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Factors inciting agroforestry adoption based on trees outside forest in Biosphere Reserve of Yangambi landscape (Democratic Republic of the Congo)

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Abstract The Biosphere Reserve of Yangambi (BRY) landscape is facing the challenge of conserving biodiversity while supporting the food security of local communities. Farmers, in search of fertile soil, travel long distances to establish their fields, sometimes in the core area of the reserve. Faced with this reality, agroforestry is an alternative that could contribute to improving local livelihoods while protecting forests and biodiversity in this protected area (PA). This study was conducted in order to identify factors which motivate and/or inhibit farmers for adopting agroforestry practices. To this end, household surveys were conducted in three villages bordering the BRY, namely Bengamisa, Lilanda and Yaselia. The results revealed that only the age of farmers influence significantly agroforestry adoption and 56.2% of the respondents deliberately leave naturally occurring agroforestry species in their farmlands. In order to benefit from the collection of edible caterpillars and fruits, improvement of soil fertility,

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extraction of medicinal products, production of charcoal and exploitation of timber. However, 43.8% of respondents who were not in favor of agroforestry feared accidents due to windfall, as well as for the collapse of agricultural production. The ethnobotanical analysis revealed that *Petersianthus macrocarpus* sp. and *Erythrophleum suaveolens sp.* had the highest use value due to their multi-functionality in the BRY landscape. Thus, the extension work to promote these species could increase the rate of agroforestry adoption and contribute to sedentarization of farmers which in turn reduce the rate of deforestation and promote biodiversity conservation in BRY landscape.

Keywords Agroforestry adoption · Incentive factors · Rejection factors · Biosphere Reserve Yangambi landscape · Democratic Republic of the Congo

Introduction

The rainforests of the Congo basin are home an incredible biodiversity and sustain the livelihood of about 60 million riparian people. They provide ecosystem services and various timber and no-timber forest products (NTFP) which are playing a critical role for surrounding populations (Mayaux et al. 2013; Kafuti et al. 2022). However, these survival activities, especially slash-and-burn agriculture, are increasing forest degradation and deforestation (Gillet et al. 2016). Associated with the marked demographic explosion occurring in tropics, this agricultural system is linked with dramatic biodiversity loss, high exposure to global warming effects and exacerbated deforestation (16,6 ± 0.5MHa from 2000 to 2014), as well as low farming productivity (Luedeling et al. 2014; Tyukavina et al. 2018).

Several strategies have been developed at the global scale to slower the rate of deforestation and protect biodiversity. These include the creation of PA, forest certification schemes, community forestry and the mechanism Reducing Emissions from Deforestation and Forest Degradation and biodiversity conservation (REDD+) (Mora and Sale 2011; Fayolle et al. 2018; Lescuyer et al. 2019). Unlike other strategies, the REDD+ mechanism recognizes agroforestry as a way to reconcile ecosystem conservation with the socio-economic well-being of local residents (Minang et al. 2014). Under its national REDD+ program, the Democratic Republic of the Congo (DRC) has undertaken two flagship programs, (i) the Integrated REDD program or "PIREDD" and the "Programme d'investissement pour les Forêts de la RDC" or "PIF-DRC" (Reyniers 2019). In Isangi, the PIREDD was implemented in BRY landscape in order to reduce anthropogenic pressures as well as to promote the conservation of ecosystem services in this PA (Kipute et al. 2023). A key recommendation of the PIREDD through this landscape was to set agroforestry as sustainable production method for local communities. Unfortunately, this recommendation was not widely adopted by farmers, despite the multiple ecological and socio-economic advantages of agroforestry for biodiversity and people. Agroforestry system (AFS) diversifies household incomes through its multi-functionality and contributes to the mitigation of global warming through carbon sequestration in the biomass and soil (Nair et al. 2010). It ensures the preservation of biodiversity through ecological interactions and sedentarization of famers through its guarantee for the maintenance of soil fertility (Toth et al. 2017; Seghieri and Harmand 2019).

Some studies have been carried out in North and South America (Mercer 2004; Jara-Rojas et al. 2020), Indonesia (Sabastian et al. 2017) and in Central Africa precisely in Cameroon (Adesina et al. 2000) to investigate the factors of agroforestry adoption. These empirical studies focused on multiple linear regression (Probit or Logit) had deplored the existing gap between methodological advances in agroforestry practices and its adoption rate by local communities (Mercer 2004). Social determinants as the age, family size, marital status, seniority in agriculture and education level was reported as significant factors for agroforestry adoption (Adesina et al. 2000; Pattanayak et al. 2003). However, these social determinants are dynamic over time and can't be transposed to other locations where the socio-economic context is totally different. Particularly in the BRY landscape, where the governance of natural resources is more complex (Kipute et al. 2021). Most of the reported failures of agroforestry programs are due to the lack of consideration of the socio-economic particularities of concerned communities in formulation of AFS.

Therefore, investigating the factors which can influence farmers to adopt and maintain agroforestry system as their consent production mode is a necessary perquisite of a successful implementation of this sustainable production method. Hence, the implementation and the spreading of AFS could be easier through tropics. We hypothesized that, the incentivizing factors for agroforestry adoption would be tightly related to the benefits that famers get from this production system. In this study, we aim to (1) identify incentives to adopt agroforestry in BRY, (2) discern the constraints which influence the rejection of agroforestry and (3) evaluate the use value of agroforestry trees identified through the BRY landscape. In order to enable publics services and development agencies with technical basis for conceiving agroforestry schemes which are socially adoptable.

Methodology

Study location

This study was conducted in the BRY landscape, located in Tshopo province, in northeastern of DRC. This landscape contains BRY, which has been listed as a world heritage site by UNESCO since 1977. It is characterized by exceptional biodiversity and vegetation dominated by dense and humid forest (Toirambe 2011). This landscape has a tropical climate, Af type according to Köppen's classification (Luambua et al. 2021). This landscape extends over 225,000 ha of BRY, and includes enclaves in buffer zone and others villages located within 30 km of the PA border (Kipute et al. 2021). The BRY is located between 24°18′ and 25°08′ East longitude; 00°43′ and 01°08′ North latitude with an altitude between 400 and 500 m.

The surveys were conducted in Bengamisa (Bangole, Bakombila and Basolombi clans), Lilanda (Yafake, Yambele, Yaisowa and Lilanda clans) and Yaselia (Yalungu and Yaselia clans) villages (Fig. 1). Administratively, these villages belong respectively to the grouping of Bamanga-Bengamisa (which is mainly occupied by the Bamanga people) Yambawu and Yelongo (where the Turumbu people predominate) (Kyale et al. 2019). According socio-economics characteristics, the Bamanga and Turumbu people are primarily dependent on agriculture and other complementary activities like fishing, hunting, collection of the NTFP and charcoal commercialization (van Vliet et al. 2022; Kipute et al. 2023). Ecologically, the villages studied have similarities in their vegetation, although in Yaselia, the mature forests are farther from the houses. Whereas in Bangole and Lilanda, the forests are closer and have more specific richness index.

The choice of these villages is a function of (i) their location near the main axis linking BRY to major consumption centers, (ii) their high demography and (iii) the implementation of agroforestry projects in the past (PIREDD/Isangi, Makala Project and Governance Multiple Landscape, "GML").

Data collection

Household surveys

Data on production modes, useful woody species and patterns for adoption or rejection of AFS were collected through interview surveys. The questionnaires were administered to 169 farm households (i.e., 52 in Lilanda, 60 in Yaselia and 57 in Bengamisa). The sampling rate was 10% of households per village considered as saturation degree. This rate was based on demographic data obtained from health services in these entities.

In practice, the systematic sampling method was applied for a representative sample in this landscape. According to Beaud (2003), this approach consists of selecting respondents using an unbiased criterion. For instance, the criterion was a step of 3 households by considering the chief residence as a reference. This approach allows correct selection of households in this landscape, where the agricultural statistics are not available for applying the random method.

Hence, tree questionnaires (i.e., introduction, agroforestry and conventional agriculture) were operationalized to collect data from households. Each present head of household was asked to respond to the introduction questionnaire, which ascertained his/her social determinants and production mode and the second questionnaire was related to his/her production mode: agroforestry or conventional agriculture.

Ethnobotanical inventory of agroforestry species

This method was used to identify different useful and naturally occurring woody species that famers permitted in their fields. In practice, different useful species were listed with their vernacular names by

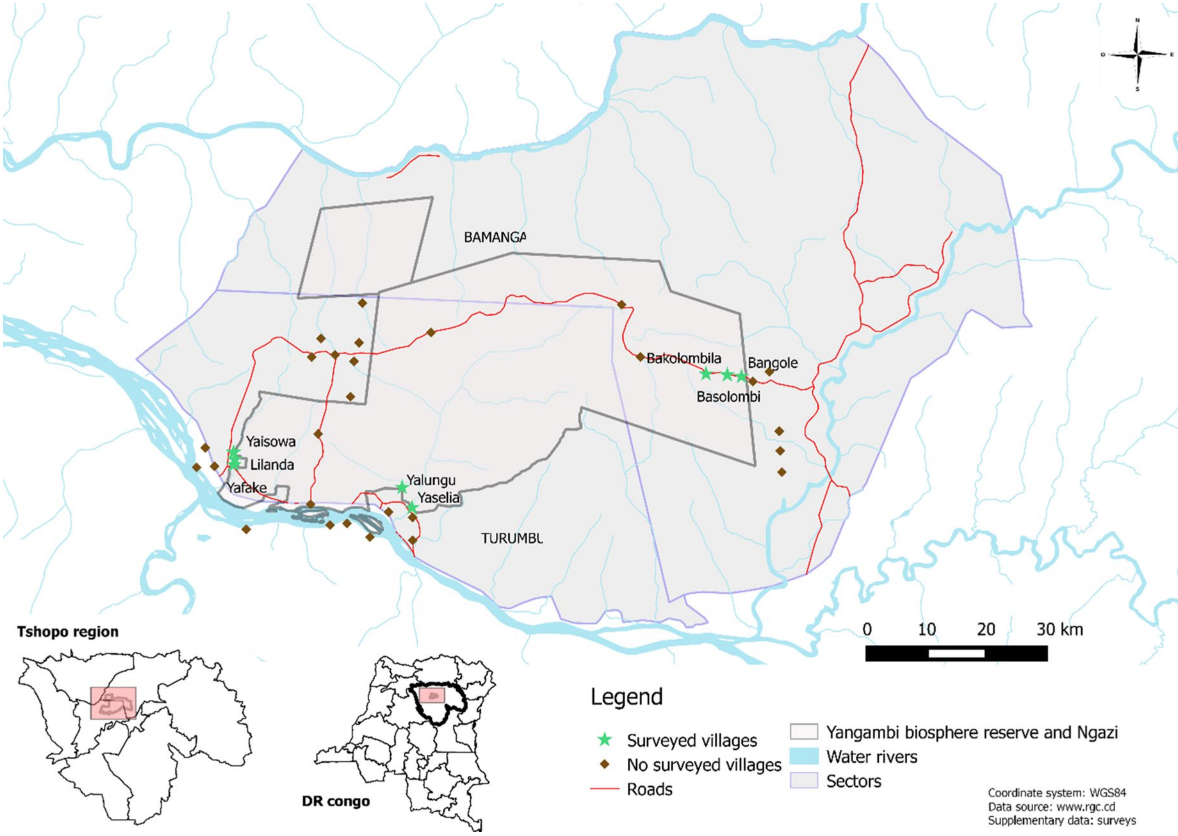

Fig. 1 Localization of surveyed villages (most of them are situated in transition zone) in the BRY landscape within DRC

respondents during the surveys. The qualitative inventory in agroforestry farms allows identification of these agroforestry species. In each village, the local guide facilitated the herbarium and barks collection, which were brought to botanists for identification. The herbarium was constituted through collection of tree leaves and bark slices with the machete. Dichotomous key based on observation, smell and touch allowed the identification of 48 agroforestry tree species.

Data analysis

The proportions of adoption or rejection agroforestry factors were calculated by village. For each factor, the proportion is the sum of its frequency multiplied by 100 and inversely proportional to the total number of respondents who have adopted/rejected agroforestry in BRY landscape Eq. (1).

$$Prop_{Fact} = \sum_{i=1}^{n} \frac{F_{ii}}{N} * 100 \tag{1}$$

where: $Prop_{Fact}$: proportion of each factor that encourages adoption /rejection of agroforestry; F_{ii}: frequency of listed factor by respondents and surveyed village; N: sample size (i.e., agroforestry and conventional agriculture).

These analyses were performed using R-Studio software version 4.0.3 with ggplot2 package for producing graphs (R Core Team 2022). For testing the difference of adoption/rejection factors of agroforestry by surveyed villages, we computed, chi-square test of independence between these parameters. Moreover, the multiple linear model, "*Logit*" had been computed to establish the social determinants which can influence agroforestry adoption through the BRY landscape. Furthermore, this model allowed to test the main hypothesis of this research. The independent variables in this model are presented in the Table1 below:

As the explained variable, the production mode has two modalities, including conventional agriculture and AFS. The empirical Eq. (2) below presents this model.

$$Logit(Y) = \log\left[\frac{P}{(1-P)}\right] = \beta_\theta + \beta_1 X_1 + \beta_2 X_2 + \beta_3 X_3 + \beta_4 X_4 + \beta_5 X_5 + \beta_6 X_6 + \beta_7 X_7 + \beta_8 X_8 + \beta_9 X_9 + \beta_{10} X_{10} + \beta_{11} X_{11} \quad (2)$$

In addition, the use value of woody species was calculated to better understand the incentives of agroforestry adoption in BRY landscape. For each species, the relative use value (RUV) and the total use value by agroforestry species (TUV) were determined. The RUV is the ratio of the frequency per utility for each agroforestry tree species and the sample size (number of respondents practicing agroforestry), all multiplied by 100. However, TUV is the sum of the RUV for each agroforestry species listed in the BRY landscape (Belem et al. 2008). Equations (3) and (4) illustrate the calculation of use values operationalized in this study.

Table 1 Independent variables of logit model

Variables explicative	Symbol	Code/Unit	Mean	Standard deviation
Gender	X_1	0 = Female 1 = Male	–	–
Awareness on agroforestry	X_2	0 = No 1 = Yes	–	–
Level of education	X_3	0 = Illiterate 1 = up to primary 2 = up to secondary 3 = Superior studies	–	–
Household size	X_4	0 = > 5 Persons 1 = < 5 and > 10 Persons 2 = < 0 and > 20 Persons 3 = < 20 Persons	8,3	4,02
Age of head of household	X_5	0 = < 20 and > 35 years 1 = < 5 and > 50 years 2 = < 50 and > 65 years 3 = < 65 and > 80 years	42,3	12,8
Seniority in the agricultural sector	X_6	0 = > 5 years 1 = < 5 and > 10 years 2 = < 10 and > 20 years 3 = < 20 and > 30 years 4 = < 30 years	31,02	16,5
Support from NGDOs	X_7	0 = No 1 = Yes	–	–
Marital status of respondent	X_8	0 = Bachelor 1 = Married 2 = Divorced 3 = Widow	–	–
Tribe of respondent	X_9	0 = Turumbu 1 = Bamanga 2 = Others	–	–
Land tenure	X_{10}	0 = No (Allochthons) 1 = Yes (Autochthons)	–	–
Previous cultural	X_{11}	0 = Fallows 1 = Secondary forest 2 = Matures forest	–	–

$$RUV = \frac{\sum_{i=1}^{n} F_{ij}}{N} * 100\ ; \quad (3)$$

$$TUV = \sum_{i=1}^{n} RVU \quad (4)$$

where F_{ij}: Frequency per utility and agroforestry species and N: sample size of agroforestry producers.

Theoretical framework

The framework analysis for this study is based on self-efficacy theory proposed by McGnity et al. (2008). Hence, the factors reported by the farmers play an important role in their decision to adopt and maintain agroforestry in the BRY landscape. Furthermore, according to Düvel (1994) in Thangata and Alavalapati (2003) adoption behavior is a mental process governed by a set of intervening variables, individual needs, knowledge about the technology, and individual perceptions about methods used for meeting those needs in a specific environment. Therefore, this study considered the patterns which lead farmers to leave useful species in their fields as veritable incentive factors of agroforestry adoption in the BRY landscape.

Results

Incentives factors of agroforestry adoption in the BRY landscape

Our results show that 56.2% of farmers surveyed deliberately leave some useful trees on their farms. These farmers listed eleven factors that motivate them to practice agroforestry (Fig. 2).

We found that farmers in the studied region practice agroforestry to diversify their livelihoods. This agroforestry practice is essentially temporal and based on the useful local tree species found on the farms. The majority of farmers in these surveyed villages were motivated to leave agroforestry tree species on their farms for the collection of edible caterpillars. This factor alone accounted for 48.5% in *Yaselia*; 44% in *Bangole* and 33% in *Lilanda*.

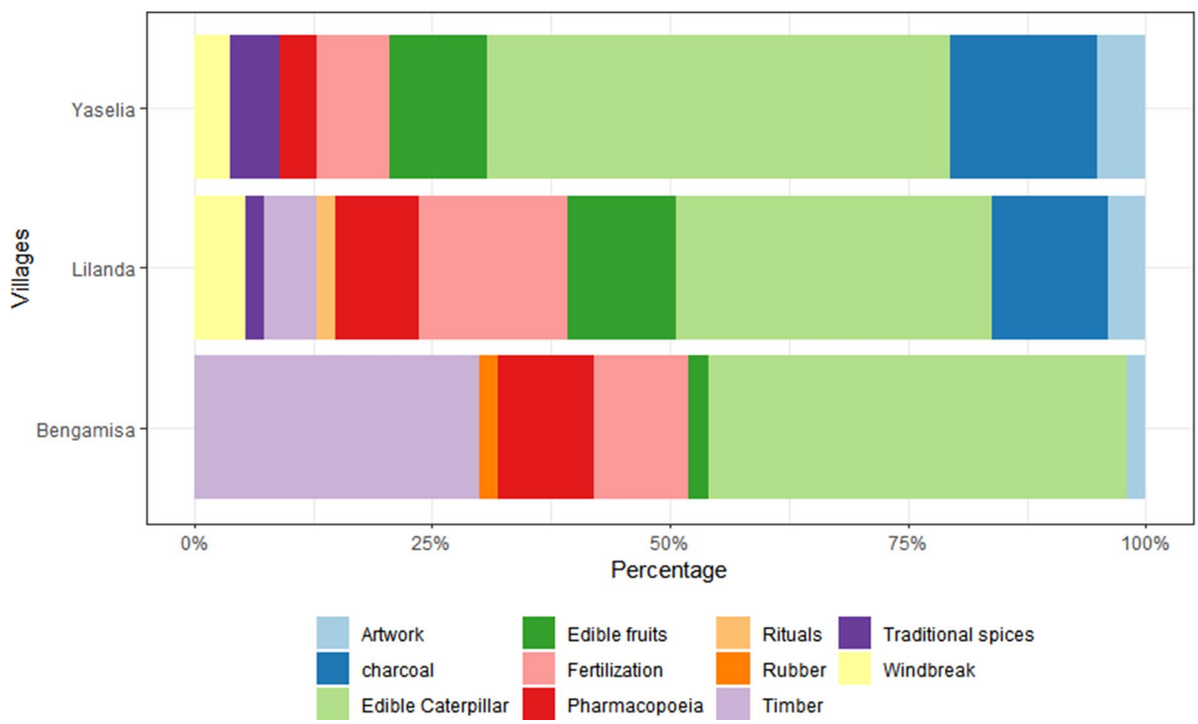

Fig. 2 Proportions of rejection factors of agroforestry in the BRY landscape

The others incentive factors had different proportions depending on the specific realities of each surveyed village (X-squared = 69.445, df = 20, *p*-value = 2.244e-07). Artisanal timber exploitation represented 30% in *Bangole* and less than 5.5% in *Lilanda*, due to abundance of mature in these villages. Maintenance of soil fertility represented 15.5% in Lilanda, 10% in *Bangole* and 7.5% in *Yaselia*. However, the charcoal making was reported only in *Yaselia* and *Lilanda* at 15% and 12% respectively. The extraction of medicinal products was more common in *Bangole* (10%) and *Lilanda* (8.5%) than in *Yaselia* (4%), while the gathering of edible fruits is less common in *Bangole* (2%) than in the other two villages (11.5% in *Yaselia* and 10% in *Lilanda*). Finally, factors such as the making of artworks (i.e., tom-toms, mortars, pestles, dugout canoes, whaleboats); windbreak (shade plants, plants with fruit and/or flowers that attract game birds or furry animals); the practice of ancestral rites (palaver trees and spell casting) and the gathering of traditional spices as well as rubber, was reported in few proportions, but they are culturally linked with the behavior of the farmers and could encourage them to adopt agroforestry in this landscape.

Use value of agroforestry species in the BRY landscape

The ethnobotanical inventories in the different agroforestry farms resulted in 48 useful tree species. These species are either multi-purpose or single-purpose (Table 1 in supplementary materials).

Petersianthus macrocarpus was the agroforestry species most preferred by respondents (45.1%), followed by *Erytrophleum lasianthum* (15.3%). These two species were preferred for the quality of the edible caterpillars they host. The second category included *Gilbertiodendron dewevrei*; *Prioria balsamifera; Scorodophleus zenkeri; Entadrophragme cylindricum; Pycnanthus angolensis; Percospsis elata, Pentaclethra. macrophylla* with a TUV between7% and 10%. These species are majorly legumes and were left standing to maintain soil fertility. The third category comprised *Piptadeniastrum africanum and Percea americana,* (TUV was between 7 and 5%), which are providing edible fruits and medicinal products highly appreciated by local communities.

Influence of social determinants on adoption of agroforestry in the BRY landscape

The Logit model applied in the BRY landscape had resulted in no significant prediction (*p*-value = 0.6021). In fact, much explanatory factors had negative coefficients and did not significantly influence the production mode in this landscape (Table 2).

The age of the head of household, remain the main social determinant that significantly influences the adoption of agroforestry in *Yangambi (p-value = 0.0383)*. In fact, the young farmers left scarcely useful species one their farmland than the old men who knows the cultural and socio-economic value of agroforestry species. The education level and the household size have positives coefficient in the

Table 2 Logit model of agroforestry adoption based on social determinants

	Estimate	Std. Error	Z value	*P*-value
Intercept	0.77776	1.49161	0.521	0.6021
Gender	− 0.60347	0.95634	− 0.631	0.5280
Awareness about AFS	− 0.47468	0.52987	− 0.896	0.3703
Education Level	0.45749	0.37878	1.208	0.2271
Household size	0.03578	0.05020	0.713	0.4759
Age of head of household	0.45658	0.22044	2.071	0.0383*
Seniority in agricultural sector	− 0.19006	0.15864	− 1.198	0.2309
Support from NGDOs	− 0.19596	0.40519	0.484	0.6286
Marital status of respondent	− 0.64138	0.55268	− 1.160	0.2458
Tribe of respondent	− 0.47760	0.31804	− 1.502	0.1332
Land tenure	1.03020	0.82073	1.255	0.2094
Previous cultural	− 0.04854	0.21902	− 0.222	0.8246

, **, * and ns are significant codes: 0 '' 0.001 '**' 0.01 '*' 0.05 'ns model, but they are not significantly influencing the adoption of agroforestry in the BRY landscape. The others factors had negative coefficients and do not significantly influence the adoption of agroforestry in the BRY landscape.

Rejection factors of agroforestry in the BRY landscape

We found also that 43.8% of respondents refuse to practice AFS due to nine major constraints listed in the BRY landscape (Fig. 3).

The major constraint that demotivates farmers to adopt agroforestry in *this landscape* is the shade created by agroforestry species on their fields. It represents alone 36% in *Bangole*; 33.5% in *Yaselia* and 27.5% in *Lilanda*. The cultivation within the young fallows, where the woody species have small diameters, hinders agroforestry adoption at 17.5%, 16.5% and 12.5% respectively in *Bangole*, *Lilanda* and *Yaselia* villages. In addition, this respondents group had also mentioned the risk of wind throw on farmland that could result in fatalities. This constraint was recorded at a frequency of 26% in *Yaselia*, 11.5% in *Lilanda* and 10% in Bangole. While their supposition for the decreasing of food crops yields in AFS was recorded at 15.5% in *Lilanda*, 13.5% in *Yaselia* and 12.5% in *Bangole*. The lack of useful plantlets associated to the use of young fallow, had represented 13.5% in *Lilanda*, 11.5% in *Bangole* and 6% in *Yaselia*. Other constraints, such as the difficulty of burning the farmland and weeding, the trampling of crops and the increased attacks due to marauding birds, are often technical and not negligible.

Discussion

Incentives factors of agroforestry adoption in the BRY landscape

Agroforestry in the BRY landscape involves the deliberate release of useful forest species by local people on their farms. These woody species are often spread throughout the farm and maintained before burning. Excluding oil palms, which are abundant on farms in this landscape, forest species left on farms perform several functions, both socio-economic (source of

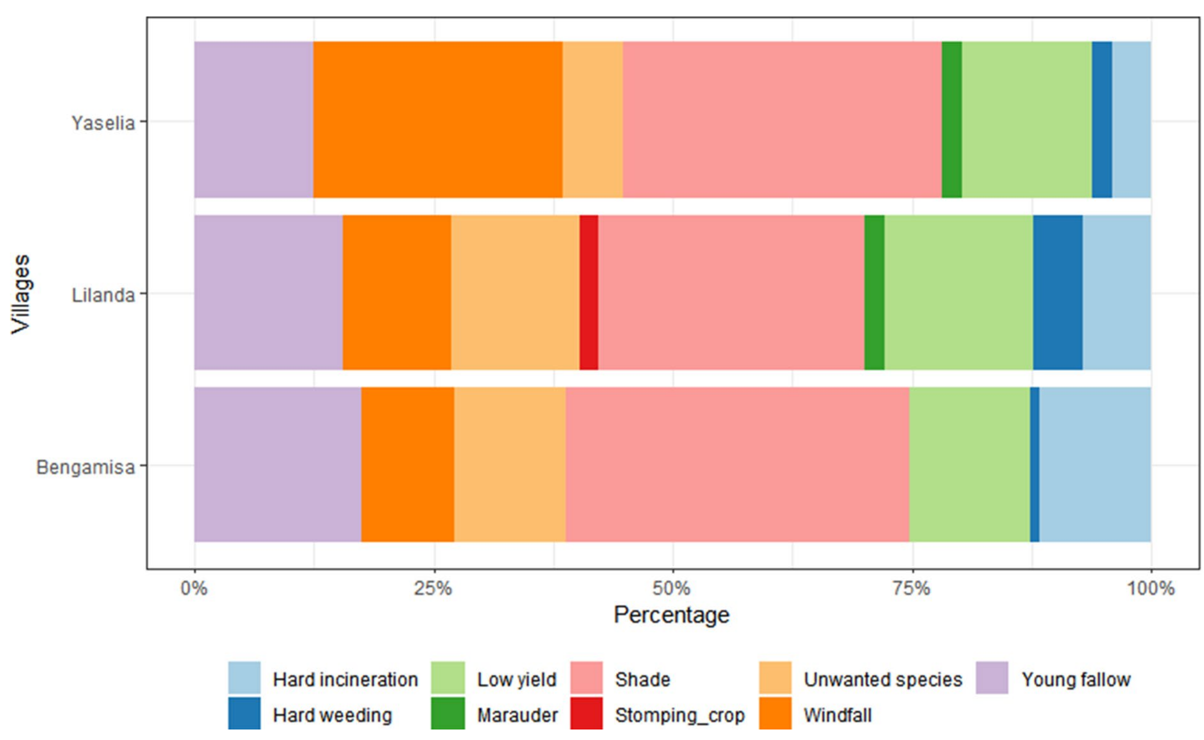

Fig. 3 Proportions of rejection factors of agroforestry in the BRY landscape

livelihoods, shade for workers, various NTFP) and ecological (windbreaks, fertilization and ecological niche for several species). This analysis conforms with the findings of Adesina et al. (2000), which sustain that AFS are adapted depending on the environment and the socio-economic context.

According this study, the incentives factors of agroforestry adoption correspond to the patterns which lead farmers to leave agroforestry species on their fields. Moreover, AFS in developing countries are at confluence of several challenges, such as improving food security, reducing environmental degradation and reducing poverty (Toth et al. 2017). For instance, Mercer (2004) and Mbow et al. (2014) had confirmed that, the adoption and maintenance of agroforestry by farmers is the result of a complex process depending on various factors related to household characteristics, community issues, socio-economic incentives, access to information, local institutional arrangements as well as agricultural macro-policies. Thus, in the BRY landscape, these factors are namely: the gathering of edible caterpillars and fruits, artisanal logging, charcoal making, extraction of medicinal products, art making, fertilization of farms, and traditional rites.

Furthermore, Degrande et al. (2006) had found in Nigeria and Cameroon, that farmers prefer agroforestry species that they know utility for their livelihoods. These results corroborate with the realities of studied region, where the residents prefer more local multipurpose species such as *Petersianthus macrocarpus* for their livelihoods comparatively to the exotic species. In addition, any decision to introduce agroforestry species somewhere should be in-depth, based on feasibility studies of farmers' preferences and perceptions (Atangana et al. 2014). This argument is justified in the BRY landscape, where factors cited above are more likely to encourage farmers to adopt agroforestry (Dyani et al. 2020; Basti et al. 2021). These factors are very much linked to local tree species and contribute to the riparian's survival and reduce deforestation rate in this landscape.

Use value of agroforestry species

This indicator allows classification of agroforestry species according to farmer preference in the YBR landscape. It is a key to better analyze the local perceptions as well as the adoption and maintenance of agroforestry. It still known that all woody species have an ecological importance, but in agroforestry, farmers look for multifunctional and useful species in order to benefit their positive externalities (Garrity 2004).

After investigation, *Petersianthus macrocarpus* was found to be the most preferred species in this landscape with a TUV of 45.1%. This species hosts two kinds of edible caterpillars most appreciated by riparian and its bark and leaves are used to treat several diseases. This species is also exploited by artisans for its timber quality, and finally it serves as a windbreak for cereal crops. The ecological particularity of this species is its phyllotaxis, which allows crops to benefit light and its resistance to fire. It's followed by *Erythrophleum lasianthum*, which had a TUV of 15.3%, is also a caterpillar species and maintains soil fertility as a leguminous plant. Its wood is often used for bridges because of its high density.

In contrast with the results found by Degrande et al. (2006) in Cameroon and Nigeria, this study found that farmers in the BRY landscape, prefer more caterpillar species on their farms than fruit trees that can easily grow in their home gardens. Reason why the TUV of fruit species is less than 7%. In addition, the fields are often far from the residences of local people (Kipute et al. 2021); exposing fruits and field products to thieves and marauding birds.

However, the TUV calculated in this study are comparable to those obtained by Jagoret et al. (2011) in central Cameroon through cocoa-based agroforestry farms. For example, *Entadrophragma cylindricum* has a TUV of 6.8% in Cameroon while it had registered 7.6% in Yangambi (DRC). Moreover, the methodology used to calculate this indicator is similar to the one applied by Belem et al. (2008) in Burkina Faso, although his results are based on species from a different eco-zone than Yangambi. Furthermore, Batsi et al. (2021) also found agroforestry species such as *P. macrocarpus; P. angolensis; P. americana; D. edulis and P. soyauxii* in cocoa farms in the *Bengamisa* landscape. These corroborate the results found in this study, which give a TUV for each species. The main difference is that, this study does not consider oil palm as an agroforestry species because it is abundant in this landscape and is not a woody species (Rosenstock et al. 2019).

Influence of social determinants on farmers' agroforestry adoption

Empirical studies in agroforestry adoption still use regression analysis for determining social determinants as adoption factors of agroforestry (Pattanayak et al. 2003). Nevertheless, these regressions are not informing the farmers willing to adopt or to maintain agroforestry as a production method in theirs farms. In the case of this study, the multiple linear regression between production mode and social determinants revealed that only "age" is a significant factor. Indeed, young producers prefer to cut down everything in their fields than the old man (≥ 45 years) who know the cultural and socio-economic value of agroforestry species. This can compromise the biodiversity conservation through the BRY in future, if public services and development agencies will not increase awareness to incite young producers to practice AFS in this landscape.

These results are similar to those found in Malawi by Thangata and Alavalapati (2003) where the age of farmers had a significant influence on agroforestry adoption. Furthermore, McGinty et al. (2008) also found that, the age factor in Brazil is very significant for agroforestry adoption. Moreover, Pattanayak et al. (2003) in his landmark study on agroforestry adoption mentioned that the age of farmers influences agroforestry adoption at 29%. Therefore, awareness of young producers by development agencies and technical accompaniment by government are crucial to ensure ecosystems services through this landscape within the vulgarization of preferred species and sustainable practice. Additionally, the government can provide agricultural input (seeds, agroforestry plantlets, etc.) to encourage young producers to practice more sustainable agriculture.

The other explanatory factors in this regression have negative coefficients and do not significantly influence agroforestry adoption in this landscape. These results partially corroborate those obtained by Adesina et al (2000) in Cameroon, where land tenure and education of the respondents did not significantly influence the adoption of agroforestry. Nevertheless, awareness (contact with agroforestry technicians) and gender in their regression analyses were highly significant.

Rejection factors of agroforestry in the BRY landscape

Approximately 47.3% of respondents are not practicing agroforestry in BRY landscape. They are justifying their demotivation with several reasons including: shading of woody species on food crops, use of young fallows, risk of wind throws of burnt species, lack of useful species, fear of yields reduction of food crops, difficulties of incineration and weeding, attraction of marauding birds, and the trampling of food crops by caterpillars and fruit pickers. However, these constraints are significantly different between surveyed villages (X-squared = 28.206, df = 16, p-value = 0.02987) due to their socio-ecological characteristics and conception of AFS by farmers.

These farmers believe that food crops have a high demand for light to give expected crude yields, so leaving woody species on their farms would significantly reduce their crop yields. Even more, as they are located within forests land, they suppose that forest resources are inexhaustible. Although, this forest is currently located in BRY, which is a biodiversity sanctuary and is restricted to riparian access. From the preceding, the real constraint to agroforestry adoption in this landscape is the lack of technical mastery by farmers to manage trees and crops on their farms (Toth et al. 2017).

In contrast to Dupraz and Canpillon (2005), who hypothesized that agroforestry species can diminish the useful area and decrease the crops yield; the traditional agroforestry practiced in the *BRY* is different because it's based on association of food crops with remains of useful species. The height of these species allows light penetration, while their falling leaves constitute organic matter that is mineralized and brings nutrients into the soil for the benefit of food crops (Dyani et al. 2020). In addition, these species are generally leguminous and are contribute to the maintenance of soil fertility through symbiotic fixation of atmospheric nitrogen (Rosenstock et al. 2013).

Conclusion

This study had founded that the factors inciting agroforestry adoption in Yangambi landscape are linked with the livelihoods of riparian communities, namely: the gathering of edible caterpillars and fruits, the pharmacopoeia and the artisanal exploitation of timber and charcoal. Others factors encouraging the adoption of agroforestry practices include the benefits of trees as a windbreak and for the maintenance of soil fertility. Farmers prefer woody species like *Pericopsis angolensis*, *Pterocarpus soyauxii*, *Millettia laurentii*, *Cola acuminata*, *Cola nitida*, *Garcinia kola*, *Ricinodendron heudelotii*, *Dacryodes edulis*, *Autranella congolensis*, *Entandrophragma angolense*, *Gilbertiodendron dewevrei*, *Prioria balsamifera*, *Scorodophleus zenkeri*, etc. over exotic due to their advantages. However, farmers who were not in favor of agroforestry justified their rejection of this practice by citing the shade produced by woody species, the fear of windfall and reduced crop yields, as well as the difficulties of burning and weeding.

Thus, the promotion of agroforestry in this landscape by development agencies and public services will be more successful, if they are able to provide the preferred agroforestry species in order to satisfy the needs of local communities. Additionally, farmer field schools are necessary to encourage farmers who reject this sustainable practice in the BRY landscape. Furthermore, additional research is essentials to improve the growth rate of these local species and establish their correct spacing in simultaneous agroforestry in order to sedentarize farmers practicing shifting cultivation. In fact, the sedentarization of farmers could decrease the deforestation rate and increase their incomes by eliminating the need to clear and burn the land, a burdensome practice. Indeed, development agencies must raise awareness especially, among the young people on this sustainable method, which will in turn preserve their cultural heritage. Hence, the spread of the agroforestry schemes based on real needs and preferences of riparian communities could enhance biodiversity conservation in the BRY and sustainable the livelihoods in this landscape.

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Declarations

Conflict of interest The authors declare no competing interests.

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