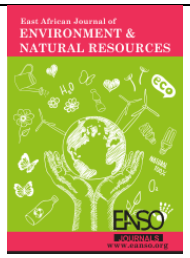

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Original Article

Techno-Economic and Socio-Cultural Determinants of Beekeeping Integration within Agricultural Production Systems of Landowners in and Around the Luki Biosphere Reserve (Kongo Central, DR Congo)

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Beekeeping, Agricultural Systems, Landowners, Economic Integration, Agroecology, Land Tenure Security, Luki Biosphere Reserve.

ABSTRACT

Land capital and compensation preferences emerge as the principal determinants governing the integration of beekeeping into the agricultural production systems of landowners in and around the Luki Biosphere Reserve (LBR) in the Democratic Republic of Congo. This study investigates the techno-economic and sociocultural factors shaping this integration, with the aim of identifying key barriers and proposing context-specific interventions. A purposive sampling strategy was employed, targeting farmers who demonstrated an explicit interest in the concentrated apiary approach, following preparatory consultations with local village authorities to facilitate engagement. Findings indicate that landowners most receptive to beekeeping adoption possess extensive and diversified landholdings, spanning multiple agroecological zones, with diverse cropping systems and a significant proportion of fallow land. While demographic characteristics such as age and gender were found to be non-determinant, apicultural knowledge, and compensation arrangements, specifically a preference for long-term agreements (exceeding five years) and annual in-kind payments representing at least 10% of production, play a pivotal role in decision-making. The study underscores the crucial importance of economic incentives and capacity building to foster the sustainable integration of beekeeping practices. Accordingly, development initiatives promoting concentrated apiaries should primarily target landowners with secure tenure rights, substantial and diversified land assets, and a readiness to engage under mutually advantageous partnership terms.

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INTRODUCTION

The protection of existing protected areas in developing countries, particularly the Luki Biosphere Reserve (LBR) in the Democratic Republic of Congo, is becoming increasingly complex (Nsenga, 2001). Human activities such as shifting slash-and-burn agriculture, charcoal production, and logging are degrading the forest ecosystems and agroecosystems of this reserve, leading to massive deforestation (Bamba et al., 2008). Despite conservation laws (Law No. 14/003 of February 11, 2014), the LBR continues to face the overexploitation of its natural resources, thereby threatening its biodiversity (Nyange, 2014). Moreover, access to agricultural land is a limiting factor for many farmers in Luki, where most of the population does not own land, either through customary or legal means (Péroches, 2019). On the one hand, land tenure is the primary factor distinguishing agricultural operators; on the other hand, land allocation is often influenced by individuals with the highest social status (Diyazola, 2021).

As a result, community activities in Luki, including agriculture, informal trade, charcoal production, and logging, have led to the destruction of 20% of forests over the past decade (OSFAC, 2016). Furthermore, the exponential population growth and widespread poverty among local communities contribute to failing agricultural practices and an increased reliance on charcoal production (Nyange, 2014; Kabeya et al., 2024).

In this context, beekeeping in and around the LBR is emerging as a sustainable alternative to the destructive use of natural resources. It contributes to diversifying local production systems and improving the incomes of local populations (Shembe, 2021), while also securing fallow land for longer periods (Péroches, 2019). However, despite its traditional practice, beekeeping struggles to become systematically integrated into rural activities due to various constraints, particularly the

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lack of secure land access for non-native beekeepers (Péroches, 2019). To overcome these land tenure challenges, ULB-Cooperation proposes grouping novice beekeepers within a secure area of at least one hectare, requiring close collaboration between beekeepers and landowners of diverse profiles to develop sustainable solutions (Diyazola, 2021).

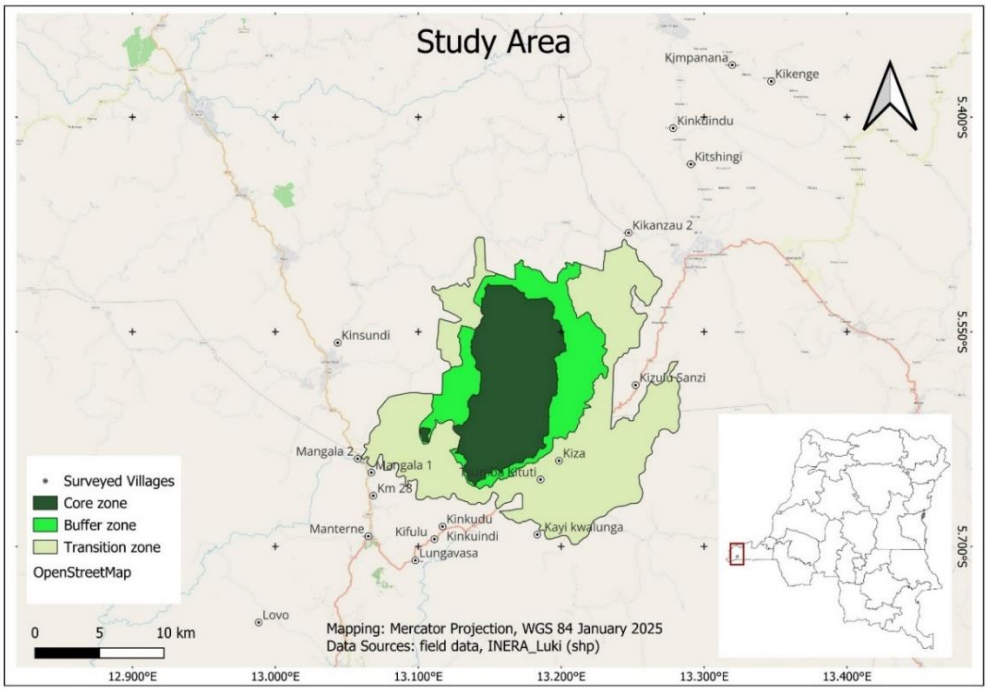
The integration of concentrated beekeeping within agricultural farms in Luki and surrounding areas would depend on several factors, including the land area of the host farm. The support provided by associations to their beekeeper members would play an important role in the installation, but this would not be sufficient to guarantee the success of their beekeeping activities. Beekeeping and the land conditions in which it is practiced would be compatible. Thus, this study aims to understand landowners' motivations for integrating beekeeping, based on the hypothesis that technical, sociological, and cultural factors may hinder this integration. Consequently, it highlights the importance of identifying and characterizing potential hosts for apiaries to develop sustainable solutions. Furthermore, it seeks to guide the "concentrated apiaries" strategy toward the most receptive landowners in the Luki region by characterizing potential hosts, determining the most favorable collaboration modalities, and identifying the technical, sociological, and cultural determinants of beekeeping integration into farming systems.

METHODS

Study Area

This study was conducted in and around the Luki Biosphere Reserve (LBR), a unique ecosystem and remnant of the Mayombe forest massif, designated as a UNESCO-recognized reserve since 1979. The area spans across three territories Lukula, Muanda, and Seke-Banza, in the Kongo Central province of the Democratic Republic of Congo. It comprises a primary sub-equatorial forest surrounded by secondary forests, savannas, agroforestry plantations, and inhabited zones, including villages located within the reserve itself (enclaves) as well as those situated between 1 and 5 km from its boundaries (Djami et al., 2023).

Figure 1. Location of the Study Area in Luki Biosphere Reserve, Kongo Central, DRC



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The rapid population growth in the region exerts enormous pressure on the protected area, particularly in the buffer zone, which has led to the implementation of projects aimed at reducing local inhabitants' dependence on forest resources (Diyazola, 2021; Kabongo Kabeya et al., 2024). The population surrounding the reserve increased from 28,590 in 1993 to 138,589 in 2014 (Michel Mbumba et al., 2020; Nsenga, 2001; Nyanga, 2020). A total of 33 villages were selected based on their location and the impact of their activities on the reserve, including those within the ULB-Cooperation intervention zone, as well as others to expand the study sample and ensure regional representativeness.

Materials

A pre-designed electronic questionnaire, created on the KoboToolbox platform, was administered individually to each participant using a smartphone via the KoboCollect application. Upon completion, the electronic form was uploaded and submitted to the platform's server. The questionnaire included fourteen questions on respondents' sociodemographic characteristics, land ownership, and the conditions for establishing an apiary on their land. Each interview lasted between 60 and 75 minutes.

Data Collection

The data collection was conducted in two distinct phases: from January to March 2021 and from August to September 2021. Subsequently, focus group discussions were organized, involving 10 to 20 farmers, regardless of whether they had been interviewed during the first phase, to validate individual responses, particularly regarding land rental practices and specific beekeeping arrangements. Finally, field observations were carried out on cultivated lands and unused plots to assess respondents' various agricultural activities and their compatibility with beekeeping.

Sampling

A non-probability sampling method was used to target a specific category of farmers. In each village, individuals who expressed interest in the concentrated apiary strategy were selected, and meetings were scheduled to explain the study objectives. This process was preceded by interviews with village leaders to prepare for the activity and encourage participation.

During meetings with farmers, a selected number of individuals (2 to 6) were targeted for interviews, depending on their availability. As a result, a total of 111 farmers participated in the study, with 35 interviewed during the first phase and 76 during the second phase.

The distribution of respondents across the 33 surveyed sites is as follows:

Kinzambi Zolele (3), Kinkazu/Noki Dia Zulu (3), Kifudi (2), Mangala 1 (4), Mangala 2 (3), Lungavasa (3), Manterne (3), Km 28 (4), Kinsundi (4), Mayama Kaka (3), Kiza Nsanzi (4), Tshumba Kituti (6), Kayi Kulunga 2 (2), Kayi Kulunga 1 (2), Kimbenza Nkazu (5), Mao Village (3), Kifulu (2), Kimalele (3), Manzonzi (3), Lovo (4), Mikondo 2 (3), Kinkuindi (2), Kimpanana (2), Kinkenge (3), Ntombo Kingoma 1 (4), Kimufu (4), Kinkudu (5), Kizulu Sanzi (2), Kitshingi (4), Kinkazu 1 (3), Kinkudu (3), Kibuatu (4), Kimbula (6).

The characterization of respondents, expressed in terms of variables, included gender, age, production system, beekeeping knowledge level, land capital, fallow land capital, available land area for beekeeping, agroecological zone diversity, cultivated agroecological zones, cropping system diversity, practiced cropping systems, compensation modalities, revenue-sharing arrangements, and rental duration. These variables provided a precise analysis of farmers' characteristics and agricultural practices in relation to beekeeping. The key questions constituting the survey questionnaire are formulated as follows: Can

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you tell me about your family and your land, including your level of education, the training you have received, your ownership status, the size of your land, as well as the cropping systems (SDC) and agro-ecological zone (ZEA) you have? Can you also describe your agricultural activities, their environmental impact, their profitability, your appreciation of beekeeping and the place it occupies, as well as your knowledge of individual beekeeping (RI), concentrated beekeeping (RC), and COPAMA (Collective of Beekeepers of Mayombe)? Would you agree to collaborate with a beekeeping association by hosting RCs on your land in exchange for benefits to be discussed? What would be your position regarding this collaboration and what mode of collaboration would seem appropriate to you? Tell me about your experience with the beehives you already host, the improvements in ZAE recorded thanks to beekeeping, the advantages and disadvantages encountered, and your vision of collaboration with beekeepers. Have your incomes evolved since the installation of the beehives and what is your vision for the future regarding a potential collaboration with beekeepers?

Data Processing and Analysis

Raw data transferred from the KoboToolbox platform were extracted in Excel format, carefully cleaned, prepared, and formatted for analysis in SPSS. Descriptive analysis was conducted on each study variable, with frequencies presented after processing in Excel. Results were displayed in tables and graphs. For quantitative data, statistical parameters such as mean and standard deviation were calculated and interpreted.

The determinants of beekeeping integration into farming systems were identified through a factorial analysis using SPSS 28. This analysis aimed to synthesize the most significant information contained in the multivariate dataset characterizing the surveyed farmers. Consequently, the various variables were reduced into principal components, referred to as factors, to facilitate interpretation. The statistical formulas used are as follows:

- $\text{Percentage (\%)} = \left(\frac{n}{N}\right) * 100$
- $\text{Mean (M)} = \left(\frac{\sum \text{Values}}{\text{Nomber of values}}\right)$
- $\text{Standard Deviation } (\sigma) = \sqrt{\frac{1}{N}\sum_{i=1}^{N}(x_i - \mu)^2}$
- $\text{Variance } (\sigma^2) = \left(\sqrt{\frac{1}{N}\sum_{i=1}^{N}(x_i - \mu)^2}\right)^2$
- $\text{Determinants } (A) = \sum_{j=1}^{n}(1)^{i+j}a_{ij}\det(A_{ij})$
- $\text{Cronbach's Alpha } (\alpha) = \frac{k}{k-1}\left(1 - \frac{\sum_{i-1}^{k}\sigma_{Yi}^2}{\sigma_X^2}\right)$

RESULTS

The results are structured into three levels. The first level concerns the characteristics of potential land donors for beekeeping sites in the Luki region. The second level presents the most preferred cooperation modalities. Finally, the third level analyzes the technical, economic, and cultural determinants of integrating beekeeping into agricultural systems.

Characterization of Potential Land Providers for Concentrated Apiaries

Potential beekeeping land providers were characterized based on socio-demographic criteria, agro-land ownership, and knowledge of beekeeping.

Socio-Demographic and Agro-Land Characteristics of Respondents

Gender and Age

The results indicate a male dominance among respondents (95%). Most respondents are elderly, with 39% aged over 60 and 35% between 51 and 60

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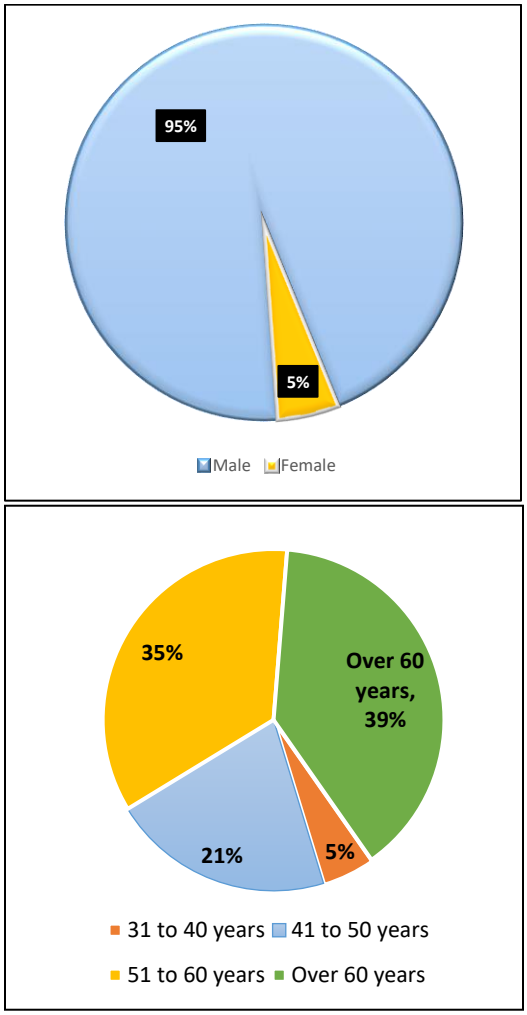
years old. Younger age groups are less represented: 21% of respondents are between 41 and 50 years old, and only 5% fall within the 31–40 age range. The data suggest that beekeeping in the region is primarily practiced by older men, which may pose challenges for knowledge transmission and generational renewal in this sector.

Figure 2: Gender and Age of Respondents



Land Tenure Status and Land Capital

The results reveal a diversity of land tenure statuses and land capital among respondents. The majority are customary landowners (60%), classified into first, second, and third-order categories. Tenant farmers under INERA or other entities represent 23%, while 12% are tenants of traditional land right holders. Only 5% acquired land through individual purchase. Nearly half of the respondents (48%) own properties larger than 20 hectares. In contrast, 17% hold between 1 and 5 hectares, and 14% own between 6 and 10 hectares. Intermediate land sizes are less common, with 13% of respondents owning between 16 and 20 hectares and 9% between 11 and 15 hectares. These figures suggest a predominance of customary land rights and a polarization between large and small landowners.

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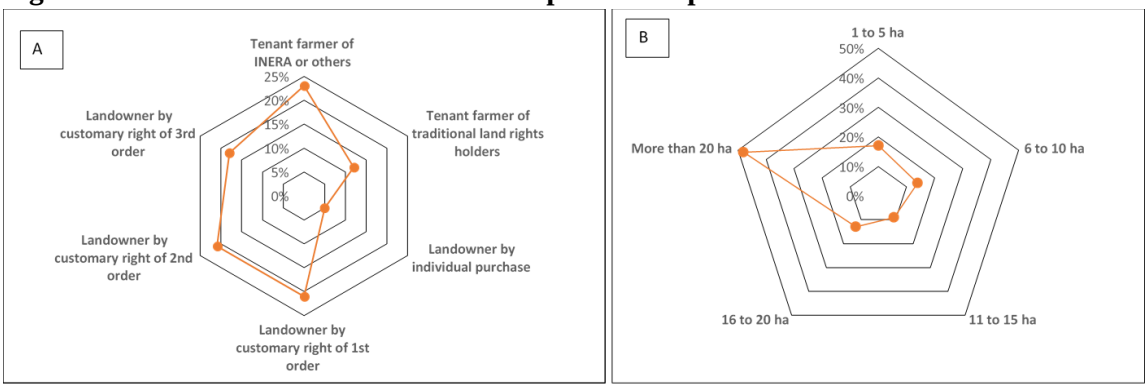
Figure 3. Land Tenure Status and Land Capital of Respondents



Fallow Land, Agroecological Zone (AEZ) Diversity, and Cropping System (CS) Diversity

On average, land is distributed across three agroecological zones, with the most represented being AEZ 3 (savannas), AEZ 2 (wetlands), and AEZ 4 (croplands and short fallow areas). Regarding cultivated land, respondents implement a variety of cropping systems (four on average). The most common systems include CS 4 (taro cultivation), CS 3 (sweet potato), CS 5, and CS 2 (short-cycle crops such as pigeon pea, cowpea, and groundnut) intercropped with cassava.

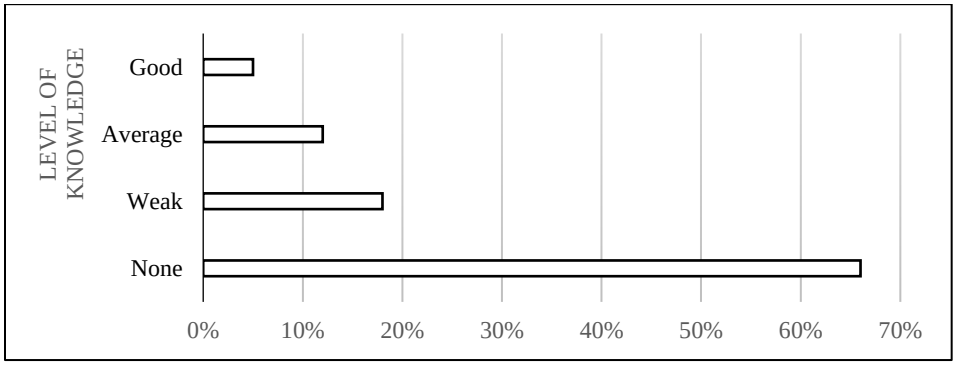
Table 1. Fallow Land Capital (in ha), Agroecological Zone Diversity, and Cropping System Diversity

Parameters	Fallow Land Capital (in ha)	Agroecological Zone Diversity	Cropping System Diversity
Mean	10.1	3	4
Standard Deviation	6.9	1	1
Minimum	0.5	1	1
Maximum	20	5	6

Beekeeping Knowledge

Most respondents (66%) have no knowledge of beekeeping, indicating a significant need for training and education in this field. Among them, 18% have a low level of knowledge, 12% possess an intermediate level, and only 5% have a good understanding of beekeeping. These figures suggest that, despite a potential interest in beekeeping, the surveyed farmers largely lack the necessary skills and expertise in this area.

Figure 4. Level of Beekeeping Knowledge Among Respondents



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Analysis of Collaboration Modalities

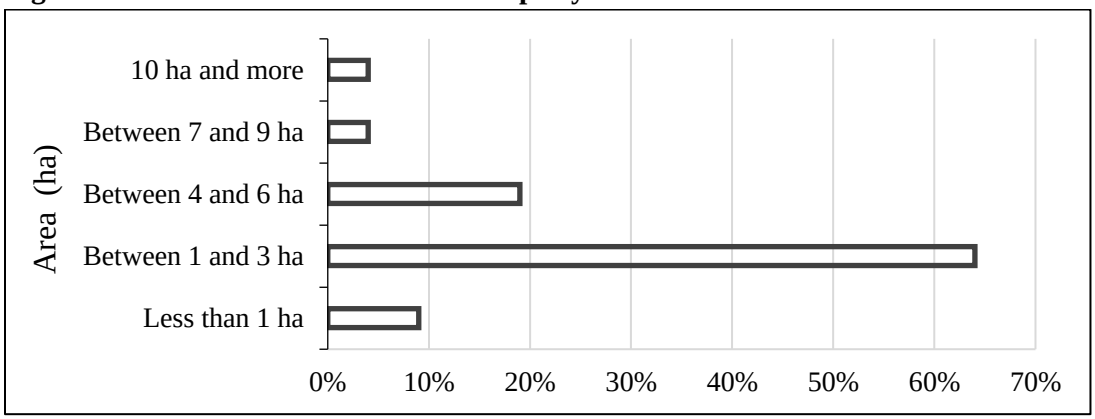
This section presents the various collaboration modalities desired by landowners in their agreements with tenants. These include the land area available for beekeeping, annual compensation, resource-sharing mechanisms, and the duration of land leasing.

Implementation Modalities of the Concentrated Apiary Strategy by Respondents

Land Area Allocation for the Apiary

Most farmers (64%) are willing to allocate between 1 and 3 hectares for beekeeping, indicating a significant willingness to support this activity on modest yet sufficient land areas for an apiary. A notable proportion (19%) is prepared to offer between 4 and 6 hectares, while only 9% of farmers consider dedicating less than one hectare. Finally, a small minority (4%) is willing to allocate between 7 and 9 hectares or even 10 hectares and more, demonstrating a higher level of commitment from certain farmers toward beekeeping.

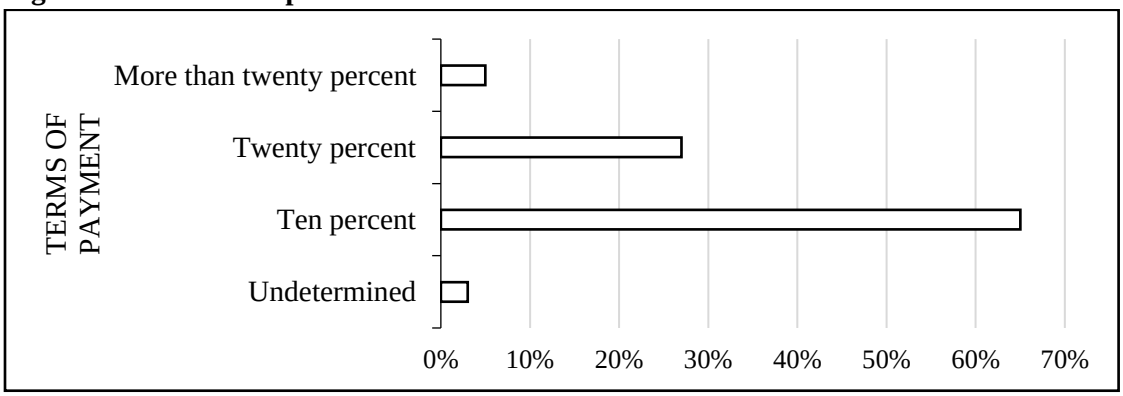
Figure 5: Land Area Allocation for the Apiary



Annual In-Kind Compensation Modalities

Most farmers (65%) prefer an annual in-kind compensation equivalent to ten percent of the production. A significant proportion (27%) is in favor of a twenty percent compensation, while a small minority (5%) is willing to accept more than twenty percent. Finally, 3% of farmers have not yet determined their compensation modalities. These figures indicate a clear preference for moderate compensation, with some openness to higher percentages.

Figure 6. Annual Compensation in Kind



Preferred Resource-Sharing Modalities

Nearly half of the respondents (49%) prefer a resource-sharing arrangement of fifty percent,

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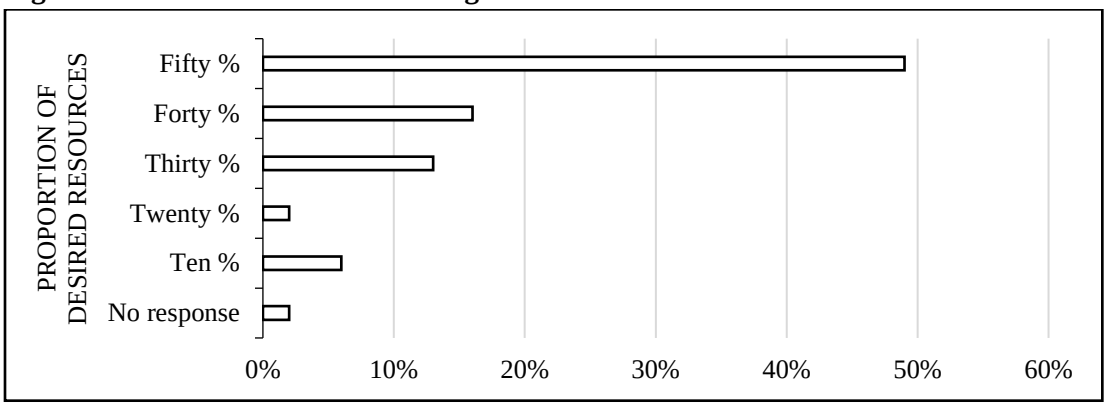
indicating a strong preference for an equitable distribution. Among the respondents, 16% prefer a 40% share, while 13% opt for 30%. Resource-sharing percentages of 10% and 20% are less popular, with 6% and 2% of respondents selecting them, respectively. Finally, 2% did not express a preference. These figures highlight a clear trend toward more balanced and equitable resource-sharing arrangements.

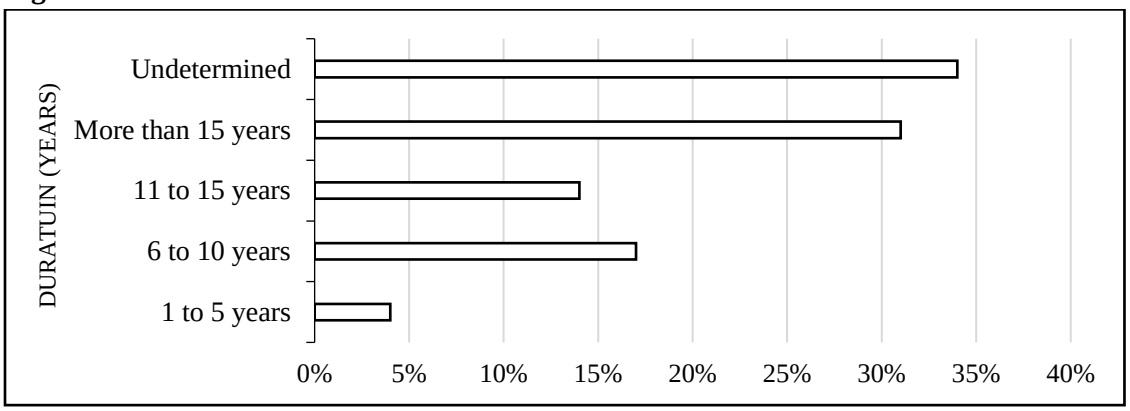
Figure 7. Preferred Resource-Sharing Modalities



Preferred Lease Duration

The results indicate a diversity of preferences regarding the desired lease duration. A notable proportion of respondents (34%) prefer an indefinite lease duration. Among those with a specific preference, 31% opt for a lease period of more than 15 years, reflecting a willingness for long-term engagement. Conversely, 17% of respondents prefer a lease duration of 6 to 10 years, while 14% choose a period of 11 to 15 years. Only 4% of respondents favor a lease duration of 1 to 5 years. These figures reveal a trend toward longer lease commitments.

Figure 8. Preferred Lease Duration



Analysis of the Technical, Economic, and Socio-Cultural Determinants of Apiculture Integration into Agricultural Systems

The technical, economic, and socio-cultural determinants of apiculture integration were identified through factorial analysis. Twelve variables were included in this model.

Model

The factorial analysis identified three main dimensions, collectively explaining 53.531% of the total variance. The first dimension, with a Cronbach's Alpha of 0.740, accounts for 25.903% of the variance, indicating good internal consistency. The second and third dimensions

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explain 14.555% and 13.073% of the variance, respectively, with Cronbach's Alphas of 0.466 and 0.396. The overall Cronbach's Alpha is 0.921, suggesting a high reliability of the model.

Table 2. Summary of Models

Dimension	Cronbach's Alpha	Explained Variance	
		Total (Eigenvalue)	% of Variance
1	0.740	3.108	25.903
2	0.466	1.747	14.555
3	0.396	1.569	13.073
Total	0.921a	6.424	53.531

Presentation of Components

The results presented in Table 3 illustrate the contributions of different variables to the three main dimensions identified through factorial analysis. The first component includes variables related to the agro-land characteristics of the landlord, such as their land capital (total and fallow), land status, the diversity of agro-ecological zones exploited, the cropping systems practiced, and the duration of land rental. The second component concerns knowledge of beekeeping. The third component relates to the main exploitation modalities, including the percentage of remuneration in kind and the sharing of beekeeping resources.

Table 3: Presentation of Components

Parameters	Dimension		
	1	2	3
Age	0.029	-0.231	-0.521
Land tenure status	0.627*	-0.077	-0.276
Level of knowledge in beekeeping	0.101	0.851**	-0.194
Total land capital	0.785*	-0.311	-0.233
Fallow land capital	0.561*	-0.191	0.389
Available land area	-0.585	0.381	0.083
Diversity of agroecological zones	0.676*	0.392	-0.187
Diversity of cropping systems	0.656*	0.560	0.105
Percentage of remuneration	0.304	0.224	0.679*
Share in resource distribution	-0.025	-0.263	0.617*
Rental duration	0.582*	-0.311	-0.014
Gender	0.337	0.049	0.286

The first dimension is strongly influenced by total land capital (0.785), land tenure status (0.627), agroecological zone diversity (0.676), and cropping system diversity (0.656). The second dimension is primarily determined by the level of apiculture knowledge (0.851) and, to a lesser extent, the available land area (0.381). The third dimension is dominated by the percentage of revenue-sharing (0.679) and the share of resource distribution (0.617). These findings indicate that land resources and agricultural practice diversity are the most influential factors in the first dimension, while apiculture knowledge and revenue-sharing modalities play a more significant role in the second and third dimensions.

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DISCUSSION

Important but Non-Determining Socio-Demographic Factors

The study reveals that most potential landowners for concentrated apiaries in the Mayombe region are men over 50 years old. This situation is explained by the dominant position of elderly men in land management, owing to traditional Kongo customs. Matrilineal lineage lands are often administered by elderly men with veto power, while property rights are primarily held by men, with women remaining dependent on their husbands or uncles (Muanda, 2010). This male predominance, particularly among elderly notables holding traditional positions (customary chiefs, village chiefs, clan leaders, etc.), limits women's roles in land ownership, despite their essential role in the transmission of land inheritance. Although women play a crucial role in the inheritance process within matrilineal clans or families, their influence diminishes or disappears when it comes to possessing veto power. Consequently, gender and age variables are not determining factors in the acceptance of the concentrated apiary strategy.

These findings align with those of Mburu et al. (2017) and Siwatu et al. (2024), which highlight the strong male dominance and ageing of the beekeeping profession, as well as the challenges in attracting younger generations. They emphasize obstacles to knowledge transfer due to the profession's limited appeal and the lack of suitable training programs. Furthermore, Sandra (2012) underscores the risk of skill and expertise loss, stressing the need for incentive policies to encourage youth participation, particularly among women, to ensure the sector's sustainability.

Determining Factors Related to Agro-Land Characteristics and Land Lease Duration

The study indicates that various production system profiles are likely to support the adoption of the concentrated apiary strategy on their lands, provided they have greater land security and capital. These factors, as observed in this study, are closely linked to land use (cultivation, fallow, or land reserve, leasing) and its occupation duration. These observations corroborate the findings of Mikobi and Mitais (2020) while broadening the scope of landowners to other types of production systems that can also play this role, including secured tenant farmers with land rights holders and state services (Brigade and INERA). These entities already collaborate with local farmers in their respective domains (e.g., transition zones of the reserve). Legally, customary land tenure exists in the area; however, lands owned by other types of landowners account for significant proportions and are frequently sought after by agricultural operators. It is also essential to consider Local Development Committees (CLD), which have implemented protection measures due to interventions by WWF and ERAIFT.

The study also reveals that potential landowners for concentrated apiaries possess relatively large land holdings. Owning substantial land capital allows owners to diversify its use (fallow, reserve, leasing, etc.), particularly in a context where the average usable agricultural area in the region is only 2.3 ha (Mikobi & Mitais S., 2020).

This also enables these landowners to allocate significant areas for beekeeping, facilitating the installation of one or multiple apiaries (Diyazola, 2021). Consequently, this study establishes that most potential landowners are willing to allocate between 1 and 3 hectares or more for beekeeping activities. The available land for apiary installation is a crucial factor for its sizing and, when combined with the melliferous potential, determines the carrying capacity of the apiary, expressed in the number of hives per hectare.

Moreover, the study demonstrates that landowners with estates spanning multiple agro-ecological zones (at least three) and practicing at least four different cropping systems are the most favorable to the concentrated apiary strategy. These landowners are more inclined to diversify land use to maximize

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profits and secure their income. Mikobi & Mitais S. (2020) revealed that most existing concentrated apiaries are in Agro-Ecological Zones (AEZ) 3 and 4 (savanna zone and short fallow cropping zone); young fallows (3 to 5 years) are the most preferred. These are areas where vegetation cover is present, regenerating, and relatively diverse. From a technical standpoint, a concentrated apiary should be established in an environment with sufficient melliferous potential to support productive beekeeping activities. AEZ 1 is particularly restrictive due to human settlements.

It has been established that offering multiple redistribution modalities for reforestation products positively influences landowners' behavior. Additionally, when reforestation with fruit-bearing plants is proposed, the probability of obtaining more land increases. This indicates that landowners' behavior is more influenced by financial and material interests than by environmental considerations.

The duration of land leasing has emerged as a determining factor in accepting the concentrated apiary strategy. This reflects landowners' desire to benefit from the long-term advantages of land occupation. Most potential landowners expressed a preference for lease terms exceeding five years, with many favoring longer durations (15 years or more, even indefinite). Short-term contracts would therefore be less attractive for ensuring sustainable and acceptable cumulative benefits for landowners.

Factors Related to Beekeeping Knowledge and the "Concentrated Apiary" Strategy

This study shows that 66% of respondents lack expertise in beekeeping, even though they have heard of it and observed practitioners. Access to beekeeping training remains very limited in the region, and in several surveyed villages, this sector was non-existent. However, the willingness of stakeholders to learn is remarkable. This indicates a predisposition to explore a relatively unfamiliar sector whose benefits were presented to them during preliminary interviews for some, while others observed these advantages through existing practitioners.

This situation demonstrates that improved understanding of the concentrated apiary strategy, as communicated to them, can encourage landowners to adopt it on their lands or even engage in beekeeping themselves. Indeed, among the landowners of existing concentrated apiaries within the ULB-Cooperation project, both beekeepers and non-beekeepers have become aware of and recognized the benefits of implementing such a strategy on lands they previously considered marginal.

Factors Related to the Interest in Lease Products and Other Shareable Products Offered by the Apiary

Most landowners agree with the principle of compensation and product sharing, albeit under different modalities. Regarding compensation, most potential landowners are in favor of a 10% share of production in kind, based on the quotas applied to agricultural products in the area. Concerning the sharing of other products, nearly half of the landowners expect a sharing arrangement that grants them 50% of the non-honey products derived from the apiaries.

This links the acceptance of the concentrated apiary strategy to the interest in shareable products from which the landowner directly benefits, an aspect that should not be overlooked. First, the honey production quota is set at one-tenth, followed by a larger share of fruits and other Non-Timber Forest Products (NTFPs). In this regard, MJE (2020) reported theoretical models indicating a mean lease or tenancy benefit of up to $110/ha/year. However, this calculation did not consider the long-term value of fruits and other collectable products.

The practice of enriching spaces with melliferous woody or non-woody species, as advocated by the concentrated apiary strategy, appears to be longstanding in the region, unless carried out by

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tenants for more specific plants. In this context, Nyange (2014) highlighted those farmers reforesting areas within and around the RBL to recover and enhance degraded savannas by local population activities. These farmers use fast-growing species to establish apiary forests, fodder parks, firewood plots, and boost fruit production.

Trees resulting from environmental enrichment provide a wide range of products and services (fuelwood, timber, NTFPs, restoration of degraded ecosystems, etc.). Initially, the products are shared between the landowner and beekeepers according to the concentrated apiary strategy promoted by ULB-Cooperation, and later, after the contract term, they revert exclusively to the landowner. Thus, reforestation carried out with the landowner's consent and for their benefit is more likely to be accepted. WWF (2012) states that a significant number of farmers prefer to reforest outside the RBL for their interests, aiming to restore lands surrounding the reserve. This practice is not restrictive, even when carried out by tenants, as long as resource use and management rules are well-defined.

According to Malézieux and Bartholomew (2003), trees serve as habitats (primary or secondary) or refuge zones for various animal species (small mammals, insects, birds, etc.) and plant species (fungi, Gnetum africanum, medicinal plants, etc.). Young (1989) emphasized the contribution of trees to soil fertility through leaf litter and root residues. This aspect is particularly relevant as, after the exploitation period by beekeepers, the landowner may wish to cultivate the land again.

CONCLUSION

To address the question of which factors are determinant for the acceptance of the concentrated apiary strategy by potential landowners within their estates, this exploratory study has provided precise answers. The analysis of the characteristics associated with these potential landowners, as well as the preferred collaboration modalities, has shown that the determining factors are primarily agro-land-related and depend largely on the collaboration offers presented in terms of immediate benefits derived from the implementation of this strategy. The socio-demographic characteristics of landowners, namely gender and age, have proven to be non-determinant. The study revealed that the profile of a potential landowner corresponds to an individual with secured land tenure (land right holder, owner, sharecropper), possessing a relatively significant land capital, distributed across diverse agroecological zones, with agricultural land occupied by various farming systems, and a non-negligible portion left fallow or used marginally. This leads to the conclusion that the development initiatives for concentrated apiaries should be targeted towards this profile of landowners rather than others. The most acceptable collaboration modalities for these landowners would include: an annual in-kind compensation of at least 10% of the production, an equal share of other apiary products, and a land use duration exceeding five years. However, the study raises the issue of a more precise evaluation of the long-term cumulative benefits related to the implementation of the concentrated apiary strategy for landowners, which have so far been limited to the perception of shareable interests. To evaluate the long-term impacts of integrating beekeeping on deforestation rates, studies should include regular monitoring of deforestation rates via satellite images and field surveys, an in-depth analysis of the agricultural practices of landowners, an assessment of the economic benefits generated by beekeeping, as well as the conduct of detailed case studies. It would also be relevant to conduct regular surveys with farmers to gather their perceptions and practices, and to evaluate the impact of beekeeping on local biodiversity. These approaches will help to better understand the lasting effects of beekeeping on forest conservation and to identify the best practices to promote ecologically beneficial beekeeping.

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Declaration of Competing Interest

The authors declare that they have no conflicts of interest that might appear to influence the outcome of this paper.

Author's Contributions

Kalambulwa, N.A., drafted the article, Diyazola-Vweba J., collected, processed the data, methodology and draft the results., Vunzi J. and Kikeba L., collected data, Lopa L.J., and Muhindo K.O., read the draft and made corrections and Ntoto R.A. made the final revision.

BIBLIOGRAPHIE

Bamba, I., Mama, A., R Neuba, D. F., Koffi, K. J., Traoré, D., Visser, M., Sinsin, B., Lejoly, J., & Bogaert, J. (2008). Actions anthropiques sur la dynamique spatio-temporelle de l'occupation du sol Influence des actions anthropiques sur la dynamique spatio-temporelle de l'occupation du sol dans la province du Bas-Congo (R.D. Congo). In *Article original Issouf BAMBA et al. Sci. Nat* (Vol. 5).

Diyazola, J. (2021). *Étude des déterminants de l'intégration des ruchers concentrés dans les systèmes d'activités autour de la Réserve de Biosphère de Luki en République Démocratique du Congo.* [Travail de fin d'étude de master 2, option Moquas,]. Montpellier Sup Agro.

Djami, Y. K., Fonteyn, D., Ngabinzeke, J. S., Meeys, M. N., Poulain, F., Tipi, E. L., & Vermeulen, C. (2023). Status of terrestrial mammal populations in the Luki Biosphere Reserve (Democratic Republic of Congo). *Biotechnology, Agronomy, Society and Environment*, *27*(4). https://doi.org/10.25518/1780-4507.20430

Kabongo Kabeya, C., Muchiza Bachinyaga, I., & Monga Ilunga Dikoshi, R. (2024). Caracterisation-des-conditions-socio-economiques-des-communautes-locales-en-lien-avec-lintegrite-des-aires-protegees-en-RDC-cas-de-la-Reserve-de-Biosphere-de-Luki-dans-la-province-du-Kongo-central. *Journal of Applied Biosciences*, 20713–20730.

Kabeya, C., Nkombe, A., Biayi, G., Kazaba, P., Trefon, T., 2024. Evaluation de la perception des ressources naturelles par les communautés locales du domaine de chasse et réserve de Bombo-Lumene à Kinshasa : vers une approche intégrée pour la conservation et le développement durable.

Malézieux, E., & Bartholomew, D. P. (2003). Plant nutrition. In *The pineapple: botany, production and uses* (pp. 143–165). CABI Publishing. https://doi.org/10.1079/9780851995038.0143

Mburu, P. D. M., Affognon, H., Irungu, P., Mburu, J., & Raina, S. (2017). Gender Roles and Constraints in Beekeeping: A Case from Kitui County, Kenya. *Bee World*, *94*(2), 54–59. https://doi.org/10.1080/0005772X.2016.1275490

Michel Mbumba, B., Martin Bitijula, M., Jean de Dieu, M., Damase, K., & Mafuka Mbe-Mpie, P.

Article DOI: https://doi.org/10.37284/eajenr.8.1.2935

(2020). Opportunités et défis de l'agroforesterie dans et en périphérie de la Réserve de Biosphère de Luki au Kongo central en République Démocratique du Congo. *Revue Africaine d'Environnement et d'Agriculture,* 23–31.

Mikobi, C., & Mitais S. (2020). *Diagnostic agraire et étude des mesures de gestion du foncier mises en place par les partenaires. Rapport de consultance.*

Muanda, T. (2010). *Étude sur l'accès à la terre chez les petits producteurs d'huile de palme et des produits forestiers non ligneux dans le district du Bas-fleuve.*

Nsenga, L. (2001). Etude de la gestion des aires protégées en République Démocratique du Congo. Cas de la Réserve de Biosphère de Luki, Mayombe. *ERAIFT, Kinshasa.*

Nyanga, C. (2020). The role of mangroves forests in decarbonizing the atmosphere. In Carbon-Based Material for Environmental Protection and Remediation. *IntechOpen.*, 1.

Nyange, N. M. (2014). *Participation des communautés locales et gestion durable des forêts : cas de la Réserve de la biosphère de Luki en République Démocratique du Congo* [Thèse (Ph. D.) --Université Laval, 2014.]. Québec : Université Laval, [2014].

OSFAC. (2016). *Occupation et utilisation du sol : Réserve de Biosphère de Luki. Projet pilote REDD-WWF-Belgique.*

Péroches, A. (2019). *Formation/action au diagnostic agraire dans le village de Tsumba Kituti, au sein de la réserve de biosphère de Luki.*

Sandra, H. (2012). *Etude des savoirs écologiques traditionnels des apiculteurs Wakonongo, Mpanda, Rukwa, en vue d'une valorisation dans le cadre de la gestion moderne de l'apiculture en Tanzanie* [Thèse de Bachelor]. aute école specialisée de Suisse occidentale.

Shembe, E. (2021). *Analyse de la chaîne de valeur miel autour de la Réserve de Biosphère de Luki au Kongo central en République Démocratique du Congo selon la méthode VCA4D.*

Siwatu, D. M., Nzunda, E. F., & Ngaga, Y. M. (2024). Gender Dynamics in Beekeeping: An Examination of Roles of Men and Women in the Beekeeping Value Chain in Chamwino District, Tanzania. *East African Journal of Agriculture and Biotechnology*, *7*(2), 24–38. https://doi.org/10.37284/eajab.7.2.2243

WWF. (2012). *Plan d'aménagement de la réserve de la biosphère de Luki. Dans le cadre du programme de développement et de conservation de la Réserve de Biosphère de Luki. Dans Projet d'appui à la gestion durable et à la conservation des écosystèmes forestiers de la RDC, phase 2, 34 p.*

Young. (1989). *Agroforestry for soil conservation. ICRAF Science and Practice of Agroforestry.*

