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RESEARCH ARTICLE

What motivates West African cocoa farmers to value trees? Taking the 4 W approach to the heart of the field

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Abstract

1. West Africa, the largest cocoa-producing region globally, has experienced significant deforestation in recent decades, leading countries to implement large-scale agroforestry policies; however, most studies on farmers' adoption of agroforestry fail to consider the social (Who?), historical (When?), geographical (Where?), and ecological (What?) factors that influence their motivations to value trees.
2. Drawing from a sample of 150 farmers responsible for the management of 12,096 trees, we quantified the motivations of farmers for 10 material and immaterial uses of trees and used a Bayesian modelling framework to explore the relative importance of the 4 W framework in explaining general motivations, specific to each use, as well as the varying levels of specialization in tree management strategies among farmers.
3. The distribution of use values by category shows that the highest values are associated with (i) agronomic uses (such as shade for cocoa trees and soil fertilization), (ii) food for human consumption, (iii) social purposes, and (iv) medicinal uses.
4. All four aspects of the 4 W framework significantly contribute to understanding farmers' deep motivations, while the influence of each 4 W determinant varies based on the specific material and immaterial uses being considered.
5. The level of specialization or diversification in cocoa farmers' motivations is significantly influenced by their knowledge of tree species and cocoa tree density, with knowledgeable farmers exhibiting greater diversification, while higher cocoa tree density and the presence of remnant trees lead to more specialized strategies that hinder agroforestry adoption.

6. From a political perspective, it is urgent that stakeholders involved in the promotion of agroforestry consider all dimensions of the farmer-field system. The diversity of farmers' life histories (Who), of cultivated landscapes (Where), of field systems (What), and of time trajectories (When) present both constraints and opportunities with which farmers must contend to transition to much-desired agroforestry systems.

KEYWORDS
4W approach, agroforestry, cocoa, Côte d'Ivoire, farmers' strategies, use-values

1 | INTRODUCTION

West Africa is the world's leading cocoa-producing region, accounting for more than 70% of global cocoa production (Wessel & Quist-Wessel, 2015). Historically, the expansion of cocoa cultivation has led to significant deforestation (Aleman et al., 2018). Cocoa farming is mainly practiced by small-scale farmers, for whom it is typically the main source of income (Sonwa et al., 2019). Originally, cocoa was an understory plant native to the Amazon rainforest (Clement et al., 2010), but it has been domesticated to the extent that it can now be grown in full-sun monocultures. Although these monocultures are highly productive for the first 20–30 years, this intensive approach is not sustainable in the long term, either agriculturally or environmentally (Green, 2017). A recognized strategy to improve the sustainability and resilience of agricultural production is the introduction of trees, and shifting from full-sun systems to agroforestry systems (Niether et al., 2020). Recent studies suggest that maintaining up to 30% tree cover can sustain consistent agricultural production, with decreases observed beyond this threshold (Blaser et al., 2018). In light of this, agroforestry has been promoted by both the public and private sectors, especially by international companies through certified sustainability programs (Dieng & Karsenty, 2023).

In the socio-ecosystems of West Africa, trees are vital, offering both material and immaterial goods and services to rural communities (Darboe et al., 2023). Trees directly support agricultural practices by aiding in water management, improving soil fertility, providing shade, and helping to control pests. Additionally, trees provide material benefits that are integral to farmers' daily lives, such as food, traditional medicine, building materials, tools for artisanal crafts, and income from the sale of wood or non-timber forest products (Heubach et al., 2011). These material uses play a significant role in improving living conditions for rural populations (Darboe et al., 2023). Equally important, though often overlooked, are the immaterial uses of trees, which are connected to cultural practices (such as ceremonies, beliefs, and the transmission of knowledge), social aspects (such as resource sharing, landmarking, and community integration), and aesthetic values (including the appreciation of tree beauty and the sense of well-being they provide). Although these immaterial uses are harder to quantify, they are crucial to meeting the social and emotional needs of individuals and communities (Codjo et al., 2017). Farmers may choose to focus on a particular use of trees based on their needs and aspirations, either specializing in one or a few uses or adopting a more generalist approach that incorporates multiple uses. This creates a spectrum of valorization strategies, from a 'generalist' approach, where a diverse array of uses is embraced, to a 'specialized' approach, where only select uses are prioritized (Coelli & Fleming, 2004).

Numerous studies have explored the determinants of the adoption of agroforestry by farmers in West Africa (e.g. Amerino et al., 2024; Asaaga et al., 2020; Atangana et al., 2014; Kouassi et al., 2021; Sanou et al., 2019). Some have focused on personal contingencies related to the individual characteristics of each farmer, as well as institutional factors tied to public policies implemented in the field (Amerino et al., 2024; Sanou et al., 2019). Others have examined sociocultural contingencies (Atangana et al., 2014) and land-related factors (Asaaga et al., 2020). However, spatial contingencies related to the diversity of landscapes surrounding agricultural systems and temporal contingencies related to regional and local cocoa production trajectories have been largely overlooked in understanding the factors driving agroforestry adoption. The agrarian system approach provides a comprehensive framework for understanding farmers' choices in managing complex systems (Dufumier, 1996; Mazoyer & Roudart, 2006). This approach extends beyond the individual field, placing agricultural practices within a broader sociocultural and geographic context that both shapes and is shaped by these practices (Van Hecken et al., 2019). Analysing this context requires considering the relationships between various components, including the characteristics of the agroecosystem, the farming methods used (knowledge, practices), the historical transformation of the environment, and the interactions within the landscape (Cochet, 2012). This comprehensive approach can be summarized by four key questions (the 4W): Who manages the system? What is the system? Where is the system located? And since When has it existed? (Calvet & Clément, 2015; Kosciw et al., 2009). To the best of our knowledge, this multidimensional method has not yet been widely applied in ecological sciences, particularly in studying the relationships between trees and farmers in cocoa agroforestry systems.

- The identity (Who?) of the farmer plays a crucial role in understanding the motivations behind why cocoa farmers value trees. This is particularly important because cocoa cultivation may be undertaken by native individuals with deep empirical knowledge of their local environment, or by non-native migrants, often from

Sahelian countries, who initially have little familiarity with local trees (Ruf, 2001). Furthermore, the cocoa farming community is diverse, with a wide range of ages and levels of education, which can influence its connection to the natural environment, including trees (Gyau et al., 2014).

- The nature (What?) of the field is another key factor to consider. Field sizes vary significantly, from less than a hectare to several hectares, with smaller fields possibly allowing planters to have better knowledge of and consideration for trees. Fields may contain numerous remnant trees left standing during forest clearing or be entirely open to sunlight (Zo-Bi & Hérault, 2023). The density of planted cocoa trees also varies, depending on whether the planter adopts a strategy of 'letting everything grow' or selectively cultivating the most productive cocoa trees (Jagoret et al., 2017).
- The history of cocoa cultivation (When?) is essential to understand the system. In Ivory Coast, cocoa farming has evolved through successive production cycles, known as loops, starting with the oldest loop in the East and extending to newer loops in the West (Figure 1). As these loops age, the biophysical environment changes (reduction of forest cover, microclimatic changes), with soil fertility becoming particularly low in the oldest loops (Ruf, 2001). Within the same loop, fields can vary greatly in age, depending on the farmer's decision and financial ability to renew the field as cocoa plants age and productivity declines. The history of the field is closely tied to soil fertility and can influence the farmer's motivation to value tree-derived products beyond just cocoa beans (Suárez et al., 2021; Wartenberg et al., 2018).
- The immediate forest environment (Where?) around the field is crucial in determining the potential for natural tree regeneration (Amani et al., 2021), and consequently, the planter's ability to select trees within the field (Kouassi et al., 2023). Similarly, the proximity of the field to the planter's residence significantly affects the farmer's long-term and daily commitment to managing trees and their associated products.

A significant number of studies have examined various factors to understand how farmers value trees in agroforestry systems and their economic contributions to household incomes. However, most of these studies have been highly specialized, focusing on specific disciplines, such as sociology, history, geography, or ecology. A holistic understanding of these management strategies would provide more relevant and context-specific insights to develop effective agroforestry support policies (Gyau et al., 2014; Sood & Mitchell, 2006). The overall objective of this work is to understand the motivations of West African cocoa farmers in valuing trees within their cocoa

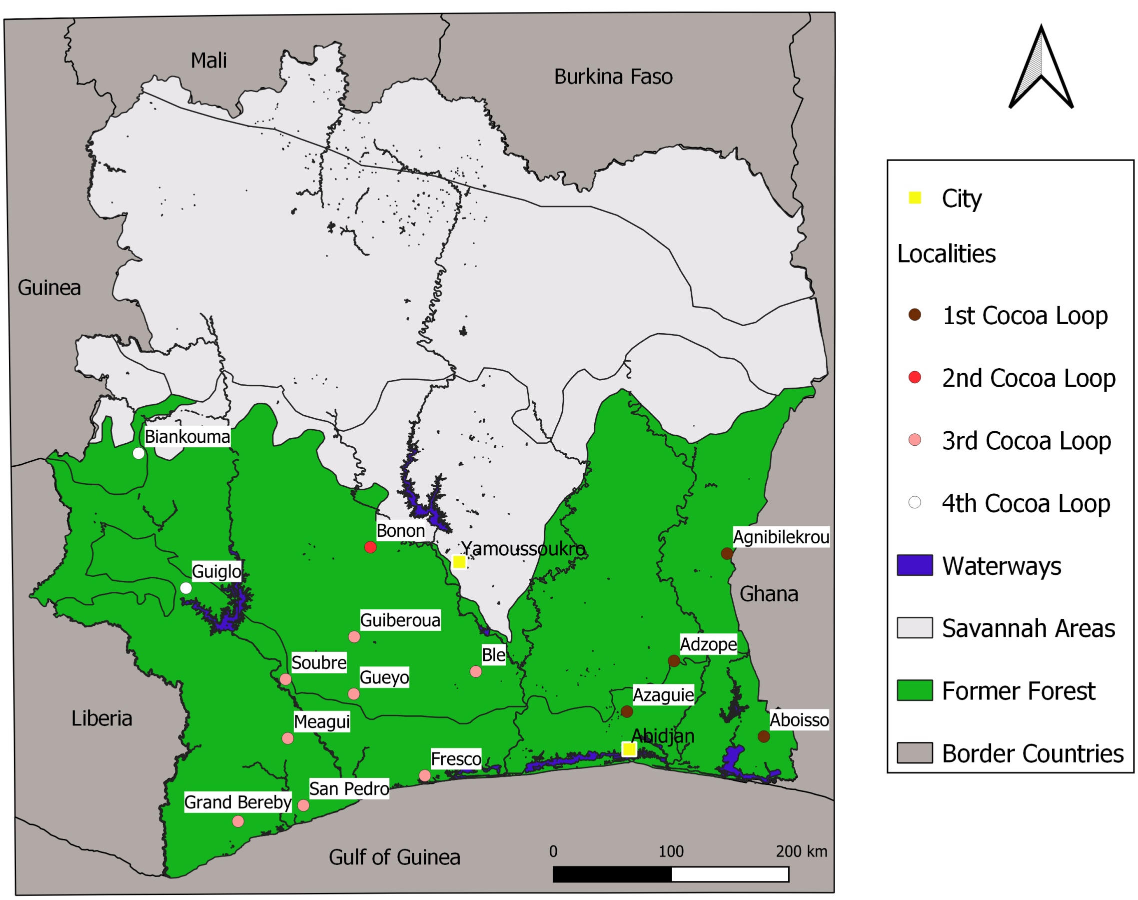


FIGURE 1 Map showing the locations of the 15 study sites, coloured according to the historical gradient of cocoa cultivation expansion in the forest zone of Côte d'Ivoire.

fields. To achieve this, we will use the 4W approach to address three specific questions.

1. What is the relative importance of the 4W factors (who, where, when, what) in explaining the overall motivations of cocoa farmers to value trees?
2. Do these factors differ among the main categories of material and immaterial uses?
3. How do these factors explain whether farmers adopt generalist strategies (valuing all uses) versus specialist strategies (focusing on only a few uses) in managing trees in their fields?

2 | METHODS

2.1 | Study sites

The study plots have been chosen at 15 sites, covering the former forest zone of Côte d'Ivoire (Figure 1). These sites are located along a South–North climate gradient (mean annual temperatures range from 22.6 to 26.2°C and annual rainfall range from 1900 to 1100 mm), which also corresponds to a South–North vegetation gradient (from evergreen forests to semi-deciduous forests). To capture the diversity of cocoa fields, we selected 10 cocoa plots at each site based on three criteria: (i) structural complexity, ranging from nearly full sun cocoa monocultures to complex cocoa agroforests; (ii) age of the cocoa fields, from young to mature plots; and (iii) cocoa tree yield, from less productive to highly productive plots. The study plots vary in size, ranging from 0.3 to 5 hectares, serve as sampling units, and correspond to the farming management unit. The 15 sites are distributed within all successive cocoa loops, extending from some in the east of the Ivory Coast, representing the first loop, to the west of the country, where the last loop is situated.

2.2 | Ethics Statement

The objectives of this work were presented to each village chief and permission was requested and granted to conduct surveys in their respective villages. Subsequently, the study objectives and ethical guidelines for handling the collected data were explained to each cocoa farmer and his family before the interview. This explanation clarified that they had (i) the freedom to unilaterally end their participation at any time, (ii) the freedom to refuse to answer any questions without needing to justify themselves, and (iii) the right to pause the interview for any reason as often as needed. Farmers who verbally expressed their agreement and understanding then signed a declaration outlining the ethical guidelines followed and authorizing the use of personal data (age, origin, etc.) and survey responses. The collected data were later anonymized according to a data anonymization procedure established in advance. The interviews were conducted primarily in French by the first author of this work, assisted by one or two interpreters for the local language. Each interview with a producer lasted an average of 4 h.

2.3 | Data collection

All cocoa fields were geographically delineated using GPS. All trees present in the cocoa fields, with a minimum diameter at breast height of 10 cm, were identified at the species level. The origin of each tree (planted, remnant, spontaneous) was also recorded according to the farmer's declaration. Data collection was then carried out through semi-structured recorded interviews. A mixed methods approach was adopted, integrating both qualitative and quantitative aspects.

The qualitative approach involved going to each tree with the cocoa producer to gather all the uses for which they decided to keep each. Seeing the tree helped farmers remember all the reasons for their selection. During this ~2-h phase (depending on the number of tree species present), a free walk through the cocoa field allowed stopping at each species, without exception, to engage the farmer in discussing the material and immaterial uses of these species by scanning all organs (root, trunk, bark, branch, leaf, flower, fruit, sap, bud, etc.). Conducting the interviews allowed qualitative characterization of the knowledge of farmers about trees. Ten major categories of uses were identified accordingly (Table 1).

Subsequently, a quantitative approach was used to assess the value of use attributed by each farmer to each tree species in his field. The adopted approach involved the use of the stone ranking method developed by Sheil et al. (2004) and applied by Jagoret et al. (2014) in cocoa fields in Cameroon. A comprehensive table with tree species listed in rows and 10 use categories in columns was presented to each cocoa farmer. Each farmer had a bag with an ample number of small stones, more than enough for the exercise. The farmer was then asked to place between 0 and 10 stones in each cell of the table, based on the importance they assigned to each combination of tree species and use. Due to the 10 categories of use, the farmer could distribute up to 100 stones per tree species.

Explanatory variables (see details Table 2) were gathered with cocoa farmers during interviews or collected ex situ based on the national land use map for the year 2015 (Traoré et al., 2024):

- *Who*—Variables indicating the personal characteristics of cocoa farmers: *Origin* of the farmer (native or not native), *Knowledge*, *Education Level*, and *Status* (landowner? or not). This variable encapsulates land tenure security practices. Two categories were identified: the producer owns the land (with a land title) or does not. Non-owners included sharecroppers, who have the right to use the land in exchange for a portion of the harvest, and tenants who rent the land for a monetary payment (in one case).
- *What*—Variables describing the diversity of cocoa fields: *Area* of the field, density of *Cocoa Trees* and relative importance of *Remnant Trees*. Remnants trees are isolated left-alive trees from the former old-growth forest before cocoa farming (Ordonez et al., 2014) and serve as a valuable source of timber (Doua-Bi et al., 2021; Elogne et al., 2023).
- *Where*—Variables accounting for the diversity of spatial positions of the studied fields: Distance *Plot Home*, percentage of *Forest*

TABLE 1 Summary table of the 10 categories of uses studied and descriptive statistics (medians and quantiles) of the field scores calculated per use.

Use categories	Details	1st quantile	Median	3rd quantile
Agronomy	Support for cocoa-growing (shade, soil fertilization)	113	227	472.8
Building	Building materials	9	38.5	90.7
Craft	Craft materials	0	49.9	68.5
Cultural	Related to culture and traditions	0	0	37.5
Aesthetic	Beauty and personal well-being	0	0	8
Financial	Source of income	0	50	166.5
Food	Food and drink	80.7	117.5	348
Fuel	Firewood and charcoal	0	20.5	133.2
Medicinal	Traditional medicine	28	75.5	183.8
Social	Linked to life in society	16.7	97	281

TABLE 2 Overview of 4 W variables investigated to explain the farmer's motivation to value trees in cocoa fields in Côte d'Ivoire.

W type	Short name	Description (units)	Values or [min; max]	Sources
Who	Origin	Native is someone who is native in the locality/ Non-native who comes from another locality	0 = native; 1 = non-native	Interviews
	Knowledge	Recognition level of tree seedlings (Supporting Information: Appendix 1)	[4; 37]	Interviews
	Status	Owner of cocoa field or not	0 = owner (inheritance, gift, purchase); 1 = not owner (tenant, worker)	Interviews
	Education level	Farmer's level of education	0: None; 1: Primary; 2: High school; 3: University	Interviews
What	Area	Field area (ha)	[0.36; 5.16]	GPS
	Cocoa Trees	Cocoa tree density (stem/ha)	[500; 2820]	Counting on four 1000 m^2 subplots
	Remnant Trees	Proportion of remnant trees per hectare (%)	[0; 100]	Tree dataset
Where	Plot Home	Distance from cocoa field to house (m)	[0; 37,500]	GIS
	Forest Edge	Distance from the cocoa field to the nearest forest (m)	[4; 3442]	GIS
	Forest Cover	Percentage of Forest cover within 10 km (%)	[0.1; 55.0]	GIS
When	Plot Age	Age of cocoa field: From creation until 2023 (year)	[8; 84]	Interviews
	Cocoa Loop	Oldest loop to newest loop	1 = Oldest loop; 2 = 2nd loop; 3 = 3rd loop; 4 = Newest loop	Vroh et al. (2019)
	Previous	Previous land use	0 = not forest; 1 = forest	Interviews

Cover in the landscape, and distance to *Forest Edge*. The latter two variables are related to the state of deforestation around the field.

- *When*—Variables designating the history of the field to capture the diversity of system trajectories: *Plot Age* of the cocoa field, the number of the *Cocoa Loop*, and the *Previous* Forest before or not.

2.4 | Statistical analysis

First, we explore the multidimensional correlations between the use values (obtained by summing the use values per category of use for all trees within the cocoa field, standardized per hectare) and the explanatory variables of the 4 W. To do this, we used Self-Organizing Maps (SOM), as implemented in the R package *kohonen* (Wehrens & Kruisselbrink, 2018). SOM is an unsupervised classification method that is based on the multidimensional correlations of input variables while accounting for nonlinearities between them. To identify the optimal number of cocoa farmer groups, we used the silhouette index of the *cluster* package (Maechler et al., 2023). This allowed us to create a typology of cocoa farmer profiles, each type being homogeneous both in terms of use values and explanatory variables.

Then, to answer the three specific research questions; 3 response variables X_p have been calculated per field p

- M_p, the global motivations, obtained by summing up the use values of all trees within a cocoa field, standardized per hectare,
- M_p^U, the motivations by category of use U, obtained by summing the use values per category of use of all trees within the cocoa field, standardized per hectare.
- S_p, the level of specialization of uses, which we have defined as the opposite of the observed diversity of uses. To obtain it, we calculated, for each field, the first-order diversity of M_p^U, transformed into a Hill number. Since the maximum possible value is 10 (all uses have exactly the same level of motivation, i.e. maximum diversity), we transformed the obtained value by subtracting it from 10. Thus, we obtain a measure of the specialization of uses. Calculations were performed using the 'entropart' package in R (Marcon & Hérault, 2015).

To estimate the effect of explanatory variables (Table 2) on general motivations M_p and by category M_p^U, we fitted a Negative Binomial model to the data, considering that the observed response variables are discrete and sometimes over-dispersed. The effects of covariates *i* were then tested by incorporating them into an exponential function, considering that the λ parameter of the negative binomial distribution is defined on R+.

$$X_p \sim NB(\lambda_p, \text{phi}) \text{ with } \lambda_p = e^{\left(\sum_{i=1}^{i=n} (\theta_{\text{cov}} * \text{Cov}_i)\right)}$$

where Cov_i denotes the explanatory variable *i* listed on Table 2.

Next, to estimate the effect of explanatory variables on the level of specialization of uses S_p, we fitted a lognormal model to the data, considering that the observed response variable is defined on R+. The effect of covariates *i* was then tested by incorporating them into an exponential function, considering that the μ parameter of the lognormal distribution is defined on R+.

$$X_p \sim \text{log}N(\mu_p; \sigma) \text{ with } \mu_p = e^{\left(\sum_{i=1}^{i=n} (\theta_{\text{cov}} * \text{Cov}_i)\right)}$$

where Cov_i denotes the explanatory variable *i* listed on Table 2.

All covariates were standardized to allow a direct comparison of their effects. The model was parameterized and inferred using Stan (Carpenter et al., 2017) with a Bayesian approach. The codes used to infer the models are provided in Supporting Information: Appendix 3.

3 | RESULTS

We inventoried 12,096 tree individuals belonging to 291 species, 178 genera grouped into 51 families. Among these trees, 3389 (28%) are remnants, 5039 (42%) are spontaneous, and 3668 (30%) are (trans) planted. Among the cocoa farm managers interviewed, there is a high proportion of men: 145 men compared with 5 women. Farmers range in age from 22 to 74 years old. Finally, 95 (63%) of the farmers are indigenous, and native to the production villages, while 55 (37%) came from other villages. The general motivations, obtained with the stone method, range from 36 to 4969, with a median of 702. Regarding the use values distributed by category of use (Figure 2), the values are highest for uses (i) agronomic (shade for cocoa trees, soil fertilization), (ii) food, that is, human consumption, (iii) social, and (iv) medicinal purposes with respective medians of 227, 117.5, 97, and 75.5.

The SOM analysis identified four groups of cocoa farmers (Figure 3):

- The "Heritage Harvesters" ($n=46$) are native farmers with a high level of education, whose plantations are in older cocoa-growing areas. They value the cultural, social, agronomic, and wood-related uses of trees, but are not motivated by financial or food-related uses.
- The "Frontier Planters" ($n=80$) consist of non-native producers located in newer cocoa-growing areas. These farmers are not motivated to value trees for any of the uses considered.
- The "Forest Landers" ($n=3$) are a very small group of non-landowning farmers with very low education levels. Their cocoa fields are the result of recent deforestation and are densely planted with cocoa trees. These Forest Landers are motivated by the agronomic, financial, firewood, social, and aesthetic uses of trees.
- The "Resource Foragers" ($n=21$) are non-native producers with plantations in new cocoa-growing areas, where densities of remnant trees are low. Resource foragers highly value almost all uses of trees, except for aesthetic purposes.

3.1 | Global motivations

Each of the 4 W influences in some way the overall motivations of cocoa farmers (Figure 4 and Supporting Information: Appendix 4). Regarding the 'Who', the most motivated cocoa farmers have the following characteristics: good seedling recognition ability and non-owners of the plot. For the 'What', motivations are high when fields have the following characteristics: small areas and few remnant trees. Concerning the 'Where', motivations are high when the field is in a landscape with low forest cover. For the 'When', motivations increase in the following historical contexts: the forest was the previous land use, the cocoa fields are old, and when they belong to the oldest cocoa loops.

3.2 | Detailed motivations

3.2.1 | Who

Native farmers are solely motivated by aesthetic uses, whereas the nonnatives are motivated by wood building, craftsmanship, as well as cultural, commercial, and social uses (Figure 5). Non-owner farmers value trees for agronomic purposes, construction materials, craftsmanship, and fuel, whereas owners focus solely on cultural uses (Figure 5d). Cocoa farmers with low educational levels are motivated only by cultural uses of trees, while those with higher education are motivated by agronomic, building, and financial uses. The more farmers recognize seedlings, the more motivated they are, regardless of their use.

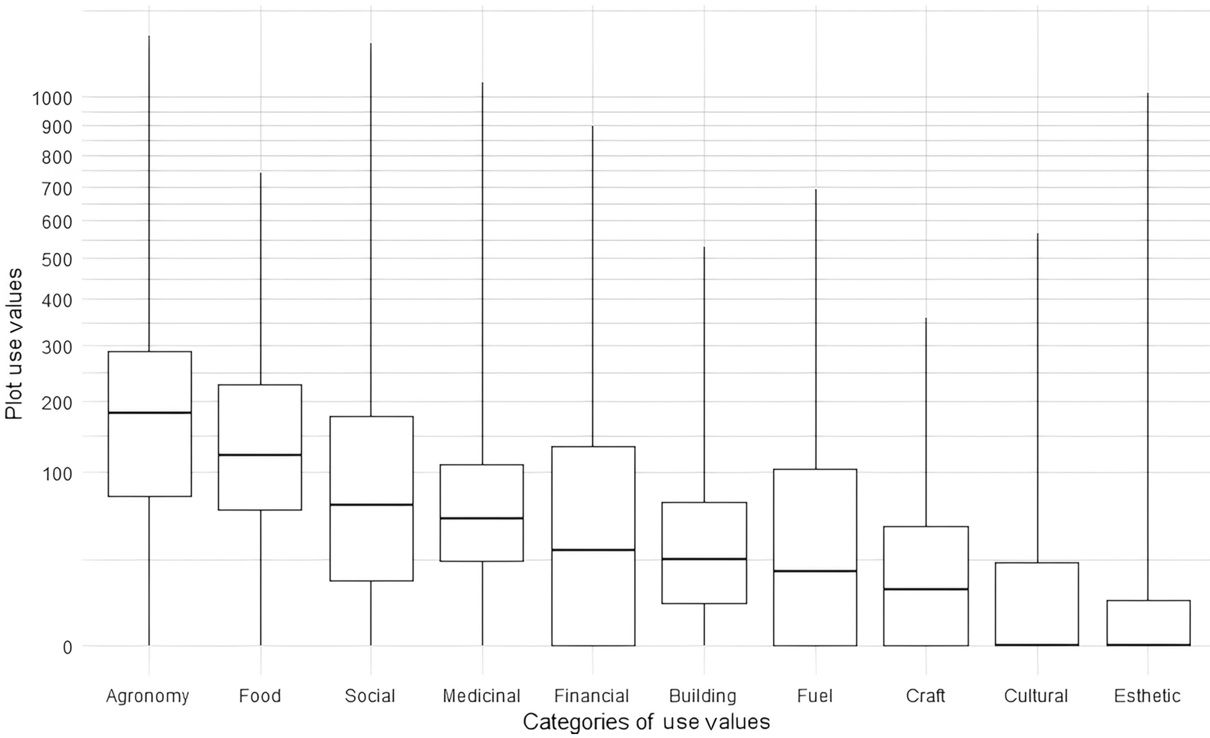


FIGURE 2 Box plot of the distribution of the value scores per use category.

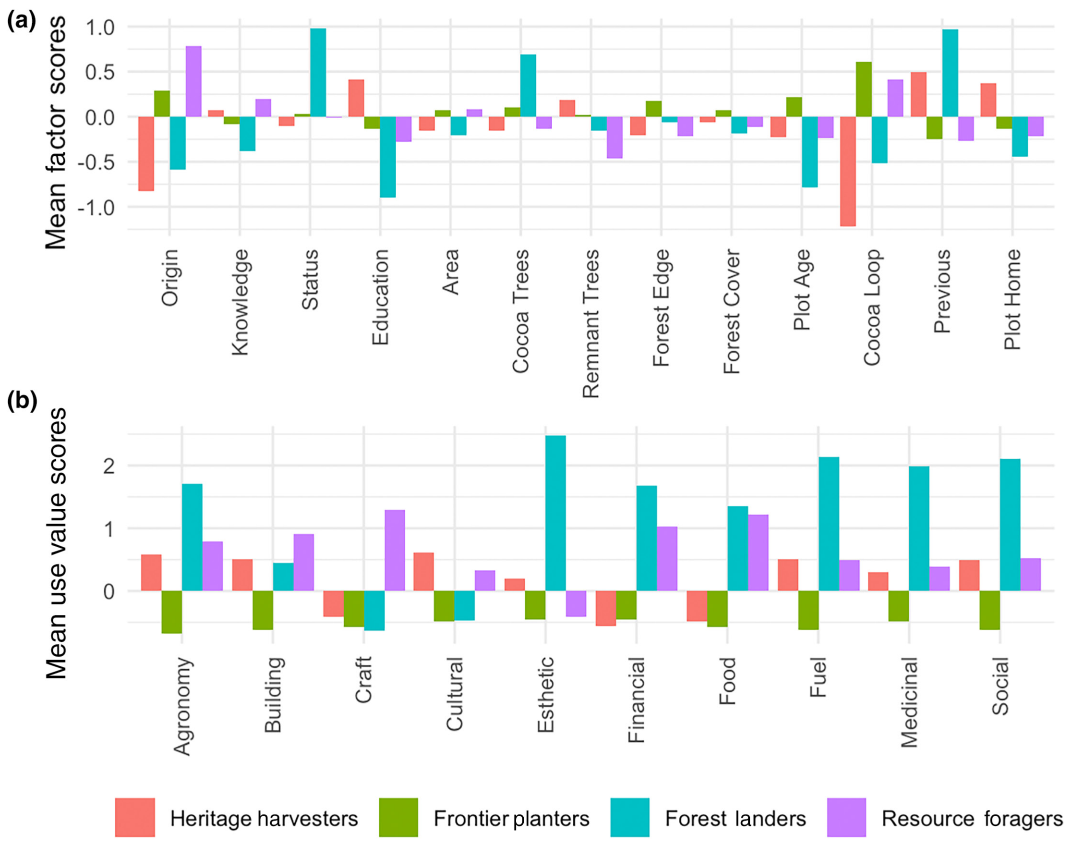


FIGURE 3 Signature of the 4W factors and mean use values of the four groups of cocoa farmers identified with self-organizing map analysis. A value below zero means that the group in question has a lower value compared with the other three groups for the factor (a) or use (b) considered, and vice versa.

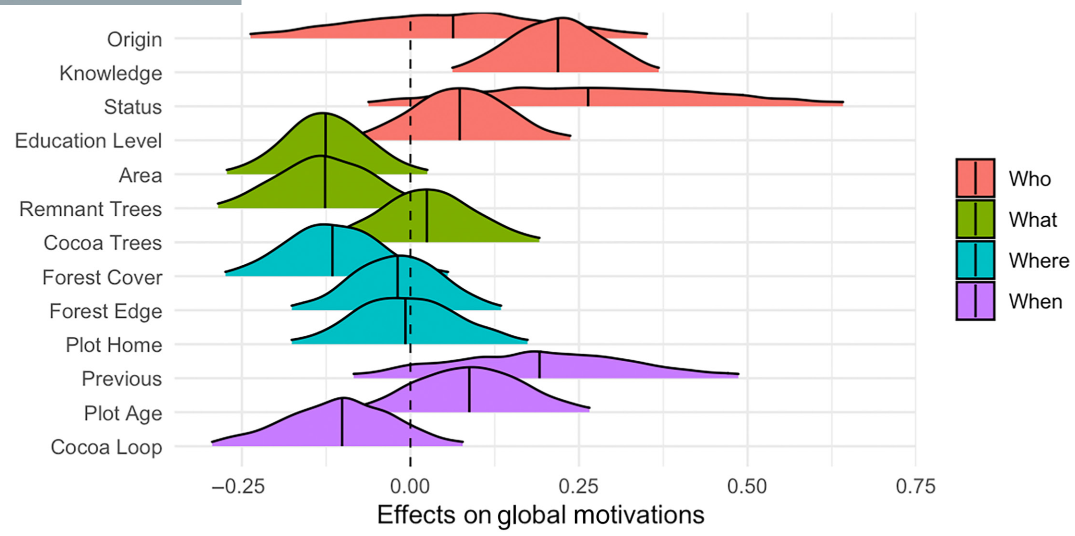


FIGURE 4 Effect of variables related to 4 W (Who red, What blue, Where green, When purple) on the overall motivations of planters.

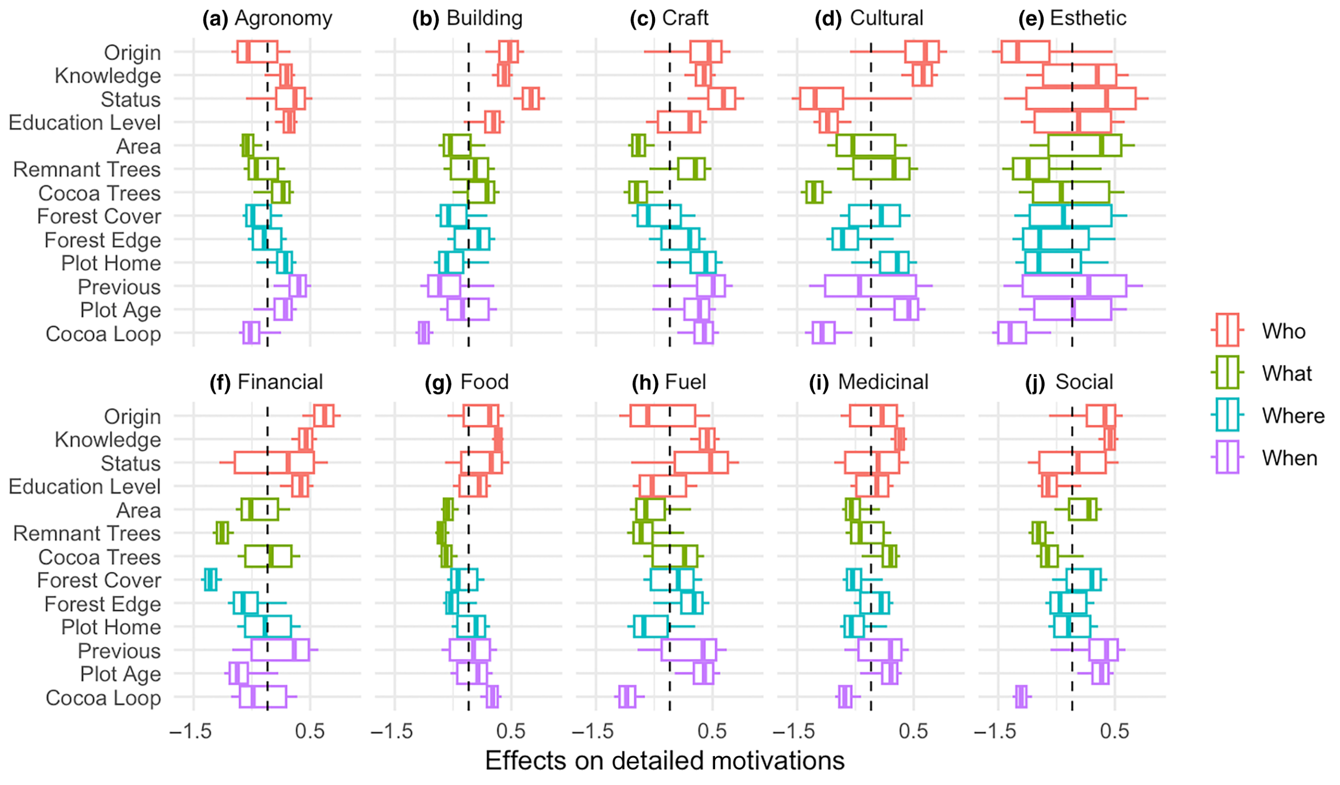


FIGURE 5 Effects of factors Who, What, When, Where on detailed motivations of cocoa farmers. Effects of factors Who, What, When, Where on detailed motivations of cocoa farmers about uses values for categories (a-j).

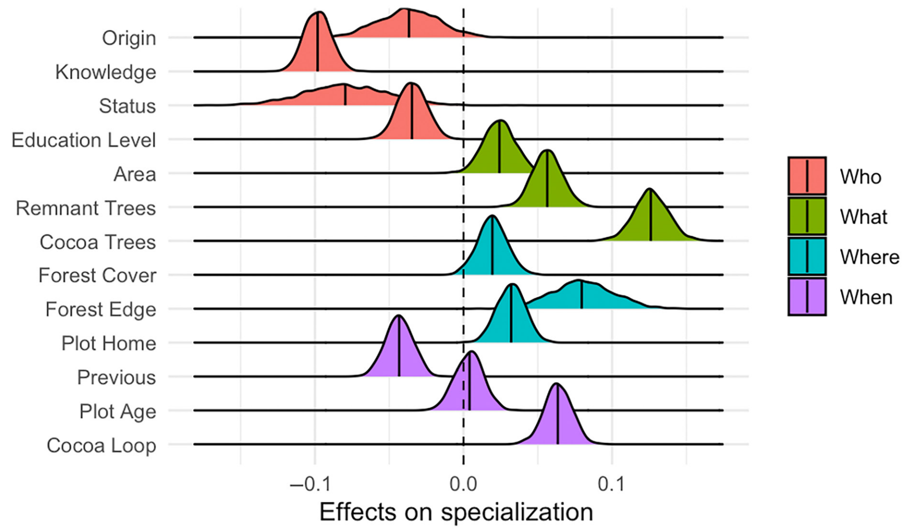
3.2.2 | What

Large-scale cocoa plantations are associated with very low motivations among cocoa farmers (Figure 4), for a majority of tree uses (Figure 5), unlike small-scale cocoa plantations (0.5–1.5 ha). A high number of remnant trees is generally associated with low motivation, except for materials for craftsmanship, where motivation is somewhat stronger. Conversely, fewer remnant trees shift motivations towards aesthetic, financial, food, fuel, and social uses. Finally, high cocoa tree densities increase motivations for agricultural, building, and medicinal uses, but decrease motivations for craftsmanship, cultural, food, and social uses.

3.2.3 | Where

A strong link is noted between low forest cover and motivations for tree uses in the field, especially for agronomic, building, financial,

FIGURE 6 Effects of factors Who, What, When, Where on the level of specialization of uses of cocoa farmers.



and medicinal purposes (Figure 5a,b,f,i). As the distance from the forest edge increases, motivations for craftsmanship and fuel use increase. In contrast, fields close to the forest edge show higher motivations for cultural, financial, and food uses. Regarding the distance from the field to the village, greater distances are associated with increased motivations for agronomic, crafts, and cultural uses, while proximity to the villages boosts motivations for building, fuel, and medicinal uses.

3.2.4 | When

Motivations are high when cocoa plantations are established immediately after forest clearing, especially for trees that provide agronomic services, craft and fuel materials, and social benefits (Figure 5a,c,h,j). As cocoa plantations age, motivations grow for agronomic, craft, cultural, fuel, medicinal, and social uses. Only financial uses are emphasized when plantations are young. In the most recent cocoa loops, motivations for craft and food uses are high, whereas in older loops, agronomic, building, cultural, aesthetic, fuel, medicinal, and social uses are more valued.

3.3 | Specialization of uses

The links between the level of specialization of uses and the 4W variables are very strong, regardless of the specific W (Figure 6 and Supporting Information: Appendix 4). For 'who', use specialization is associated with low knowledge of tree seedlings, land ownership, being native, and having a low level of education. For 'what', specialization is related to high density of cocoa trees in the field, a large number of remnant trees, and to a lesser extent, large field size. For 'where', specialization is influenced by long distances from the forest and/or family home and the high forest cover in the landscape. Finally, for 'when', use specialization is associated with prior nonforest land use and the newest cocoa loops.

4 | DISCUSSION

Our study aimed to clarify why cocoa farmers value different tree uses in their cocoa plantations. We examined these motivations at three levels: overall, by specific use, and from the perspective of use specialization. Our findings confirm that the value attributed to trees is strongly influenced by various aspects of the 4W framework: the identity and history of the farmer (Sanial et al., 2023), the specific characteristics of the plantation (What?), the surrounding territorial context (Where?), and the historical trajectory of the plot (When?). In particular, at all levels of analysis (global, specific, strategic), each of the 4W plays a significant role, with no single W emerging as the predominant driver. This has important implications for supporting the development of agroforestry, which must effectively consider not only the farmer and the biophysical characteristics of the plantation but also the spatial and historical context in which the plantation is located.

4.1 | From the variety of personal trajectories arises the diversity of motivations

The origin of cocoa farmers—whether they are native or non-native—often significantly influences their use of trees for both material (e.g. building, crafting, financial) and immaterial (e.g. cultural, aesthetic, social) use (Figure 5). It is commonly assumed that non-native farmers prioritize short-term profitability in cocoa production, as noted by Ruf (1995). They often use strategies like shadeless cocoa cultivation with fewer trees and rapidly introduce high-yield varieties, which generally leads them to place less value on trees due to limited knowledge of their uses from their migration history (Ahenkorah et al., 1987). However, our findings present a more nuanced picture. Although this assumption is accurate for the Frontier Planters group, it does not apply to the Resource Foragers group, who value trees more extensively in their fields (Figure 3). It is surprising that native farmers tend to value trees primarily for aesthetic purposes and are less motivated by trees of cultural significance compared with non-native farmers (Figure 5d). One might expect native farmers to have a stronger connection to culturally significant trees, given their direct ties to nature and their desire to preserve sacred knowledge and certain tree species for future generations (Maweu, 2011). This unexpected result likely reflects a generational shift among cocoa farmers. Younger farmers may feel more distant from traditional knowledge and consider it outdated, which could explain why native farmers today show less interest in culturally important trees compared with their non-native counterparts (Battiste, 2002; Pinton & Grenand, 2007).

Overall, non-landowners are much more motivated than landowners (Figure 4). Specifically, landowners focus mainly on cultural uses (Figure 5d), while non-landowners value other uses. Most non-landowners access land through verbal agreements, where they either share a portion of their harvest with the landowner (sharecropping) or equitably share the land in production with the landowner (Colin & Ruf, 2009). Despite their precarious status, non-landowners often possess significant traditional knowledge, likely due to their more direct connection with the land they work (Sanial, 2019). They view tree products as free benefits offered by nature. However, in sharecropping agreements, non-landowners sometimes have limited access to certain products reserved for landowners, such as those used for commercial (Figure 5f) and medicinal (Figure 5i) purposes. Landowners can restrict these products to benefit directly from revenues or to prevent excessive bark stripping that could harm tree survival (Amahowe et al., 2018).

The level of education among farmers generally increases their appreciation for the importance of trees (Figure 4), as supported by the literature (Kendal et al., 2012; Lohr et al., 2004; Murniati et al., 2022). This is particularly true for agronomic and building uses (Figure 5a,b) that Heritage Harvesters highly value (Figure 3). However, cultural and social uses are primarily valued by farmers with lower levels of education (Figure 5d,j). Cultural and social motivations often relate to significant events and practices. For example, *Cola nitida* nuts are used in certain religious and traditional marriages, the barks of *Milicia excelsa* and *Distemonanthus benthamianus* are used in traditional initiation ceremonies, and the branches of *Elaeis guineensis* are used to protect villages from misfortune. The negative relationship between education level and interest in cultural and social uses (Figure 5d,j) may suggest that less educated farmers are more likely to uphold traditional knowledge passed down from their families. They may also face greater social pressures related to preserving and passing on cultural heritage to future generations (Dei et al., 2022).

When farmers recognize young trees, they show strong motivation for various uses (see Figures 4 and 5). It makes sense that more knowledge about the environment leads to greater interest (Trosper & Parrotta, 2012). On the contrary, a lack of knowledge about trees and their uses causes disinterest and makes it harder for farmers to identify trees in their plots and understand their importance (Lougbegnon et al., 2016). Therefore, training farmers to recognize young trees is likely a key step in promoting agroforestry within cocoa farming systems.

4.2 | The nature of the field shapes the motivations of the farmer

First, field size is crucial: farmers with small plots are significantly more motivated to value trees (Figure 4). On smaller plots, farmers have a better view of their entire field, are more familiar with it, and can make more informed decisions to improve productivity (Julien et al., 2019). Additionally, farmers with small plots often have lower incomes and are therefore more likely to maximize the use of all field components, including trees. Those with small land areas also tend to adopt cultivation methods that reduce production risks due to their vulnerability (Johns, 1998), and diversifying production with tree products supports this approach.

Secondly, the presence of remnant trees (large forest trees) significantly impacts field structure (Yao & N'Guessan, 2006). Generally, cocoa farmers are not motivated by these trees and do not favour high densities of them (Figure 4). These trees reduce light availability for cocoa trees (Anglaaere et al., 2011), increase the risk of brown pod rot (Mvondo et al., 2022), and compete for soil nutrients (Jagoret et al., 2017). Furthermore, in Ivory Coast, forestry companies are allowed to enter cocoa plantations to harvest forest species without the farmers' knowledge, often causing significant damage to cocoa trees (Louppe & Ouattara, 2016). However, if these trees are not harvested by the companies, they provide a large amount of usable wood (Kouassi et al., 2023) for the farmers' personal needs, increasing their motivation to use timber, even though extraction can harm the cocoa trees (Figure 5b).

Lastly, the density of cocoa trees in the field generally does not affect the motivations of farmers (Figure 4). However, high densities are linked to strong motivations for agronomic and medicinal uses. This may seem counterintuitive since high densities are usually associated with monocultures and minimal shade from remaining trees. Although Ivorian technical guidelines recommend planting 1333 cocoa trees.ha^{-1} (Sonwa et al., 2019), our data include fields with over 2800 cocoa trees.ha^{-1}. In these densely planted cocoa fields, there are very few associated trees. However, the few trees that are kept are carefully chosen for their agronomic (Figure 5a) or medicinal (Figure 5i) benefits.

4.3 | Tell me your spot, I will reveal your motivations

The distance between the village and the cocoa field does not have a consistent impact on farmers' motivations (Figure 4). This is because the effects of distance vary by use (Figure 5). For fields farther from the village, farmers tend to value trees for agricultural, craft, and cultural purposes. These uses are generally nondestructive and are often preserved because trees that are hard to access are less likely to be overharvested (Yanai, 1998), making it beneficial for farmers to keep them (Amahowe et al., 2018). In contrast, when cocoa fields are closer to the village, farmers are more motivated to use trees for destructive purposes, such as fuel or building materials (Figure 5b,h), since these are easier to transport.

The forest environment of cocoa plots varies depending on whether deforestation began a few decades ago or at the beginning of the 20th century (Aleman et al., 2018: Amani et al., 2022). The link between forest cover and farmer motivations is strong and negative (Figure 4). Our interviews consistently show that farmers value forest trees more than agroforestry trees, even if they are the same species and size. Forest trees are considered healthier, better for traditional medicine, and important for spiritual activities. Utilizing forest trees for material purposes also helps preserve trees on the farm for future use (Cooper et al., 2018; Ickowitz et al., 2014; Johnson et al., 2013). Only in the absence of forest cover do cocoa farmers show a strong interest in the intensive use of trees on their plantations. This highlights the essential role of forests in West African communities and underscores the significant loss to human societies from forest disappearance (Kouassi et al., 2021; Pouliot et al., 2012).

4.4 | The need for time trajectory in unravelling the present

The unique history of cocoa cultivation loops significantly influences farmers' motivations (Figure 4). Cocoa farming began in the southeast quarter of Côte d'Ivoire (Figure 1) and gradually expanded westward and northward (Vroh et al., 2019). Over time, the focus on cocoa yields intensified, leading to monoculture and a reduction in associated trees (Clough et al., 2009; Odijie, 2018). This shift explains the negative link between newer loops and farmers' motivations (Figures 4 and 5). Recently, with the rise of diseases in cocoa fields, development actors have strongly encouraged farmers to reintroduce trees into the newer 'full sun' loops to enhance sustainability (Blaser-Hart et al., 2021; Niether et al., 2020). However, these efforts, often seen by farmers in the new loops (e.g. Frontier Planters, Figure 3) as external pressure, have not been very successful, as these farmers remain unmotivated by agronomic tree uses (Figure 5a).

Cocoa plantations established on land without a prior 'forest' history typically replace areas previously used for agricultural crops, such as maize, rice, other food crops, or rubber trees. In these cases, intensive soil use often leads to complete removal of associated trees, and prolonged cultivation depletes the tree seed bank of the soil, limiting the natural regeneration potential (Amani et al., 2021; N'Guessan et al., 2019). On the other hand, cocoa plantations on land with a 'forest' history benefit from a diverse range of potential tree species and resources (Appiah et al., 1997; Quintana-Ascencio et al., 1996). This explains why there is generally a positive link between farmer motivations and prior forest cover (Figure 5). The fact that motivations are particularly strong when cocoa plantations have few remnant trees, but a prior forest land use history (Figure 4) suggests that cocoa farmers prefer to actively select and value trees of interest in postforest cocoa fields, rather than passively accepting the remnants from the forest.

As cocoa plantations age, farmers' motivation to use trees within their plantations tends to increase, except for financial purposes (Figures 4 and 5). Cocoa yields typically decline significantly a few decades after a plantation is established, especially with intensive cultivation varieties (Franzen & Borgerhoff Mulder, 2007). This decline in productivity leads farmers to (i) actively seek other uses for the trees in their fields (Amfo & Ali, 2020), and (ii) consider the long-term agronomic sustainability of their fields (Figure 5a). Consequently, farmers begin to focus on the trees within their plantations, valuing the benefits these trees can offer, including craft, fuel, and medicinal uses (Figure 5c,h,i).

4.5 | Recognizing trees: The key to diversifying uses

Studying the level of specialization or diversification of motivations offers a nuanced understanding of farmers' strategies and the barriers to adopting agroforestry. Two key factors strongly influence this: knowledge and cocoa tree density.

Firstly, cocoa farmers with the highest levels of seedling recognition exhibit the greatest diversification (Figure 6). On the contrary, those with lower levels of knowledge tend to adopt a specialized strategy, focusing on the few species they know. Without sufficient knowledge, they may confuse species, fail to select or retain valuable ones, overlook the richness of their fields, and miss opportunities to design more productive systems (Joshi & Joshi, 2000). Therefore, improving farmers' ability to recognize trees and their knowledge of possible uses is crucial to encouraging optimal diversification.

Secondly, the density of cocoa tree planting has an inverse effect: higher density leads to a more specialized strategy. In high-density plantations, there is little room for trees due to the large area occupied by cocoa trees, resulting in strong interspecific competition (Jagoret et al., 2017). In such cases, farmers tend to focus on one or a few uses that can ensure 'minimal' production, avoiding investment in multiple uses that may not meet the threshold for commercialization or usability (Belcher & Schreckenberg, 2007). Since the 20% least productive trees accounted for 3% of the harvest (Wibaux et al., 2018), a strategy to promote diversification could involve reducing tree density by removing these less-productive cocoa trees, thus freeing up space to diversify associated trees and their uses.

Lastly, the proportion of remnant trees per hectare also influences the use specialization (Figure 6). A higher abundance of remnant trees increases specialization. In reality, many cocoa farmers have not actively chosen to preserve these trees, but are gradually eliminating them (Ruf, 2011). Remnants are not highly valued because they are seen as potential habitats for rodents (Smith Dumont et al., 2014). In fields with a high number of remnants, the canopy is nearly closed (Somarriba et al., 2024), blocking light from reaching the soil. As a result, farmers cannot introduce new trees to diversify their uses, leading to hyper-specialized fields.

5 | CONCLUSIONS

In the West African context of extreme forest cover scarcity (Aleman et al., 2018) and depletion of timber resources, agroforestry has been advocated as a primary solution to ensure the sustainability of the agricultural and forestry sectors (Zo-Bi & Hérault, 2023). Trees and non-timber forest products are of great importance in meeting the fundamental needs, both material and immaterial, of rural societies in West Africa (Heubach et al., 2011; Suleiman et al., 2017). The 4W approach used in this study provides a framework that greatly facilitates a holistic understanding of the motivations of cocoa farmers for the various uses of trees, which is essential to identify the 'right' trees for the transition to agroforestry. Each dimension of the 4W is crucial for understanding the complexity of farmers' general and specific motivations, as well as their specialized field management strategies. In social sciences, there has often been a tendency to focus primarily on the farmer's personal history and the socioeconomic environment in which they operate as the main factors driving management decisions (Sanial et al., 2023). In ecological and forest sciences, the emphasis has often been on the local and regional biophysical environment, assuming that forest cover restoration can be understood solely through the ecological potential of the environment (Rother et al., 2023). In economic and historical sciences, the recurring pattern of the boom-and-bust cycles of cocoa cultivation has led to the assumption that the history of a field within these dynamics is sufficient to explain farmers' strategies (Atangana et al., 2021; Ruf, 2001).

Our results indicate the need to consider all dimensions of the farmer-field system. The diversity of farmers' life histories (Who), the variety of cultivated landscapes (Where), the characteristics of the fields themselves (What), and the historical trajectories (When) create constraints that the farmer must navigate to effectively manage his field system. Therefore, if policymakers and development actors want to encourage cocoa farmers to conserve or restore trees in their fields, it is essential to contextualize each case. Every pair of farmer-field has a unique history, environment, and characteristics that must be acknowledged in the co-construction of agroforestry systems that align with the deepest motivations of farmers.

Based on our results, the next research steps could include:

- Conduct a long-term study to track how farmers' motivations and tree management strategies evolve over time as they adopt agroforestry practices. This could provide deeper insight into the effectiveness of different strategies and the sustainability of these practices.
- Develop and assess the effectiveness of training programmes aimed at improving farmers' ability to recognize and value different tree species. This could include the creation of educational materials and workshops tailored to different regions and farming contexts.
- Collaborate with policy makers to integrate the 4W framework into the design of agroforestry promotion policies. This could involve pilot projects to test how well policies that consider Who, When, Where, and What dimensions resonate with and support farmers in different contexts.

These steps would not only build on current research findings but also pave the way for more innovative and sustainable agroforestry practices in cocoa farming, ultimately benefiting both farmers and the environment.

AUTHOR CONTRIBUTIONS

Marie Ruth Dago: conceptualization, methodology, data supply, formal analysis, investigation, data curation, writing original draft, visualization. Irie Casimir Zo-Bi: investigation, review and editing, supervision. Isaac Kouamé Konan and Aimé Kouadio Kouassi: data supply, review and editing. Stéphane Guei, Anny N'Guessan, Elsa Sanial, and Souleymane Traoré: review and editing. Patrick Jagoret: writing, review and editing project administration, funding acquisition. Bruno Hérault: conceptualization, methodology, validation, formal analysis, investigation, data curation, writing – original draft, visualization, supervision.

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CONFLICT OF INTEREST STATEMENT

The authors have no conflict of interest to declare.

DATA AVAILABILITY STATEMENT

Datasets used in this study are available at https://doi.org/10.5061/dryad.47d7wm3q5.

STATEMENT ON INCLUSION

To foster greater inclusivity and global representation in ecology research, we, the authors of this study, are committed to transparency and collaboration. Led by scientists from the Ivory Coast, where the study was conducted, and with the first author being a woman currently pursuing her Ph.D., we aim to embody diversity in both leadership and authorship roles. Throughout the course of our research, we have strived to engage with a wide range of cocoa farmers, including cocoa farmers from diverse ethnic backgrounds within the region. Furthermore, we have actively involved a significant proportion of foreign farmers, ensuring a multiplicity of perspectives and experiences in our study. From the outset, all authors were integral to the research and study design process, ensuring that our collective diversity of perspectives was considered and incorporated. Feedback on the questions to be addressed and the methodological approaches to be used was sought from all stakeholders, promoting inclusivity and collaboration. To facilitate collaborative work and ensure equal participation, we utilized an author platform (authorea) that allowed the coauthors to contribute to the manuscript interactively. This platform enabled seamless communication and cooperation, allowing for the integration of diverse perspectives and input throughout the writing process. Using this technology, we were able to improve inclusivity and ensure that all authors had the same opportunity to shape the narrative of the study. We believe that this approach not only promotes transparency and equity but also strengthens the integrity and richness of our research outcomes.

In citing relevant literature, we made a concerted effort to include works authored by scientists from the region, and where applicable, to consider publications in the local language, further enriching our engagement with local knowledge and expertise. We recognize the importance of transparency in our efforts to promote inclusivity and global representation in ecology research. By revealing the actions taken to collaborate with stakeholders, provide opportunities for intellectual input, and share results within the region where our study was conducted, we hope to contribute to broader initiatives aimed at fostering diversity and inclusion within the scientific community.

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DATA SOURCES–APPENDIX 1

Sanial, E. (2019). *À la recherche de l 'ombre, géographie des systèmes agroforestiers émergents en cacaoculture ivoirienne post-forestière*. Thèse de Doctorat. Université de Lyon.

SUPPORTING INFORMATION

Additional supporting information can be found online in the Supporting Information section at the end of this article.

Appendix 1. Data collection for the knowledge variable.

Appendix 2. Correlation matrix of the explanatory variables.

Appendix 3. Stan codes.

Appendix 4. Modeling results.

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