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Adaptation strategies of cocoa producers in the face of forest rarefaction in the Sub-Prefecture of Bonon (West-Central Côte d'Ivoire)

Kobenan Pierre N'GOURAN[1], Golou Gizèle ZANH[2*], Akoua Tamia Madeleine KOUAKOU[2], Pingue Mikouaba COULIBALY[2] and Yao Sadaiou Sabas BARIMA[2]

[1]*Agroforestry Training and Research Unit, Jean Lorougnon Guede University, BP 150 Daloa, Côte d'Ivoire.*
[2]*Environmental Training and Research Unit, Jean Lorougnon Guede University, BP 150 Daloa, Côte d'Ivoire.*
[*]*Corresponding author; E-mail: zanhgoloug@gmail.com; Tel:+225 0506438001*

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ABSTRACT

Côte d'Ivoire is the world's largest producer of cocoa beans. However, cocoa is cultivated on forest precedent, resulting in a drastic reduction in forest reserves. Faced with land scarcity and falling productivity farmers have developed adaptation strategiesThis work was carried out in order to determine the adaptation strategies of cocoa farmers in the face of forest scarcity in the Bonon Sub-prefecture. To achieve this, a Landsat 2021 satellite image with 30 m resolution was used, followed by field visits to verify land-use classes and enable the land-use map to be produced. In addition, a questionnaire survey was carried out to determine farmers' strategies. The results showed that the study area is made up of 4 land-use classes. The main reasons given by Bonon growers for the scarcity of forests were agricultural activities and population growth. To cope with these constraints, farmers have developed strategies such as replanting cocoa trees, switching to other crops and diversifying their sources of income. As a result of this work, it can be recommended that farmers adopt cocoa-based agroforestry to ensure the sustainability of cocoa farming in Côte d'Ivoire.

Keywords: Adaptation Strategies, Cocoa Replanting, Forest Scarcity, Cocoa Farming, Côte d'Ivoire.

INTRODUCTION

Since the late 1960s, Côte d'Ivoire, like most countries in Sub-Saharan Africa, has focused its economic development on the agricultural sector. This agricultural policy has enabled Côte d'Ivoire to become the world's leading producer of cocoa beans, with over 42% of global production. Cocoa resources account for 30% of Côte d'Ivoire's GDP, nearly 40% of the country's export earnings and the livelihoods of over six million Ivorians, a quarter of the total population (Conseil National des Exportations, 2022). However, cocoa is generally grown on a preceding "forest" crop. This cultivation practice has resulted in a drastic reduction in Ivorian forest cover. Indeed, the Ivorian forest, which represented almost 16 million hectares in 1960, has undergone rapid degradation, and is estimated to be 2.97 million hectares in 2020 (Cuny et al., 2023). This reduction in forest cover, combined with the overall drop in rainfall throughout the country in the 1970s, led to the gradual relocation of the main players

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in cocoa production from the pre-forest zones of the East to the forest zones of the West-Centre, and then the South-West and West of the country (Assiri et al., 2016) for the creation of new farms. The dynamic expansion of cocoa cultivation in the forested part of the country has thus made this cash crop the main driver of deforestation, especially in the Ivorian Centre-West (Ruf & Schroth, 2004 ; Konan et al., 2023) Cocoa was introduced to Côte d'Ivoire in 1888, precisely in the south-east (Tano, 2012), and expanded to other regions between 1910 and 1950 (Schroth et al., 2004). The Centre-Ouest zone took over production between 1960 and 1970 (Zanh et al., 2019) and became the second cocoa loop by the end of the decade. Unfortunately, cocoa production in this zone was beset by a number of difficulties, including disruption of rainfall patterns and falling cocoa farm productivity. In addition to the depletion of forest areas, increasingly aging orchards, declining soil fertility and the proliferation of diseases such as cocoa *Swollen shoot* virus and brown rot (Ruf, 2018; Zanh et al., 2019). Faced with forest scarcity, the main question is what adaptation strategies have cocoa farmers put in place to ensure the sustainability of cocoa farming in West-Central Côte d'Ivoire? To answer this central question, this study was set up to assess cocoa farmers' adaptation strategies in the face of shrinking forest areas in the Sub-prefecture of Bonon (West-Central Côte d'Ivoire).

MATERIALS AND METHODS

Presentation of the study area

The present study took place in West-Central Côte d'Ivoire in the Sub-prefecture of Bonon, around 100 km from the political capital (Yamoussoukro) in the Marahoué region between 6°14′0″ and 5°52′0″ west longitude and 7°10 ′ 0″ and 6°45′0″ north latitude. The Sub-prefecture of Bonon is under the influence of the red Bandama River (Kouakou et al., 2018). The dry season extends from November to February with an average monthly rainfall of 73.84 mm and an average monthly temperature of 26.3°C. The rainy season extends from March to October, with a September rainfall peak of 106.80 mm and a maximum temperature of 27.90°C over the last thirty years. Located on the edge of the Bouaflé classified forest and the Marahoue National Park, the Sub-prefecture of Bonon lies in a mosaic zone of forests and savannahs that are favorable to agricultural production (Zigbé, 2021). The population of the Bonon Sub-prefecture is made up of natives (Gouro), non-natives (Malinké, Baoulé, Lobi, Senoufo etc.) and non-natives (Burkinabés, Malians, etc.). (Gohourou, 2020).

Part of this study, work was carried out in five villages in the Sub-Préfecture of Bonon. These were Dabouzra, Ouarebota, Koffikro, Blaisekro 2 and N'Gattakouakoukro (Figure 1).

Data collection methods

Cartographic data collection

The Landsat 2021 image was used for this study. It was supplied free of charge by the United States Geological Survey (USGS) and downloaded from the Earth Explorer portal (http://earthexplorer.usgs.gov/). The image was taken during the dry season. In fact, images acquired during this season show a large spectral difference between land use classes and enable anthropized areas (crops, fallow land, bare soil and housing) to be differentiated from areas of natural vegetation (forest) (Oszwald et al., 2010; Toyi et al., 2018).

Survey data collection

For data collection, surveys were carried out using semi-structured interviews with cocoa farmers in the five target villages (Dabouzra, Ouarebota, Koffikro, Blaisekro 2 and N'gattakouakoukro). This method enables the interviewees' discourse to be oriented around different themes previously defined and recorded in the questionnaire (Blanchet and Gotman, 2010). The questionnaire was administered to people aged 18 and over who owned at least one cocoa farm.

Data analysis

Digital image processing began by extracting the study area from the entire scene using ENVI 5.3 software. Following this manipulation, a color composition of the extracted vegetation study area was produced, with the aim of synthesizing the information required for good discrimination of formation types. The color composition of the Landsat 8 OLI TIRS image selected is a combination of spectral bands 5-4-3, corresponding to the near infrared, red and green bands respectively. The spectral characteristics of these bands facilitate the discrimination of different vegetation types (Oszwald, 2005). Furthermore, the choice of training and control plots was made taking into account the accessibility and representativeness of all vegetation classes defined by the false color display of satellite images. As part of this study, a supervised classification based on the maximum likelihood algorithm was carried out. Accuracy measurements obtained through the confusion matrix (kappa coefficient and overall accuracy) were used to verify the classification performance before validation. Finally, post-classification processing ended with the steps of improving the cartographic rendering of the classification results (removal of isolated pixels, homogenization of classes and filtering) and cartographic dressing, which enabled us to obtain the land use map. The map was produced in ArcGis 10.2.

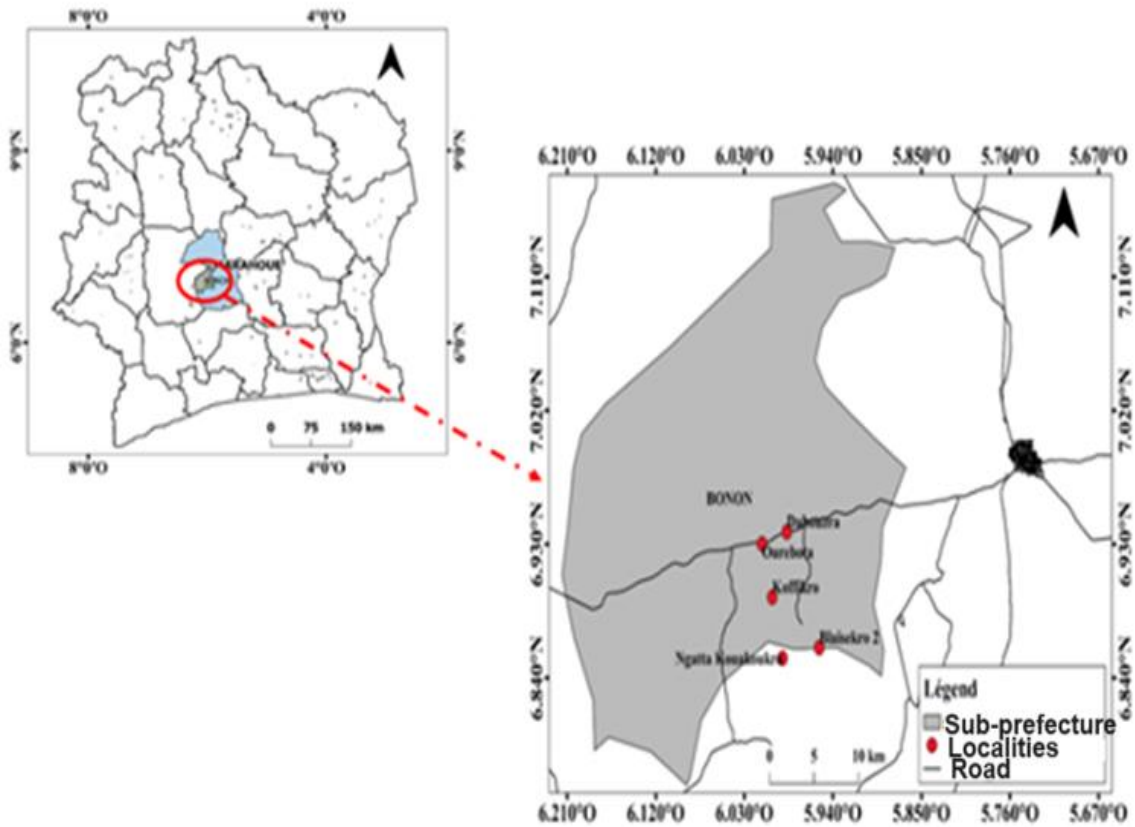

Figure 1: Geographical location of Bonon Sub-prefecture in West-Central Côte.

RESULTS

Land-use mapping in the Sub-prefecture of Bonon

The 2021 land-use map for the Bonon Sub-prefecture shows four (04) land-use classes (Figure 2). These are the mature perennial crop, crop-fallow, bare soil-habitat and secondary forest classes. The results show that the mature perennial crop class is mainly made up of cocoa orchards and/or other perennial crops (coffee, cashew) aged 10 years or more. The fallow-crop class is made up of non-mature perennial crops associated with food crops and fallow land. Furthermore, the confusion matrix indicates good image classification, with a Kappa coefficient greater than 0.85 and a mapping accuracy of 96.05% (Table 1). In addition, the bare soil-habitat and mature perennial crop classes record the best pixel classification rates, with values of 92.11% and 91.11% respectively. Lastly, the map shows a dominance of the non-forest class (mature perennial crop, crop-fallow and bare soil-habitat) in the Bonon Sub-prefecture, with a rate of over 80% (Table 1).

Landscape composition of the Bonon Sub-prefecture

Analysis of the landscape composition shows that in 2021, the Bonon Sub-prefecture was dominated by the mature perennial crop class with a rate of 48.55% or 47575.26 ha, followed by the bare soil-habitat class which occupied 27.66% or 27102.96 ha of surface area. The secondary forest (degraded) and crop-fallow classes accounted for 12.81% (12551.58 ha) and 10.98% (10754.82 ha) respectively (Figure 3).

Socio-demographic characteristics of cocoa farmers

The age of the people surveyed ranged from 24 to 78, with an average of 33. Analysis of these results revealed three age classes: 0-35, 35-60 and over 60 (Figure 4). The majority of those surveyed were in the 35-60 age group, with a rate of 58.70%. Next, those under 35 account for 23.91%. Finally, farmers aged 60 and over account for the lowest proportion at 17.39% of the 46 growers surveyed, 89.13% were men and only 10.86% women (Figure 5).

Three communities were involved in cocoa farming in the Sub-prefecture of Bonon (Figure 6). Allochtones were the most numerous at 45.65%, followed by autochtones and allogenic at 43.48% and 10.87% respectively. Of the 46 farmers surveyed, 93.48% were married, compared with 4.34% single and 2.17% widowed (Figure 6).

Cocoa farmers in the study area had a relatively high level of education. Over 69% of farmers were educated, with 36.95% having completed primary school, 30.43% secondary school and 2.17% higher education. On the other hand, 30.43% of farmers were not educated (Figure 7).

Agronomic characteristics of cocoa farms

Three main types of previous cultivation were identified in the Bonon Sub-prefecture. These were forests, fallow land and old plantations of perennial crops (coffee and cocoa). The results showed that half (50%) of the plantations were established on fallow land, compared with 39% on forests and 11% on old perennial crop plantations (Figure 8).

Furthermore, the age of cocoa plantations in the study area varied between 1 and 52 years. These plantations could be divided into three age classes: [0 to 15 years] ;] 15 to 30 years[and≤ 30 years (Figure 9). Plantations aged over 30 years were the most represented, with a rate of 50%, followed by those aged between 15 and 30 years and less than or equal to 15 years, with proportions of 26.08% and 23.92% respectively.

The surface areas of the main plantations ranged from 1 to 8 ha, with an average of 3 ha. However, three size classes were defined (Figure 10). These were plantations with an area of 1 to 3 ha, with a proportion of 69.56%, followed by the class of plantations with an area of 4 to 6 ha, with a proportion of 21.74%, and those with an area of 7 to 8 ha, with a proportion of 8.69%. Analysis of the results also revealed three main causes of forest depletion. These were agricultural activities, population growth and logging (Figure 11). Of these, agricultural activities were the most dominant, accounting for 73.91%. Population growth and logging are the least cited, with a rate of 4.35% each. However, the results showed that 17.39% of

producers surveyed said they were unaware of the causes of forest depletion.

Strategies adopted by producers

The survey results showed that cocoa farmers were adopting five main (5) strategies to cope with forest scarcity: replanting cocoa plantations, diversifying into other crops (it can be defined as the introduction or development of new speculations in addition to existing speculations on a farm), diversifying into non-agricultural activities, reconverting to other crops (Reconversion refers to replanting, which consists in partially or totally replacing the existing crop with a new one that is adapted to the environmental conditions) and using phytosanitary products (Figure 12). Among these strategies, replanting cocoa farms was the most widely adopted, with a rate of 41.3%. It could be seen that 28.26% of cocoa farmers had opted for non-agricultural activities and 21.74% for crop diversification. On the other hand, those who reconverted cocoa trees to other crops and those who used phytosanitary products were the least numerous, with a proportion of 4.35% each.

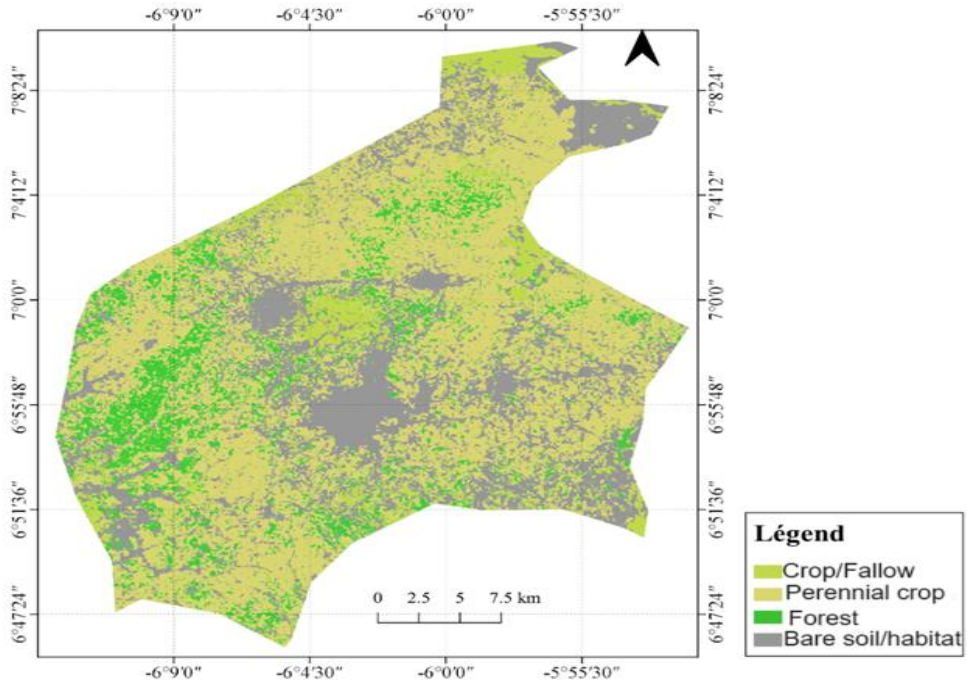

Figure 2: Land use map of the Bonon Sub-prefecture (West-Central Côte d'Ivoire) in 2021.

Table 1: Confusion matrix (%).

	Mature perennial crop (%)	Bare soil-habitat (%)	Degraded forest (%)	Crop-fallow (%)
Mature perennial crop	91.11	0	11.36	0
Bare soil-habitat	2.22	92.11	0	12.1
Degraded forest	6.67	0	88.64	5.65
Crop-fallow	0	7.89	0	82.26
	Overall accuracy = 96.05%; Kappa coefficient = 0.85			

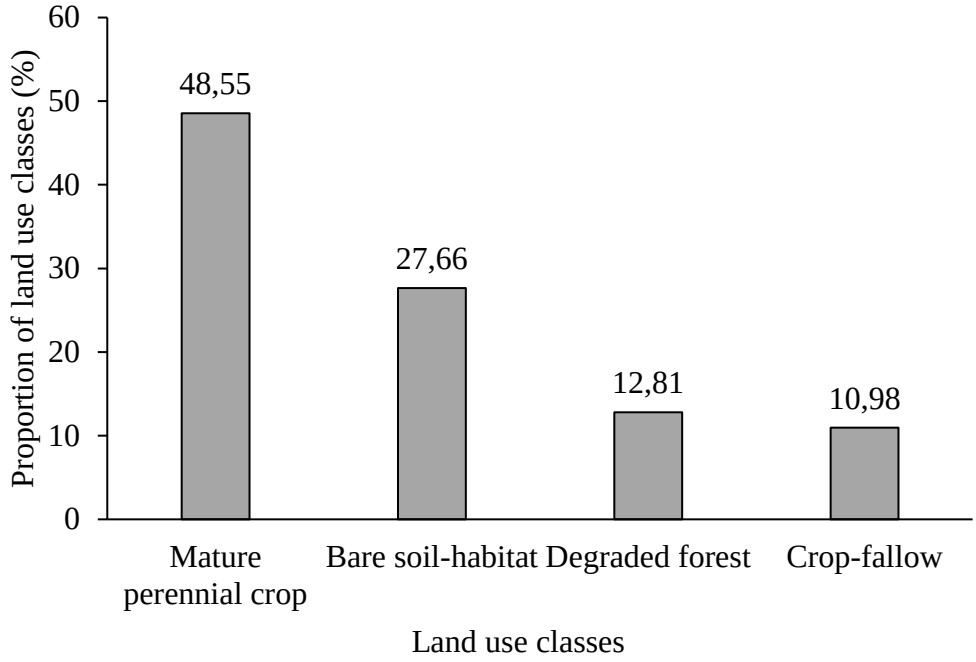

Figure 3: Proportion of land-use classes in the Sub-prefecture of Bonon (West-Central Côte d'Ivoire) in 2021.

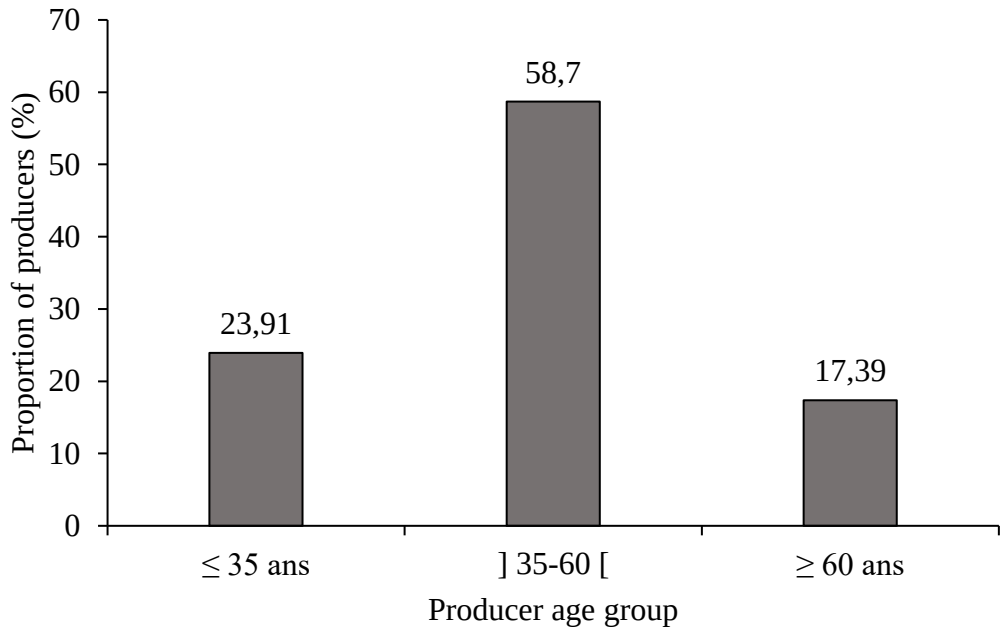

Figure 4: Age distribution of cocoa farmers in the Bonon Sub-prefecture (West-Central Côte d'Ivoire).

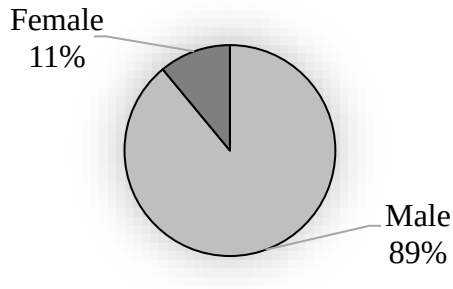

Figure 5: Distribution of cocoa farmers by gender in the Sub-prefecture of Bonon (West-Central Côte d'Ivoire).

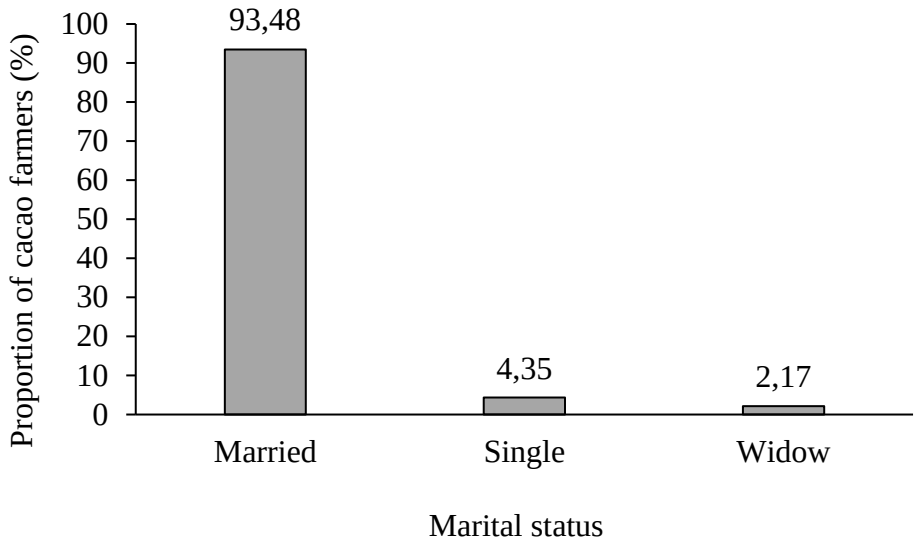

Figure 6: Marital status of cocoa farmers in the Sub-prefecture of Bonon (West-Central Côte d'Ivoire).

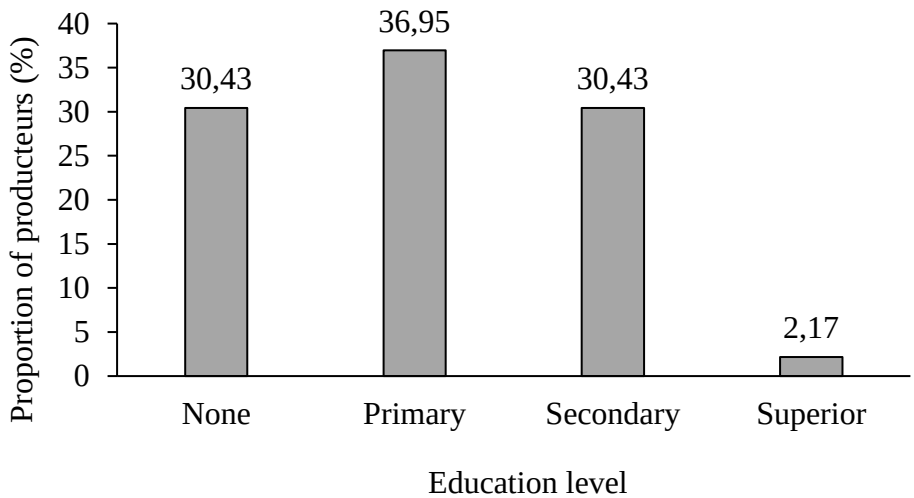

Figure 7: Education level of cocoa farmers in the Sub-prefecture of Bonon (West-Central Côte d'Ivoire).

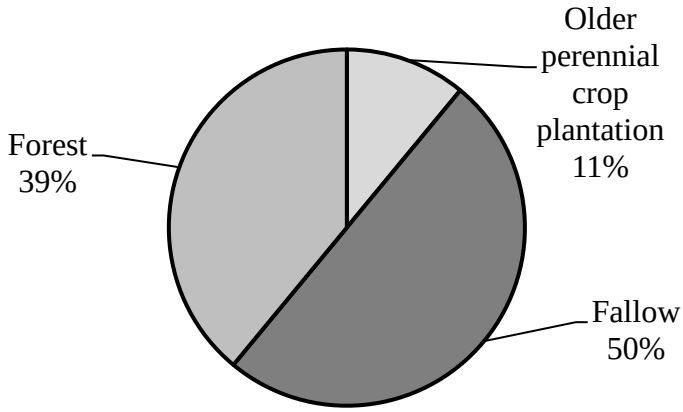

Figure 8: Repartition of cocoa farm cultivation precedents in the Sub-prefecture of Bonon (West-Central Côte d'Ivoire).

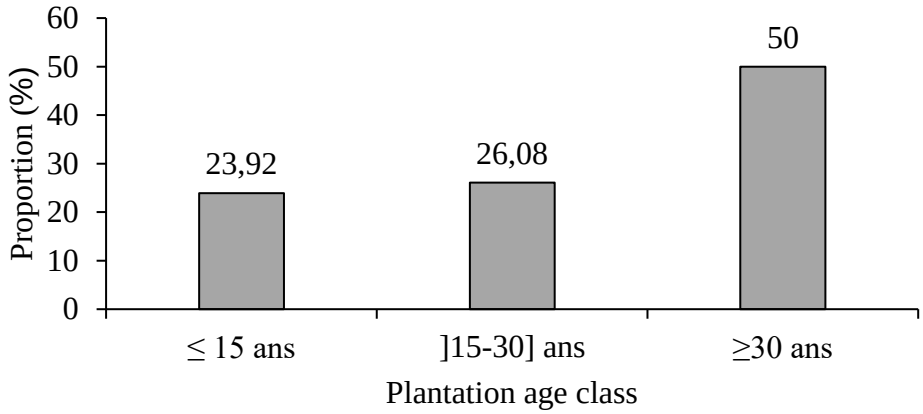

Figure 9: Age distribution of cocoa plantations in the Bonon Sub-prefecture (West-Central Côte d'Ivoire).

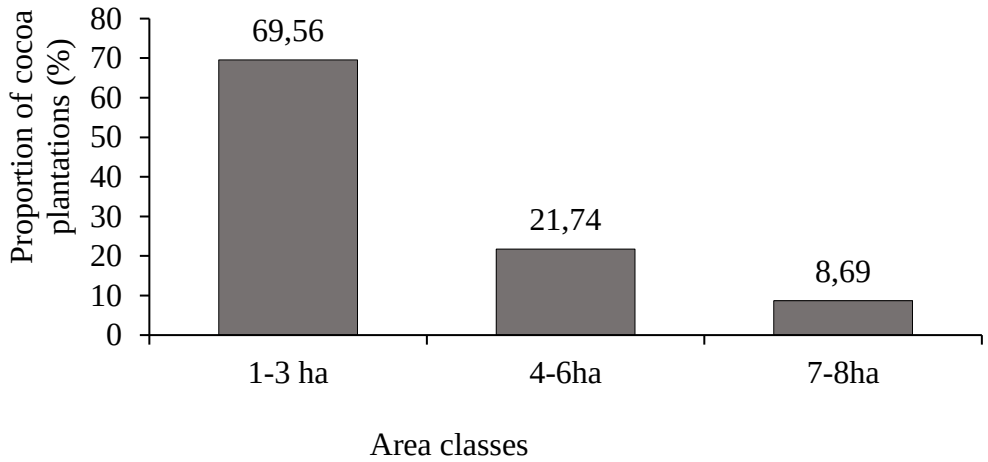

Figure 10: Distribution of cocoa plantations by area class in the Bonon Sub-prefecture (West-Central Côte d'Ivoire).

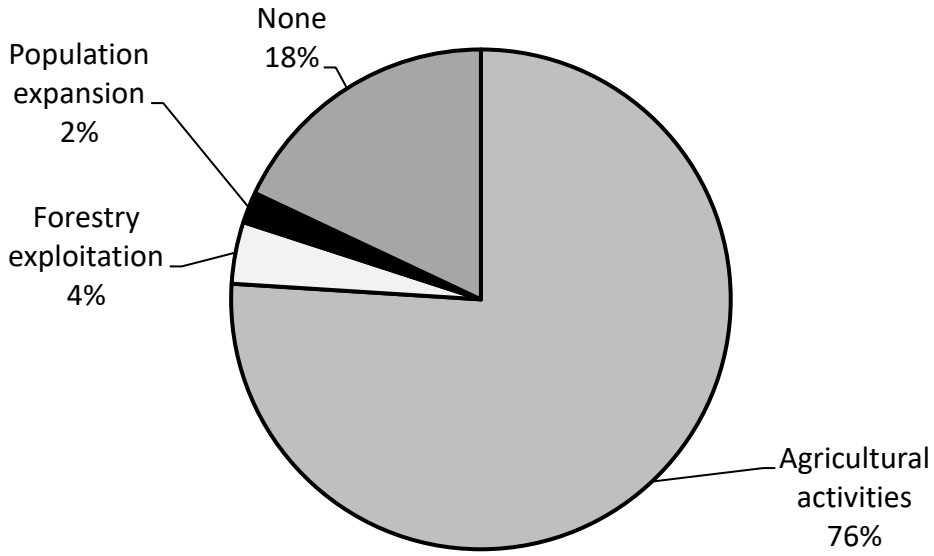

Figure 11: Proportion of different causes of forest depletion in the Sub-prefecture of Bonon (West-Central Côte d'Ivoire).

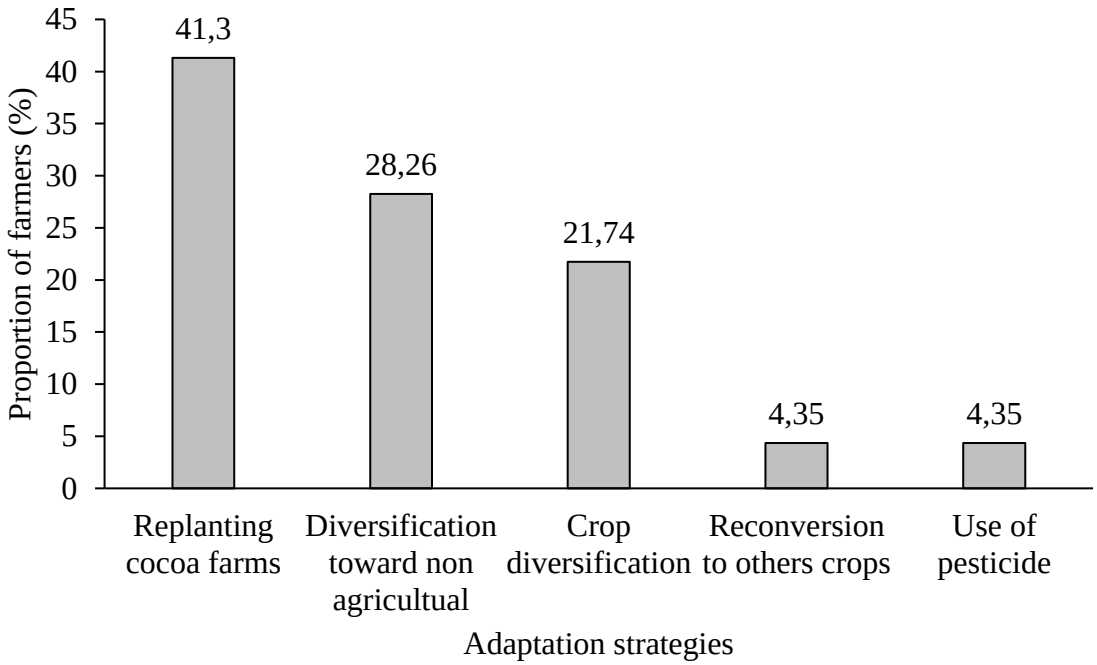

Figure 12: Different strategies adopted by cocoa farmers in response to forest scarcity in the Bonon Sub-prefecture (West-Central Côte d'Ivoire).

DISCUSSION

Rarefaction of the forest in the rural landscape of the Sub-préfecture of Bonon

Using satellite imagery and land-use mapping techniques, the land-use map of the Bonon Sub-prefecture was drawn up. Classification accuracy is 96.05%, with a Kappa coefficient of 0.85. These results reflect good classification (Kabba and Li, 2011). This high value of the Kappa coefficient can be explained by knowledge of the study environment (Trepanier et al., 2002; Toyi et al., 2018). However, the high mapping accuracies may also be due to the reduced number of classes used when selecting training sites (Mama et al., 2014). The mapping results reveal the pressure of anthropogenic activities on the landscape of the Sub-prefecture of Bonon. Indeed, the map reveals that over 85% of the Sub-prefecture is covered by anthropized spaces in this case, perennial crops, bare soil and habitats but also annual crops and fallow land. The high rate (85%) of non-forested areas therefore explains the scarcity of forests in the Bonon area, and could even be in a state of land saturation. These results confirm those obtained by Kangah et al. (2016) in the Odjoukrou territory in the southern part of Côte d'Ivoire and those of Zanh et al. (2018) in the rural space of the Haut-Sassandra classified forest (FCHS) in West-Central Côte d'Ivoire. These authors asserted, based on a land-use analysis, that these rural spaces (Odjoukrou terroir and FCHS periphery) were characterized by very strong anthropogenic pressures and the intensification of agricultural activities. According to these authors, there are virtually no forest reserves left for new plantations.

In addition, analysis of the results revealed three main causes of forest depletion in the Sub-prefecture of Bonon: agricultural activities, population growth and logging. However, the expansion of agricultural activities (73.91%) was the most frequently cited reason. This dominance of agricultural activities is linked to population growth, which implies a strong demand for food resources and economic needs. Indeed, the Marahoué region and mainly the Sub-prefecture of Bonon has welcomed large waves of agricultural migrants since the early 1970s (Krouba et al., 2018). These agricultural migrants, mainly from Central Côte d'Ivoire and Burkina Faso, have significantly altered the landscape of the Bonon area (Cardon et al., 2000). Indeed, farmers increased the size of their plantations in order to better provide for their families. Moreover, cocoa plantations were generally established after the forest had been cleared. This agricultural practice has had a major impact on Bonon's forest formations. Our results corroborate those of Tshibangu (2001), Adou et al. (2018) and Ballo et al. (2022), who have shown in their work that agricultural practices are 70% responsible for deforestation on the African continent.

The results also highlighted the impact of seedling mortality during cocoa replanting on intrusion into forest relics. Indeed, growers intending to renew their old plantations are confronted with a high rate of seedling loss, leading to perpetual restarting. Faced with these difficulties, which are due to seasonal variability and land impoverishment, farmers are looking for new land to create cocoa plantations. Indeed, the high mortality rate of cocoa plants is thought to be due to lower rainfall and soil infertility in cocoa-growing areas (Tano, 2012; Ruf, 2018; Kouassi, 2021).

Cocoa farmers adopt new strategies

The results of the surveys showed that over 80% of the population surveyed was of Ivorian nationality, 43.48% of whom were indigenous (Gouro), compared with 45.65% allochtones and 10% allogenic. This high proportion of non-natives can be explained by the migration of these peoples from the north and center of the country to forest areas in search of suitable cocoa-growing land. Indeed, Assiri et al. (2009) have shown that the strong

presence of allochtones in the Centre-West zone is due to the displacement of the pioneer front from the Centre-East region to the West-Central and South-East regions of the country between the 1960s and 1990.

What's more, 69% of growers are educated, with levels ranging from primary to higher education. In fact, this high level of education among farmers is due to a new generation of growers who are generally children of farmers and school dropouts who have opted to return to the land after an unsuccessful search for employment in town. However, this finding contradicts the results of Adji et al. (2020). These authors have shown that populations in the cocoa loops of Côte d'Ivoire are generally illiterate or unschooled. The difference between these results could be due to the difference in the size of the populations surveyed, but also in the sampling areas.

In the Sub-prefecture of Bonon, cocoa farmers have adopted five strategies to deal with the many constraints associated with cocoa farming, including the increasing scarcity of forest. These include replanting cocoa farms, diversifying crops, reconverting to other crops, using agricultural inputs (fertilizers and phytosanitary products) and diversifying into other non-agricultural activities. To cope with the increasing scarcity of forest and the consequent need to create new cocoa plantations, farmers have favoured replanting cocoa plantations, which involves introducing new cocoa plants into old plantations (over 30 years old). This replanting also involves recolonizing degraded fallow land on soils depleted of mineral elements (Ruf, 2018). Indeed, in several cocoa-producing regions, the observation is the same i.e. farmers have decided to stay put to produce cocoa through replanting (Assiri et al., 2009; Kpangui, 2015; Cissé et al., 2016). Thus, other farmers have decided to orient their strategy towards crop diversification, perhaps less profitable but more favorable to the environmental constraints of the area. Consequently, these producers combine cash crops such as coffee and cashew nuts in cocoa plantations or convert their cocoa plots into rubber trees. Other producers are diversifying into non-agricultural activities, which could provide them with an additional source of income given that cocoa farms are aging and not very productive, with infertile soils (Petithuguenin et al., 2004; Ruf, 2018; Zanh et al., 2019). Furthermore, diversified farms respond better to price drops or unfavorable agricultural policy for the grower compared to those who have their plantations based on a single crop (Ruf, 2018). Finally, some growers (4.35%) use phytosanitary products as a strategy to improve their yields. Indeed, the adoption of mineral fertilizer stems from the concern of some planters worried about dealing with the early mortality of their cocoa trees on non-fertile soils (Ruf, 2018).

Conclusion

The aim of this study was to assess the adaptation strategies of cocoa farmers in the face of forest scarcity in the Bonon Sub-prefecture. The result of this study provides a better understanding of the Bonon rural area, based on remote sensing and field data. It found that the installation of cocoa crops in this area has been to the detriment of the forest. Indeed, analysis of the land-use map of the Bonon Sub-prefecture reveals the existence of 4 land-use classes: mature perennial crops (48.55%), bare soil-habitats (27.66%), degraded forest (12.81%) and crop-fallow (10.98%). As a result, most of Bonon's landscape is entirely anthropized, and there is virtually no forest left. The main reason for this depletion of forest is agricultural activity (73.91%), driven by demographic growth. To cope with these difficulties, farmers have developed strategies that include replanting cocoa trees (41.3%), creating non-agricultural activities (28.26%) and crop diversification (21.74%).

COMPETING INTERESTS

The authors declare that they have no competing interests.

AUTHORS' CONTRIBUTIONS

KPN-G is the the principal author of the manuscript. KPN-G, GGZ and ATMK contributed to the collection data. GGZ analyzed survey data and ATMK analyzed map data. GGZ wrote the manuscript, which has been critically reviewed for intellectual content by ATMK, KPN-G and YSSB. All authors have read and approved the final version of the manuscript.

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