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Farmers' Perception of Ecosystem Services Provided by Historical Rubber Plantations in Sankuru Province, DR Congo

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Abstract: The province of Sankuru, located within the Democratic Republic of Congo, is distinguished by its extensive rubber plantations, which have a long history in the region. These plantations have had a considerable impact on the region's agrarian landscape over time. In addition to the exploitation of latex, for which the conditions are currently very limited, these plantations provide goods and services to the local population and are dominated by rural communities that are highly dependent on these natural resources. This study aimed to characterize the socio-demographic and agrarian profile of historical rubber plantations while assessing the occurrence of the ecosystem services (ESs) they provide. Particular attention will be paid to the farmers' perceptions of these services, an essential element for the rational management of natural resources. This study used a mixed methodological approach, integrating semi-structured interviews, focus groups, and statistical analyses including chi-square testing and multiple correspondence factorial analysis (MCAFA) to obtain and analyze the data comprehensively. The results indicate that historical rubber plantations in Sankuru provide 21 ESs, which are grouped into four categories: eleven provisioning services, four regulating services, four cultural services, and two supporting services. It has been observed that local communities attach significant importance to the provision of services including the provision of firewood (96.67%) and the utilization of forest resources for traditional pharmacopoeia (91.33%). These plantations have come to be regarded as valuable cultural heritage by local communities over time. The younger generation evinces a greater interest in utility services than the older generation, which displays a preference for cultural services. However, older people demonstrate a more profound understanding of cultural and regulatory services. By emphasizing

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the species that contribute to ESs and recognizing plantations as cultural heritage, the study enhances the comprehension of the significance of local ecosystems. These findings provide a crucial foundation for directing local policy toward integrated management of historic rubber plantations in Sankuru. By considering the perceptions of local people, the study contributes to the sustainable conservation of these plantations for the present and future generations.

Keywords: farmers' perceptions; ecosystem services; historical plantations; rubber; Sankuru; DRC

1. Introduction

Rubber plantations (*Hevea brasiliensis*) play a pivotal role in the global economy as they are the primary source of latex for the natural rubber industry [1]. Nevertheless, the significance of these agroforestry ecosystems extends beyond their economic function; these ecosystems also provide a variety of ecosystem services (ESs) including climate regulation, carbon sequestration, soil conservation, and biodiversity maintenance [2]. Rubber plantations have been demonstrated to exhibit multifunctionality, thereby positioning them among the semi-natural systems most analogous to dense tropical forests [3]. These attributes are particularly salient in contexts such as the Democratic Republic of Congo (DRC), where the environmental and socio-economic issues are inextricably linked.

The rubber plantations of Sankuru province offer a distinctive illustration of this phenomenon. While initially established to support the exploitation of natural rubber, today, these plantations face structural challenges including their geographical isolation, lack of adequate infrastructure, and severe logistical constraints. These factors have a deleterious effect on the economic viability of the plantations [4–6]. These plantations, which were abandoned for nearly six decades, have undergone a gradual transformation into complex agroforestry landscapes. These ecosystems are distinguished by the presence of spontaneous species, which contribute to ecological diversity and the provision of a diverse array of ESs that are utilized by local communities [6,7].

The sustainable management of forest ecosystems including perennial plantations such as rubber plantations has emerged as a global priority in response to the mounting challenges associated with deforestation and the degradation of natural resources. From 2002 to 2023, the DRC witnessed a substantial loss of 6.86 million hectares of forest, amounting to a 36% reduction in its original forest cover [8]. The deforestation has significant ramifications for livelihoods, particularly in regions such as Sankuru, where approximately one million individuals are directly reliant on forest resources [9–11]. The region's strategic position as a crossroads for biodiversity conservation is underscored by its ecological richness and the presence of endemic species such as the Bonobo (*Pan paniscus*) [7]. Its proximity to the Salonga National Park further enhances its significance in this regard.

Furthermore, it exemplifies the difficulties inherent to integrated ecosystem management in a disadvantaged and marginalized socio-economic context. In such contexts, anthropogenic pressures—such as natural resource exploitation and limited access to infrastructure—render the implementation of effective conservation strategies more challenging [5]. Despite their abandoned state, rubber plantations continue to offer crucial ESs including carbon sequestration, water regulation, and biodiversity preservation [12]. However, the interactions between these ecosystems and local communities remain poorly understood. The farmers' perceptions of the ESs provided by these plantations directly influence their management decisions, however, these aspects remain largely understudied [13]. A more comprehensive understanding of these perceptions is essential for developing

sustainable management strategies and enhancing the resilience of regional agroforestry landscapes. To this end, the present study employed a conceptual framework of ESs, which differentiates between provisioning, regulatory, supporting, and cultural services [14], offering a relevant approach. This framework elucidates the multifarious benefits that populations derive from ecosystems while facilitating the implementation of policies focused on sustainable natural resource management [15,16]. Moreover, the theory of social interaction developed by Bourdieu in 1986 [17] underscores the significance of socio-economic and cultural elements in the perception and utilization of ESs by local communities.

However, current ES assessments predominantly adopt an ecological and economic perspective, frequently overlooking the social dimensions [13,18]. Nevertheless, in order to fully comprehend intricate socio-ecological systems, it is of paramount importance to incorporate social ones [15,16]. Such an integration serves to enhance the relevance of assessments by considering the complex and multifaceted human–nature relationships and their implications for sustainable management. Therefore, a synthesis of theories concerning ESs, sustainable agriculture, and social dynamics is necessary to analyze the ecological benefits associated with rubber plantations as well as their economic and social impact on the daily lives of local producers. The development of this conceptual framework underscores the significance of stakeholder dialogue in fostering a collaborative approach that promotes environmental preservation as well as local economic well-being. This approach could also help formulate practical recommendations for decision-makers to optimize the benefits derived by these communities while ensuring the ecological sustainability of their farming practices.

This study examined how local communities in Sankuru province perceive and value the ESs provided by historical rubber plantations. The study was based on the central hypothesis that these plantations play a significant socio-environmental role, contributing to local socio-economic development through the ESs they provide. More specifically, the study aimed to test two hypotheses: (i) the farmers' perceptions of ES are influenced by their personal experiences and socio-economic context, and (ii) these perceptions impact management practices and agricultural decisions, with implications for ecosystem sustainability.

This research endeavors to address existing gaps in the extant literature on ESs in a tropical context, employing both conceptual and empirical contributions. Furthermore, the objective was to propose strategic orientations for collaborative natural resource management, involving policymakers, researchers, and local communities. The overall aim of this work is to promote the environmental, economic, and social sustainability of Sankuru's historic rubber plantations while strengthening stakeholder dialogue to facilitate concerted and inclusive management. Specifically, the study will (i) determine the socio-demographic profile of local farmers living near historic rubber plantations in Sankuru province; and (ii) analyze the occurrence of ecosystem services within these plantations and assess the farmers' perceptions of the potential ecosystem services of these historic plantations.

This article is structured as follows. First, an introduction highlights the importance of rubber plantations and their role in the local socio-economic landscape. A review then explores the concepts of ecosystem services and their implications for sustainable natural resource management practices. The methodological section describes the approaches used to collect and analyze the local farmers' perceptions of the ESs provided by historic rubber plantations in Sankuru. The results are then presented, highlighting the occurrence of ESs from these plantations. Finally, the discussion interprets these findings in light of the study's conceptual framework and formulates practical recommendations aimed at improving natural resource management in the region, taking into account the economic

well-being of local farmers. The article concludes with a summary of the main findings and avenues for future research on this important topic.

2. Methodology

2.1. Study Area

The study area is located in the province of Sankuru in the Democratic Republic of Congo (DRC). Specifically, the study area included the territories of Lodja and Lomela (Figure 1). The DRC is composed of 26 provinces, one of which is Sankuru. Situated in the heart of Central Africa, Sankuru is further administratively divided into six territories: Katako-Kombe, Kole, Lodja, Lomela, Lubefu, and Lusambo. The administrative center of Sankuru province is Lodja [10,19]. The province is surrounded by seven other provinces of the DRC. The northern border of the province is delineated by the Ndjale and Salonga Rivers, which form the boundaries of Salonga National Park. The geographical coordinates of the park range from 1° to 2° south latitude and 23° longitude, thus delineating its position between the province and Tshuapa province. The northeastern periphery of the province is distinguished by the Yameme and Balinga Forests, which act as a natural divide between it and Tshopo province. To the southeast, Lake Mankamba serves as a natural boundary between the province and Lomami province, while to the southwest, the Nkunduyi River marks the border with Kasaï Central province. To the east, the Lomami River serves as a natural boundary between it and Maniema province. Similarly, the Sankuru and Lukibu Rivers demarcate its western border, separating it from Kasaï Central and Kasaï Oriental [5,6,19].

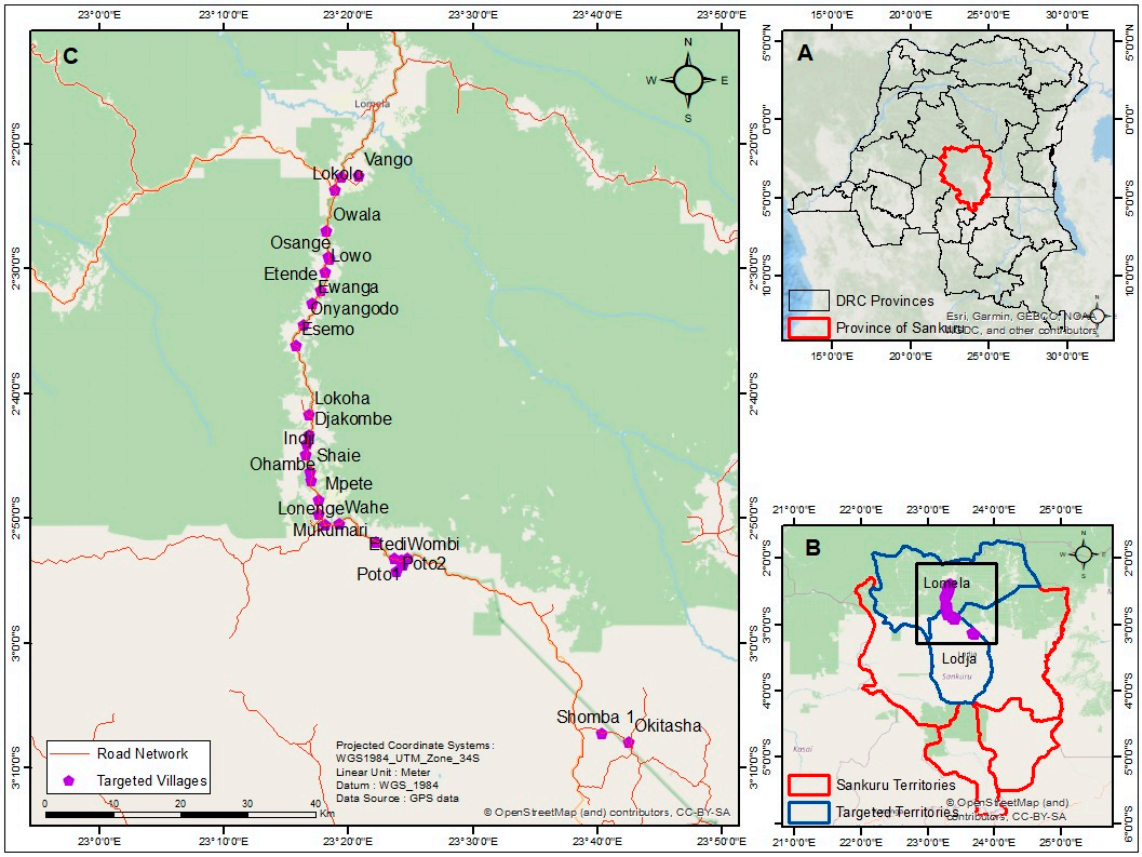

Figure 1. Map of the survey sites in the Lodja and Lomela territories. Map (**A**) depicts the province of Sankuru within the Democratic Republic of the Congo (DRC). Map (**B**) illustrates the location of the target villages within the two territories. Map (**C**) presents a map of the various villages surveyed.

The Sankuru region is distinguished by an equatorial climate in the northern reaches, which gradually transitions to a humid tropical climate in the central and southern regions. The dry season, marked by a decline in precipitation, extends from May to August, while the rainy season, characterized by increased rainfall, occurs from September to April. In the northern region of the province, the highest levels of precipitation occur in December and from mid-April to mid-May. The region's mean annual temperature is 25 °C, with annual rainfall varying between 1500 mm and 2000 mm/year [5,19]. These conditions are conducive to the successful cultivation of rubber trees. Sankuru province, which encompasses an area of 109,278 km^2, has a population of approximately 4,362,736, representing a density of 39.9 inhabitants per km^2. The predominant ethnic group in this region is the Tetela, whose ancestry can be traced back to a common progenitor named Mongo. The Tetela are part of the Akutshu Membele group of Central African Bantus. The Tetela population is predominantly concentrated in the southeastern region of the Congo River basin, a geographical area delineated by the confluence of the Lomami and Congo Rivers [19].

2.2. Data Collection

The methodological approach was based on documentary research (information related to the farmers' perceptions of ecosystem services (ESs) including the environment, biodiversity, natural resource management, and conservation, field surveys, and direct observations. A mixed method approach was employed, integrating both qualitative and quantitative techniques. The surveys were conducted between 4 October and 31 December 2023. However, an exploratory study was initially conducted to determine the sample size and the selection of villages to be surveyed more accurately.

2.2.1. The Selection of Villages and Determination of the Sample Size Based of the Following Criteria

A total of 300 individuals participated in semi-structured individual interviews. The sample size was determined based on a database maintained by the Belgian Federal Government Development Agency (ENABEL) in the Democratic Republic of the Congo (DRC), which lists the total number of rubber planters in the Lodja and Lomela territories. The list provided insights into the proportion (p) of rubber plantation owners, thus facilitating the process of identifying the most appropriate villages for survey in each sector. The two territories under examination encompassed the Bahamba I, Batetela, Ahamba Mange, and Vungi sectors, in which rubber is cultivated. Of the 2169 hectares of peasant rubber plantations surveyed by ENABEL [20], the Bahamba I sector accounted for the largest area, at 1343 hectares, followed by the Ahamba Mange sector with 612 hectares, Batetela with 134 hectares, and the Vungi sector with 79 hectares of village rubber plantations.

Subsequently, the 300 respondents were distributed across four sectors (Figure 1 and Table 1) situated within the Lomela and Lodja territory, encompassing 30 villages. The selection of the 30 villages was determined by the substantial extent of rubber plantations in these regions. The distribution was conducted through a process of weighted random stratification. A total of 186 respondents were located in the Bahamba 1 sector, 85 in the Ahamba Mange sector, 18 in the Batetela sector, and 11 in the Vungi sector. This represents 13.83% of the study population (rubber plantation owners), thereby ensuring a representative sampling rate for the study area. This approach facilitated the comprehensive collection and analysis of data. The study aimed to gain a comprehensive understanding of the perspectives and experiences of rubber plantation owners in the study area by encompassing a diverse range of respondents from different sectors.

Table 1. Summary of the number of villages and households surveyed in the Lomela and Lodja territories. The geographical coordinates of the 30 villages surveyed are available for download in the Supplementary Materials of this article (Table S1).

Territory	**Lomela**		**Lodja**		**Total**
Sector	**Bahamba I**	**Batetela**	**Ahamba Mange**	**Vungi**	
Distribution (%)	62	6	28.3	3.7	100
Number of villages	18	2	8	2	30
Number of Households surveyed	186	18	85	11	300

The number of respondents per sector was then calculated according to the formula proposed by Dagnelie [21]:

$$n = \frac{U^2_{0.975} \times p(1-p)}{d2} \quad (1)$$

In this equation, n represents the expected sample size, which is yet to be determined; p denotes the proportion of individuals in a village situated in proximity to rubber plantations; $U_{0.975} \approx 1.96$, signifies the quantile of a standard normal distribution for a probability value of 0.05, as outlined by Fandohan [22]. Finally, d represents the marginal error, which was set at 8%.

2.2.2. Characteristics of the Study Population

The study's participants were primarily individuals engaged in tapping activities, along with those who owned rubber plantations. To obtain the requisite information, a purposive sampling of respondents was conducted. The selection criteria were as follows: ownership of rubber plantations in the study area; availability to participate in the survey; age between 20 and 80 (determined based on the socio-demographic characteristics of those involved in the rubber sector in the study region); and residence in the region for at least 10 years (to account for experience and local knowledge).

2.2.3. Questionnaire Survey and Interview Guide

In order to explain the study method and obtain the free, prior, and informed consent (FPIC) of the local population for their active participation in the study, interviews were conducted with members of the local community. The objective of this phase was to identify, in a participatory manner, the ESs associated with rubber plantations in Sankuru. As the identification of ESs is driven by human well-being, it was of particular importance to engage all stakeholders in order to ascertain their values and needs [23]. The classification of goods and services was conducted in accordance with the four categories of ecosystem services delineated by the *Millennium Ecosystem Assessment*: provisioning services, regulating services, supporting services, and cultural services [14]. ESs encompass all the environmental goods and benefits that plant and animal species provide, without any active effort on their part [14,23]. With the assistance of a facilitator proficient in the local dialect (Tetela), individual interviews and focus groups were conducted.

The names of woody species and non-timber forest products were recorded in the local dialect, and subsequent scientific identification was conducted with the assistance of a few individuals versed in the study area. Subsequently, we conducted further research by consulting scientific articles, specialized books, and databases dedicated to flora and fauna and their ESs. In particular, we consulted the Global Biodiversity Information Facility (GBIF) (https://www.gbif.org/) (accessed on 18 June 2024) and the Catalogue of Life (https://www.catalogueoflife.org/) (accessed on 18 June 2024). These references facilitated the identification of woody species, non-timber forest products, and animal

species referenced by the population during surveys and focus groups. The research proceeded with an investigation of the families and genera of the various plant species. The nomenclature employed adhered to the standards set forth by the Angiosperm Phylogeny Group (APG) IV [24], which can be accessed at (https://africanplantdatabase.ch) (accessed on 11 June 2024). The scientific and commercial equivalence of woody species in the Tetela dialect is provided as Supplementary Materials to this article and is available for download (Table S2).

In general, thirty (30) focus groups were established, with an average of five (5) to ten (10) participants per group. This resulted in one focus group being conducted in each village. This allowed for the initial dataset to be subjected to analysis and verification. Furthermore, the respondents assisted in the expression of collective opinions and facilitated the adaptation of the survey questionnaire to the field context. Prior to commencing the field survey, the questionnaire was tested and verified with a number of communities to ensure that the questions were clearly understood. Subsequently, certain questions were modified to better align with the specific context of the region.

The survey questionnaire was completed through direct observation in the field. To facilitate comprehension by the respondents, we were fortunate to have the assistance of local guides, customary chiefs from each village, and other knowledgeable individuals. The questionnaire was divided into three sections: (i) socio-demographic characteristics of the respondent (age, gender, marital status, level of education, ethnicity, household size, religion, subsistence resources, etc.); (ii) agrarian system; (iii) identification of the occurrence of ESs provided by rubber plantations; (iv) perceptions of the state of resources and of the goods and services provided by these rubber plantations. The survey questionnaire used is part of the Supplementary Materials in this article and is available for download (Table S3).

Furthermore, the respondents were requested to assign a score on a 5-point Likert scale (comprising five probable response categories) to a number of questions. 1: Not at all important; 2: Less important; 3: Moderately important; 4: Important; 5: Very important [25]. The term "ecosystem services" was not explicitly utilized in the survey; rather, the concrete benefits that people derived directly from rubber plantations were mentioned to facilitate comprehension among the respondents [18].

2.3. Data Analysis and Processing

The data were then entered and processed in a summary manner on Kobo Collect, after which they were exported to Excel for presentation in the form of tables and graphs. The data were subjected to statistical analysis using Excel and the R Studio interface [26]. The variability of the different forms of use was evaluated by determining the following parameters.

2.3.1. Citation Frequency

For each category of use, the citation frequency (*CF*) was determined. This value is calculated using the following formula:

$$CF = \frac{Number\ of\ quotations\ for\ the\ service\ used}{Total\ number\ of\ respondents.} \times 100 \quad (2)$$

When the CF value is close to zero, the species can be considered to have minimal utilization. Conversely, a CF value approaching one hundred indicates that the species is highly utilized [27]. The number of times a service was cited by a respondent was calculated and grouped according to the four ES categories. Significant differences in citation frequencies according to the four defined ecosystem service categories were assessed using a chi-square test of the comparison of proportions [28].

2.3.2. Use Value (UV)

For each species listed, a use value (UV) was determined, as defined by Angel [29]. The use value is a method of expressing the relative importance of each species for the population of provisioning, regulating, supporting, and cultural [30,31].

$$UV = \frac{\Sigma U}{n} \quad (3)$$

In this equation, U represents the number of citations per species, while n denotes the number of informants.

2.3.3. Informative Consensus Factor (*ICF*)

The degree of agreement among populations regarding the use of wood resources was determined by calculating the informant consensus factor (*ICF*), also referred to as the informative consensus factor. The *ICF* value ranges from 0 to 1. A high *ICF* value (near 1) is obtained when only one or a small number of species is cited by a large proportion of informants for a given use category. Conversely, a low *ICF* value (near 0) is obtained when a large diversity of species is cited for the same use [30]. The CFI is calculated using the following formula:

$$ICF = \frac{Nur - Nt}{Nur - 1} \quad (4)$$

In this context, *Nur* represents the number of citations for each category, while Nt denotes the number of species within the same category.

2.3.4. Level of Fidelity (*LF*)

The level of fidelity (*LF*) of a species was calculated in relation to different categories of use by the following formula [30]:

$$LF = \frac{Species\ number\ quotations\ for\ one\ category}{Species\ number\ quotations\ for\ whole\ categories} \times 100 \quad (5)$$

In order to assess the socio-demographic factors that determine people's perception of ESs, a data matrix was constructed. This matrix contained the socio-demographic characteristics of the respondents and their perceptions of ESs by category (provisioning, regulation, support, and cultural). The perception of an individual regarding a specific category of ES was calculated by summing the scores attributed to the services within that category that the individual had cited, and then dividing this sum by the total number of respondents. Radar diagrams were employed to illustrate the extent of people's perception of ESs in accordance with the socio-demographic variables.

2.3.5. Statistical Analysis

In addition to the descriptive analysis, a multiple correspondence factorial analysis (MCAFA) was carried out using R software version 4.4.1 [26] to determine the importance of essential services according to socio-demographic characteristics (religion, level of education, age, and gender as well as different groupings). Furthermore, a Fisher test was conducted to ascertain whether there was a statistically significant discrepancy in the diversity of services identified for each ES category (provisioning, cultural, support, and regulation) in accordance with the proportions expressed by the respondents. The chi-square test of independence was employed to ascertain whether the frequency of quotations and the level of fidelity differed according to the species utilized. The various analyses were conducted at the minimum threshold of 5% using R software [26].

3. Results

3.1. Respondent Profile

The results of the analysis of the respondent profile (Table 2), which indicates that the majority of rubber plantation owners were within the 31–40 age bracket (33%), followed by those in the 20–30 age bracket (27.33%). The most prevalent tribe was that of the Bahamba, with 62% of respondents identifying as such, followed by the Ahamba, with 28.33%. The Batetela and Vunge tribes constituted 6% and 3.67% of the total, respectively. Almost half of the respondents had received a basic primary education (49.67%), while 46.33% had completed secondary education, although the majority had not completed their studies. Only 1.7% of respondents had obtained a university education, while 2.3% had not completed any formal schooling. The majority of respondents were married (92.33%), with 6% identifying as single and 1.7% as widowed. Approximately 50% of the respondents had between six and ten family members.

Table 2. Socio-demographic characteristics of the respondents (n = 300).

Variables		Number	Percentage
Gender	Female	76	25.33
	Male	224	74.67
Age	[20–30]	82	27.33
	[31–40]	99	33.00
	[41–50]	78	26.00
	[51–60]	29	9.67
	[61–70]	11	3.67
	≥70 years	1	0.33
Tribe	Ahamba	85	28.33
	Bahamba	186	62.00
	Batetela	18	6.00
	Vunge	11	3.67
Education level	Primary	149	49.67
	Secondary	139	46.33
	University	5	1.67
	Out of school	7	2.33
Marital status	Married	277	92.33
	Single	18	6.00
	Widowed	5	1.67
Household size	[0–5]	68	22.67
	[6–10]	150	50.00
	[11–15]	68	22.67
	[16–20]	10	3.33
	≥21	4	1.33
Religion	Catholic	77	25.67
	Kimbanguism	24	8.00
	Protestant	131	43.67
	Traditional	62	20.67
	Islam	1	0.33
	None	5	1.67
Energy source	Wood	300	100
Man activities	Salaried activities	15	5.00
	Farming	300	100
	Hunting	182	60.67
	Fishing	156	52.00
	Fish farming	124	41.33

In terms of religious affiliation, 43.67% of respondents identified as Protestant, while 25.67% identified as Catholic. Conversely, 20.67% of respondents indicated adherence to a traditional religion, with only 8% identifying as Kimbanguists. The study area is characterized by a multidisciplinary system. Indeed, communities frequently engaged in a multitude of activities concurrently, most notably agriculture, which is a practice shared by all, and the utilization of firewood. Furthermore, communities engaged in other activities

including hunting (60.67%), fishing (52%), and fish farming (41.33%). This multifaceted engagement with diverse activities exemplifies the intricate nature of livelihood strategies in the region, underscoring the adaptability of local communities in response to evolving environmental and economic circumstances.

3.2. Agrarian System of Rubber Plantations

An analysis of the agricultural system showed that there were four types of rubber plantations in the Lodja and Lomela areas of Sankuru Province: state plantations, peasant plantations, private plantations, and plantations owned by Catholic monks. The state plantations, which cover an area of about 700 hectares, are located in Mukumari and are managed by the National Institute of Agronomic Studies, Mukumari Station. Private plantations cover 500 hectares and are located in Kutu-Songo, 18 km from Mukumari, in the Batetela sector of the Lomela territory. These are located near villages in the Bahamba I and Batetela sectors of the Lomela territory, and in the Ahamba Mange and Vungi sectors of the Lodja territory. In the Bahamba I sector, in particular, the area cultivated by farmers was the largest. Each family owns at least one hectare of rubber trees. There are also religious plantations of around 500 hectares in Vango, in the Bahamba I sector of the Lomela territory. These plantations are owned by Catholic monks. It should also be noted that these plantations have been in existence since 1945 (i.e., for over 75 years).

3.3. Occurrence of Identified Ecosystem Services by Category

The study revealed (Figure 2) that 21 ecosystem services were identified. The identified ecosystem services were grouped into four categories: provisioning services, cultural services, regulating services, and supporting services. The category of provisioning services was the most represented, while the category of supporting services was underrepresented. Of the 21 ecosystem services identified, the provision of firewood (96.67%), heritage (95.33%), traditional pharmacopoeia (91.33%), timber (85.67%), caterpillar collection (79.33%), and bushmeat (72.33%) were the most frequently cited. The least frequently mentioned services were those related to edible fruit picking (4%) and esthetics (7.33%) (please refer to Figure 2 for further details). The Fisher test indicated a statistically significant discrepancy (p-value = 0.00385 **) between the proportions expressed regarding the perceived utility of provisioning services. This finding corroborates the hypothesis that the majority of the population benefitted more from firewood in this category of ecological services. With regard to the cultural services category, the test indicated a highly significant difference (p-value = 0.00001 ***) in the proportions expressed, attesting to the considerable importance attached to the heritage (cultural use) of historical rubber plantations, in comparison with other services such as plot demarcation, recreation, and esthetics. With regard to support services, the test demonstrated a statistically significant difference (p-value = 0.04511 *) between the proportions expressed, underscoring the population's recognition of the role of Sankuru's historical rubber plantations in carbon sequestration, particularly in relation to their shade function. Ultimately, the test revealed a notable discrepancy (p-value = 0.00212 **) among the services delineated in the regulating services category, substantiating the assertion that rubber plantations serve a pivotal function in safeguarding wildlife habitats.

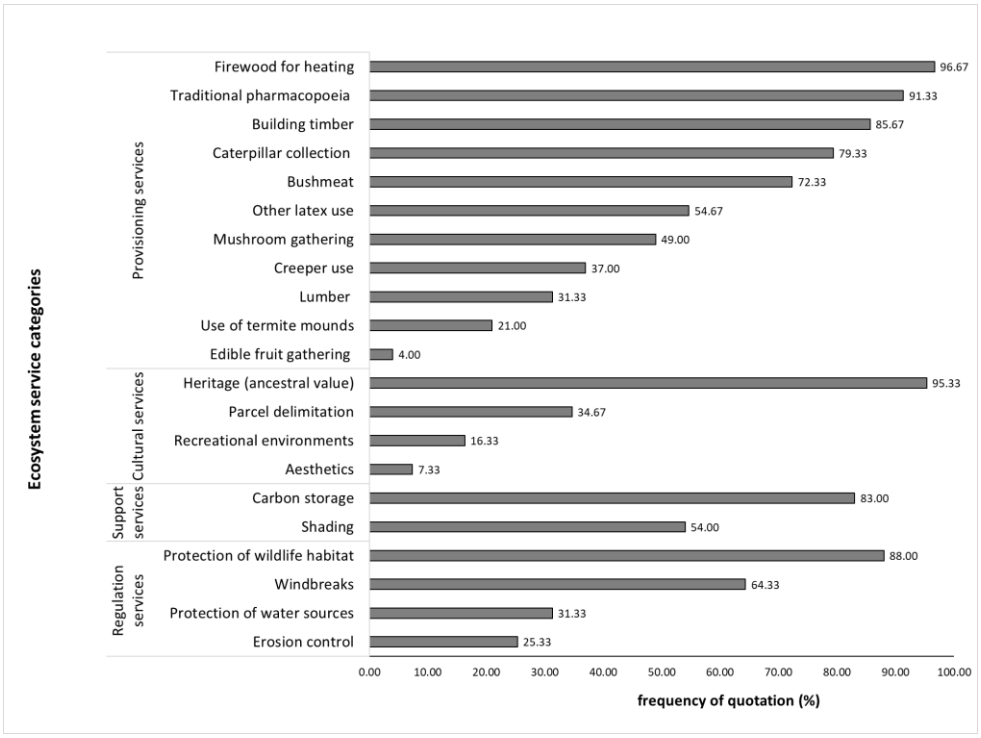

Figure 2. Ecosystem services identified by the local community. The figure describes the four ESs identified by the respondents, with their frequency of citation. Illustrative photos of historic rubber plantations and the various ecosystem services provided are available to download in the Supplementary Materials to this article (Figure S1).

3.4. A Typology of Supply Services Identified in the Study Area

3.4.1. Consensus Factors for Provisioning Services

In the course of the analyses, the communities in question identified a number of woody species that were utilized for the provisioning of five distinct services, namely: firewood, construction wood, timber, traditional pharmacopoeia, and caterpillar collection. The informant consensus factors for timber across the five categories of ecosystem provisioning services were calculated and are presented in Table 3. As evidenced by this table, there was a notable consensus regarding the utilization of trees across the five categories of ecosystem provisioning services identified. The level of consensus was notably high for species that provide fuelwood (97%), timber (97%), and caterpillar trees (97%). It can therefore be concluded that there was a high degree of consensus regarding the species that were cited for these services. Additionally, there was a high degree of consensus regarding the use of construction wood (96%) and the species employed in traditional pharmacopoeia (91%).

Table 3. The information consensus factors (ICF) for each use category.

Services Category	Used Citation (Nur)	% Used Expressions	Number of Species (Nt)	ICF
Firewood for heating	290	96.67	11	0.97
Building timber	257	85.67	12	0.96
Lumber	94	31.33	4	0.97
Traditional pharmacopoeia	274	91.33	26	0.91
Caterpillar collection	238	79.33	7	0.97

Indeed, the overwhelming majority of species cited by the communities (26 out of 39) were utilized in the traditional pharmacopoeia. Table 3 also demonstrates that the provision of firewood represented the service with the highest percentage of reported utilization

at 96.67%. This was followed by pharmacopoeia (91.33%), construction wood (85.67%), caterpillar collection (79.33%), and timber (31.33%).

3.4.2. Use Value of Ecosystem Provisioning Services and Different Species Used Different Woody Species Inventoried

A total of 39 woody species, classified into 37 genera and representing 21 distinct botanical families, were documented in the rubber plantations (Figure 2). The most represented families were Fabaceae (11 species), followed by Euphorbiaceae (5 species) and Clusiaceae (4 species). The 39 species contributed to the provision of the five categories of ecosystem services, as detailed in Table 4. Table 4 identifies the most commonly utilized species across the five categories, as determined by the species use values (UVs).

Table 4. List of woody species used, service categories, and use values (UVs).

Family	Genres	Species	ES Category	UV
Annonaceae	Cleistopholis	*Cleistopholis glauca* Pierre ex Engl. & Diels	Bo, Ph	0.10
	Xylopia	*Xylopia cupularis* Mildbr.	Ph	0.13
Apocynaceae	Alstonia	*Alstonia congensis* Engl.	Ph	0.09
	Funtumia	*Funtumia elastica* (P. Preuss) Stap	Bch, Bc, Ph	1.07
Bombacaceae	Ceiba	*Ceiba pentandra* (L.) Gaertn.	Ph	0.10
Burseraceae	Canarium	*Canarium schweinfurthii* Engl.	Ph	0.05
Caesalpiniaceae	Cynometra	*Cynometra alexandri* C. H. Wright	Bch	0.30
Clusiaceae	Mammea	*Mammea africana* Sabine	Ph	0.11
	Garcinia	*Garcinia kola* Heckel	Ph	0.52
		Garcinia punctata Oliv.	Bc	0.46
	Symphonia	*Symphonia globulifera* L.f.	Bc, Bo	0.16
Dracaenaceae	Sansevieria	*Sansevieria liberica* Gérôme & Labroy	Ph	0.02
Ebenaceae	Diospyros	*Diospyros alboflavescens (Gürke) F.White*	Bc	0.45
Euphorbiaceae	Macaranga	*Macaranga monandra* Müll.Arg.	Bch, Bc, Ph	1.30
	Plagiostyles	*Plagiostyles africana* (Müll.Arg.) Prain	Bch, Bc, Ph	0.91
	Croton	*Croton mubango* Müll.Arg.	Ph	0.26
	Uapaca	*Uapaca guineensis* Müll. Arg.	Rche, Bch	1.44
	Grossera	*Grossera macrantha* Pax	Bc	0.09
Fabaceae	Albizia	*Albizia gummifera* (J.F.Gmel.) C.A.Sm.	Rche, Bch, Bo, Ph	1.20
	Erythrophleum	*Erythrophleum suaveolens* (Guill. & Perr.) Brenan	Rch	0.82
	Leonardoxa	*Leonardoxa romii* (De Wild.) Aubrév.	Bch, Bc	0.73
	Brachystegia	*Brachystegia laurentii* (De Wild.) Louis ex Hoyle	Bch	0.09
Fabaceae-Caesalpiniaceae	Scorodophloeus	*Scorodophloeus zenkeri* Harms	Ph	0.08
	Gilbertiodendron	*Gilbertiodendron dewevrei* (De Wild.) J. Léonard	Ph	0.02
Fabaceae-Faboideae	Amphimas	*Amphimas ferrugineus* Pierre ex Pellegr.	Rche	1.00
		Amphimas pterocarpoides Harms	Bch	0.04
Fabaceae-Mimosoideae	Tetrapleura	*Tetrapleura tetraptera* (Schumach. & Thonn.) Taub.	Ph	0.04
	Pentaclethra	*Pentaclethra macrophylla* Benth.	Ph	0.26
	Piptadeniastrum	*Piptadeniastrum africanum* (Hook. f.) Brenan	Rche, Bch, Ph	**1.93**
Flacourtiaceae	Oncoba	*Oncoba welwitschii* Oliv.	Rche, Bch, Bc	0.54

Table 4. *Cont.*

Family	Genres	Species	ES Category	UV
Huaceae	Afrostyrax	*Afrostyrax lepidophyllus* Mildbr.	Ph	0.11
Lecythidaceae	Petersianthus	*Petersianthus macrocarpus* (P. Beauv.) Liben	Rche, Bc, Ph	**1.95**
Meliaceae	Carapa	*Carapa procera* DC.	Ph	0.09
	Entandrophragma	*Entandrophragma angolense* (Welw.) C. DC.	Bo, Ph	0.10
Myristicaceae	Staudtia	*Staudtia kamerunensis var. gabonensis* (Warb.) Fouilloy	Bc	0.42
Rhamnaceae	Maesopsis	*Maesopsis eminii* Engl.	Ph	0.15
Rubiaceae	Aidia	*Aidia Micrantha* (K. Schum.) F. White	Bc, Ph	0.15
	Morinda	*Morinda morindoides* (Baker) Milne-Redh.	Ph	0.18
Urticaceae	Myrianthus	*Myrianthus arboreus* P.Beauv.	Ph	0.03

Legend: Rche = caterpillar collection (caterpillar tree), Ph = pharmacopoeia, Bo = timber, Bc = building timber, Bch = firewood.

The 39 species in question contributed to the provisioning of five categories of ecosystem services, as illustrated in Table 4. The species with the highest vulnerability index (VU) scores were *Petersianthus macrocarpus* (1.95), *Piptadeniastrum africanum* (1.93), *Uapaca guineensis* (1.44), *Macaranga monandra* (1.30), *Albizia gummifera* (1.20), *Funtumia elastica* (1.07), and *Amphimas ferrugineus* (1.00).

Mushroom Species Consumed

The mushroom species identified contributed to the provision of one of the supply services, namely mushroom picking. In total, eight distinct species of mushroom were identified, belonging to six different families. Table 5 illustrates the most prevalent species, as determined by their use value (UV). The species of mushroom with the highest UVs were *Lentinus brunneofloccosus* (0.94), *Cantharellus congolensis* (0.88), *Auricularia cornea* (0.87), and *Schizophyllum commune* (0.84).

Table 5. List of mushroom species consumed and their use value (UV). Rcha = mushroom picking.

Familly	Species	Local Name	ES Category	UV
Auriculariaceae	*Auricularia cornea* Ehrenb. (1820)	Atole	Rcha	0.87
Cantharellaceae	*Cantharellus congolensis* Beeli (1928)	Dongono	Rcha	0.88
Lyophyllaceae	*Termitomyces globulus* R. Heim & Gooss.-Font	Etolo	Rcha	0.12
	Termitomyces microcarpus (Berk. & Br.) Heim (1942)	Kokalokonda	Rcha	0.05
Marasmiaceae	*Marasmius bekolacongoli* Beeli (1928)	Lombadu	Rcha	0.03
Polyporaceae	*Lentinus squarrosulus* Mont. (1842)	Koyo	Rcha	0.05
	Lentinus brunneofloccosus Pegler (1971)	Mbadu	Rcha	0.94
Schizophyllaceae	*Schizophyllum commune* Fr. (1815)	Tshukunu	Rcha	0.84

3.4.3. Different Animal Species Caught

In the context of rubber plantations, the consumption of bushmeat represents one of the supply services provided by the surrounding animal species. In this regard, nine animal species were identified by the communities as contributors to this particular service. The results are presented in Table 6, which highlights the most commonly consumed species based on their use values (UVs). The animal species with the highest UVs were *Hystrix africaeaustralis* (0.72) and *Philantomba monticola* (0.53).

Table 6. List of animal species caught in the study area and their use values (UVs).

Species	Commercial Name	Local Name	Type	UV
Cricetomys gambianus	Gambia Rat	Otomba	Rodent	0.52
Dendrohyrax dorsalis	Tree Daman	Mende	Mammal	0.16
Hystrix africaeaustralis	Porcupine	Eko	Rodent	0.72
Manis spp.	Pangolin	Loka	Mammal	0.22
Nesotragus spp.	Antelope	Mengela	Mammal	0.48
Philantomba monticola	Blue duiker	Mboloko	Mammal	0.53
Potamochoerus spp.	Boar	Sombo k'okonda	Mammal	0.01
Serpentes spp.	Snake	Oloyi	Reptile	0.23
Simiiformes spp.	Monkey	Kema	Mammal	0.18

3.5. Frequency of Citation and the Level of Fidelity of the Various Species in the Supply Services

3.5.1. Traditional Pharmacopoeia

Of the 39 species identified by the communities, 26 were utilized in traditional pharmacopoeia. Table 7 presents a list of the species most commonly utilized in the pharmacopoeia, accompanied by their respective frequency of citation (FC) and levels of fidelity (LF). Furthermore, it offers insights into the specific parts utilized in each species and their associated medicinal applications.

Table 7. Species most commonly used in traditional pharmacopoeia in the areas studied and their frequency of use.

Species	Local Name	FC%	NF%	Parts Used	Medical Uses
Cleistopholis glauca Pierre ex Engl. & Diels	Otole	3	29	Gum, leaves, bark	Wounds, boils, fever
Xylopia cupularis Mildbr.	Owelewele	13	100	Leaves, seeds	Stomachache, diarrhea
Alstonia boonei Engl.	Okuka	9	100	Leaves, bark	Diarrhea, dysmenorrhea
Funtumia elastica (P. Preuss) Stap	Osomba	11	10	Bark	Stomach pain
Ceiba pentandra (L.) Gaertn.	Otamba	10	100	Seeds, bark	Cough, ascites, pneumopathy, epileptiform seizures
Canarium schweinfurthii Engl.	Owole	5	100	Bark	Dysentery
Mammea africana Sabine	Okodi	11	100	Seed, bark	Burns, syphilis
Garcinia kola Heckel	Otendo	52	100	Seed, bark	Cough, hypertension
Sansevieria liberica Gérôme & Labroy	Lokoto	2	100	Leaves	Rheumatism
Macaranga monandra Müll.Arg.	Oloko	82	63	Leaves, bark	Migraines
Plagiostyles africana (Müll.Arg.) Prain	Onenge	17	19	Cambium, bark	Earaches, venereal diseases
Croton mubango Müll. Arg.	Onyanga	26	100	Bark	Splenomegaly, tuberculosis
Albizia gummifera (J.F.Gmel.) C. A. Sm.	Owamba	2	2	Leaves, bark	Venereal diseases, asthma, wounds
Scorodophloeus zenkeri Harms	Ohidi	8	100	Bark	Skin rashes, splenomegaly
Gilbertiodendron dewevrei (De Wild.) J. Léonard	Wete	2	100	Bark	Otitis, gastritis
Tetrapleura tetraptera (Schumach. & Thonn.) Taub.	Olese	4	100	Fruit	Asthma

Table 7. *Cont.*

Species	Local Name	FC%	NF%	Parts Used	Medical Uses
Pentaclethra macrophylla Benth.	Owala	26	100	Seed, bark	Hypertension, rheumatism, hemorrhoids, constipation
Piptadeniastrum africanum (Hook. f.) Brenan	Okungu	98	96	Bark	Tooth decay, splenomegaly, convulsions, pelvic pain
Afrostyrax lepidophyllus Mildbr.	Ongenge	11	100	Leaves, bark	Hernia, psychosomatic disorders
Petersianthus macrocarpus (P. Beauv.) Liben	Too	82	42	Leaves, bark	Anemia, antispasmodic, anti-inflammatory, venereal diseases
Carapa procera DC.	Bolokoto	9	100	Leaves, bark, roots	Hypertension, diabetes, pharyngitis
Entandrophragma angolense (Welw.) C. DC.	Pake	2	21	Bark	Ulcers
Maesopsis eminii Engl.	Osungu	15	100	Bark	gonorrhea, constipation, splenomegaly, and verminosis
Aidia Micrantha (K. Schum.) F. White	Kendju	6	41	Leaves, roots	Trypanosomiasis
Morinda morindoides (Baker) Milne-Redh.	Kongo bololo	18	100	Leaves, roots	Gonorrhea, hemorrhoids, lumbago
Myrianthus arboreus P. Beauv.	Okumu	3	100	Leaves, bark	Paralysis, epilepsy, convulsions

The most frequently utilized species was *Piptadeniastrum africanum*, with a citation frequency of 95% and an accuracy level of 96%. The most commonly utilized portion of this species was the bark, which has been demonstrated to possess therapeutic properties in the treatment of conditions such as tooth decay, splenomegaly, convulsions, and pelvic pain.

The remaining species, namely *Petersianthus macrocarpus* and *Macaranga monandra*, exhibited comparable citation frequencies of 82%, with fidelity levels of 43% and 63%, respectively. The leaves and bark of these species were employed in the treatment of anemia, antispasmodics, venereal diseases, and migraines. It is noteworthy that over half of the species utilized in pharmacopoeia exhibited a fidelity level of 100%.

3.5.2. Firewood

It should be noted that not all of the species cited by the respondents were utilized for the purpose of firewood. Of the 39 species identified by the communities, only 11 were utilized as firewood (Figure 3). The most frequently cited woody species were *Funtumia elastica*, *Uapaca guineensis*, *Plagiostyles africana*, *Leonardoxa romii*, and *Cynometra alexandri*, with frequencies of 87%, 79%, 63%, 63%, and 30%, respectively. Conversely, there were a few species that exhibited remarkable fidelity, particularly *Brachystegia laurentii*, *Amphimas pterocarpoïdes*, and *Cynometra alexandri*, which had a fidelity level of 100%. Additionally, *Leonardoxa romii* and *Funtumia elastica* exhibited fidelity levels of 85% and 82%, respectively. The chi-square test of independence indicated that the frequency of quotations and the level of faithfulness varied significantly between species with regard to the use of firewood by the population (X-squared = 9.3414, df = 10, p-value = 0.0012 **).

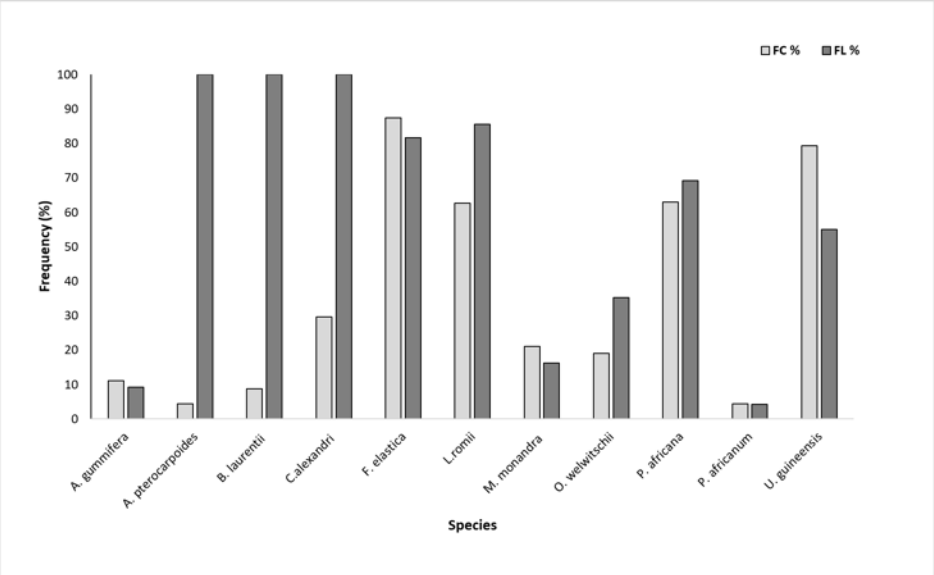

Figure 3. Citation frequencies and fidelity levels for species used as fuelwood supplied by rubber plantations in Sankuru.

3.5.3. Construction Timber

Figure 4 illustrates the frequency of quotations and the level of fidelity of species utilized for timber. A total of 12 woody species were identified as contributing to the supply of timber within the communities. The most frequently cited woody species were *Garcinia punctata*, *Diospyros alboflavescens*, and *Staudtia kamerunensis*, with citation frequencies of 46%, 45%, and 42%, respectively. Furthermore, these same species exhibited a remarkably high level of fidelity, with a notable 100% incidence. Subsequently, *Oncoba welwitschii* was cited with a frequency of 56%. The chi-square test of independence indicated that the selection of timber sourced from historical rubber plantations was influenced by the species chosen by the population (X-squared = 8.9497, df = 11, *p*-value = 0.01139).

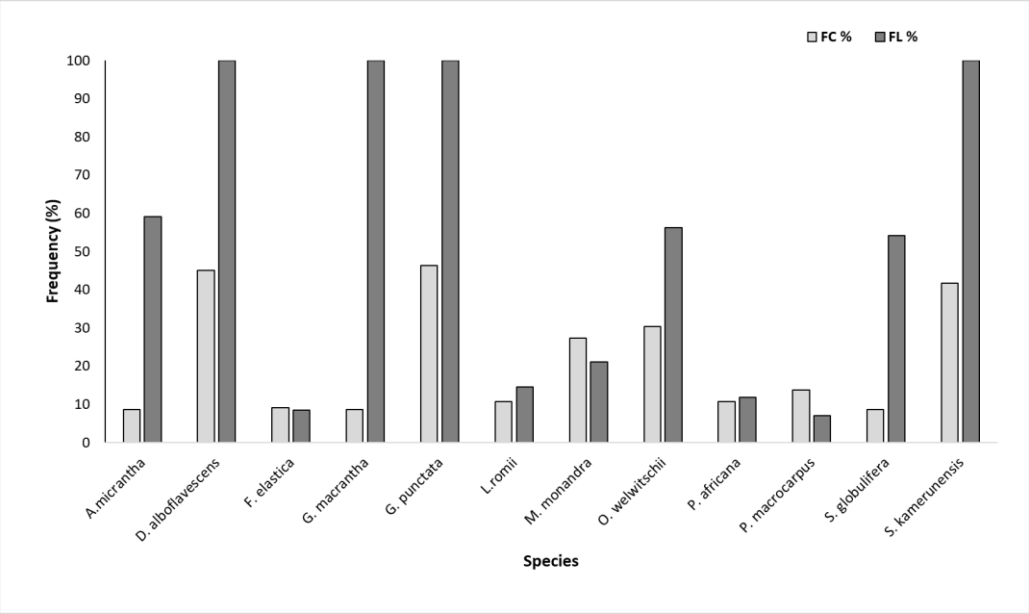

Figure 4. Citation frequencies and fidelity levels of the species used for timber in the Lodja and Lomela territories in Sankuru.

3.5.4. Timber

With regard to timber, only four woody species were identified (Figure 5). The most frequently cited species was *Albizia gummifera*, occurring in 21% of citations. Conversely, *Entandrophragma angolense* and *Cleistopholis glauca* demonstrated relatively high levels of fidelity (79% and 71%, respectively). The chi-square test of independence indicated that the selection of timber sourced from historical rubber plantations in Sankuru was not associated with species (X-squared = 4.321, df = 3, *p*-value = 0.4412 *). This suggests that timber harvesting is contingent upon the availability of these species within the rubber plantations.

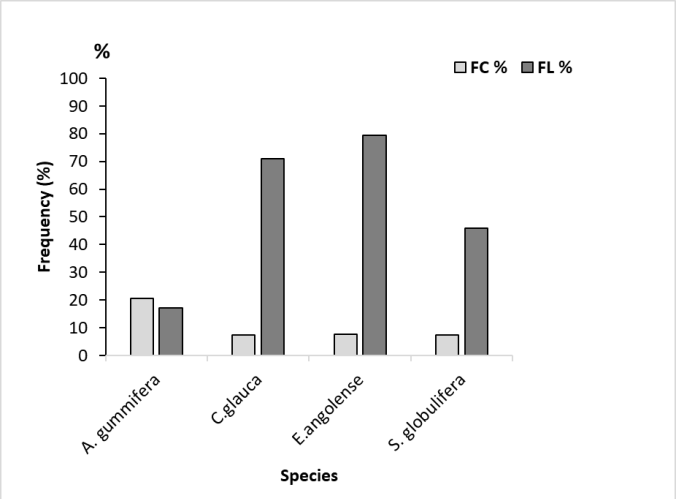

Figure 5. Citation frequency and fidelity levels of the species used for timber.

3.5.5. Bushmeat Consumption

Figure 6 illustrates the nine animal species identified by the respondents as sources of bushmeat. Of the nine species identified, the most frequently cited were *Hystrix africaeaustralis*, *Cantharellus congolensis*, and *Cricetomys gambianus*, with frequencies of 72%, 53%, and 52%, respectively.

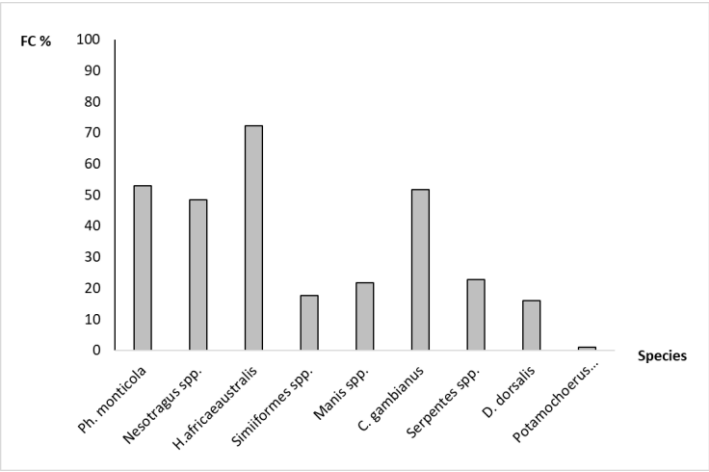

Figure 6. Frequency of animal species cited.

3.6. Farmers' Perceptions of Ecosystem Services Provided by Rubber Plantations in Sankuru

3.6.1. Perception of Provisioning Services

Figure 7 illustrates the perceived significance of supply services to local communities, as evaluated on the Likert scale. The majority of respondents indicated that firewood was a highly important supply service, with 21% considering it important and 64% considering

it very important. Additionally, over 60% of respondents indicated that traditional pharmacopoeia was of great importance to them, while over 50% also considered bushmeat to be of great importance. Nevertheless, the overwhelming majority (96%) viewed the collection of edible fruit as less significant, with only 3% deeming it important and 1% considering it moderately important.

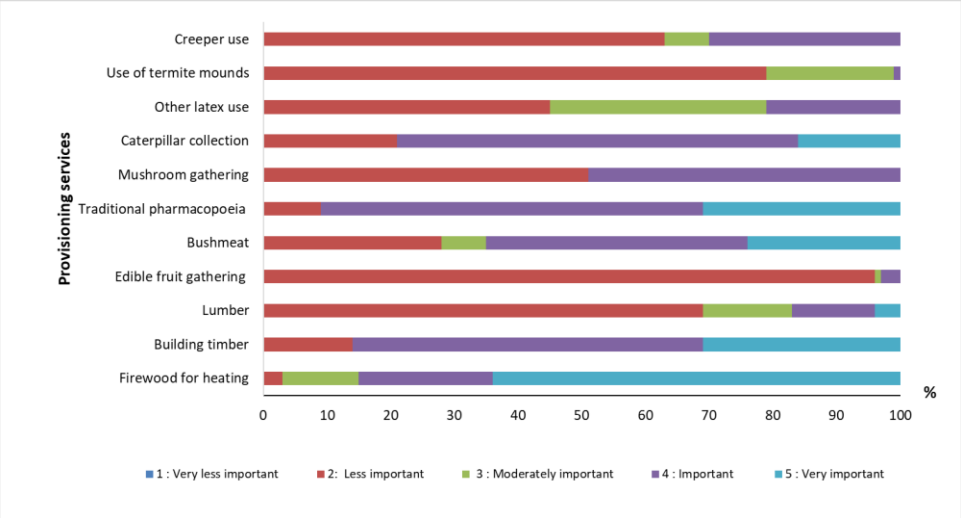

Figure 7. Perception of provisioning services.

3.6.2. Perception of Cultural Services

Figure 8 illustrates the perceived importance of cultural services as rated on the Likert scale by the local communities. It is evident that 95% of respondents viewed rubber plantations as cultural heritage inherited from their forebears. However, with regard to the aspects of esthetics (84%) and recreation (93%), the overwhelming majority of respondents indicated that they were of lesser importance.

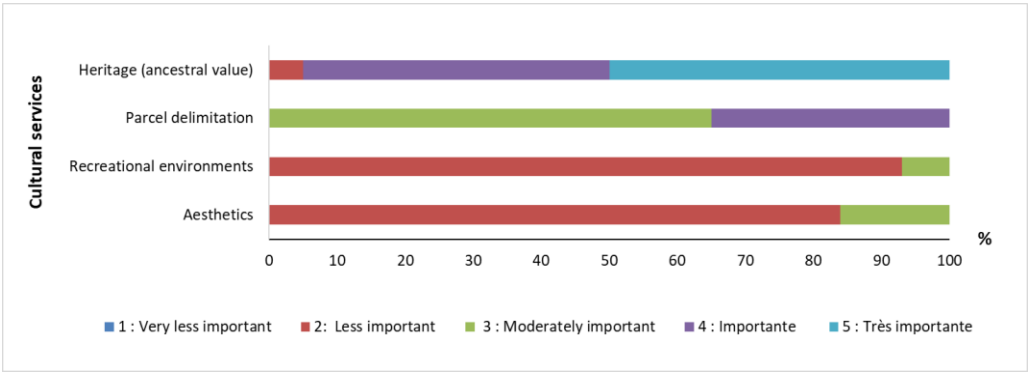

Figure 8. Perception of cultural services.

3.6.3. Perception of Support Services

Figure 9 illustrates the perceived significance of support services to the local communities, as evaluated using the Likert scale. Of the two services included in the support services category, namely shade and carbon storage, the majority of respondents (54%) indicated that shade was an important service. In the case of carbon storage, 83% of respondents acknowledged the significance of this service.

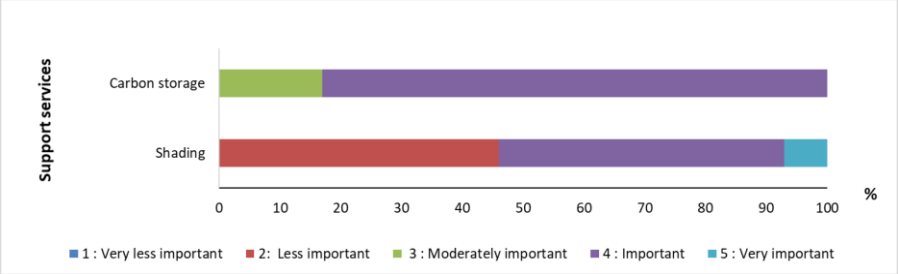

Figure 9. Perception of support services.

3.6.4. Perception of Regulating Services

Figure 10 illustrates the perceived importance of regulating services as rated on the Likert scale by the local communities. With regard to the aforementioned regulating services, wildlife habitat protection and windbreaks were regarded as significant by the communities in question, with 78% and 60% of respondents, respectively, indicating their importance. Nevertheless, a minority of the communities viewed water source protection and erosion control services as significant (29% and 18%, respectively).

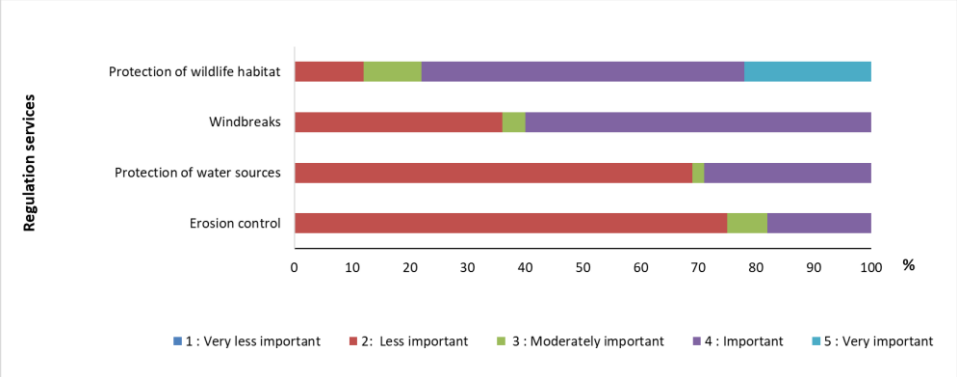

Figure 10. Perception of regulating services.

3.7. Importance of Ecosystem Services Provided According to Respondent Profile

Figure 11 illustrates the distribution of ecosystem services among communities residing in proximity to rubber plantations, classified according to religious affiliation (a), educational attainment (b), age and gender (c), and various groupings (d). The variance in interactions between religion and ecosystem services was explained by 72.48% of the data on factorial axes 1 and 2 (Figure 11a). With regard to the level of education, interactions were explained for 86.33% of the variance contained in the initial data on factorial axes 1 and 2 (Figure 11b). Conversely, the interactions between gender and ecosystem services were explained for 51.25% of the variance contained in the initial data on factorial axes 1 and 2 (Figure 11c). With regard to each grouping, interactions were explained for 60.42% of the variance contained in the initial data on factorial axes 1 and 2 (Figure 11).

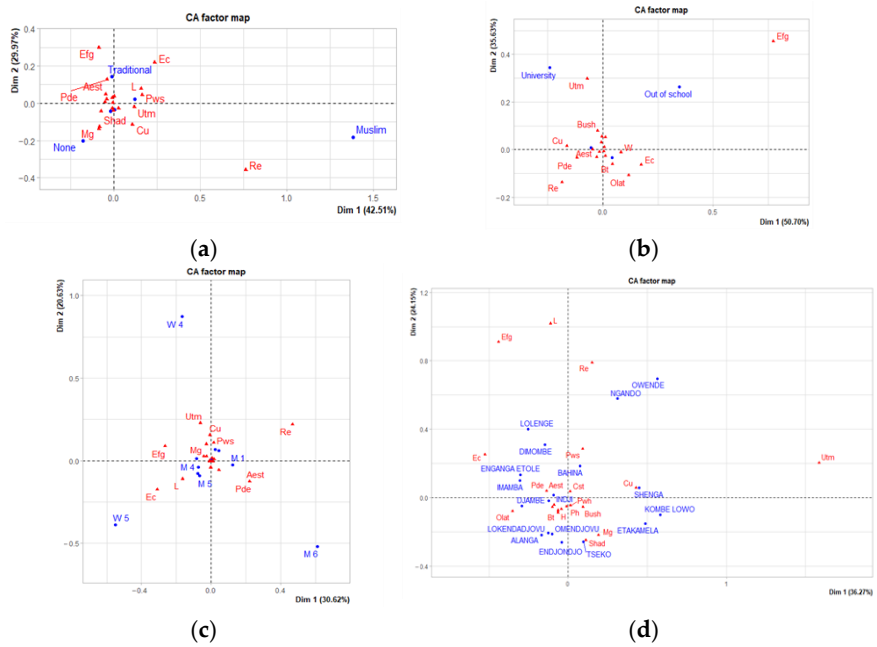

Figure 11. Importance of ecosystem services by respondent profile ((**a**) religion, (**b**) level of education, (**c**) age and gender and (**d**) grouping). With Aer: erosion control, Pse: water source protection, Bv: windbreak, Phas: wildlife habitat protection, Shade: shading, Stc: carbon storage, Esth: esthetics, Mr: recreational areas, Dp: plot boundaries, Pa: heritage (ancestral value), Cfc: edible fruit gathering, Ust: termite mound use, Bo: timber, Ul: creeper use, Rcha: mushroom gathering, lat: other latex use, Gb: bushmeat, Rche: caterpillar collection, Bc: construction timber, Ph: traditional pharmacopoeia, Bch: fuelwood, M1 and F1: men and women aged 20 to 30, M2 and F2: men and women aged 31 to 40, M3 and F3: men and women aged 41 to 50, M4 and F4: men and women aged 51 to 60, M5 and F5: men and women aged 61 to 70.

4. Discussion

4.1. Methodological Approach

This study employed social science methodologies to examine the perceptions of farmers in Sankuru province regarding the ecosystem services (ESs) provided by historical rubber plantations. As Orenstein and Groner [32] observed, social approaches are of great significance in the assessment of ESs. Moreover, numerous authors who have investigated the nexus between ecosystem services and peasant perception have employed a comparable methodology. For instance, Sina et al. [33] employed a social approach in their investigation of the perception of ESs provided by *Acacia senegal* (L.) wild stands in southwestern Niger. Similarly, Ngom et al. [30] examined the perception of provisioning ESs provided by the woody stand of the Ferlo Biosphere Reserve in Senegal. Yildirim et al. [34] employed social approaches to examine the perception of ESs and elucidate the environmental capital of a territory, along with its associated development issues, in the Karaburun peninsula in Turkey. In a similar vein, Ndiaye et al. [31] employed social approaches to examine the community perception of ecosystem goods and services furnished by woody species in the Upper Casamance region of Senegal.

Furthermore, the study employed a number of parameters utilized by other authors to evaluate the variability of ES uses including citation frequency (CF), use value (UV), informant consensus factor (ICF), and level of fidelity (LF). For example, Nghonda et al. [27] examined the citation frequency of non-timber forest products to identify the most commonly utilized non-timber forest products of plant origin. Similarly, Ngom et al. [30] and Badiane et al. [35] employed use value, informant consensus factor, and fidelity level to ascertain the relative importance of each species in provisioning services for the population.

However, these indicators are not exhaustive, and it is imperative to develop novel tools to more comprehensively understand how ecosystem services are utilized by populations.

In order to examine the significance of ESs in accordance with the respondent profile, a multiple correspondence factorial analysis (MCAFA) was conducted. A new MCAFA was conducted to analyze the individuals' preferences regarding their sense of environmental stewardship, considering various data matrices. In a similar vein, Rambeloarisoa et al. [36] employed MCAFA to categorize fokontany based on the ESs ascribed to them by local populations in Madagascar. Similarly, Habonayo et al. [37] explored the interactions between protected areas and ecosystem services in Burundi using MCAFA.

4.2. Socio-Demographic Profile of Respondents

Despite the random sampling methodology employed, a greater number of male respondents (74.67% of the total sample) were interviewed (Table 2) as women were either less willing to participate in the surveys or were otherwise engaged in domestic responsibilities. Moreover, the majority of heirs to Sankuru's rubber plantations are male [6,7].

As evidenced by the findings of several scholars such as Dave et al. [38] and Mobunda et al. [39], in numerous traditional African societies, the role of family head is predominantly occupied by men. This may potentially influence the willingness of women to express their opinions. The mean age of respondents was 38 years, with 33% falling within the 31–40 age range and 27% within the 20–30 age range. The population surveyed in this area is relatively young. These results are similar to those of Beuve-mery [4], who in his study in the same area had more than 50% of respondents under the age of 35. Almost half of the respondents claimed to have attended primary school (49, 67%), but very few continued their studies, resulting in a respondent rate of university level of 1.7%. This is in line with the claim of Michel et al. [5] and De Roover [6] that secondary school enrollment is lower than primary school enrollment in the region. It should be noted that the majority of respondents were married (92.33%) and most of them had large families. The predominant religions were Protestantism and Catholicism.

Furthermore, the study area was distinguished by a notable degree of multidisciplinary, wherein local communities engaged in a diverse array of activities to sustain themselves. Agriculture was a pervasive practice, engaged in by all members of the community. It not only serves as a source of sustenance, but also as a means of livelihood. Firewood represented the primary source of energy for all households. It was evident from the observations that the responsibility for this task was typically borne by women. With regard to hunting, 60.67% of respondents claimed to engage in this activity. Indeed, despite the pressure that wildlife resources are already under, bushmeat is widely consumed in the area. Michel et al. [5] asserted that a massive and illegal influx of bushmeat could mainly be observed in the city of Lodja, noting that the province faces landlocked conditions and extreme widespread poverty.

These findings illustrate the intricate interrelationship between socio-economic dynamics, cultural practices, and environmental sustainability in the study area, emphasizing the necessity for comprehensive strategies to address livelihood challenges while ensuring the conservation of ecosystems and the management of natural resources.

The application of agrarian analysis facilitated the identification of four distinct types of plantations, along with an understanding of their associated social, economic, and environmental implications. This provides a valuable perspective for understanding the specific rural dynamics associated with each type of rubber plantation in Sankuru. This comprehensive insight can inform the formulation of effective policy measures by policymakers to oversee these plantations and develop suitable agricultural policies that

facilitate sustainable rural development while addressing the region's increasing food security concerns.

4.3. Occurrence of Ecosystem Services Provided by Rubber Plantations

A total of 21 ecosystem services were identified by local communities (Figure 2), which were grouped into four categories: provisioning services, cultural services, regulatory services, and support services. The respondents indicated that provisioning services were the most significant, with eleven services identified, followed by cultural services, with four services identified. These findings are consistent with those reported by Chabi et al. [23], who identified 27 services including nine provisioning services and eight cultural services. The provision of firewood (96.67%) and traditional pharmacopoeia (91.33%) were identified as significant supply services. Similarly, Ndiaye et al. [31] identified these two services as fundamental for communities utilizing the woody stands of the Ferlo Biosphere Reserve in Senegal. Indeed, provisioning services are defined as services that enable people to obtain marketable or consumable goods through the exploitation of ecosystems, as previously highlighted by other researchers [14,31]. In terms of cultural services, 95.33% of the local communities surveyed identified these old rubber plantations as a heritage site. For the majority of communities in Sankuru province, these plantations represent an ancestral value that they feel obliged to preserve and protect as a tribute to their ancestors. In addition to the continued harvesting of rubber latex, which is in decline, local communities in Sankuru province derive numerous benefits from the old rubber plantations, of which they are largely aware. It is therefore essential that the local communities are able to understand and recognize the value of these services in order to facilitate informed decision-making and the implementation of sustainable management strategies that will ensure the preservation of both the cultural heritage and ecological integrity of the region.

4.4. Use Values of Ecosystem Services of Provisioning and Different Species Used

Of the 39 woody species identified by local communities as contributors to the provision of five categories of provisioning ecosystem services, some are utilized to a greater extent than others. The species with the highest UVs included *Petersianthus macrocarpus* (1.95), *Piptadeniastrum africanum* (1.93), *Uapaca guineensis* (1.44), *Macaranga monandra* (1.30), *Albizia gummifera* (1.20), *Funtumia elastica* (1.07), and *Amphimas ferrugineus* (1.00). These values are often regarded as an indication of species that are subject to high utilization pressure [30,31]. It is also noteworthy that the informative consensus factor (ICF) exceeded 90% for all five ecosystem service categories that rely on specific woody species. These findings are consistent with those reported by Ndiaye et al. [31], who also observed a high informative consensus factor (ICF) for the various categories of tree utilization. With regard to the mushroom species that contributed to the collection service, the species with the highest UVs were *Lentinus brunneofloccosus* (0.94), *Cantharellus congolensis* (0.88), *Auricularia cornea* (0.87), and *Schizophyllum commune* (0.84). These species are of particular importance to the local communities, serving as a source of sustenance. Among the animal species consumed, the highest UV were observed for *Hystrix africaeaustralis* (0.72) and *Philantomba monticola* (0.53). Despite their previous designation as plantations, these areas have now become home to a rich biodiversity, in addition to the existing rubber tree plantations.

4.5. Use Values, the Role of Regulating Ecosystem Services, and Market Access

The results of this study show that rubber plantations in Sankuru province provide important regulating services, in particular carbon storage and windbreak functions. These services are essential for the ecological sustainability of local ecosystems, contributing to climate change mitigation and agricultural land protection. Bustillo et al. [40] showed that

Yangambi rubber plantations in the Democratic Republic of Congo sequester an average of 337.33 Mg/Ha. The results of this study indicate that these plantations play an important role in mitigating greenhouse gas emissions by sequestering CO_2 in the biomass. However, these observations require direct measurements of the above and below ground biomass to accurately quantify the carbon storage of these historic plantations. However, carbon measurements based on standardized methods, such as the plot-based carbon stock method and the use of sensors to assess CO_2 concentrations, would be required to provide a more reliable and robust estimate of the carbon storage potential of these plantations. It is also crucial to study the capacity of these plantations to sequester carbon in the long-term, particularly by studying the variations in carbon stocks over time, depending on the age of the plantations and the agricultural practices used.

Furthermore, market access is a pivotal socio-economic factor that exerts a direct influence on the management of natural resources and the exploitation of ecosystem services provided by Sankuru's rubber plantations. Despite the established presence of rubber plantations in the region, local farmers in Sankuru encounter challenges in accessing markets for the sale of their produce, thereby limiting their capacity to fully benefit from the regulatory and production services offered by these plantations. The dearth of transport infrastructures, organized sales outlets, and efficient distribution mechanisms further exacerbates this situation. Research conducted by Kpoviwanou et al. [41] on agroforests in Africa demonstrates that improved market access leads to the adoption of sustainable farming practices, as farmers are incentivized to manage their natural resources more responsibly and invest in their long-term management. In the context of Sankuru's historical rubber plantations, enhanced market access has the potential to empower farmers to better valorize their products, thereby facilitating more effective management of the plantations and the ecosystem services they provide. The integration of socio-economic dimensions into the analysis of ecosystem services promises to offer a more nuanced understanding of the interplay between local economic dynamics and market access on plantation management and the sustainability of ecosystem services. The integration of these socio-economic dimensions into natural resource management is imperative to ensure the long-term sustainability of Sankuru's historic rubber plantations and the optimization of the ecological services they provide.

4.6. Citation Frequencies and Fidelity Levels of Species Used

The plantations under study are rich in woody species utilized in pharmacopoeia, and their communities possess detailed knowledge of the diseases that these plants can treat. The species most frequently utilized in pharmacopoeia is *Piptadeniastrum africanum*, with a citation frequency of 95% and an accuracy level of 96%. The plant is used to treat a number of conditions including tooth decay, splenomegaly, convulsions, and pelvic pain. It is noteworthy that over half of the species utilized in pharmacopoeia exhibited a fidelity level of 100%. As stated by Ndiaye et al. [31], a fidelity level of 100% indicates that the species in question does not contribute to any other ecosystem service. In terms of the diverse applications of wood, eleven species were utilized as fuelwood, twelve as construction wood, four as timber, and seven as caterpillar trees. These findings are consistent with those of previous studies by Mpanzu et al. [42], Madjimbe et al. [43], and Azenge and Meniko [44], which confirm that woody plants are a primary source of energy and provide people with fuelwood and timber. The woody species most frequently cited as fuelwood were *Funtumia elastica*, *Uapaca guineensis*, *Plagiostyles africana*, *Leonardoxa romii*, and *Cynometra alexandri*. Indeed, firewood represents the primary source of energy in the region. It is evident that women had a preference for specific species, particularly *Funtumia elastica* and *Cynometra alexandri*. Additionally, the *Petersianthus macrocarpus* species is regarded as a

caterpillar tree and is held in high esteem by the majority of communities. As also asserted by Lhoest et al. [18], Xiaoqi Wang and Xuevan Zhao [45], Ambombo et al. [46] and Ndiaye et al. [31], it is a multi-use species.

4.7. Farmers' Perceptions of the Ecosystem Services Provided by Rubber Plantations

In terms of supply services, the majority of respondents indicated a high level of importance for firewood and traditional pharmacopoeia, while the gathering of edible fruits was perceived as less significant. These findings are at odds with those of Yildirim et al. [34], in which medicinal plants were identified as being of lesser significance. These results demonstrate that perceptions are firmly rooted in the needs of the local communities in each region. The assessment of cultural services indicates a general recognition of their significance, particularly with regard to heritage. This finding lends support to the results obtained earlier regarding the customary interest of local communities in these plantations. However, unless an effort is made to elucidate the significance of regulatory and support services to communities, they are typically unaware of these services, as they are often challenging to discern. Similarly, Gbéyi [47] observed a similar phenomenon in Benin, while Dejene et al. [48] documented a comparable trend at the Guraferda rubber plantations in southwestern Ethiopia.

Moreover, the decision of local communities in Sankuru to refrain from converting rubber plantations into agricultural fields can be seen as an indication of their recognition of the cultural and historical significance of these plantations, which have been inherited from their ancestors. These plantations are regarded as a symbol of the cultural heritage of the local communities. By maintaining these lands despite the absence of latex exploitation, they uphold the traditions and practices of their forebears, thereby ensuring an intergenerational continuity. This demonstrates a profound respect for the historical and cultural values that inform their identity. The maintenance of these plantations over time thus represents an act of resilience against the deforestation that threatens the region's natural resources. This consistency is echoed in a study conducted by Smith et al. [49], which underscores the vital role of preserving traditional farmland in upholding cultural identity and intergenerational continuity within a local community. The decision of local communities in Sankuru to refrain from clearing rubber plantations in favor of agricultural fields is indicative of a prioritization of cultural heritage, sustainable resources, and a community vision that emphasizes harmony with the environment. This underscores their dedication to their traditions and their aspiration to safeguard their cultural identity in an ever-changing world.

4.8. Importance of Ecosystem Services by Socio-Demographic Characteristics

The application of multiple correspondence factorial analysis (MCAFA) facilitated an investigation into the distribution of ecosystem services as reported by communities residing in proximity to rubber plantations. The distribution was examined in relation to various socio-demographic factors including religion, level of education, age, gender, and different groupings. The findings indicated that the majority of provisioning ecosystem services were reported more frequently by men and women in the 20–30 and 31–40 age groups, respectively. Conversely, older men in the 40–60 age range reported the cultural and regulatory services with greater frequency. This finding is consistent with the results of a study conducted by Mobunda et al. [39], who highlighted that those older farmers placed a high value on ecological and cultural regulation services due to their extensive experience and historical understanding of farming systems. Younger individuals appeared to exhibit a greater inclination toward provisioning services in comparison to their older counterparts. This finding is at odds with the assertion by Maddison [50] that experience should be prioritized over age when it comes to valuation. While traditionally, older individuals have

been regarded as the most knowledgeable, recent observations indicate that it is currently younger people who are exploring existing ecosystems the most. This phenomenon can be attributed to two primary factors: the low school enrollment rates observed in rural areas and the high incidence of early dropout from education due to financial constraints. This finding is consistent with the results reported by Rambeloarisoa et al. [36]. It is also noteworthy that there was a consensus among academics regarding the significance of these plantations for carbon storage. Their level of education allowed them to readily discern the various regulatory, support, and cultural services.

These findings align with those of previous studies conducted by Martín-López et al. [51], Wang et al. [52], and Sundqvist [53], which demonstrated that the perception of sustainable ecosystems varied significantly according to the level of education attained. The findings of this study indicate that an increase in the farmers' educational attainment was associated with an enhanced awareness of ecosystem services (ESs), which, in turn, was associated with the adoption of sustainable management practices. Moreover, the majority of supply services were readily discernible by the communities, irrespective of religious affiliation. The communities belonging to the Alanga, Dinombe, Endjondo, Imamba, Indji, Lokendjovu, Omendjovu, and Tseko groups were found to exhibit a strong preference for firewood, pharmacopoeia, and wildlife habitat protection. In contrast, lumber was a significantly more prevalent material among the Dinombe, Lolenge, and Ngando groups. The findings of this study indicate that rubber plantations have the potential to serve as a sustainable source of firewood. As indicated by Pinizzotto et al. [2], numerous farmers view fuelwood derived from rubber plantations as a viable and cost-effective alternative to traditional energy sources. Timber harvested from rubber plantations in Sankuru is utilized in the construction of doors and furniture for residential structures within local communities. These findings are consistent with those of Yuan et al. [54], who highlighted that rubber-based agroforests offer an additional source of income through timber sales.

The findings of this study demonstrate that, in addition to latex production, these plantations can serve as a significant source of various ESs that are beneficial to the farming communities in close proximity. It is therefore imperative to enhance the knowledge base of the local communities so that they can comprehend the functioning and interactions of ecosystems, the diverse benefits they offer, and the threats and pressures that can erode these benefits. An integrative and participatory approach to natural resource management may prove more effective in aligning the farmers' perceptions with the sustainable development objectives.

4.9. Implications of Farmers' Perception of Ecosystem Services for the Sustainability of Historical Rubber Plantations

The findings of this study demonstrate the pivotal role that historical rubber plantations play in the survival of local farmers (Figure 2). The perception of these services by local farmers is a determining factor in the sustainable management of plantations and the preservation of natural resources in Sankuru province. Local farmers, as the primary managers of these plantations, possess profound knowledge of the local ecosystem and its functioning. Their perception of environmental services (ESs) has the potential to exert a substantial influence on farming practices, biodiversity conservation, and plantation resilience to environmental change [27]. The farmers' awareness of these services has the capacity to motivate them to adopt more sustainable practices such as agroforestry, integrated soil management, and natural resource conservation. Furthermore, the farmers' perceptions of the cultural and social services associated with rubber plantations, such as their role in preserving local identity and transmitting traditional knowledge, may also have an impact on plantation sustainability.

Local farmers regard rubber plantations as cultural heritage, which encourages them to protect and manage them sustainably. This cultural appreciation of rubber plantations has the potential to reinforce the local communities' commitment to forest conservation and the preservation of traditional agricultural practices. Moreover, this cultural appreciation has the potential to encourage community development initiatives that integrate ecological and social aspects. Furthermore, the perception of rubber plantations as a source of supply can encourage farmers to adopt practices that promote long-term productivity. Such practices include sustainable soil management and crop rotation. Moreover, a comprehensive understanding of the farmers' perceptions of ecosystem services can serve as a foundation for decision-makers to formulate conservation policies tailored to local realities [30,31]. By acknowledging the values and priorities of rural communities, decision-makers can develop management strategies for rubber plantations that address the farmers' socio-economic needs and ecological requirements.

For instance, the implementation of awareness-raising and training programs on ecosystem services has the potential to encourage environmentally friendly farming practices, thereby enhancing the living conditions of rural populations. The farmers' perception of ecosystem services plays a pivotal role in the sustainable management of historical rubber plantations [36]. A more profound comprehension of these services by farmers can motivate them to adopt more sustainable agricultural practices, enhance the ecological functions of plantations, and fortify their resilience in the face of environmental challenges [49]. Consequently, it is imperative to incorporate these perceptions into rural development and natural resource management strategies to ensure the sustainability of rubber plantations and the preservation of local ecosystems.

5. Conclusions

This study aimed to promote the environmental, economic, and social sustainability of Sankuru's historic rubber plantation ecosystems while strengthening stakeholder dialogue to facilitate concerted and inclusive natural resource management. The results highlight the critical importance of these plantations in maintaining ecosystem services that support both the local economy and the environment. The study highlighted the importance of socio-demographic characteristics in the perception and use of ESs. While young people seemed to be more interested in provisioning services than older people, older people knew more about cultural and regulating services, and the minority of academics surveyed knew more about supporting services such as carbon storage. It is therefore important to emphasize the importance of these historic rubber plantations in providing multiple ESs for the benefit of the population in the study area, and not just in latex production.

Over time, these plantations have become valuable cultural heritage for local communities. This perception has a direct impact on the way that these plantations are managed. This awareness is essential to ensure the sustainability of these plantations, particularly in the face of environmental challenges such as climate change and deforestation. However, it has become clear that the sustainability of historic rubber plantations cannot be ensured without an inclusive and collaborative approach. Dialogue between different stakeholders—including farmers, local authorities, researchers, and non-governmental organization (NGOs)—is essential to promote natural resource management policies that meet the environmental, economic, and social needs of rural communities. In this sense, the farmers' perceptions of ecosystem services play an essential role in the formulation of national natural resource management policies.

The results of this study suggest that national natural resource management policies need to integrate the farmers' perceptions and local knowledge, particularly with regard to ecosystem services in Sankuru rubber plantations. The adoption of participatory prac-

tices and the establishment of multi-stakeholder governance mechanisms will strengthen the resilience of perennial cropping systems to environmental challenges while ensuring sustainable economic development for local communities. It is imperative to promote an integrated and inclusive management model for these historic plantations. This will also ensure the sustainable management of these valuable ecosystems for the benefit of present and future generations. The study therefore highlights the need for further in-depth research on these rubber plantations, particularly in terms of floristic diversity and carbon sequestration potential, taking into account the particular context of Sankuru province and the perceptions of the local people when these abandoned historic plantations were integrated.

Supplementary Materials: The following supporting information can be downloaded at: https://www.mdpi.com/article/10.3390/conservation5010007/s1, 1. Database Excel; Table S1: Geographical coordinates of 30 villages surveyed; Table S2: Scientific and commercial equivalence of woody species in the Tetela dialect; Table S3: Survey questionnaire; Figure S1: Some products supplied by Sankuru's historic rubber plantations.

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