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Research Article

Local Perceptions of Ecosystem Services Provided by Forest and Mangrove Ecosystems in the Saloum Delta National Park, Senegal

Assane Ka[1, *], Serigne Modou Sarr[1], Bocar Samba Ba[2], Alioune Badara Diop[6], Aliousseyni Ly[4], Papa Diene Faye[1, 5], Dogo Seck[3]

[1]Doctoral School of Science and Technology and Social Sciences, Higher Institute of Agricultural and Rural Training Senegal, Alioune DIOP University, Bambey, Senegal

[2]Department of Agri-Food Economics and Consumer Sciences, Faculty of Agricultural and Food Sciences, Laval University, Quebec, Canada

[3]National Academy of Science and Technology of Senegal, Dakar, Senegal

[4]Institute of Water and Energy Sciences Including Climate Change, Pan African University, University of Tlemcen, Tlemcen, Algeria

[5]Interdisciplinary Doctoral School in African Development, Senghor University, Alexandrie, Egypt

[6]School of Integrated Planning and Management of Forests and Tropical Territories, Regional Post-University, Kinshasa, Congo

Abstract

This paper focused on the perceptions of communities living along the Saloum Delta National Park (SDNP), located in the Saloum Delta Biosphere Reserve (SDBR), of the ecosystem services (ES) provided by the mangrove and forest ecosystems. Through semi-structured surveys of 103 individuals in seven villages, the analysis revealed that the SDNP offers a diversity of 21 ecosystem services classified into three categories: provisioning, regulation and cultural. The most popular ones are fishing (72.8%), oyster harvesting (65.1%), pharmacopoeia (64.1%), firewood (54.4%), aesthetics (90.3%) and protection against erosion (93.2%). The species Rhizophora mangle stands out as the best known and most widely used mangrove, with a high use value (UV= 3.09) and a strong informant consensus (FCI> 0.97). Although socio-demographic factors do not significantly influence the use of services, occupation (particularly farmers) and area play a role in the diversity of uses. The services provided by mangroves are more numerous and better known than those provided by forests, reflecting the ongoing dependence of populations on this ecosystem. These results underline the strategic importance of the PNDS in local development and point out for sustainable and participatory management of its resources, through development of fishery products, strengthening of facilities, raising awareness of rational exploitation and the restoration of degraded habitats, particularly mangroves.

*Corresponding author: assaneka86@hotmail.com (Assane Ka)

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Keywords

Saloum Delta National Park (SDNP), Ecosystem Services, Community Perceptions, Mangrove, Forest, Use Value (UV), Informant Consensus Factor (ICF)

1. Introduction

Biosphere reserves are areas of terrestrial and coastal/marine ecosystems that aim to promote solutions to reconcile the conservation of biodiversity and sustainability [1]. In addition to their function of conserving biological diversity, biosphere reserves contribute to sustainable human development through provision of goods and ecosystem services. These goods and services are referred to as "ecosystem services" [2], defined by [3] as "the benefits that people derive from ecosystems". The [3] has grouped ecosystem services into four main categories:

(i) provisioning or production services such as food, water, wood and fiber;
(ii) regulating services, which include climate regulation, flood control, disease control, water quality and waste assimilation;
(iii) cultural services, which include recreational and aesthetic values and spiritual benefits; and
(iv) supporting services, which include soil formation, photosynthesis and cyclical elements.

The Saloum Delta Biosphere Reserve (SDBR) covers 334,000 ha of the 500,000 ha covered by the Saloum Delta watershed. It occupies almost the entire estuarine zone of the Sine Saloum delta, i.e. more than 2/5ths of its area [4]. The Saloum Delta National Park (PNDS) covers 76,000 hectares. The park combines the characteristics of a marine, estuarine, lacustrine and palustrine wetland [5], and stands out for its high biodiversity potential, particularly for the important role it plays in the migration of Western Palearctic birds, in the global hydrological cycle and in the supply of water for the conservation of biological diversity, human consumption, agricultural production and recreation [5]. Local populations benefit from fish products (fish, shrimps, oysters, arches, cymbiums and murex), forest products (firewood and timber, honey, Daterium senegalensis, Saba senegalensis, pain se singe) and ecotourism products [6]. The diversity of services and specific ecosystems thus represents significant potential for the development of local populations [6].

However, a regressive trend has been reported for all ecosystems and for most animal and plant species. Tree cover has declined by more than 50% in 20 years. This decline is accompanied by a 22% loss in floristic diversity, fragmentation of ecosystems and threats of habitat loss. The gallery forests are the most threatened on the mainland. The over-salination of certain channels is at the root of the loss of biodiversity in the mangrove ecosystem. The maritime part is currently marked by marine erosion, which in places is making certain bird and sea turtle breeding islands vulnerable. Reduced rainfall is also one of the main causes of this deterioration in the wild habitat. Added to this are the covetousness of people living on the periphery (who are highly dependent on natural resources because of their relative poverty), pressure from land ownership and wildlife poaching [4, 7, 5].

In addition, the protected area management approach currently being implemented makes these sites important levers in the fight against poverty on their periphery. The Government of Senegal, with the support of the Sustainable Management of Wetlands to Strengthen Food Security and Ecosystem Resilience in West Africa (GDZHAO) project, is aiming to provide these sites with the means to cope with poverty.

(GDZHAO), aims to provide wetland users and managers with tools for planning, negotiating and monitoring conservation and sustainable development actions in wetlands. The implementation of sustainable management mechanisms requires data on the goods and services associated with peripheral populations.

It is in this context that the present study is being carried out, with the general aim of understanding the perceptions of local people regarding the various ecosystem services provided by the Saloum Delta National Park (SDNP).

2. Saloum Delta National Park (SDNP) Presentation

2.1. Geographical Context

This study was carried out in the Saloum estuary, located on the Petite Côte in west-central Senegal. The area lies between latitudes 13°35' and 14°10' North and longitudes 16°50' and 17°00' West. The estuary, classified as an inverted estuary due to its atypical hydrological functioning, takes the form of an arm of the sea penetrating deep into the land, framed by particularly dense mangrove vegetation. It covers an estimated area of around 80,000 hectares and is structured around three main islands: Gandoul in the north, Bettenty in the centre and Fathala in the south [8-10]. These island units are separated by a heavily silted-up estuarine zone, known locally as "Diombos" [11].

The mangrove is mainly located in the western part of the Saloum region. It is bounded by the department of Fatick to

the north, the Gambia to the south, the Atlantic Ocean to the west, and part of the department of Foundiougne to the east [12]. Geomorphologically, the Saloum estuary is made up of four main distinct areas:

(i) barrier beaches of recent and Quaternary origin,
(ii) sandy terraces of between 1 and 2 metres in height,
(iii) terraces of between 0.5 and 1 metre in height, and
(iv) mangrove swamps and tannes.

There are three main types of tannes: flooded tannes, living tannes and herbaceous tannes. Fieldwork was carried out at seven (07) study sites located in the commune of Toubacouta: Missirah (13°40'; 16°30'), Djinack Bara and Diatoko (13°60'; 16°53'), Massarinko (13°35'; -16°28'), Bettenty (13°40'; 16°37'), Bagadadji (13°39'; -16°29') and Bossinkang (13°72'; 16°57') (see Figure 1).

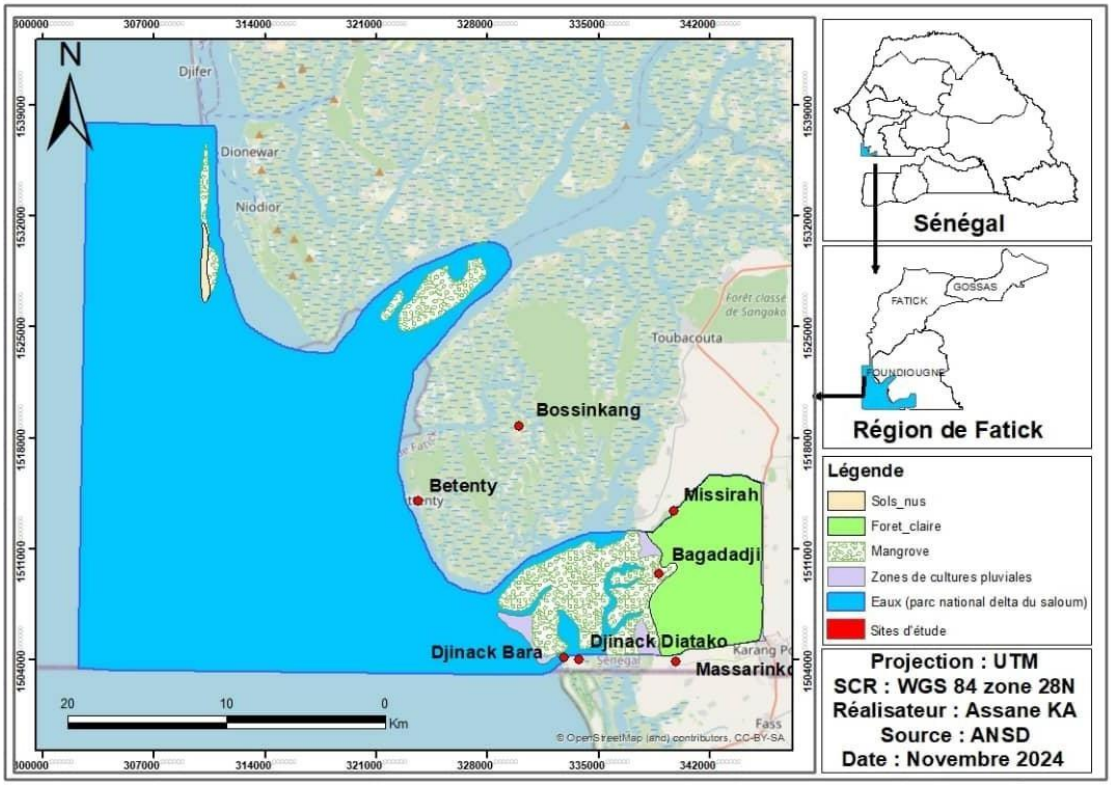

Figure 1. *Study area.*

2.2. Socio-Economic and Climatic Data of Toubacouta Municipality

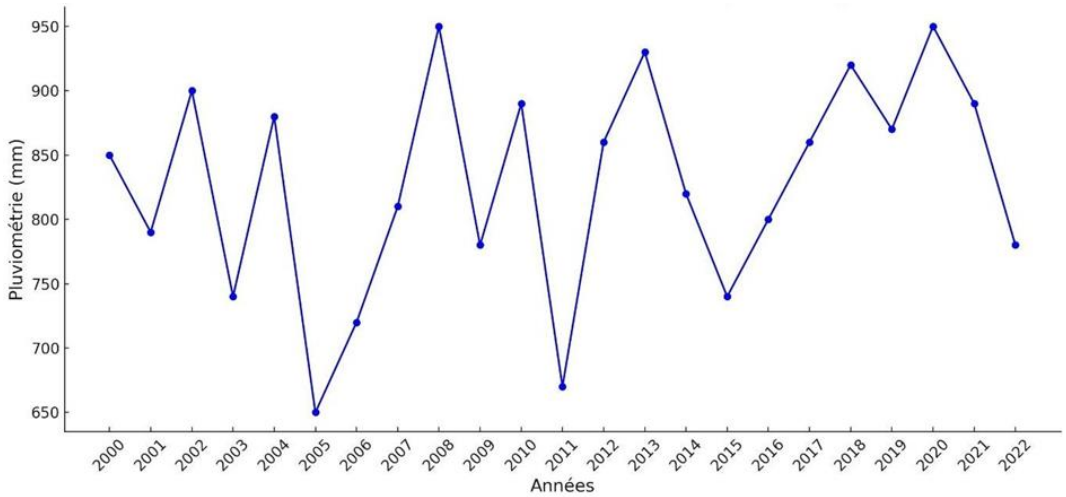

Figure 2. *Rainfall in Toubacouta from 2000 to 2022 (ANACIM, 2022).*

The municipality of Toubacouta covers an area of 170 km^2 and has an estimated population of 37,529, with an average density of 220 inhabitants/km^2 [13]. The population is characterised by a high proportion of young people. The main sources of income include agriculture, fishing, livestock farming, the collection of non-timber forest products, as well as activities related to tourism and handicrafts. Other economic sectors, such as salt extraction and shellfish processing, also play a significant role. Involvement in these different activities is often influenced by the ethnicity and preferences of the men in the community.

In terms of climate profile, Toubacouta is located in a tropical Sudano-Guinean climate zone. This is characterised by a relatively short rainy season, lasting around three months, and a long dry season lasting nine months. The main winds affecting the region are the continental trade winds and the monsoon [14]. Annual temperatures range from 20.6 ℃ to 36.8 ℃, while average annual rainfall varies between 600 and 900 mm [14].

2.3. Soil, Flora and Hydrological Characteristics of the Municipality of Toubacouta

The municipality has a markedly heterogeneous soil profile, with five main soil types. These include ferruginous tropical soils, known locally as "Dior soils". These are characterised by their light texture and high permeability. There are also predominantly sandy-clay soils, known as "Deck-Dior", which combine a loose structure, stability and a high organic matter content. Hydromorphic or 'Deck' soils are particularly rich in nutrients and organic matter. Then there are the tannas, which cover around 5% of the total surface area. These soils, which are acidic and salty, have limited fertility, making their agricultural use uncertain [14].

The natural vegetation of Toubacouta is diverse. It includes gallery forests, wooded savannahs and shrubby savannahs. The commune is also bordered by mangrove formations, represented by species such as Rhizophora racemosa G. Mey, Rhizophora mangle L., Avicennia africana P. Beauv, Laguncularia racemosa (L.) C. F. Gaertn. and Conocarpus erectus L. Behind the mangrove is a narrow area of tanne, home to halophilic vegetation. This consists of a herbaceous layer dominated by Sesuvium portulacastrum L. and Paspalum vaginatum Sw., and a shrub layer including Tamarix senegalensis DC, Elaeis guineensis Jacq. and Acacia sieberiana DC.

The ecological conditions of the municipality, especially in the diversity of flora, the presence of several watercourses, a relatively humid climate and the existence of protected areas such as Néma, Sangako and the Saloum Delta National Park (PNDS) favour a notable wealth of fauna [14]. Finally, Toubacouta's hydrographic network is very dense. It is made up of run-off water and at least 151 low-lying areas throughout the municipality [14].

3. Methodology

3.1. Sampling

In order to understand the community's perception about the socio-economic and ethnobotanical importance of the PNDS, surveys were carried out among the local population. For the sake of representativeness, seven (07) villages located on the park were involved. These were Bagadadji, Djinack Bara, Bettenty, Massarinko, Missirah, Djinack Diatoko and Bossinkang. To determine the number of people in each village, the databases of the Agence Nationale de la Statistique et de la Démographie (ANSD) and the PNDS were used. The number of people to be surveyed was selected on the basis of Ficher's formula 1. Out of 15003, 103 were selected, representing a sampling rate of 0.69%. The sample size for each village was proportional to its size in the total population (Table 1).

$$nf = \frac{n}{1+\frac{n}{N}}$$

n = 1/d^2 nf= sample size;
d = degree of error =10%;
N = total number of people.

Table 1. *Distribution of respondents by village.*

Villages	Number of people	Sample
Bagadadji	196	3
Massarinko	686	5
Djinack Bara	618	4
Bettenty	7486	49
Missirah	2978	20
Djinack Diatoko	204	3
Bossinkang	2835	19
Total	15003	103

3.2. Conduct of the Surveys

The surveys conducted were semi-structured. Respondents were selected randomly and interviewed individually. The survey questionnaire covered the socio-demographic characteristics of the respondents, the importance of ecosystem services and the different forms of use.

3.3. Data Processing

The data was collected using the Kobotoolbox tool and then processed using Excel. The Tukey test, at the 5% threshold, was used to separate the means after the ANOVA test, using R software (version 3.4.2). Khi^2 tests of independence followed by correspondence factor analysis and hierarchical ascending classification were applied to classify villages according to ecosystem services and to determine the importance of ecosystem services according to socio-demographic characteristics (religion, level of education, age and gender). The ethnobotanical studies involved calculating the following parameters:

3.3.1. Frequency of Quotations

We determined the frequency of quotation (FC) for each category of use. This is obtained from formula (1) below:

$$FC = \frac{\text{Number of citations for use of the service}}{\text{Number of surveyed people}} * 100 \quad (1)$$

When FC is close to 0, the service can be considered to be lightly used, while a FC close to 100 indicates that the service is strongly used [15]. The frequency with which SEs are cited, showing the number of times, a service was cited by a respondent, is calculated and grouped according to the four SE categories.

Use value (UV)

For each service cited, a Use Value (UV) defined by Phillips et al (1994) was determined. The use value is a way of expressing the relative importance of each service for the population of provisioning services [16, 17] according to the following formula (2):

$$VU = \frac{\sum U}{N} \quad (2)$$

U: number of times a service is cited for a usage category and
N: total number of respondents

3.3.2. Informative Consensus Factor (ICF)

The level of public consensus on the uses of ES was determined by calculating the Informant Consensus Factor (ICF) defined by [16]. The value of the ICF varies between 0 and 1 and indicates a high level of consensus when it tends towards 1 [18]. A high value of ICF (closer to 1) is obtained when only one or a small number of services are cited by a large proportion of informants for a category of use. Conversely, its value is lower (closer to 0) when a wide variety of services are cited for the same use [19]. The CFI is calculated using formula (3) below:

$$\text{FCI} = \frac{\text{Nur} - \text{Nt}}{\text{Nur} - 1} \quad (3)$$

Where:
Nur = number of citations for each category,
Nt = number of services for the same category.

3.3.3. Level of Fidelity (NF)

The level of Fidelity (NF) of a species was calculated in relation to different categories of use using the following formula (4) [17].

$$NF = \frac{Number\ of\ citations\ of\ the\ species\ for\ one\ use\ category}{Number\ of\ citations\ of\ the\ species\ for\ all\ use\ categories} * 100 \quad (4)$$

4. Results

4.1. Identification of the Socio-Demographic Profile of Communities Bordering the SDNP

Analysis of variance reveals no significant difference between villages regarding age (P-value = 0.136). However, arithmetically, the oldest people were found in Bagadadji (53±22 years old), Missirah (42±7 years old) and Djinack Diatoko (42±3 years old) and the Betenty (38±12 years), Bossinkang (36±11 years), Djinack bara (39±3 years) and Djinack Diatoko (39±3 years). Massarinko (34±8 years).

There was a significant difference between villages according to their level of education (P- value= 0.0459). The majority of the PNDS population is educated in Koranic schools. In Betenty, on the other hand, 16.32% of respondents had attained primary education and 20% of respondents in Massarinko had reached university level (Table 2).

A highly significant difference (P-value< 0.0001) was observed between villages in terms of gender and occupation. Women were predominantly represented in the villages of Bagadadji (66.67%), Betenty (79.59%), Bossinkang (68.42%) and Missirah (89.47%) compared with the villages of Djinack bara, Djinack Diatoko and Massarinko, where men are more represented (100%). Fishing (fish, prawns, oysters) is the main activity in all the villages in the PNDS. However, agriculture dominates in the village of Massarinko and is practised by 60% of respondents (Table 2).

Table 2. Socio-economic and demographic characteristics.

Villages		Bagadadji	Betenty	Bossinkang	Djinack bara	Djinack Diatako	Massarinko	Missirah	P-value
Gender	Women	66,67	79,59	68,42	0	0	0	89,47	< 0,0001
	Men	33,33	20,41	31,58	100	100	100	15,79	
Age		53±22	38±12	36±11	39±3	42±3	34±8	42±7	0.136
Education rate (%)	Koranic school	100	83,67	100	100	100	80	100	0.0459
	Primairy	0	8,16	0	0	0	0	0	
	Secondary	0	8,16	0	0	0	0	0	
	University	0	0	0	0	0	20	0	
Occupation (%)	Fishman	66,67	100	100	100	100	40	100	< 0,0001
	Farmers	33,33	0	0	0	0	60	0	

4.2. Ecosystem Services Provided by the PNDS to Local Communities

The PNDS provides a variety of ecosystem services to the local population. A total of 21 services, divided into 3 categories (provisioning, regulating and cultural) were cited by the population surveyed. Provisioning (50%) was the most frequently cited category, followed by cultural services (27%) and regulation (23%). Among supply services, fish (72.82%), oysters (65.05%), pharmacopoeia (64.08%), firewood (54.37%) and shellfish (49.51%) were the most popular. For cultural services, aesthetics (90.29%), ancestral value (67.96%), tourism (30.10%) and recreational value (19.42%) are the most cited. In terms of regulating services, protection against erosion and flooding (93.20%), protection of animal habitats (47.57%) and protection against strong winds (32.04%) are the most frequently mentioned (Figure 3).

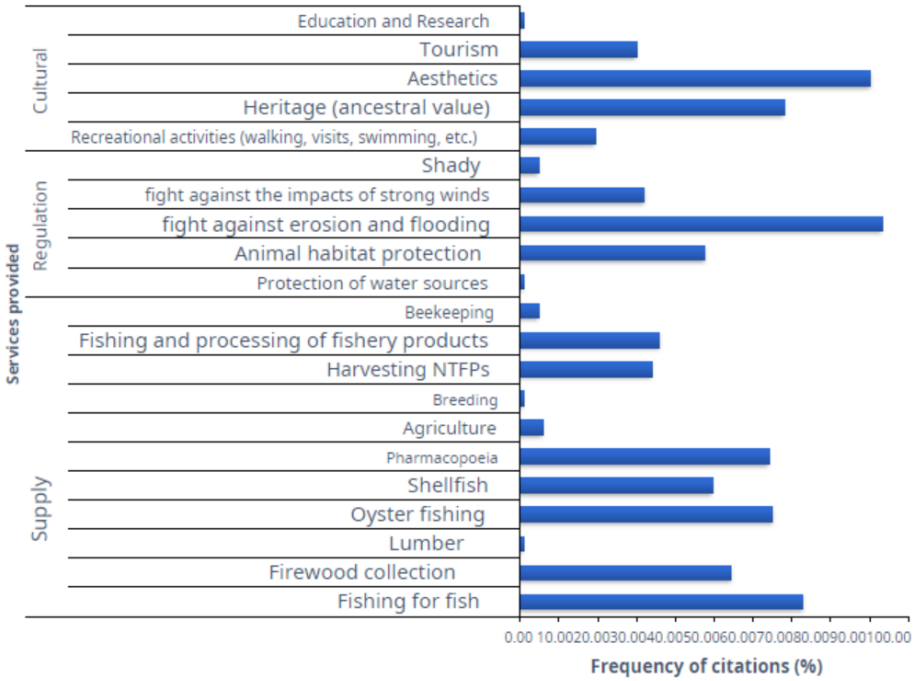

Figure 3. PNDS services ranking.

4.3. Variation in Ecosystem Services by Village

The Khi^2 independence test showed a strong dependence between villages and provisioning services (P-value = 1.87e-9), cultural services (P-value = 4.63e-6) and support or regulation services (P-value = 2.2e-16). Hierarchical ascending classification enabled us to distinguish 4 groups of villages (G1, G2, G3 and G4) according to services (Figure 4).

Massarinko represents the first group (G1), where agriculture, education and research are more common.

Group G2 consists of Bagadadji, which is characterised by beekeeping and livestock breeding.

Group G3 comprises the villages of Betenty and Bossinkang, and is characterised by a high diversity of use categories, including fishing (fish, oysters, shellfish), gathering of non-timber forest products (NTFPs), pharmacopoeia, processing of fish products, protection against erosion, wind and flooding, habitat protection, ancestral and recreational values, and wood (fuel, timber). The third group, G4, includes Missirah, Djinack Bara and Djinack Diatako, which are characterised by services related to tourism, aesthetics and shade, as well as pharmacopoeia (Figure 4).

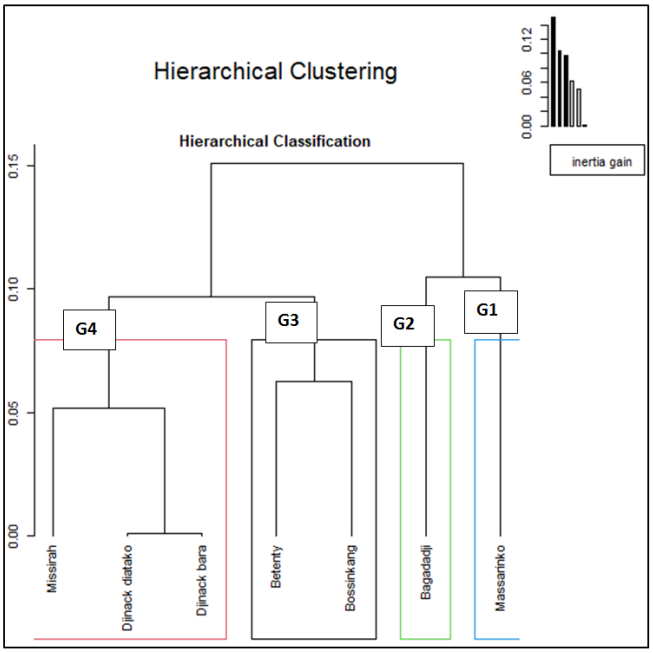

Figure 4. Ranking services provided by village.

4.4. Diversity of Mangrove Services

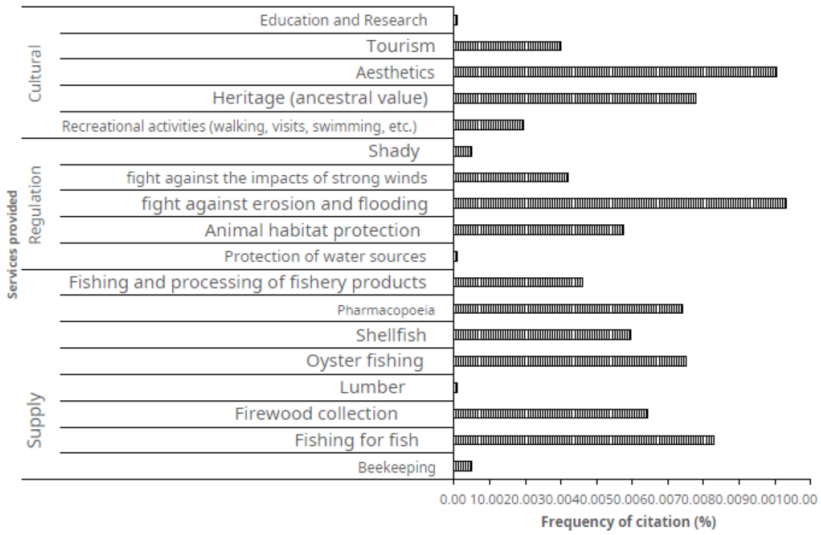

Figure 5. mangroves services ranking in PNDS.

According to the population surveyed, the PNDS mangrove provides a total of 17 services, again divided into 3 categories: supply, regulation and cultural. Fish fishing (72.82%), oyster fishing (65.05%) and pharmacopoeia (64.08%) were the most cited for the supply service. For the regulation service, the mangrove fights against erosion and flooding (93.20%), fights against violent winds (32.04%) and protects fish (47.57%). In terms of cultural services, aesthetics was cited most often (90.29%), followed by ancestral value (67.96%) and tourism (30.10%) (Figure 5).

4.5. Diversity of Forest Services

Figure 6 provides information on the ecosystem services obtained in the forest of the PNDS. This analysis shows that the respondents benefit from 6 ecosystem services divided into 3 categories: supply (70.85%), cultural (16.46%) and regulation (2.69%). Among supply needs, firewood (67.96%), NTFPs (54.37%) and pharmacopoeia (30.1%) are the most valued. For cultural needs, aesthetics is cited most often (57.28%). With regard to regulating services, shade was mentioned by 5.83% of respondents.

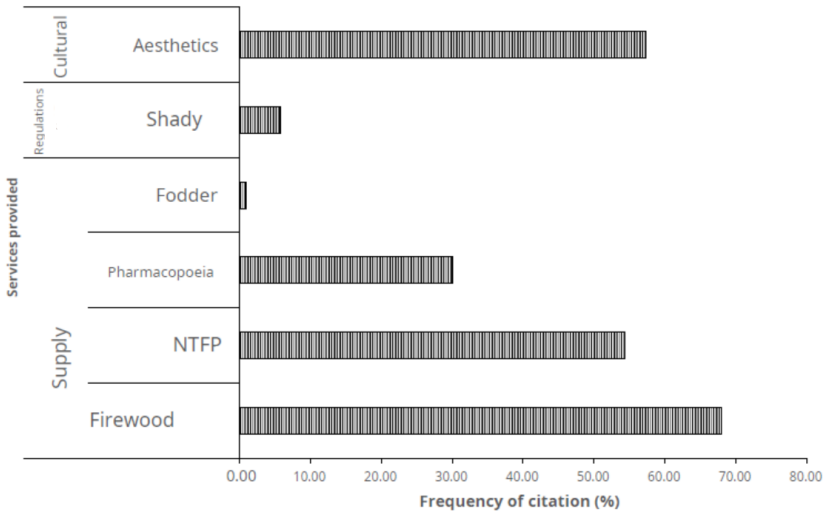

Figure 6. *Ranking services provided by the forest.*

4.6. Analysis of the Population's Perception of the Ecosystem Services of the PNDS

4.6.1. Diversity and Knowledge of Mangrove Species

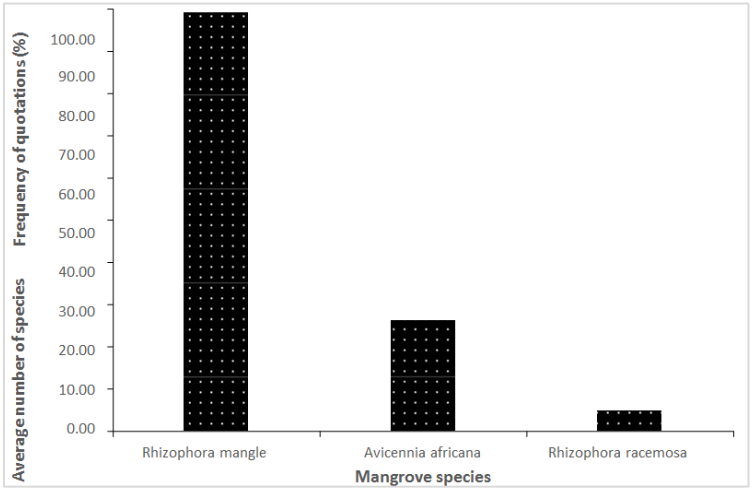

Figure 7. *Citation frequencies of known mangrove species.*

Figure 7 highlights the surveyed population's knowledge of mangrove species. Of the 6 mangrove species present in the area, Rhizophora mangle is by far the best known, cited by 99.03% of respondents. Avicennia africana and Rhizophora racemosa are also known by 26.21% and 4.85% of respondents respectively.

4.6.2. Influence of Socio-Demographic Factors on Mangrove Species

Knowledge of mangrove species depends on socio-demographic factors. Ethnicity (P-value= 0.447), gender (P-value= 0.881), level of education (P-value= 0.205), occupation (P-value = 0.179) and age (P-value = 0.0993) do not influence knowledge of mangrove species.

However, the ANOVA test showed that the number of species cited is very strongly influenced by locality (P< 0.0001). The average number of species known is 2 for the villages of Bagadadji and Bossinkang, compared with 1 for the villages of Betenty, Djinack bara, Djinack Diatako, Massarinko and Missirah (Figure 8).

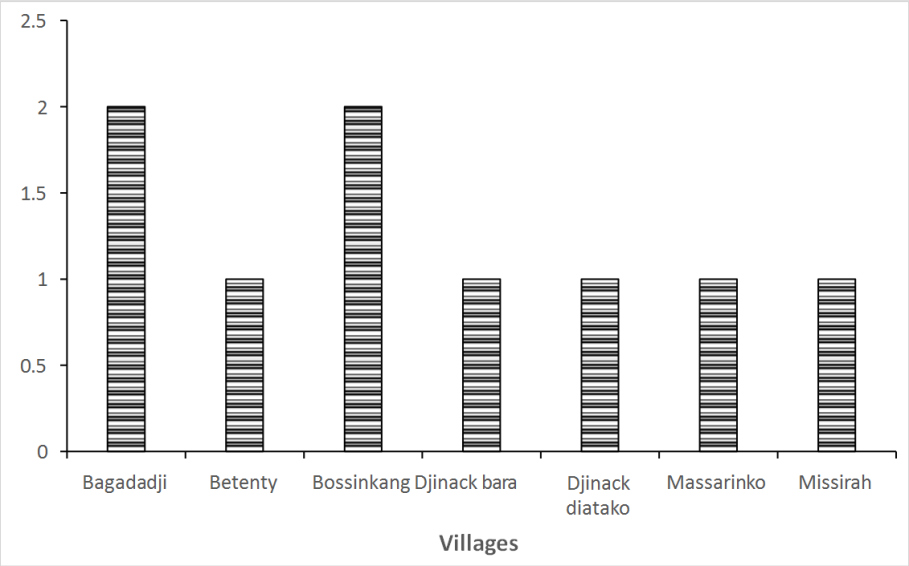

Figure 8. *Variation of known mangrove species by village.*

4.6.3. Influence of Socio-Demographic Factors on the Use of Mangrove Species

Table 3 shows the variation in the frequency of use of species according to socio-demographic parameters. The latter did not influence usage frequencies (P≥0.05). Nevertheless, the use of mangrove species was higher among women (4.29±3.05) and older people (4.12±3.03%). The Bambara (8.74%) and the Socé (4.1±2.83%) are the most decisive in the uses of the species. Farmers (4.85±3.54%) had a greater influence than fishermen (4.05±2.75%). In terms of level of education, frequencies were higher among university graduates (8.74%) and those educated in Koranic schools (4.17±2.80%).

Table 3. *Influence of socio-demographic factors on the use of mangrove species.*

Factors	Modalities	Average of use	P-value
Sexe	Hommes	3,58±1,95	0,228
	Femmes	4,29±3,05	
Age	< 45	4,12±3,03	0,907
	> 45	4,05±2,66	
Ethnic groups	Bambara	8,74±00	0,198
	Peulh	1,46±0,69	

Factors	Modalities	Average of use	P-value
Literacy	Sérère	3,88±1,75	0,0991
	Socé	4,1±2,83	
	Koranic school	4,17±2,80	
	Primary	2,43±0,56	
	Secondary	2,18±1,46	
	University	8,74±00	
Profession	farmer	4,85±3,54	0,567
	fishman	4,05±2,75	

4.6.4. Influence of Socio-Demographic Factors on Ecosystem Services

Table 4 shows the variation in the frequency of use of ecosystem services according to age, gender, ethnicity, level of education and occupation. Comparison of means tests showed no significant difference for all socio-demographic factors (P≥0.05) except for occupation (P-value=0.000493). Mangrove services are more appreciated by women (7.86±1.85%), older people (7.88±3.59%) and Bambaras (9.71±00%). In terms of level of education, the frequency of use of cash is highest among university graduates (9.71±00%). In terms of occupation, use of services was significantly more frequent among farmers (11.89±9.05%) than among fishermen (7.50±1.84%).

Table 4. *Socio-economic and socio-demographic influence on factors on mangrove services.*

Factors	Modalities	Use mean frequency	P-value
Gender	Men	7,25±3,60	0,258
	Women	7,86±1,85	
Age	< 45	7,88±3,59	0,562
	> 45	7,57±1,85	
Ethnic groups	Bambara	9,71±00	0,821
	Peulh	7,77±1,37	
	Sérère	7,23±1,29	
	Socé	7,69±2,65	
	Koranic school	7,75±2,59	
Education rate	Primary	6,80±1,12	0,505
	Secondary	6,31±1,68	
	University	9,71±00	
Profession	Farmer	11,89±9,05	0.000493
	Fishman	7,50±1,84	

4.6.5. Variation in Mangrove Services by Village

The use frequency of mangrove services varied significantly between villages (P-value = 0.035). However, mangrove services are more appreciated in the villages of Bossinkang (8.23%), Betenty (7.07%), Bagadadji (6.80%) and

Djinack Diatoko (6.80%) (Figure 9).

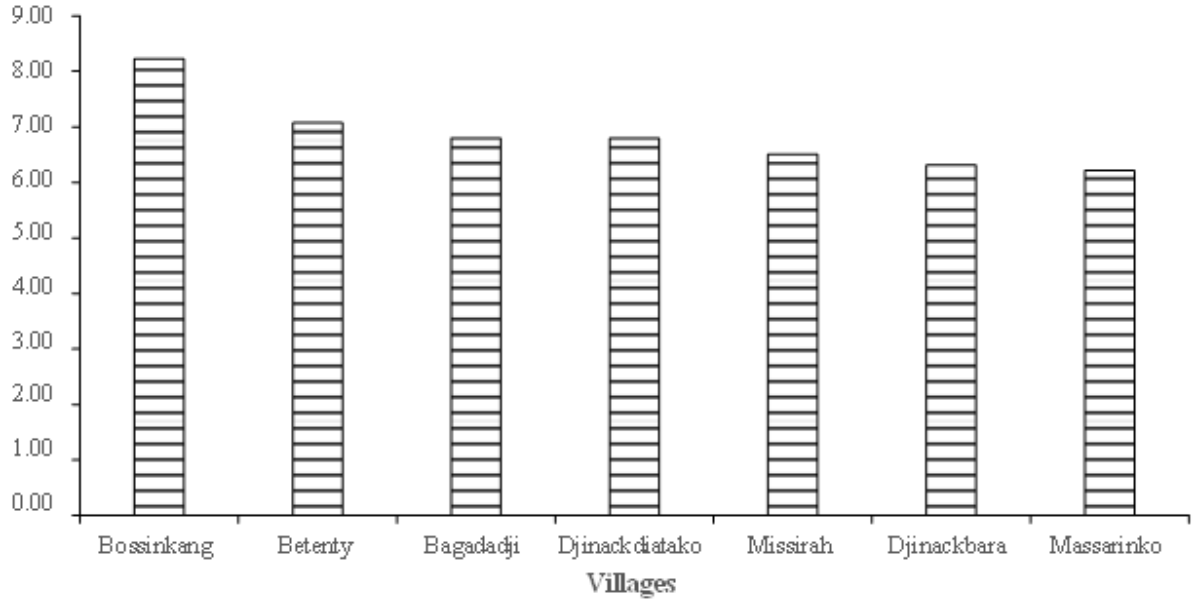

Figure 9. *Frequency use of mangrove services per village.*

4.6.6. Overall Preferences for Mangrove Species

Analysis of Table 5 shows that the use values obtained by considering the different use categories vary according to the species. Among mangrove species, Rhizophora mangle is the most valued species (VU = 3.09), followed by Avicennia africana (VU = 0.91) and Rhizophora racemosa (VU = 0.19).

Table 5. *Use values of mangrove species.*

Species	Number of citations	Use value (VU)
Rhizophora racemosa	20	0,19
Rhizophora mangle	318	3,09
Avicennia africana	94	0,91

4.6.7. Consensus Factors and Fidelity Levels of Mangrove Services and Species

Table 6 shows a broad consensus among respondents on the various ecosystem services identified in the mangrove. The CFI is greater than 0.9 for all the ecosystem services provided by the mangrove, which shows that the populations are in complete agreement about these services. In other words, high CFI values are obtained when only one or a small number of services are cited by a large proportion of informants for a category of use and which can be identified with the NF.

Table 6. *Informative consensus table of ecosystem services provided by mangroves.*

Service	Number of Citations	Number of services	FCI
Provisioning service	400	8	0,98
Regulation department	184	5	0,97
Cultural department	215	5	0,98

Examination of Table 7 shows that all the species known to the population are used by local people. Table 7 also shows a low level of fidelity (NF) varying between 7.41 and 26.73% for the most cited species and the highest use categories. The NF for the use of Rhizophora mangle is high for aesthetics (26.73%), pharmacopoeia (22.64%) and the protection of fish (16.04%). Rhizophora racemosa is used more for oyster fishing (25%) and firewood (20%). Avicennia africana is valued more for shade (14.81%) and more or less for pharmacopoeia (17.28%).

Table 7. Level of fidelity (%) of mangrove species.

Species	Aesthetics	Wood heating	Oyster fishing	Pharmacopoeia	shading	Animal protection fishery
R racemosa	20	20	25	20	0	15
R mangle	26,73	14,15	20,44	22,64	0,00	16,04
A africana	13,58	7,41	19,75	17,28	14,81	13,58
L racemosa	0	0	0	0	0	0
C erectus	0	0	0	0	0	0

4.6.8. Sociodemographic Factors Influencing Forest Species and Ecosystem Services

Table 8 shows the variation in the frequency of use of forest species according to socio- demographic factors. Comparison of means tests showed no significant difference for age, sex, ethnicity, level of education or occupation (P≥0.05). On the other hand, the frequency of use of species was more significant for women (4.65±3.78%), younger people (4.80±3.41%) and farmers (5.34±4.08%). In terms of ethnic groups, forest species were more popular with the Bambara (7.77±00%) and the Sérères (4.96±3.84%). The better educated, particularly university students (7.77±00%) and secondary school students (7.52±0.49%), are more involved in the use of species.

Table 8. Influence of socio-demographic factors on forest species.

Factors	Modalities	Mean Frequency of use	P-value
Gender	Men	4,16±3,11	0,521
	Women	4,65±3,78	
Age	< 45	3,85±3,89	0,213
	> 45	4,80±3,41	
Ethnic groups	Bambara	7,77±00	0,577
	Peulh	1,94±2,74	
	Sérère	4,96±3,84	
	Socé	4,47±3,56	
	corani school	4,24±3,55	
Education rate	Primary	6,55±4,58	0,139
	Secondary	7,52±0,49	
	University	7,77±00	
Profession	Famer	5,34±4,08	0,633
	Fishman	4,46±3,58	

Table 9 shows the variation in the frequency of use of forest services according to socio- demographic factors. Comparison of means tests showed no significant difference for age, gender, ethnicity, level of education or occupation (P≥0.05). The frequency of use of services was higher among men (2.27±1.29%) than among women (2.02±1.55%). The Bambara (4.85±00%) and the Socé (2.09±1.45%) benefit more from forest services. In terms of level of education, use is highest among university graduates (4.85±00%). In terms of occupation, farmers (3.40±1.25%) were more important in the use of forest service.

Table 9. Influence of socio-demographic factors on the use of forest services.

Factors	Modalities	Mean Frequency of use	P-value
Gender	Men	2,27±1,29	0,426
	Women	2,02±1,55	
Age	< 45	1,74±1,59	0,121
	> 45	2,27±1,40	
Ethnic groups	Bambara	4,85±00	0,311
	Peulh	1,94±2,75	
	Sérère	1,94±1,46	
	Socé	2,09±1,45	
	Koranic school	2,02±1,48	
Education rate	Primary	2,43±1,68	0,162
	Secondary	2,91±00	
	University	4,85±00	
Profession	Famer	3,40±1,25	0,0734
	Fishman	2,05±1,47	

4.6.9. Relationships Between Forest Services, Villages, and Preferences for Forest Species

A highly significant difference (P-value<0.0001) was observed between villages regarding the services obtained from

the forest. Forest services were valued more highly in Massarinko, Bossinkang and Betenty, with mean frequencies of use of 3.69%, 3.27% and 2.28% respectively (Figure 10).

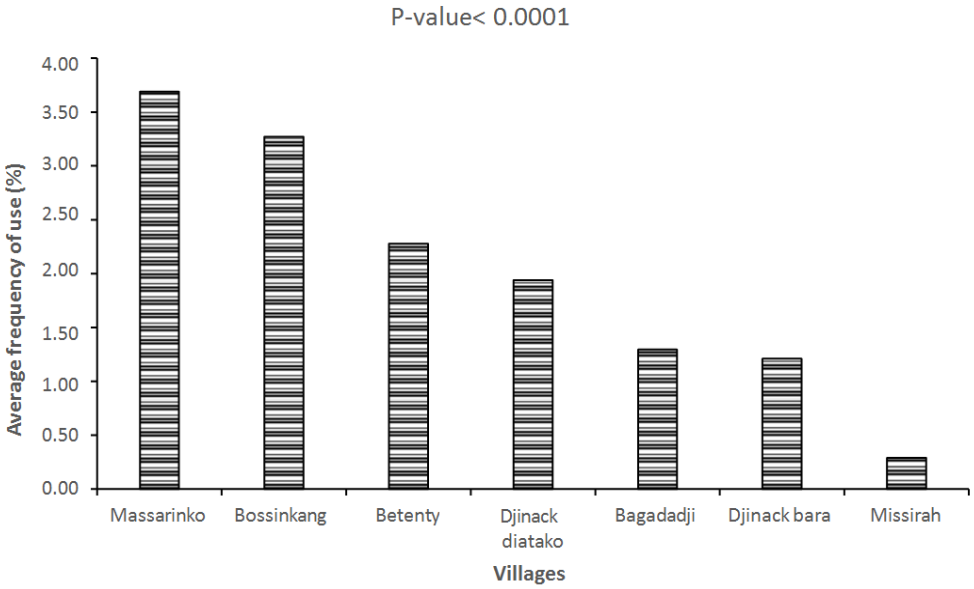

Figure 10. *Use Frequency of forest services by village*

Table 10 shows respondents' preferences for forest species in the PNDS. Overall, Neocarya macrophylla, Detarium senegalense and Cocos nucifera are the species most used by respondents, with usage values (VU) of 1.25, 1.23 and 1.09 respectively. On the other hand, the services of Adansonia digitata (VU =0.7) and Anacardium occidentale (VU = 0.36) are less appreciated by respondents.

Table 10. *Use values of forest species cited.*

Species	Number of mentions	Use value (VU)
Detarium senegalense	127	1,23
Neocarya macrophylla	129	1,25
Adansonia digitata	72	0,70
Anacardium occidentale	37	0,36
Cocos nucifera	112	1,09

4.6.10. Consensus Factors and Fidelity Levels of Forest Services and Species

Table 11 shows that local people make greater use of forest provisioning services, characterised by a use value of 78.64%, followed by cultural services (VU = 62.14%). Informants' consensus factors ranged from 0.67 to 0.99. The highest CFIs were recorded for supply and cultural services (0.99 and 0.98 respectively). However, the consensus was lower for the regulation service (CFI = 0.67). All the species cited by the population were used for provisioning, 60% for regulation and 22% for cultural services.

Table 11. *Informant consensus factors on the ecosystem services provided by the forest.*

Services	Number of citations	VU (%)	Number of species	FCI
Supply service	404	78,64	5	0,99
Regulation department	7	6,8	3	0,67
Cultural services	112	62,14	3	0,98

Table 12 shows a level of fidelity varying between 1.55 and 65.28% for the most cited species and the highest use categories. The NFs are higher for NTFPs. The NFs for the A. digitata use are high for NTFPs (65.28%) and pharmacopoeia (27.78%). N. macrophylla and D. senegalensis are more valued for fuelwood (42.64 and 41.73% respectively). A. occidentale is also valued for NTFPs (62.16%), shade (8.11%) and fodder (13.51%). C. nucifera is valued more for its aesthetic appeal (50%).

Table 12. Fidelity level of forest species.

Species	NTFP	Fuelwood	Shade	Pharmacopoeia	Fodder	Aesthetics
D. senegalensis	39,37	41,73	1,57	17,32	0,00	0,00
N. macrophylla	39,53	42,64	1,55	16,28	0,00	0,00
A. digitata	65,28	0,00	0,00	27,78	0,00	6,94
Western A.	62,16	0,00	8,11	16,22	13,51	0,00
C. nucifera	50,00	0,00	0,00	0,00	0,00	50,00

5. Discussion

5.1. Socio-Economic Breakdown of Respondents

The results show that the PNDS is predominantly populated by the Socés. A demographic dynamic was observed, with a distribution of gender according to activities in the area. The two main activities are fishing (fish and oyster fishermen) and agriculture. This type of result was also obtained by [20] who noted that fishing and agriculture were the two main activities in the communes of Oukout and Santhiaba Manjaque (Lower Casamance). The men are more involved in fishing and farming, while the women (adults) are involved in harvesting oysters. [21] and [22] have shown that oyster harvesting, the second most important activity after fishing, is practiced mainly by women in the village of Kafountine (Lower Casamance estuary) and in the PNDS. However, [23] found that 26.46% of men were involved in oyster gathering, compared with 51.26% of women. According to the same authors, young people (< 20 years old) are not very involved in oyster harvesting in the Noumbiel province of Burkina Faso.

Mangrove oyster farming in the PNDS is an unstructured artisanal activity. The majority of the population is educated mainly through schools and has no skills in this type of farming. Nevertheless, farmers carry out individual activities and, where necessary, form family-based groups to pool production resources, as shown by [24].

5.2. Diversity of Services Offered by the PNDS to Local Populations

The local populations mentioned a diversity of 21 ecosystem services provided by the PNDS. These services are divided into three categories (provisioning, regulation and cultural). This diversity is high compared with those found by [25] in the Lac de Guiers area of Senegal, where 13 ecosystem services were mentioned. This difference justifies the diversity of activities carried out in mangroves. Provisioning (50%) is the most cited category, followed by cultural services (27%) and regulation (23%). The fact that provisioning ecosystem services are often highly valued by people living in rural areas can be explained by his close relationship with ecosystems [26].

The Khi^2 test of independence showed a strong dependence between villages and the categories of services provided by the PNDS. Hierarchical ascending classification (HAC) was used to distinguish 4 groups of villages according to services. Agriculture, education and research are more common in Massarinko. Bee-keeping and animal husbandry activities are practiced in Bagadadji. The villages of Betenty and Bossinkang are characterised by a wide variety of uses, in particular fishing (fish, oysters, shellfish), NTFP gathering and the search for firewood. Tourism, aesthetics, shading and pharmacopoeia are more popular in Missirah, Djinack Bara and Djinack Diatako. According to [27], the livelihoods of most of these inhabitants derive from the exploitation of renewable natural resources, mainly living aquatic resources, forest resources, agricultural resources, livestock, beekeeping and tourism. The distribution of service categories could be explained by the position of the villages, depending on whether they are mainland or island villages. The island villages of Betenty and Bossinkang are home to fishing communities with growing needs for firewood. This same trend was observed by [27], who found large fishing households in Betenty (36) and Bossinkang (20) in their study.

5.3. Diversity of Mangrove Services

According to the population surveyed, the PNDS mangrove provides a total of 17 services, again divided into three categories: supply, regulation and cultural. The CFI is high for each of the three categories and reflects a general consensus of the local populations around these three categories of ecosystem services. The provisioning service is the most cited by the population and therefore the most important, with a high consensus factor (0.98). According to [20], this could be explained by the many food resources available in mangroves, which can be directly consumed or used by the coastal population. According to [28], traditional societies, which have occupied these coastal areas in a very discontinuous manner since the 16th century, have always used the mangrove as a

source of wood (source of energy, construction of structures, etc.), but also for fishing and agriculture. Among the mangrove supply services in the PNDS, fish fishing (72.82%), oyster fishing (65.05%), pharmacopoeia (64.08%) and firewood (54.37%) are the most cited by the population. These results corroborate those of [29] who found that the majority of the population of the Abéné marine protected area (MPA) exploits mangrove products, mainly fish. According to [17], the fishery resources most exploited in Senegal by the local population are fish (72.7%), molluscs (39.4%) and crustaceans (38.4%). The massive use of mangrove wood could be justified by the fact that oyster farming requires a greater or lesser quantity of wood for cooking oysters [20]. In fact, wood fuel in the form of firewood or charcoal is the main source of domestic energy for coastal households [30]. In their study of the Mangagoulack Community Heritage Area (MCA), [29] showed that mangroves are also used in the construction of houses, orchard fences and market gardens. Mangroves are also used in traditional pharmacopoeia, according to the local population. Its leaves are used to combat hemorrhage and fever. In the same context, [31] had already shown that mangrove leaves are used to treat certain illnesses such as malaria, diarrhea and stomach aches, and to ease women's pain before and after childbirth.

Importance was also given to cultural services, with an informative consensus factor of 0.98. Aesthetics were cited more often (90.29%) by the PNDS population, followed by ancestral value (67.96%) and tourism (30.10%). The same trend was found by [32], according to whom cultural services are the second most valued ecosystem service after provisioning services in the Kalounayes managed forest (Senegal). However, in the same forest, sacred wood was the most valued cultural service with 42% of expressions of use [32]. The high proportion of ancestral value cited shows that the population of the PNDS considers mangroves to be a cultural heritage to be conserved. [25] found a cultural service less valued by the population of the Lac de Guiers area. According to him, this weak cultural dimension is due to the fact that certain traditional customs are beginning to disappear in this area, which is undergoing constant socio-economic change. According to [6], tourism provides socio-economic benefits for improving the living conditions of local populations in the PNDS. These benefits manifest themselves in the development of economic activities (tourist guides, hotel work, etc.) which, in turn, employ part of the community.

The mangrove regulation service, despite being the third ecosystem service, is very important for the PNDS population with a high CFI (0.97). This consensus is similar to that found by [33] for the regulation service in the Lac de Guiers area, which is 0.98 Protection against erosion and flooding (93.20%), against strong winds (32.04%) and fish stocks (47.57%) were the most frequently cited services. The regulating service accounts for 7.9% of the services cited for the Kalissaye wetland of international importance (Ziguinchor, Senegal), due to the role of the mangrove as a barrier against the advancing sea [20]. In the same vein, [34] and [35] state that the mangrove is a favorable support for biodiversity as a habitat, nesting, reproduction and feeding site for many animal and plant species.

The use of mangrove ecosystem services varies significantly according to socio-professional category (P-value =0.000493). Farmers are more involved in the use of mangrove ecosystem services. This could be explained by farmers' awareness of the diversity of services provided by the mangrove. In fact, in addition to supply services, regulation services are also valued by farmers, in particular protection against erosion and flooding and the fight against violent winds, which are favorable to the development of their crops or speculations. These results are in line with those of [36], which show that farmers perceive the importance of services more strongly, particularly the supply service.

5.4. Importance of Mangrove Species and Local Knowledge

Socio-demographic factors (ethnicity, gender, level of education, occupation and age) do not influence knowledge and use of mangrove species. Only three species are known by the population. Rhizophora mangle is by far the best known species, cited by 99.03% of respondents. Avicennia africana and Rhizophora racemosa are also known by 26.21% and 4.85% of respondents respectively. Laguncularia racemosa and Conocarpus erectus are the least known species. The high citation of Rhizophora mangle could be explained by the dominance of this species in the PNDS mangrove. The same observation was made by [37], who found Rhizophora mangle in the mangroves of the Saloum Delta Biosphere Reserve, R. mangle as the most present and widespread species. However, these results are out of phase with those of [22] who noted in his study on "the ecology and spatio-temporal dynamics of mangroves in Togo", a dominance of the species R. racemosa within the conserved mangroves.

[29] also showed that Laguncularia racemosa and Conocarpus erectus are the least known species compared with the other species (Rhizophora and Avicennia germinans) in the Mangagoulack Community Heritage Area (Casamance, Senegal). At the same time, [32] showed the low representation of Laguncularia racemosa and Conocarpus erectus in the PNDS mangrove.

The number of species cited is very strongly influenced by areas (P< 0.0001). The species are better known in Bagadadji and Bossinkang. This explains the high frequency of use of mangrove services in these villages. There is therefore a dependency between knowledge of the species and their frequency of use by the populations. This dependence was also demonstrated by [29], who found high usage frequencies for species where they were better known.

Use value (UV) is a way of expressing the relative importance of each species for the population [38, 39]. Rhizophora mangle is the most highly valued species (UV = 3.09),

followed by Avicennia africana (UV = 0.91) and Rhizophora racemosa (UV = 0.19). The high VU of Rhizophora mangle further explains the high dominance of this species in the PNDS. The authors [40] have also shown that Rhizophora mangle is the only species to be present in all zones (peripheral, buffer and central).

This ranking highlights the importance of Rhizophora mangle as a primary resource for coastal communities, and suggests that mangrove management should focus on preserving this species, while taking into account the potential and values of other less-used but important species for local biodiversity.

Determining the NFs for each species enabled us to identify the major ecosystem services for each species. The NFs for Rhizophora mangle are high for aesthetics, pharmacopoeia and the protection of fish animals. Rhizophora racemosa is used more for oyster fishing and firewood. Avicennia africana is valued more for shade and more or less for pharmacopoeia. These results confirm those of [41], which showed that mangroves provide a range of products for construction, firewood, tannin, fodder, fishery resources and plant-based medicines. People's preference for Rhizophora racemosa wood has also been observed by [33] in Côte d'Ivoire and [42] in Cameroon. [43], which testify to the effectiveness of Rhizophora racemosa wood as a good fuel.

5.5. Diversity of Services Provided by the Forest

Local people mentioned a diversity of ecosystem services provided by forests and trees. They have a strong perception of both direct and indirect ecosystem services [26, 44]. The studies covered all the categories of ecosystem services provided and perceived by local people. They listed a diversity of 6 ecosystem services provided by woody species, which are distributed between the three categories of ecosystem services, namely provisioning (70.85%), regulating (16.46%) and cultural (2.69%). The predominance of provisioning services could be explained by the fact that almost all people go to the forest to gather non-timber forest products, fodder, medicines and fish. These results are similar to those obtained by [45, 46]. The values observed show that there is a precise species selection criterion and information is exchanged between populations in the context of their uses (aesthetics, fodder, PNFL, shade, pharmacopoeia, energy wood). These woody species are generally conserved and protected because they are also a significant source of income for the people who use them [47, 48]. The classification presented gives a synoptic view of the diversity of ecosystem services at the level of each species and enables us to assess the relative importance of each of the categories represented [18]. Among supply needs, fuelwood (67.96%), NTFPs (54.37%) and pharmacopoeia (30.1%) are the most valued. For cultural needs, aesthetics is cited most often (57.28%). With regard to regulating services, shade was mentioned by 5.83% of respondents. The massive use of wood is explained by the fact that this product is used as firewood to prepare their meals. These results corroborate those of [49, 50], which show that woody plants are a main source of energy and provide people with service wood and timber. Another study carried out in the municipality of Greater Letaba in South Africa showed that timber, fuelwood and edible plants were the most important ecosystem services [51].

There is a strong public consensus (67% to 99%) on the use of ecosystem services. But it is strongest for the provisioning service (99%), with a very high use value (78%). This high degree of consensus for most uses is explained not only by their availability, but also by the fact that they are linked to everyday life. The products needed for these services are used almost every day to the point of being a tradition in the area. The study also reveals that supply services are the most represented, followed by cultural services and regulatory services. The CFI for each of the three categories is high, reflecting a general consensus among local populations around these three categories of ecosystem services. The classification presented in this study and the use of CFI as a discriminating factor constitute an innovation, as they provide a synoptic view of the diversity of ecosystem services for the different species identified and enable the relative importance of each of the categories represented to be assessed [18]. Determining the NFs in each category revealed some major ecosystem services. In the provisioning services category, high NF values were obtained for fuelwood, fruit consumption (NTFPs) and the use of bark in traditional medicine. Most of these values are higher than those found in the Sahelo-Sudanian zone of Senegal according to [16].

5.6. Importance of Forest Species and Local Knowledge

Knowledge of woody species does not depend on socio-demographic factors. This consensus reflects, on the one hand, people's good knowledge of their environment [52] and, on the other hand, the reliability of ethnobotanical surveys as a means of rapidly estimating the state of vegetation in a locality [53]. These results contradict those of [54], which showed that knowledge of agroforestry species depends on socio-demographic factors such as age, level of education, ethnicity and gender. Gender is a determining attribute in the use of forest species. In the study area, women play a central role in the use of different forest species. In addition to their responsibilities as housewives, they are the main players involved in developing and exploiting these resources. Men, on the other hand, concentrate mainly on fishing activities, which limits their involvement in the use of forest species. This repartition of tasks highlights the influence of gender on practices and methods of using natural resources. These results corroborate those of numerous ethnobotanical studies, which positively associate women with traditional knowledge of phytotherapy, due to their role in domestic activities. Indeed, [55] find that it is women who are responsible for preparing recipes for their own care and that of their children in

traditional medicine. Age and level of education also have no influence on trends in the use of forest species. This can be explained by the fact that in the area, knowledge and skills are generally acquired and passed on from one generation to the next at an early age. In their studies, [56] and [57] explain the influence of age by the fact that traditional medicinal knowledge is passed on from ancestors (the wise) to descendants (the young) to such an extent that the two types of individuals have practically the same level of knowledge. This suggests that the usefulness of woody species is well considered by all socio-professional strata in the PNDS.

According to the conclusions of [58], the more ecologically important a tree species is, the more uses it has. Our results therefore highlight the usefulness of trees for ecosystem services. Of the 5 species listed, some have higher use values than others. However, the high use values of Neocarya macrophylla (1.25), Detarium senegalense (1.23) and Cocos nucifera (1.09) demonstrate their central role in meeting people's needs. These species contribute to virtually all the categories of ecosystem services identified by the local population. They are what are known as multi-use species. This could also be linked to their accessibility. In fact, the non-timber forest products of these species are a considerable source of food for rural populations, especially during the lean season [30, 16]. Woody species also provide sources of income through the sale of their fruits.

A. digitata (65.28%) and A. occidentale (62.16%) stand out among the species most commonly used for food (NTFPs). The fruits, seeds, leaves and gum of these species improve the nutritional status of rural populations [19, 59, 60]. Gathering the products of these spontaneous species also provides people with income. The preferred woody species for people's energy needs are D. senegalensis (41.73%) and N. macrophylla (42.64%). Wood fuel in the form of firewood or charcoal is the main source of domestic energy for households [19, 61]. Pharmacopoeia is a category of supply service cited by the population if we refer to the percentage of expressions of use (30.1%). Certain species (A. digitata, A. occidentale, N. macrophylla, D. senegalensis) are much in demand by the people who use them for health care, as conventional pharmaceutical products are often beyond the reach of households because of their high cost. A fourth category of service provided by woody vegetation in the various villages is fodder. The proteins found in woody vegetation in the dry season are an essential part of livestock diets [62]. A single species, characteristic of the ecosystems of the PNDS, A. occidentale, is the only one cited by respondents and the most palatable to livestock. They provide livestock with a considerable food supplement [62] to complement the herbaceous fodder in straw form, which is nutritionally unbalanced and sometimes even absent. Shade is the only use cited by local people for regulating services, and A. occidentale (8.11%), N. macrophylla (1.55%) and D. senegalensis (1.57%) are the species most in demand. Shade is particularly useful in the terroir zone, where most socio-economic activities take place in the high tropical heat [63]. C. nucifera (6.94%) and A. digitata (50%) play an essential role in the aesthetics of the region. This can be explained by the fact that these are the species most favored in reforestation for the functions of shade, landscape aesthetics and carbon sequestration [63].

6. Conclusion

Our work has enabled us to document local perceptions of the ecosystem goods and services provided by the forest and mangrove ecosystems of the PNDS, highlighting the richness, diversity and complexity of community uses and representations. The results show that local populations recognise the multidimensional importance of the park, particularly in terms of provisioning, cultural and regulatory services, with a marked prevalence of mangrove services. The analysis revealed that the mangrove, more than the forest, is a vital resource for the communities, both for its fishery resources and for the ecological and cultural functions it fulfils. Despite this recognition, uses are not significantly influenced by socio-demographic factors, with the exception of occupation for certain types of service, which shows a collective appropriation of natural resources. In addition, the high use value and high informant consensus around certain species, notably Rhizophora mangle and Detarium senegalense, underline the need to integrate local knowledge into conservation policies. These results confirm the value of adopting a participatory and integrated management approach, based on the sustainable development of ecosystem services and the effective involvement of local communities. The conservation of the PNDS, as an ecological and socio-cultural and socio-cultural heritage, represents a strategic lever for sustainable territorial development and the socio-ecological resilience of local populations.

Abbreviations

ANSD	National Agency of Statistics and Demography
FAO	Food and Agriculture Organization
CF	Frequency of Citations
FCI	Informant Consensus Factor
MEA	Millennium Ecosystem Assessment
NF	Fidelity Level
PAG	Development and Management Plan
PCD	Communal Development plan
PFNL	Non-timber Forest Products
PNDS	Saloum Delta National Park
UNESCO	United Nations Educational, Scientific and Cultural Organisation
USV	Use Value

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Author Contributions

Assane Ka: Conceptualization, Data curation, Formal Analysis, Funding acquisition, Investigation, Methodology, Project administration, Resources, Supervision, Visualization, Writing – original draft, Writing – review & editing

Serigne Modou Sarr: Supervision, Validation, Visualization, Writing – review & editing

Bocar Samba Ba: Supervision, Validation, Visualization, Writing – review & editing

Alioune Badara Diop: Formal Analysis, Investigation, Visualization, Writing – review & editing

Aliousseyni Ly: Visualization, Writing – review & editing

Papa Diene Faye: Visualization

Dogo Seck: Visualization, Writing – review & editing

Declaration of Data Availability

Data will be available on request.

Conflicts of Interest

The authors declare no conflicts of interest.

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Research Field

Assane Ka: Forestry, Protected area and biosphere reserve manager, Remote sensing, Project Management

Serigne Modou Sarr: Fisheries science

Bocar Samba Ba: Environmental economics

Dogo Seck: Tropical agriculture, Agroecology, Entomology, Post-harvest loss reduction, Food security and food safety in Africa

Aliousseyni Ly: Agronomist, Climate change & Disaster Risk Management

Papa Diene Faye: Forestry, Forest management

Alioune Badara Diop: Mangrove ecosystem, Forest management