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Farmers' perception on the impact of climate change in rubber tree production and their knowledge of rubber-based agroforestry: case study of Côte d'Ivoire

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Abstract
Native to rainforests in the Amazon region *Hevea brasiliensis* is generally found in low-altitude moist forests, forest gaps, and disturbed areas providing economic, social and ecological benefits for people. But climate change is now making rubber trees vulnerable to diseases and high temperatures. In this study, Interviews and a structured questionnaire were used to determine farmers' perception of climate change and rubber-based agroforestry. Descriptive statistics such as frequency, percentage and multinomial logit were used to analyze the data collected and identify the determining factors. The results showed that nearly all farmers in Mountain and Guinean zones cultivate rubber trees in monoculture and 80% in Sudano-Guinean zone practice monoculture. Our findings revealed that instead of the rubber tree farmers in the three climatic zones had limited knowledge of climate change and agroforestry. About 75% and 80% did not have knowledge of climate change and agroforestry, respectively. The result shows that three explanatory variables (climatic zone, gender and education level) are the factors that most influence farmers' perception of climate change. Regarding agroforestry, it is only climatic zone and educational level that influence farmers' perception. Farmers reported during interviews that the increase in temperature is at the root of the emergence of new diseases, which are causing a decrease in rubber tree yield. Efforts should be made to educate smallholder rubber farmers about rubber tree agroforestry and climate change, for sustainable agricultural practices in rubber three plantations.

Keywords *Hevea brasilliensis* · Agroforestry · Monoculture · Farmers · Climate change

1 Introduction

Côte d'Ivoire, has made agriculture the main pillar of its economy since its independence. As a key driver of development in Côte d'Ivoire, the Ivorian agricultural sector continues to demonstrate its impact by promoting industrialisation, export growth, job creation, and increased income and covers around 64% of the land surface [1]. The agricultural sector accounts for 25% of GDP and employs more than 60% of the population. The country enjoys natural conditions favourable to the development of agriculture. These include availability of large areas of fertile and cultivable land, a diversified climate and a variety of plant products. These include: coffee, cocoa, rubber tree, cotton, oil palm, yam, mango, plantain, etc. But currently, rubber farming has taken precedence over the other crops and has become the most promising one,

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as were coffee and cocoa. The rubber sector provides nearly 330,000 direct jobs, including 27 rubber processing factories [2]. It is still growing, with Ivorian production in the first nine months of 2020 reaching 843,913 tons, consolidating its position as the leading African producer. This performance represents an increase of 40% compared to the first nine months of 2019 [3]. The increase in rubber production alone justifies the importance of this crop in Côte d'Ivoire. However, the sustainability and profitability of rubber cultivation is under increasing pressure due to climate change. Agriculture is considered the most vulnerable sector to global climate change.

The Intergovernmental Panel on Climate Change [4] reported that African countries are most vulnerable to the impacts of climate change globally. Climate change has significant impacts on crop productivity and potentially has huge agricultural implications [5]. The average global temperature is increasing continuously and is predicted to rise by 2 °C by 2100 [6]. This will present a serious threat to agriculture and plantation sector [7]. Intensification, monoculture evolution, and climate change are just some of the main sustainability concerns that threaten the viability of species. However, increasing resilience and good agricultural practice as agroforestry systems can address many of these agricultural sustainability questions [8].

In the context of climate change, the improvement of the rubber tree production system in Côte d'Ivoire, as well as, the implementation of rubber-based agroforestry will enable adaptation to and mitigation of climate change impacts. Agroforestry is a system that allows for diversification and support of production. It constitutes one of the sustainable solutions for the use of limited natural resources and adaptation to climate change [9]. Furthermore, agroforestry combats soil erosion and even contributes to the creation of a microclimate (windbreaks and reduced evapotranspiration) that enhances crop yields, soil conservation, as well as, promoting beneficial insects that limit pest attacks. Crop based agroforestry systems protect crops from harsh climatic events [10, 11]. Rubber trees are highly vulnerable to effects of climate change; therefore, understanding farmers' responses to climatic variation is crucial, as this will help in designing appropriate strategies [5]. Farmers' perception of climate change and knowledge about rubber tree-based agroforestry can provide the basic information to guide research work. Some studies have been done on awareness of farmers on climate change [12, 13]. Based on our criteria our studies attempts to understand the perception of Côte d'Ivoire farmers with regard to rubber cultivation, agroforestry and climate change with intent to answer the following questions. The aim of this article is to evaluate:

- how climate change affects rubber tree production and interest in cultivating rubber trees,
- farmer's knowledge and perception of climate change and rubber based-agroforestry,
- how socio-economic factors influence farmers' perception and knowledge of climate change and rubber tree cultivation.

2 Materials and methods

2.1 Study area

The study was carried out in Côte d'Ivoire (West Africa), located between the equator and the Tropic of Cancer. Côte d'Ivoire extends from 10°30′ and 4°30′ North latitude to 8°30′ and 2°30′ West longitude [14]. It is bordered to the west by Liberia and Guinea; to the north by Mali and Burkina Faso; to the east by Ghana and to the south by the Atlantic Ocean over a distance of 550 km. It covers a land area of 322,462 km^2. The country is divided into four principal climatic zones [15]. Our study was carried out in three of the climatic zones within Côte d'Ivoire: Guinean zone in the south, Sudano-Guinean zone in the middle and mountain zone in the west (Fig. 1). The Guinean zone is characterised by a forest vegetation and a sub-equatorial climate with four seasons two rainy seasons and two dry seasons. Its average annual rainfall is over 1578mm with an average temperature of 24.42 °C [16]. Rubber farmers of Aboisso, Agboville, Sanpedro, Grand-lahou cities were randomly selected in this climate zone. The Sudano-Guinean zone has four seasons, which include two rainy seasons and two dry seasons. This zone lies in the transition between the subtropical and subequatorial climates and it is characterized by an average annual precipitation of 1200–1500 mm per year [17]. Within this climate zone, rubber farmers from Yamoussoukro, Guiglo, Daloa, Bondoukou, Daoukro towns were selected for the study. The mountain zone is characterized by a mountain climate with a long rainy season and a short dry season. The precipitations are abundant, ranging from 1700 to 2300 mm per year. Rubber farmers of Man and Danane villages of this zone were selected for the study.

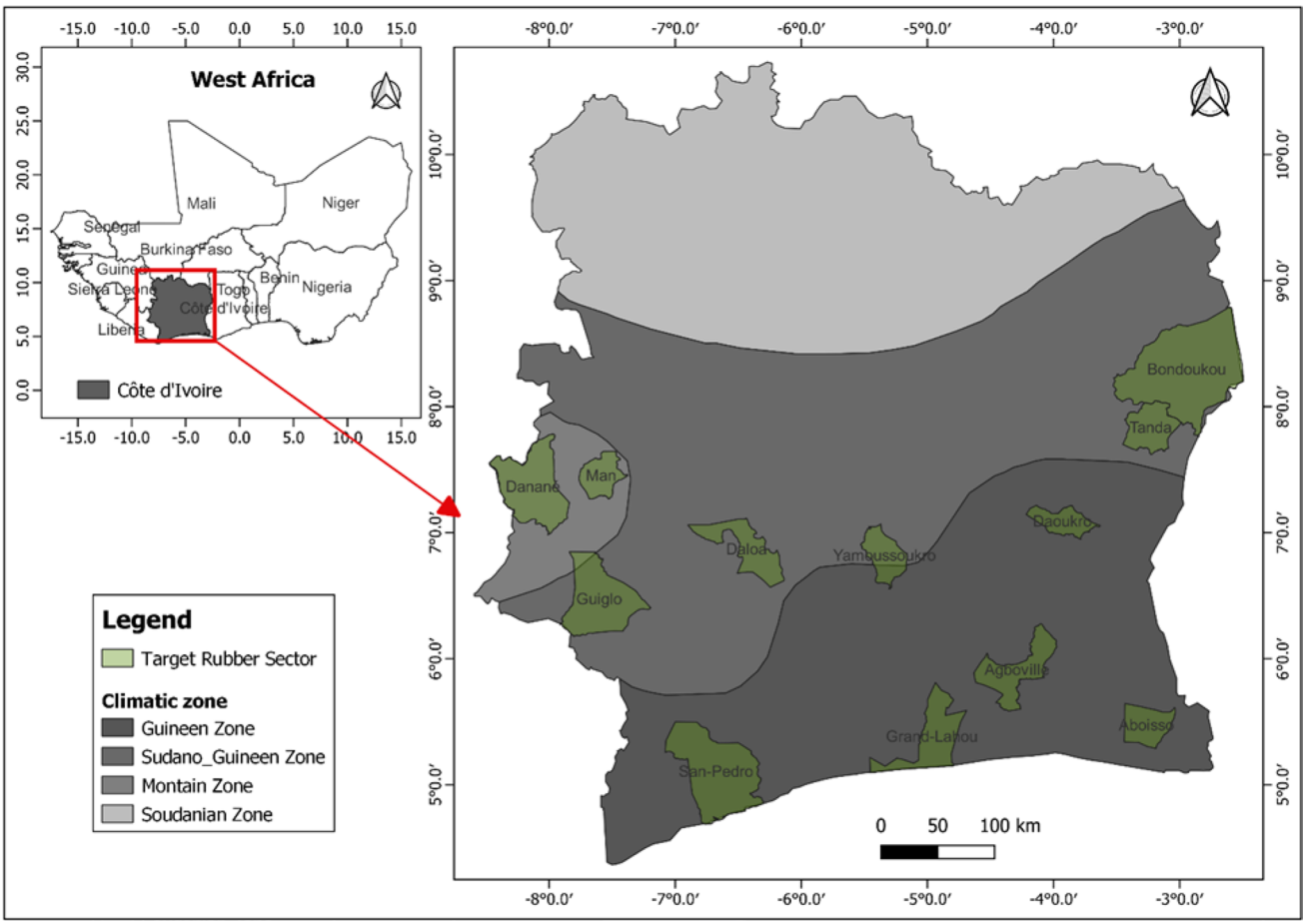

Fig. 1 Map of study area

2.2 Data collection

In this study all investigation for survey and direct observation were done in three selected climatic zones with 339 smallholder rubber farmers. Based on our criteria, the farmers selected were only those who have the rubber tree in production (over 7 years). We used the formula of Yamane (1967) [18] to calculate the sample size, which was 300 according to the simplified formula:

$$n = \frac{N}{1 + N.e^2}$$

where: n = the sample size, N = number of rubber farmers in production in each climatic zone (100.000), e = level of precision (0.1). However, a total of 339 rubber farmers were interviewed for increased precision. This formula has been used in a many studies [19, 20] because it assumes 90 percent confidence level.

The interview was conducted individually in each study area and face to face from October 2022 to April 2023. Our questionnaire was divided into three sections. The first section was on demographic background (name, age, sex, education level, marital status and principal activity) and the second section on farmer' perception of rubber-based agroforestry, a second question (clone, planting density, crop association….). The last section focused on farmers' knowledge of climate change and its impact on rubber tree (disease, frequency of disease, increase or decrease yield, and change of Season).

2.3 Data analysis

All data obtained from this study were analyzed using descriptive analysis (frequency and percentage). This was done to determine farmers' demographic information, their perceptions about rubber based agroforestry, knowledge in climate change and types of plantations. Boxplot in R version 4.3.2 software was used to represent the response of age of plantation, and principal activity. To analyze factors that influence rubber farmers'awareness of climate change and knowledge of rubber agroforestry multinomial logit regression model (MLN) was used. In many studies [19, 21] the MLN model has been used to test the factors that determine individual knowledge and perception of climate change. Multinomial logit regression predicts the probability of category membership of a dependent variable based on several independent (predictor) variables [15]. In our study, we considered socio-demographic variables of rubber tree farmers as predictors (climatic zone, locality, age, gender, educational level and principal activity) and perception variables as dependent variable (e.g., awareness of rubber tree agroforestry, awareness of climate change). This model reflects the expected changes in the probability that farmers are aware of rubber tree agroforestry or climate change with respect to one-unit change in a predictor variable keeping all other predictors constant. We considered alpha (α) less than 0.05 as statistically significant.

3 Results

3.1 Socio-demographic characteristic of respondents

Socio-economic characteristics of the respondents are presented in Table 1. Of the total number of respondents (339), respondents 38% were from Guinean zone, 27% from mountain zone, and 35% from Sudano-Guinean zone. A majority (95%) of the respondents were males and only 5% were females. Most of the respondents were married 74% while only 25% were single and 1% were widowed. About 1% of the respondents were between 18 and 35 years old, followed by 58% between 36 and 55 years old, and 41% over 55 years old. In term of level education of participants, 24% were illiterate (no formal education), then 34%, 34% and 8% had primary, Junior high and Senior high school level education, respectively. Regarding the occupation of rubber farmers (Table 2), 43% of farmers depend solely on agriculture (rubber

Table 1 Overview of the socio-demographic characteristics of 339 respondents to questionnaire in the study

Respondents	Frequency	Percentage
Climatic zone		
Guinean zone	128	38
Mountain zone	93	27
Sudano-Guinean zone	118	35
Gender		
Female	16	5
Male	323	95
Marital status		
Married	252	74
Single	84	25
Widows	3	1
Age		
[18 35]	4	1
[36 55]	198	58
> 55	137	41
Education level		
No formal education	79	24
Primary	116	34
Junior high school	116	34
Senior high school	28	8

Table 2 Main occupation and land origin of the 339 respondents to questionnaire in the study

Respondents	Frequency	Percentage
Principal activity		
Rubber farming	144	43
Rubber/business	85	25
Others	110	32
Total	339	100
Origin of land		
Owner	295	87
Rent	17	5
Others	27	8
Total	339	100

tree farming only) for their livelihoods, 25% were engaged in other livelihood activities beside rubber tree farming, and 32% were involved in others activities including rubber tree farming. Concerning the origin of land, 87% are owners, 5% rent the land and 8% had Sharecropping arrangements this methods is done by renting small plots of land from a landowner in exchange for a share of their harvest.

3.2 Famers' farm characteristic

Age of rubber tree plantations significantly differed between the three climatic zones in Côte d'Ivoire (Fig. 2). The oldest plantations (12–23 years) were located is the Guinean zone following by the Sudano-Guinean zone with age of plantations between 10–17 years, and the young plantations (9–13 years) were located in the Mountain zone (Fig. 1). With regard to the type of plantation (Fig. 3) the farmers' responses show that it was only in the Sudano-Guinean zone

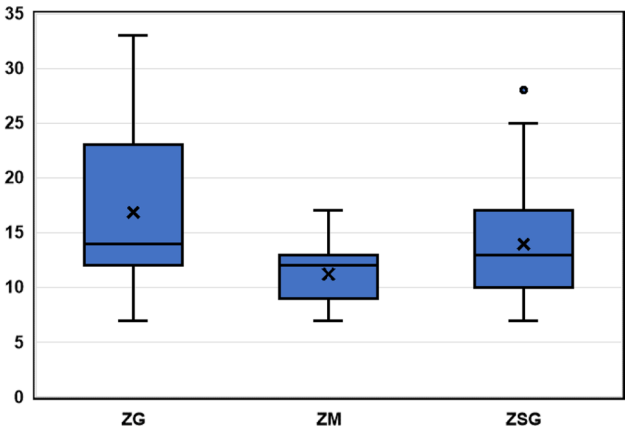

Fig. 2 Age of the different rubber tree plantation in the three climatic zone in Côte d'Ivoire

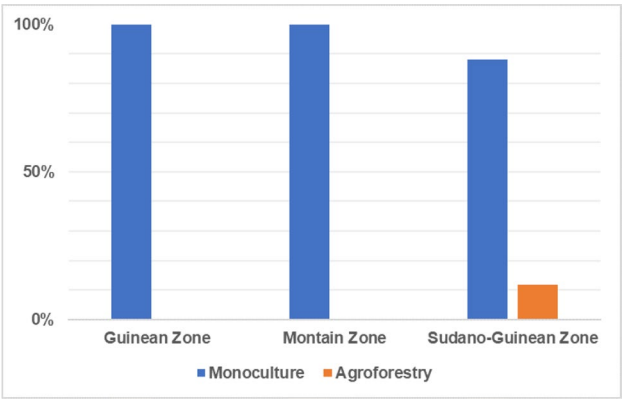

Fig. 3 Type of plantation in the three climatic zone in Côte d'Ivoire

(11.9%) that farmers admit to practicing agroforestry, while in the Mountain and Guinean zones (100%) all farmers practiced monoculture.

3.3 Level of farmers' knowledge of agroforestry

Majority of the respondents (70%) lacked adequate knowledge of rubber tree agroforestry (Table 3). However, the remaining 30% admitted having some knowledge of rubber tree agroforestry. A total of 88.5% of respondents had not received any training on agroforestry based in rubber tree. The result showed that 42.5% of the respondents complied with the rubber plantation standards of 6 m long and 4 m wide, which is equivalent to 555 rubber plants per hectare, and 49.9% of them exceeded the standards, including more than 555 rubber trees per hectare. About 79.6% of the respondents have more than one type of clone in their plantation and 17.7%, 1.5% and 1.2% of the respondents grow Gt1, Irka 230 and Jk41 clones respectively.

3.4 Farmers' perceptions about change in climate parameters (temperature and rainfall)

As indicated in the Fig. 4, most of the farmers in this study observed an increase in temperature (66.9%) and a decrease in rainfall (61.7%). Concerning rainfall timing, 5.6, 73.7, 14.2 and 6.5 of respondents observed an early arrival, late arrival, no change and don't know respectively. About rubber farmers' Perceived a change in the plant yield by each climatic zone (Fig. 5), most of the farmers in the Guinean zone reported low decreases in the rubber tree harvest (45%), while 21%, 10% and 24% observed no chance, slight and significant decrease. About 55%, 32%, 6%, 7% of respondents from the mountain zone observed low decreases, no chance, slight and significant decrease. Finally, Sudano-Guinean zone farmers reported low decreases (52%), no change (22%), slight increase (4%), and significant decrease (22%).

3.5 Factors affecting rubber farmers' awareness of climate change and agroforestry

The results of the multinomial logit regression models (Table 4) present the variables that influence respondents' awareness of agroforestry and climate change showed that variables such as climatic zone, gender, and education level were significantly associated with respondents' awareness of climate change. There was a negative relationship between respondents' climate zone and awareness of climate change, and between gender and awareness of climate change. However, a negative (no level and primary) and positive (senior higher school) relationship was

Table 3 Farmers' perception of rubber based-agroforestry and their practice

Respondents	Frequency	Percentage
Knowledge of rubber tree Agroforestry		
No	237	70
Yes	102	30
Total	339	100
Any training		
No	300	88.5
Yes	39	11.5
Total	339	100
Density of planting		
555 rubber trees per hectare	144	42.5
More than 555	169	49.9
Less than 555	26	7.6
Total	339	100
Varieties of clone you cultivate		
Gt1	60	17.7
irk230	5	1.5
jk41	4	1.2
Polyclone	270	79.6
Total	339	100

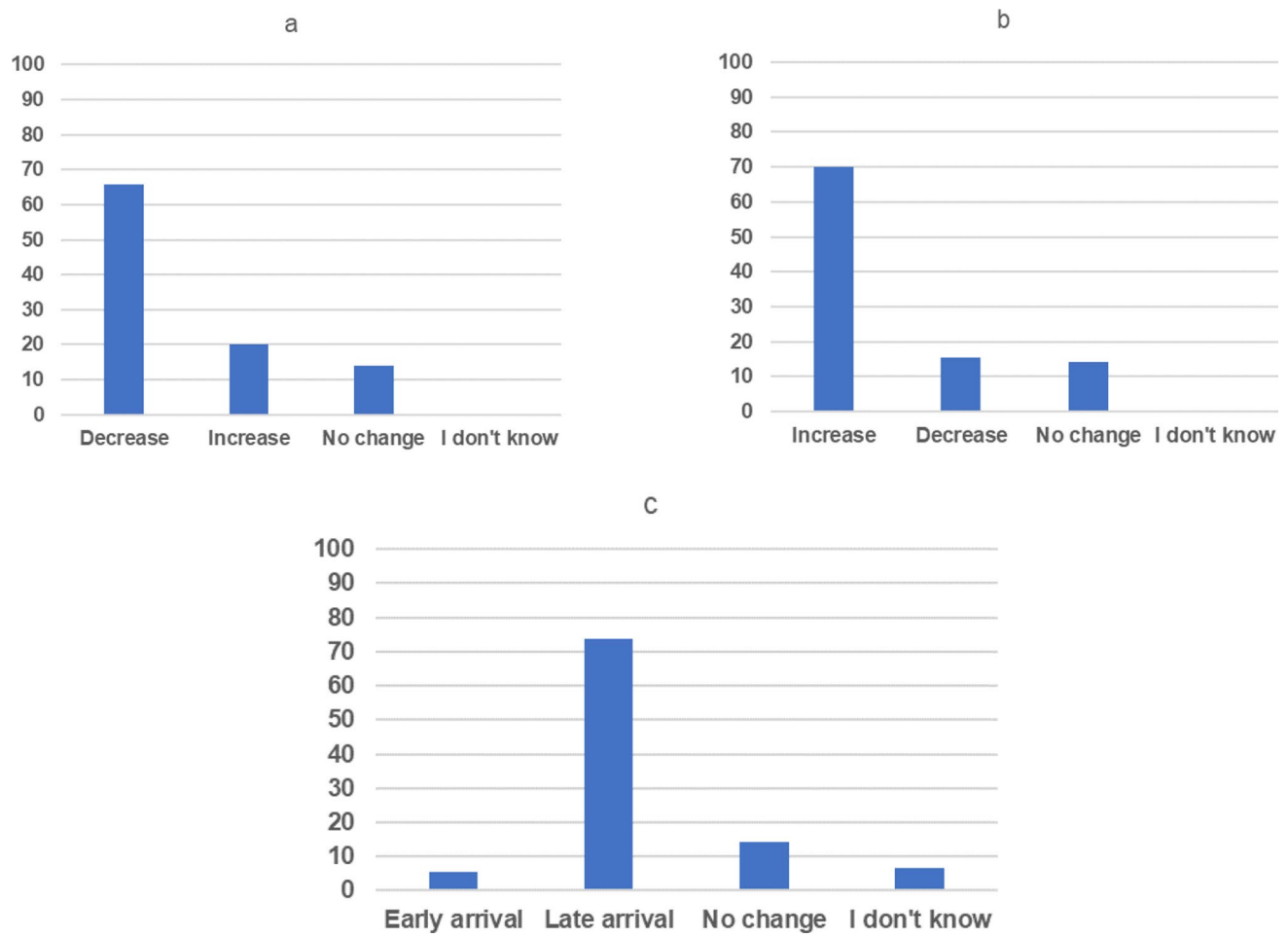

Fig. 4 Rubber farmers' perceptions concerning a change in climatic parameters: a temperature, **b** change in rainfall and **c** change in rainfall timing

obtained between farmers' awareness of climate change and educational level. Concerning farmers' awareness of agroforestry, a negative relationship was found with respondents' climate zone. The same negative relationship was found with respondents' educational level (no level and primary) which increased farmers' awareness of climate change, meanwhile a positive relationship was found between respondents' educational level (senior higher school) and awareness of agroforestry.

The rubber farmers' perceptions concerning a change in climatic parameters are shown in Table 5. Climatic zone, age, sex, educational level and principal activity was significantly influenced farmers' perception of change in rainfall. An increase in rainfall was observed by males, no education level farmers' and rubber farming. Perceived change in temperature was strongly influencing by climatic zone, sex, status, age and educational level.

3.6 Variables determining farmers' perception of change in rubber tree yield

Change in rubber tree yield (Table 6) was significant associated with respondents' age, climatic zone and status. Perception of significant decrease in rubber tree yield in respondents' climatic zone, age and status was observed. A Positive relationship between farmers age and status and their perception of slight increase in rubber tree yield were observed (Table 6). Farmers perception of significant and low decrease in rubber tree yield decrease when going to young adult to oldest. A negative relationship was observed between respondent's age and marital status and slight increase were observed.

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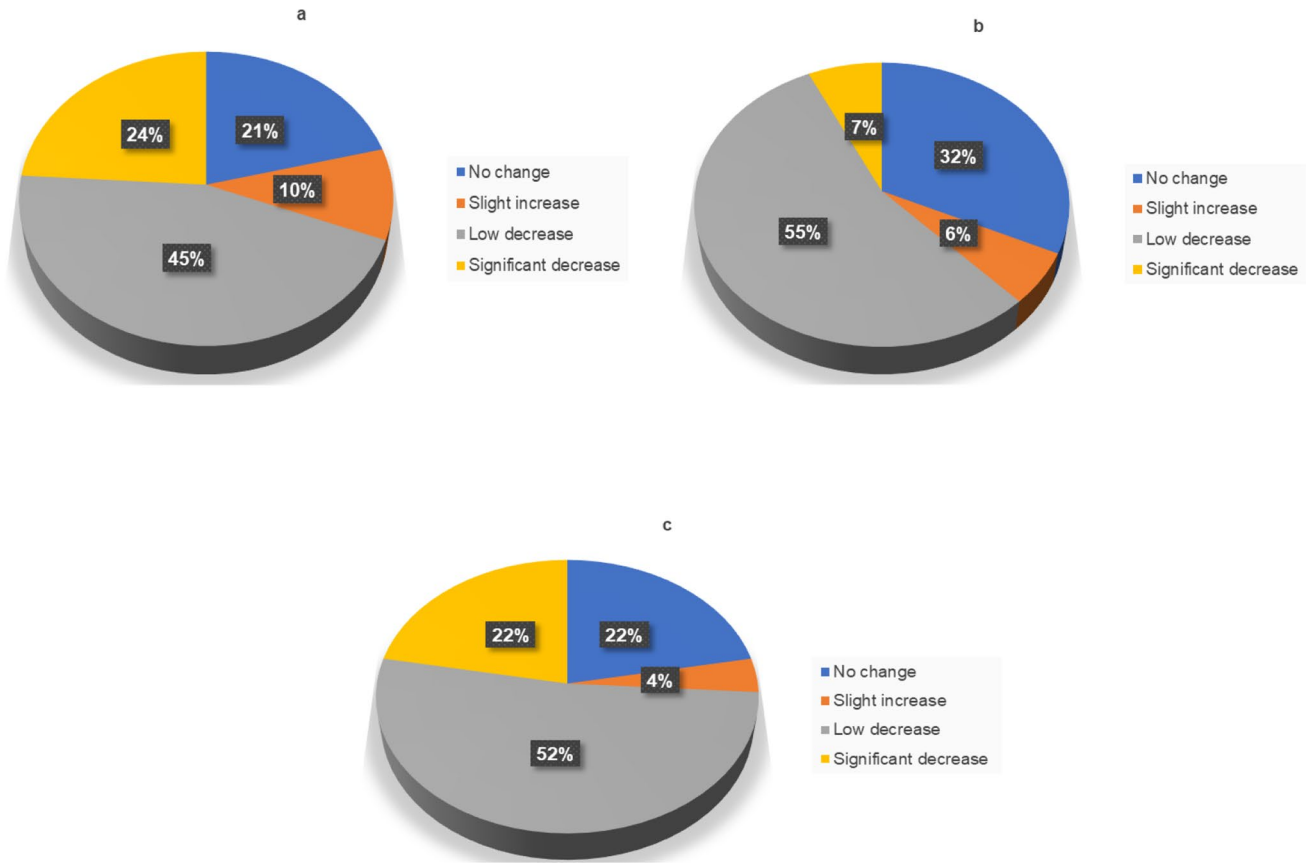

Fig. 5 Rubber farmers' perceived changes in the plant yield by climatic zone: **a** Guinean zone, **b** Montain zone, **c** Soudano-Guinean zone

4 Discussion

Climate change has become a major concern globally. It is in this context that several structures and administrations were put in place to provide solutions and not the least for climate change adaptation and mitigation. In Côte d'Ivoire, laws and regulations regarding agroforestry practices are being enforced. The Ivorian government promotes agroforestry for several reasons, the most important of which is related to the world's most alarming deforestation rates [22]. In this context, agroforestry stands out as one of the most relevant solutions, as it has been recognized for several years in the context of climate change mitigation. This study aims to capture farmers' perceptions and knowledge of agroforestry based on rubber tree and climate change. The fact that the cultivation of rubber trees began and is more pronounced in the Guinean area precisely in the south of the Côte d'Ivoire could be attributed the climate conditions which are more favorable there and it represents the oldest rubber tree plantations. The cultivation of rubber trees in Côte d'Ivoire is predominantly carried out by men. This could be explained by the fact that generally in Sub-Saharan Africa, it is men who are the owners of agricultural land as opposed to their female counterparts. This is in line with the findings of [23]. Concerning the education levels most of farmers have low levels of education (no formal education or only primary). A similar observation was made by [24] during their studies on farmers on rubber tree cultivation.

The observations from the present study show that majority of the participants are involved in rubber tree farming rather than other crops as confirmed by [19] according to which rubber trees are more cultivated by farmers in Côte d'Ivoire.

From this study it appears that the knowledge of agroforestry among rubber tree farmers was very low. This can be explained by the dominance of rubber tree monoculture in the study areas. A similar observation was made by [19] among coconut farmers who reported low levels of agroforestry among coco farmers with attributed monoculture practices. Agroforestry practice is perceived as too difficult, requiring too much technical knowledge and high initial

Table 4 Factors determining rubber tree farmers' awareness of climate change and agroforestry of multinomial logistic regression

Explanatory variable	Category	Awareness of climate change Yes CoefSig (St. Err)	Awareness of agroforestry Yes CoefSig (St. Err)
Climatic zone	Guinean zone (Ref.group)		
	Mountain zone	– 1.465* (0.596)	– 0.320 (0.549)
	Sudano_Guinean zone	– 1.571** (0.574)	– 1.090* (0.516)
Sex	Female (Ref.group)		
	Male	– 2.584** (1.263)	0.241 (2.763)
Age	[18_35] (ref.group)		
	[36_55]	– 0.125 (2.648)	13.904 (483.334)
	> 55	0.643 (2.658)	14.804 (483.334)
Educational level	Jhs (Ref.group)		
	No level	– 6.057** (1.005)	– 5.024** (0.984)
	Primary	– 4.707** (0.583)	– 5.698** (1.069)
	Shs	2.383** (1.060)	2.986** (1.070)
Status	Married (Ref.group)		
	Single	0.470 (0.455)	0.625 (0.458)
	Widows	1.796 (1.675)	4.242 (3.067)
Principal activity	Others (Ref.group)		
	Rubber farming	– 0.290 (0.485)	– 0.712 (0.489)
	Rubber seller/business	0.095 (0.585)	– 0.356 (0.601)
Deviance		**183.643**	**169.923**
AIC		**209.643**	**195.923**

Significant correlations in bold, with level of significance indicated by stars, and standard errors in brackets *α < 0.05; **α < 0.01

investment be readily adopted [23]. This indicates that the majority of farmers have little to moderate knowledge and limited access to basic information about agroforestry practices. Farmers must educate on agroforestry and understand the benefits of this. Agroforestry practices enable them to benefit from the yields of multiple crops but also helps prevent erosion and prolong soil fertility and sustainability.

Apart from the lack of knowledge in agroforestry, many other reasons, such as, economic viability, the age of the farmer, and landowners could be reasons behind the low adoption of agroforestry practices. Given these constraints, farmers are only thinking about the methods that will allow them to achieve higher yields in the short term, hence the development of monoculture. Likewise, the high percentage of tree densities in a rubber plantation clearly demonstrates the farmers' determination to achieve maximum yield. SAPH (African Rubber Plantations Company) whose main activity is the production and processing of rubber recommends that the number of rubber trees per hectare must be 555. However, this is not put into practice because there is a lack of communication and training with farmers at the very beginning of implementing rubber-based agroforestry. In this context, it would be preferable for agroforestry to be a priority by the Ministry of Agriculture in the formulation of national policies due to its ability to strengthen the resilience of small-scale farmers. In addition, further measures such as the introduction of laws will help Côte d'Ivoire strengthen the strategic, legal, and institutional conditions to facilitate farmers in adopting agroforestry. This includes improved communication between sectors and the integration of agroforestry into national policies.

Our work suggest that most Ivorian rubber farmers are not trained in rubber tree-based agroforestry, which is a negative factor for raising awareness about agroforestry practices in Côte d'Ivoire. Previous studies show that the demographic background of individuals is an important factor that influences their awareness and perception of agroforestry [25]and climate change [26, 27]. The result of the multinomial logit regression highlighted the significant importance of demographic variables such as age, gender, educational level, and the main activity in the awareness and perception of rubber tree farmers regarding climate change and agroforestry. Interviewees' awareness of rubber tree-based agroforestry was influenced by socio-economic factors like educational level and climatic zone. These results are corroborated by [28]. Thus results show that knowledge about agroforestry varies according to the intellectual level of the respondents.

Table 5 Factors determining rubber tree farmers' perception of change in climatic parameters of multinomial logistic regression

Explanatory variable	Category	Perceived change in rainfall		Perceived change in temperature	
		Decrease	Increase	Increase	Decrease
		CoefSig (St.Err)	CoefSig (St. Err)	CoefSig (St. Err)	CoefSig (St. Err)
Climatic zone	Guinean zone (Ref. group)				
	Mountain zone	− 3.237** (0.528)	− 4.947** (0.736)	− 3.847** (0.610)	− 4.407** (0.755)
	Sudano_Guinean zone	− 0.123 (0.562)	− 2.292** (0.691)	21.346** (0.227)	19.750** (0.227)
Sexe	Female (Ref. group)				
	Male	− 0.783 (0.820)	− 2.164* (1.040)	− 0.809 (0.839)	− 2.100* (1.069)
Age	[18;35] (Ref. group)				
	[36_55]	− 11.140** (0.528)	− 13.455**(0.737)	− 9.197** (0.789)	− 11.558** (0.789)
	> 55	− 11.657** (0.738)	− 13.119** (0.732)	− 10.378** (0.745)	− 11.822** (0.737)
Educational level	Jhs (Ref. group)				
	No level	− 0.277 (0.479)	− 1.298* (0.650)	− 1.607** (0.619)	− 2.587** (0.782)
	Primary	− 0.248 (0.420)	− 0.549 (0.522)	− 1.806** (0.531)	− 1.403* (0.594)
	Senior higher school	− 0.328 (0.648)	− 0.431 (0.826)	− 0.896 (0.715)	− 2.904* (1.292)
Status	Married (Ref. group)				
	Single	− 0.27 (0.465)	0.493 (0.544)	− 2.269** (0.620)	− 1.406* (0.666)
	Widow	0.174 (1.699)	1.298 (1.836)	0.446 (1.682)	1.244 (1.812)
Principal activity	Others (Ref. group)				
	Rubber farming	1.143* (0.456)	2.142** (0.583)	0.384 (0.475)	0.658 (0.568)
	Rubber seller/business	1.520* (0.583)	0.693 (0.765)	1.219 (0.773)	0.529 (0.869)
AIC		**516.502**	**516.502**	**441.064**	**441.064**
Residual D		**464.502**	**464.502**	**389.064**	**389.064**

Significant correlations in bold, with level of significance indicated by stars, and standard errors in brackets * $\alpha < 0.05$; ** $\alpha < 0.01$

The observations indicate that individuals with a higher level of education (SHS) are more informed about information related to rubber-based agroforestry than those with a lower level of education (no level and primary school). Better educated farmers perceived agroforestry practice more because they have several ways to document. Farmers must understand the importance of diversification, economic stability and the resilience faced with a fast-changing climate that agroforestry can give them. Similar findings were reported by [29]. Efforts are needed to provide knowledge on the Agroforestry in order to motivate farmers to practice Agroforestry. Training farmers on the link between land productivity and soil quality can be an opportunity that may lead them to adopt agroforestry practices. Most of the farmers reported that climatic factors impact strongly the plant's growth. Many of them identify several climatic factors as the causes of the reduction in plant yield because with the temperature increasing and precipitation fluctuations, water availability and crop production are likely to decrease [30].

Farmers' awareness and perception of climate change were mostly influenced by the socio-demographic factors such as climatic zone, educational level and gender in our findings. This result agrees with the finding of [26, 27]. It however contradicts findings of [31] which found no influence from either of the explanatory variables (level of education and gender) on farmers' perception of climate change. The gender of farmers is an important factor influencing farmers' perceptions of climate change. Thus, men are more engaging in farming activities than female [32]and are more likely to perceive the changes in climatic parameters compared to female farmers in our study areas. Similar observations were noted by [5].

The analysis of perception of farmers to climate change revealed a high increase in temperature, and decrease in the frequency of rainfall and total annual precipitation. The results also agree with [15, 33] who made the same observation. High temperatures disrupt the socio-economic structure of farmers. On the agricultural aspect, the scarcity of rainfall and the drying up of land and water ponds explain the challenges that farmers are facing. Increase in temperature is expected to reduce crop yields because most often high temperatures are often associated with drought. It could be the cause of new plant diseases that hinder our crops in plantations [34]. This is confirmed by the studies of [35] which found the

Table 6 Factors influencing farmers' perception of change in rubber tree plant's yield of multinomial logistic regression

Explanatory variable	Category	Perceived change in rubber tree plants' yield		
		Slight increase	Low decrease	Significant decrease
Climatic zone	Guinean zone (Ref. group)			
	Mountain zone	− 0.945 (0.639)	− 0.347 (0.377)	− 1.873** (0.611)
	Soudano_Guinean zone	− 0.842 (0.642)	0.254 (0.368)	0.009 (0.433)
Sexe	Female (Ref. group)			
	Male	− 0.351 (1.230)	0.264 (0.720)	− 0.725 (0.880)
Age	[18_35] (Ref. group)			
	[36_55]	− 14.706** (0.756)	− 13.196** (0.732)	7.419** (0.383)
	> 55	− 14.447** (0.745)	− 13.684** (0.735)	7.090** (0.391)
Educational level	Jhs (Ref. group)			
	No level	− 0.704 (0.713)	− 0.229 (0.391)	0.102 (0.499)
	Primary	− 0.535(0.590)	− 0.444 (0.336)	0.034 (0.427)
	Senior higher school	0.261 (0.749)	− 0.609 (0.510)	− 0.742 (0.765)
Status	Married (Ref. group)			
	Single	− 0.405 (0.620)	− 0.183 (0.342)	0.211 (0.405)
	Widow	− 3.207** (0.000)	16.305** (0.744)	16.913** (0.744)
Principal activity	Others (Ref. group)			
	Rubber farming	− 0.036 (0.589)	− 0.084 (0.354)	− 0.323 (0.462)
	Rubber seller/business	− 0.372 (0.705)	− 0.343 (0.414)	− 0.193 (0.495)
Deviance		**760.146**		
AIC		**838.146**		

Significant correlations in bold, with level of significance indicated by stars, and standard errors in brackets *α < 0.05; **α < 0.01

presence of a new foliar disease caused by a fungal pathogen. Most of these new diseases attacking rubber tree farms have not yet been dealt with. This is becoming worrying for the farmers, especially for small farmers. According to [36]. Such emerging crop diseases result in production losses of up to 50%. For works by some authors, such as [37], most of the problems related to pest and disease incidences are found more in monoculture plantations than in agroforestry systems. To reduce the impact of climate change on agriculture, experimentation, demonstration, dissemination of good agricultural practices and sacralizing forest in Côte d'Ivoire are necessary.

5 Conclusion

d'Ivoire has vast agricultural potential due to its favorable geographical conditions and agroecological zones. The pressure from agriculture, as well as, population growth, leads to a decrease in resources and instability of climatic parameters. The results of this study, which aimed to understand farmers' perception regarding climate change and agroforestry based rubber tree as an adaptation solution to climate change, shows that farmers' knowledge about rubber-based agroforestry and climate change is very limited in our study area. This is explained by the abundance and expansion of rubber tree monoculture in Côte d'Ivoire. Despite all the research activities carried out by academic and research institutions in Côte d'Ivoire on agroforestry, information regarding rubber-based agroforestry and the impact of climate change have not been sufficiently disseminated to rubber cultivator communities. The government must ensure strict implementation of policies and monitoring in the rubber sector by providing up-to-date information on the opportunities and benefits offered by agroforestry systems for rubber. The result of the respondents revealed that educational level, climatic zone and gender are the key variables that influence rubber farmers' awareness of agroforestry about awareness of climate change it is influence by educational level and climatic zone. Efforts should be made by the government and government agencies to initiate programs that will aim to educate rural farmers on the benefits, potential of agroforestry and the impact of climate change on multi-purpose agroforestry species such as rubber tree.

This research is important because it focuses on the practice and acceptance of agroforestry based on rubber trees. In Côte d'Ivoire, the expansion of rubber tree monoculture is a significant and urgent problem that needs to be addressed.

Therefore, rigorous measures must be taken in the agricultural sector to mitigate this agricultural practice. We urge future studies on this topic to take into account the significant drop in rubber tree prices to highlight the risk of monoculture. Furthermore, A potential limitation of our study is the sampling, which only considered rubber tree farm older than 7 years. For future research, we recommend considering all rubber tree farmers to better manage and educate farmers on the adoption and practice of rubber-based agroforestry.

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Author contributions A.E.K collected data, analyzed and writhed the manuscript. M.K, D.C.T and E. F. S guided and supervised the project, reviewed and approved the final manuscript.

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Data availability All the data from this study is available from the corresponding authors on reasonable request.

Code availability All the data from this study is available from the corresponding authors on reasonable request.

Declarations

Ethics approval and consent to participate The Scientific Review Committee of the Agricultural Laboratory of the Jean Lorougnon Guédé University (Republic of Côte d'Ivoire) conducted a rigorous peer evaluation of the research protocol and approved the research approach, which included data collection from rubber farmers, in accordance with ethical standards. All farmers surveyed gave their consent.

Consent for publication Informed consent was obtained from all the participants involved in the study, and the participant has consented to the submission of the case report to the journal.

Competing interests The authors declare no competing interests.

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