercial purpose is the primary activity carried out along the coast of Benin (Adite et al., 2013; Tekka et al., 2019; Gnansounou et al., 2021). Our informants also mentioned that because of the dwindling fish catch in the study communities, many local fishermen started violating the local rules of the communities, and fish around sacralised and sanctuary mangroves. They are generally sensitized, and even punished with the confiscation of fishing gear, ban of fishing, etc. depending on the case. All in all, fishermen collected fish from all the categories of mangroves mainly for selling purposes and our fourth hypothesis was not supported by the ICV of fish resources which was similar across all categories of mangroves. For plant resources on the other hand, the ICV varied significantly across the different categories of mangroves. Only plant resources collected from non-deity mangroves showed high commercial value (ICV = 95%) while those collected from sanctuary and sacralised mangroves (ICV = 13 and 27%, respectively) were of low commercial value. Thus, the majority of sold plant resources stem from non-deity mangroves while those collected from sanctuary and sacralised mangroves are used for domestic purposes, supporting our fourth hypothesis. The unlimited access to non-deity mangroves compromises the sustainability of these mangrove forests.

5.4. Drivers of the use and the commercialisation of mangrove resources (Hypothesis 5)

This study showed that the type of governance (the three categories of mangroves that we compared) highly affects the use and the commercialisation of mangrove resources. The quantities of firewood, construction wood and fish collected, as well as the use value were higher in non-deity mangroves than in sacralised and sanctuary ones (see univariate and multivariate analyses). Thus, sacralised and sanctuary mangroves are less threatened than non-deity mangroves. A similar conclusion was drawn by Zanvo et al. (2021) when comparing mangrove tree density in sacralised and non-sacralised mangroves in Benin. They reported that the higher tree density observed in sacralised mangroves was associated to the presence of the divinity “Zangbétou”. Also, Djagoun et al. (2022) concluded that the presence of local divinities promotes ecosystem services in sacred inland forests in northern Benin compared to non-sacred forests.

Beside the type of local governance (the categories of mangroves), locality also influenced the use of mangrove resources. Less construction wood was collected in the village Avlo than in Adouanko. Qualitative information revealed that the ban of unsustainable fishing activities such as juvenile and fingerling collection and the use of small-sized mesh nets are strictly respected in Avlo but not in other communities. In the Ramsar site 1017, where the study was conducted, Avlo is considered as a hotspot of mangroves in Benin. Therefore, conservation measures such as mangrove reforestation, community engagement and sensitization are well implemented there (Gnansounou et al., 2021).

As hypothesised, the number of children in the households also influences the use of mangrove resources. Respondents with >10 children harvest more firewood and fish than those having <5 children. It seems evident that large-sized families need more fuelwood for food preparation to satisfy their needs. Negative impacts of large family sizes on natural resources have already been reported by Pailler et al. (2015). Further, specific activities affect the use of mangrove resources in Benin. Salt producers collected more firewood than farmers, as already shown by other authors (Tekka et al., 2019; Adanguidi et al., 2020; Zanvo et al., 2021; Padonou et al., 2021; Gnansounou et al., 2022). Even though salt

producers are proposed novel solutions by civil society organizations such as salt production with solar energy or subsidized sales of firewood, they prefer mangrove wood, particularly from non-deity mangroves, because of their high calorific power, availability, and accessibility. In coastal Benin, the most harvested mangrove species for domestic use are *Rhizophora racemosa* and *Avicennia germinans* (Tekka et al., 2019; Gnansounou et al., 2022), because of their high calorific power and the more attractive colour they add to smoked fish (particularly *R. racemosa*). At the same time, these species are pivotal for ecosystem services due to their high capacity of carbon sequestration and their role as nursing and spawning areas for marine fish species.

5.5. Local deities and mangrove conservation: Lessons learned and insights for policy and management actions

This study showed that sanctuary mangroves are less prone to anthropogenic pressures than sacralised and non-deity mangroves as far as fish quantities, firewood- and construction wood collected from mangroves, as well as the proportions of people who collect these resources from each category of mangroves are concerned (see Table 2). Almost all interview partners (95%) collect resources from non-deity mangroves, half (54%) take resources from sanctuary, and less than a third (24%) from sacralised mangroves (Table 2). The same was true for the quantities of the different resources portraying that sanctuary mangroves may be more protected than sacralised mangroves. Only few sanctuary mangroves exist along the coast of Benin and information on their species composition, uses and local importance is limited. The initiative to sacralise mangroves is quite new causing a lot of reluctance and controversy. For instance, some informants complained about not being involved in the delineation of the sacralised areas in their communities. Christians hardly believe in the roles of local deities in mangrove conservation and with the rise of modern religion, people deny their support to the initiative refusing to accept the bans, rules and regulations associated with sacralised mangroves. Arising conflicts are managed internally or brought to local authorities for resolution. It is therefore critical to find consensus on the implementation of local deities to protect mangroves in the future. It is also indispensable for further studies to identify conflicts associated with mangrove sacralisation in Benin to strengthen this new conservation initiative. Sanctuary mangroves are generally managed locally with only limited resources available at the community level, whereas sacralisation is typically handled by local associations. To attain the desired mangrove conservation in Benin, it is essential to restore sanctuary mangroves and incorporate sacralisation into the national strategy of mangrove conservation.

Like Benin, many other coastal states have traditional rules, customary laws, deities, and local beliefs, which are, however, not being employed to conserve fragile and degraded coastal resources such as mangroves (Ahetou et al., 2016). A study conducted in the Mono Transboundary Biosphere Reserve shared by Benin and Togo found that mangroves are severely degraded on the Togolese side of the reserve, most likely because local stakeholders do not incorporate customary laws and traditional means in the conservation of the ecosystem as their counterparts in Benin, even though the two countries share similar beliefs (Gnansounou et al., 2022). Countries with these beliefs should be encouraged to make use of them to promote the sustainable management of mangroves and their ecosystem services.

6. Conclusion

There is a global consensus about the need to conserve mangroves because of the myriad of services and benefits they offer. The implementation of traditional beliefs and local deities is a positive and effective strategy that reduces anthropogenic pressures and enhances the sustainable use and preservation of mangroves. The comparison of three categories of mangroves, i.e. sacralised, sanctuary and non-deity

mangroves, underlined the importance of local deities and traditional beliefs to limit deterioration of mangroves. Sacred mangroves harbouring deities (sacralised and sanctuary mangroves) were less endangered than non-deity mangroves in terms of resources extraction (quantities of firewood, construction wood and fish collection, proportion of people who use each category of mangroves). Sanctuary mangroves are even less exposed to human activities than sacralised mangroves. Endogenous means such as traditional beliefs, customary laws and local deities can therefore contribute to the sustainable use of mangroves and are highly recommended to be applied in national and global decision-making to attain coastal resource protection and resilience. Furthermore, mangrove users such as salt producers and child-rich families should be routinely involved in the promotion of the sustainable use of mangroves. There are numerous mangroves regions to preserve in Benin, West Africa and worldwide. The importance of traditional beliefs in developing a sound conservation programme for mangroves cannot be overstated. These beliefs must first be further investigated, documented, and incorporated into projects and programmes aiming at mangrove conservation and restoration.

CRedit authorship contribution statement

Setondé Constant Gnansounou: Conceptualization, Data curation, Formal analysis, Investigation, Methodology, Visualization, Writing – original draft, Software, Validation. **Kolawolé Valère Salako:** Data curation, Formal analysis, Methodology, Validation, Visualization, Writing – review & editing, Software. **Corentin Visée:** Data curation, Formal analysis, Writing – review & editing, Validation, Visualization, Methodology, Software. **Farid Dahdouh-Guebas:** Funding acquisition, Validation, Visualization, Writing – review & editing. **Romain Glèlè Kakai:** Methodology, Validation, Visualization, Writing – review & editing, Software. **Patrick Kestemont:** Conceptualization, Funding acquisition, Methodology, Project administration, Resources, Supervision, Validation, Visualization, Writing – review & editing. **Sabine Henry:** Conceptualization, Data curation, Formal analysis, Funding acquisition, Methodology, Project administration, Resources, Supervision, Validation, Visualization, Writing – review & editing.

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.

Data availability

Data used for this study are available and can be provided by the corresponding author upon reasonable request.

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Appendix A. Supplementary data

Supplementary data to this article can be found online at <https://doi.org/10.1016/j.forpol.2023.103145>.

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