

Evaluation of the Impact of the “Clearing Practice” on Vegetation for Sustainable Cacao Culture in Côte d’Ivoire

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Abstract: *Cocoa cultivation plays an important role in the economy of Côte d’Ivoire, which is the world’s first producer of cocoa. The impact of agricultural practice on associated vegetation has not yet been studied in detail while forest surfaces are decreasing and species disappearing. We evaluate the impact of the mostly applied and common practice called “clearing practice” which consists in directly eliminating all plants competing with cacao trees. This information is needed for developing a better agricultural practice for sustainable land use in the context of global change. Detecting variation in floristic parameters reveals that in young plantations there is a high potential of species regeneration, followed by a strong reduction in plantations of 6 to 40 years of age, which is essentially due to the clearing practice. In abandoned plantations, the reconstitution phase significantly depends on the impact of clearing practice which eliminates or promotes certain species. In the studied Oumé region, forest reconstitution did not seem to be entirely compromised despite clearing practice. This could be different under unfavorable conditions and does not ensure reconstitution of vegetation. The clearing practice has to be adapted and applied to specific objectives for sustainable cacao culture.*

Keywords: agricultural practices, cash crops, plant regeneration, agricultural policies

1. Introduction

Cash crops were introduced to West Africa at the beginning of the 20th century (Benveniste, 1974). Like most countries in West Africa, Côte d’Ivoire has inherited from the colonial period the role of an exporter of tropical products (Asare, 2005; Koulibaly *et al.*, 2010a). The increase in export to over 90% of the production has made this country become the world’s largest producer of cocoa beans since 1978, with 1.9 million hectares of cocoa plantations (Hecht 1983; Esso, 2009). In 2000, Côte d’Ivoire accounted for half of the global cocoa market (compared to 38.4% in 1991), according to Hugon (2002). Production in 2014-2015 has reached 1.8 million tons (42% of the world supply) and has contributed to more than 15% of the Gross Domestic Production (ICCO, 2015).

Most of the cocoa production comes from numerous small exploitations of which 95% cover 1 to 5 hectares (Jarrige & Ruf; 1990, Diabaté, 2002). The development of cocoa cultivation took place in an extensive and itinerant way. Peasants apply a slash-and-burn practice in forests and introduce cacao plants, sometimes associated with other plants like banana for their humidity contribution. Cocoa plantations are installed at the sensitive ecological border of a forest (Assiri, 2007). This has led to dynamic expansion of fronts of pioneer species after cutting down the forest (slash and burn), and geographical progression of cocoa plantation areas from the East into the West of the country (Assiriet *al.*, 2016). Cocoa cultivation contributed about 14% to deforestation, making forest areas decrease from 15 to 2 million hectares in 1995-1996 (Chatelain *etal.*, 1996; World Rainforest Movement 2004). The development of this cash crop has also led to changes in land use (Boserup, 1965;

Koulibaly *et al.*, 2010b) and significant changes in vegetation characteristics at the expense of biodiversity (Aubreville, 1957; Darkoh, 2003, Koulibaly *et al.*, 2016). However, there is almost no knowledge about the effect that cocoa cultivation has on associated natural plant communities.

Taking into account all existing agricultural practices for installing plantations and growing cacao trees would be complex and their impact difficult to differentiate. That’s why we focus on a common and regular farming practice called “clearing practice”, which consists of a direct elimination of species being considered as competitive species with cacao trees and potentially reducing their productivity. Thus, studying the variation of floristic parameters in time and space can allow for detecting the impact of clearing during the installation of cocoa plantations. This information is needed for developing a better agricultural practice for sustainable land use in the context of global change. The objectives of this study are to (1) assess species regeneration dynamics in young cocoa plantations, (2) detect the distribution of floristic composition between differently utilized areas, and (3) develop recommendations for sustainable agricultural practice.

2. Literature Survey

Investigations that are encountered in the literature deal with the development of the national economy, future options of the export market expansion (Etounga-Manguelle, 1989, Benjamin & Deaton, 1993, Losch, 1994) and the increase in productivity, in particular by improving cropping techniques (Herzog & Bachmann, 1992, Herzog & Gotsch, 1998, Asare,

2016). The few works on impact of agriculture on vegetation have shown that the specific richness of forests adjacent to cocoa plantations has already been strongly reduced by logging and that species regeneration is compromised (Koulibaly *et al.*, 2010c). This could be explained by a lack of adult or juvenile plants especially in the forests of forest-savanna mosaic regions. Concerning regeneration dynamics in plantations, the number of cocoa trees, banana plants (associated) and other tree species varies according to the age of the plantation, with the highest number concerning the other species and in the first years (Koulibaly *et al.*, 2010b, Konanet *et al.*, 2011). The importance of the flora preserved on or introduced to cocoa plantations has been demonstrated by Piba *et al.* (2011). The severe reduction of phytodiversity by clearing practice has not been studied despite this biodiversity serving local inhabitants in everyday life. However, it is generally known that clearing practice is rarely applied in the very young plantations and becomes intense later in the Lamto and Oumé regions of Côte d'Ivoire.

3. Methods

3.1. Study Sites

Lamto Reserve region (South)

The Lamto Reserve region is located to the South of Côte d'Ivoire and belongs to the Mesophyll Sector of the Guinean Domain (Guillaumet & Adjanohoun, 1969), see Fig. 1. The vegetation is composed of semi-deciduous forests distributed in savanna which constitutes an attractive environment for agricultural activities. It is a dynamic agricultural region, dominated by cocoa cultivation. The annual average temperature is 26.8 °C with 1,176 mm of rainfall by year (Koulibaly, 2008). The Bandama is the main river of the region which runs along the western boundary of the reserve. The surveys were carried out between 6 ° 14'-15' N and between 4 ° 06' - 5 ° 03' W.

Oumé region (Western-Center)

The Oumé region belongs to the catchment of the Bandama River located in the East of the region (Girard *et al.*, 1971) in the western-central part of Côte d'Ivoire (Fig. 1). The vegetation in this region also belongs to the Mesophyll

Sector of the Guinean Domain (Guillaumet & Adjanohoun, 1969) and is characterized by a forest-savanna mosaic containing typical species like *Celtis* spp. and *Triplochiton scleroxylon* K. Schum. The average monthly rainfall from 1990 to 2004, recorded at the SODEFOR (Téné station), varies between 8.92 mm and 85.26 mm. The average annual temperature is 26.72 °C. Agriculture, which is the main activity of the population, is dominated by cocoa and coffee crops.

3.2. Sampling Design

Young plantations

Forty-six plots of 400 m² have been established in young plantations (less than 6 years). A plot of 100 m² was delimited at the center of the plot of 400 m² then divided into sixteen squares of 2.5 m² (Fig 2 A). Ten of them were selected by the probabilistic sampling method. In each square, the total height and diameter at breast height (d.b.h.) of all individuals taller than 1.5 m were recorded. Regeneration dynamics were assessed by determining separately the density of cocoa trees, banana plants and spontaneous natural species in the diameter classes.

Aged plantations and neighboring formations

The sites were selected from the map established by the CSM-BGBD project, and 6 different area types were defined to uncover variations in plant diversity under the influence of cocoa cultivation. Plantations of different ages range from 1 to 40 years, fallow (abandoned plantations) and neighboring vegetation such as forest fragments in the Oumé region. There were 24 plantations divided into 4 age classes ([1-5 years], [6-10 years], [11-20 years] and [21-40 years]), 3 plantations abandoned for up to 40 years, or fallows and 3 fragments of forest. After an itinerant inventory in each category of vegetation, square plots of 500 m² were installed and subdivided into 5 sub-squares of 100 m². (Fig. 2B). In each subplot, total height and diameter at breast height (d.b.h.) were measured for all individuals up to 2 m. A hierarchical classification and a Canonical Correspondence Analysis based on the presence or absence of species allowed for describing the variation in floristic diversity.

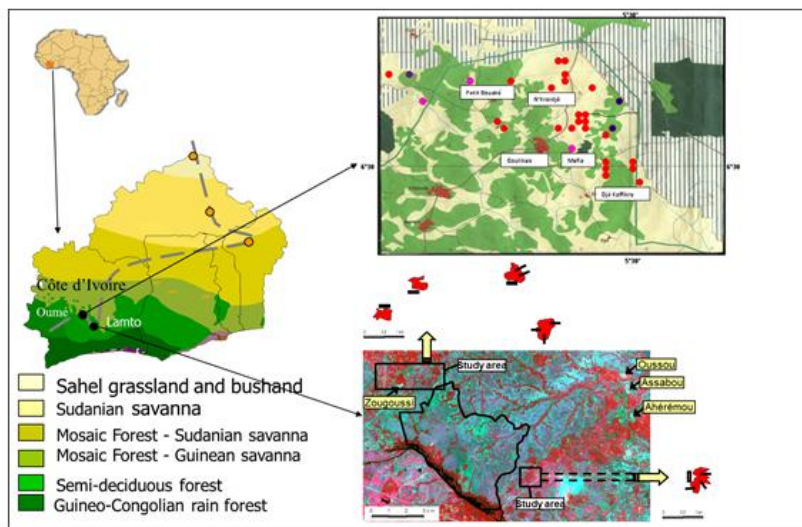


Figure 1: Study sites in the Lamto Reserve and Oumé regions in Côte d'Ivoire. Plots position : colored dots and black bars. Sources : Koulibaly, 2008. Bureau National d'Etudes Techniques. Projet CIAT-TSBF/GF/2715-02.

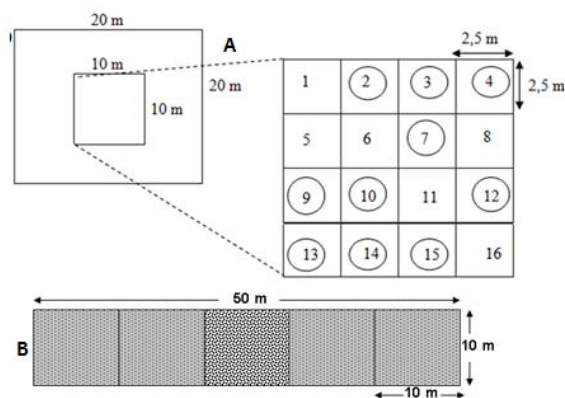


Figure 2: Sampling design (A) regeneration dynamics and (B) floristic relevés in Lamto and Oumé regions.

4. Results

4.1 Regeneration dynamics in young cocoa plantations (low clearing practice)

In the 1st year of plantation, cacao saplings planted in the soil had not yet reached the stratum of 1.5 m of height (Fig. 3). The number of banana plants was high in the diameter class up to 10 cm d.b.h. The other species were represented in the classes of 1 to 5 cm d.b.h. and 5 to 10 cm d.b.h. These were food plants, cultivated in association with the cacao tree such as *Capsicum annum*L., or invasive species such as *Chromolaena odorata*(L.) R. M. King & H. Rob., or shrubs spared during clearing to serve as carrier plant for yam, such as *Milletia zechiana*Harms.

During the 2nd year, the number of banana plants remained high in the class up to 10 cm d.b.h. The cacao tree appeared in the three diameter classes up to 1 cm d.b.h. This happened at the expense of banana trees/plants whose number decreased strongly in the class of 1 to 5 cm d.b.h. The other species were recorded for all diameter classes. In the smallest one we found *Exolobus patens*(Decne.) Fourn., *Loeseneriella africana*(Willd.) R. Wilczek ex N. Hallé and *Mondia*

wythei(Hook. f.) Skeels. Between 1 and 5 cm d.b.h. they were *Deinbollia pinnata* (Poir.) Schum. & Thonn., *Spondias mombin*L. and *Solanum nigrum*L. The number of individuals was lower in the class from 5 to 10 cm d.b.h. because of some food plants that no longer produce or disappear as a result of plantation clearing, such as *Capsicum annum*. The diameter class up to 10 cm d.b.h. was represented by *Dialium guineense*Wild. and *Spondias mombin* that had been kept at the installation of the plantations.

In the 3rd year, cacao trees were present in all diameter classes with a high density in the class of 5 to 10 cm. The number of banana plants remained high in the largest diameter class. For the other species, the class of 1 to 5 cm d.b.h. contained young individuals of *Antiaris toxicaria*Lesch. var. *africana*(Engl.) C. C. Berg, *Griffonia simplicifolia* (Vahl ex DC.) Baill., *Motandra guineensis*(Thonn.) A. DC and *Chromolaena odorata* which may resprout in great numbers as a consequence of primary cutbacks. The class up to 10 cm contained, for its part, individuals of *Blighia sapida*Koenig, *Celtis philippensis*Blanco, *Cola millenii*Schumann, *Lecaniodiscus cupanioides*Planch. and *Mangifera indica*L. The class of 5 to 10 cm d.b.h. was essentially represented by individuals of *Spondias mombin* while other species were less abundant.

During the 4th year, cacao plants abundantly and exclusively represented the class of 5 to 10 cm d.b.h., indicating that henceforth the cocoa plantations contained a considerable number of large cacao trees. Individuals of other species, with diameters between 5 and 10 cm d.b.h., which would compete with the cacao trees, were no longer present. Intensification of clearing practice did not allow plants of other species to reach larger diameters. Individuals of cacao trees were already heading for the production of cocoa beans, hence a notable spread of branches. The number of individuals of other species was reduced in the class of 1 to 5 cm d.b.h. This class included *Chromolaena odorata*, *Ficus exasperata*Vahl and *Motandra guineensis* (Thonn.) A. DC. Individuals with a diameter of up to 10 cm d.b.h. were only represented in this 4th year due to spontaneous colonization

or / and having been spared, such as *Elaeis guineensis* Jacq., *Mangifera indica* and *Persea Americana* Mill.

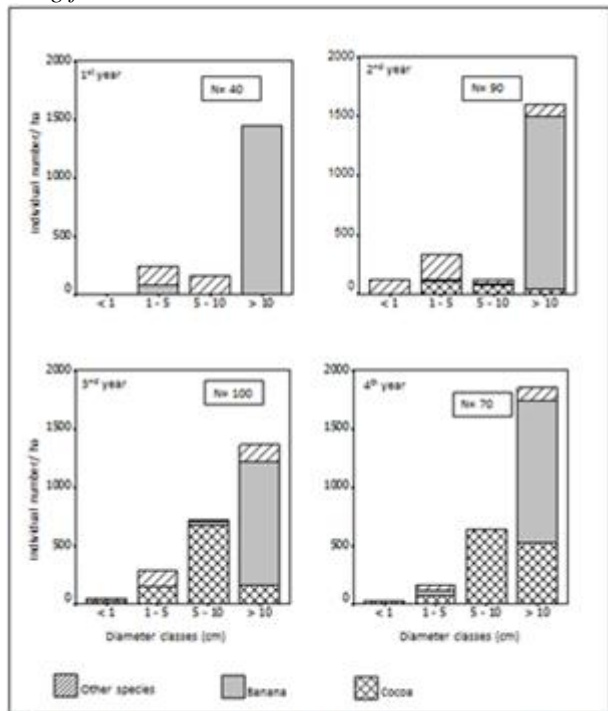


Figure 3 : Mean density of individuals taller than 1.5 m in the different diameter classes during the first years of cocoa development n : plots number

Floristic parameters of aged cocoa plantations (intensive clearing practice) and neighboring vegetation

According to the degree of floristic resemblance, the hierarchical classification revealed a first division between forest fragments and utilized areas (Fig. 4). At the second level, the young plantations (1-5 years) were separated from other habitats. At the third classification level, fallows were separated followed by a corresponding separation of aged plantations, in this order: 21 to 40 years, 6 to 10 years, and 11 to 20 years.

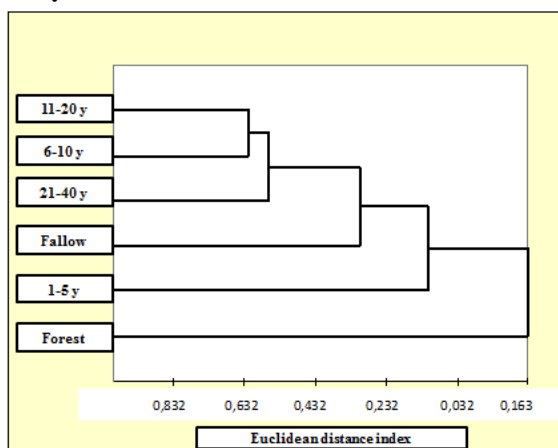


Figure 4: Hierarchical classification of 6 predefined areas based on Euclidean distance index.

The Canonical Correspondence Analysis shows different groups according to two most dominant axes (Fig. 5). The difference between the forest fragments and the areas under cacao cultivation arises progressively along axis 1. The negative part of axis 1 contains records of forest fragments (group A), immediately followed by young plantations (group B). Fallows and aged plantations are in the positive part, which form group C. Young plantations which still contain an appreciable potential of forest species are close to

forest fragments. Group C represents the agricultural practice impact which changed diversity, generally by reducing the number of forest species. So these latter plots are far from the forest group. Axis 1 could reflect the impact of progressive and intense clearing during cacao development. Axis 2 reveals a clear separation of the forest fragments into 2 groups. On the positive side, there are forests 1 and 2 proximate to young plantations and fallows. On the negative side, there is group I, which contains forest 1, in proximity to the most aged plantations (group II). Axis 2 indicates a combination of effects related to the soil and the general impact of clearing.

5. Discussion

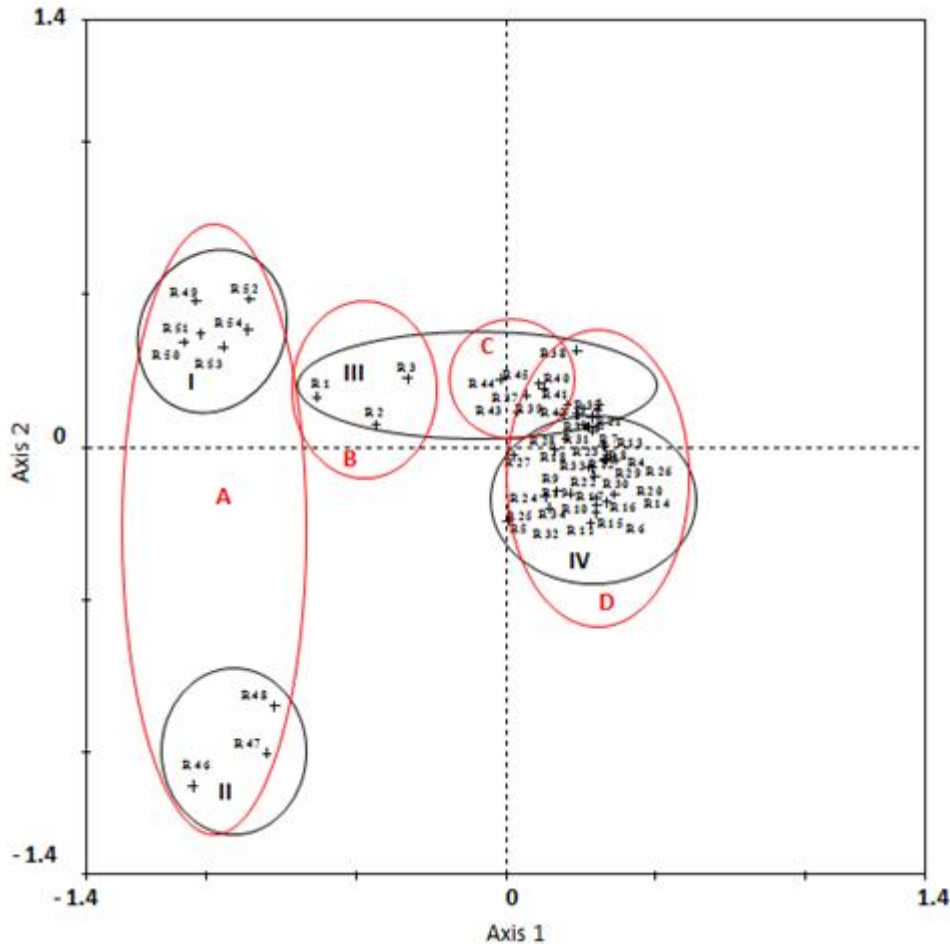
In the young plantations, right after their installation by slash and burn, the clearing method is rarely applied. In the first years, plant diversity is a function of species regeneration from stems or seeds, adding to cultivated secondary food species and all species which were spared during the installation of the plantation, partly showing a diameter greater than 10 cm d.b.h. The occurrence of certain species that had pre-existed in the flora of the initial forest island most likely is due to germination triggered by the practice of setting fires in cultures (Schnell, 1971). The potential for regeneration in young plantations was high in the areas of the Lamto Reserve and of Oumé. This observation was also made in the cashew plantations and in the region of the classified forest area of Monogaga (Koulibaly *et al.*, 2016; Adou & Kouakou, 2006). As shown by the hierarchical classification, this group of species clearly distinguishes young plantations from other utilized environments as their floristic composition remains close to the forest. In fact, these species are mainly forest species, indicating that regeneration in young plantations would lead to reforestation. This is consistent with previous work in the Lamto area (Spichiger & Pamard, 1973) which showed that food cropping in forest-savanna borders is an accelerator of reforestation. These young plantations represent a first phase in the development of cocoa plantations with a considerable potential in species regeneration.

Aged plantations represent a second phase of development in which the number of spontaneous natural species is greatly reduced due to intense clearing. The peasant eliminates certain species for promoting the development of young cacao trees. He only protects few species which are useful for food, medicine or other domains. The conservation of shade trees in the field was culturally determined and was done in the past, at the expense of crop yields, as these trees have multiple uses (Herzog & Bachmann, 1992). In contrast, the low number of adult tree species saved in plantations today contributes to reducing diversity. Yet cocoa agroforests are also important for farmers as they are less harmful to the environment than pure monocultures (Gockowski *et al.*, 1998). Also, Dawoe *et al.* (2016) demonstrated that the association of cacao with other natural species allows for enrichment of the soil; it has further been shown that these species may provide higher storage of carbon than the cacao tree (Dawoe *et al.*, 2016).

A third phase can be defined through the pruning and removal of some cacao trees to allow the increase tree

volume for more productivity. This cultural method favors the reopening of the canopy and makes this environment conducive to the development of species of both light and shade, leading to a gradual increase in the number of species. *Millettia zechiana* Harms, *Trichilia heudelotii*, *Albizia zygia* (DC.) J. F. Macbr., *Ficus exasperata*, *Mallotus oppositifolius* (Geisel.) Müll. Arg., *Albizia adianthifolia* (Schum.) W. F. Wight and *Sterculia tragacantha* Lindl. are typically found in abandoned plantations or fallows. In this phase, there is no clearing anymore as the plantation will be abandoned or replanted. In

case of abandonment, the previous impact of clearing would already have oriented the floristic composition through eliminating or promoting certain species. Consequently, the dynamics of vegetation reconstitution significantly depend on this step. Dawoe *et al.* (2016) demonstrate that keeping more natural species facilitates the reconstitution once these plantations are abandoned. In the Oumé region, abandoned plantations or fallows are floristically close to young plantations, indicating that the clearing practice did not entirely compromise regeneration of forest species.



6. Conclusion

In the young plantation, there is a strong potential for regeneration of forest species regenerating by resprouting or seeds, and plants saved during the installation of the plantation. This potential which is floristically close to the forest is lost in the 4th year of plantation due to intensification of clearing practice. The aged plantations present an impoverished flora under the reductive impact of clearing technique that will restore gradually in the abandoned plantation. This loss does therefore not lead to an irreversible situation in the study region of Oumé. Abandoned plantations or fallows are floristically close to the young plantations and contain forest species. However, the application of clearing practice, if it is necessary for production, should be better oriented to facilitate the reconstitution of the community especially in less humid regions.

7. Recommendations

The loss of biodiversity within cocoa plantations could become irreversible under unfavorable weather conditions and does not ensure subsequent reconstitution of vegetation. The clearing practice has to be refined and adapted according to specific objectives and the composition of natural vegetation accounting for the considerable potential for restoration of the natural post-cultural vegetation type. Moreover, today these plantations constitute true refuges of natural species what is important to consider for the local populations whose life depends on them. In view of the declining forest patrimony, the aging of plantations, the high parasitic pressure on the pods, but also the aging of farmers, the detection of the floristic reservoir potential of cocoa plantations should encourage Côte d'Ivoire to develop adaptive approaches to preserve the environment. The choice of agricultural practice and the accompanying policies remain to be refined in the current context of global change

to guarantee the availability of good environmental conditions and natural biological resources in spite of cultivation practices.

8. Acknowledgements

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