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RESEARCH PAPER

Ivorian cocoa farmers' perception of agroforestry: Support tools for decision making

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Abstract

This study analyzes cocoa farmer's perception on agroforestry and their adaptation strategies to climate change. It involved 316 farmers subjected to a semi-open and participatory questionnaire to assess the socio-demographic characteristics as well as their cocoa farms, their strategies to fight climate change, their preferences in terms of cocoa companion trees and their perception on agroforestry practice. The results show that more than 80% of producers are in favor of agroforestry. However, less than 25% received adequate training in agroforestry in the departments of Agnibilékro, Abengourou and Divo, and less than 15% apply agroforestry technologies to their farms. In Soubré, 50% of producers receive training and practice them on their farms. The main coping strategies of farmers are the use of fertilizers, plant protection products and shading trees. The advantages of the trees advocated by research are not always in accordance with the experience and financial requirements of producers. Agroforestry adoption by cocoa farmers would now depend on the ability of the technology to sustain cocoa yield while providing diversified resources to the farmers and some protection measure to the pests and diseases.

Keywords: Cocoa, Agroforestry, Côte d'Ivoire, Climate Change

Introduction

Ivorian cocoa annual production reached 2 million tons at the expense of the forest reserve with an annual deforestation rate around 2.78% (Koné *et al*., 2014). The deforestation has exacerbated the ecosystems with the loss of biodiversity, an important seasonal variation, an increase of greenhouse gases (Schroth *et al*., 2009 ; Läderach *et al*., 2009), the degradation of soil health and the recurrent appearance of fungal and viral pathogens (Jagoret *et al*., 2014). Moreover, decades of unsustainable practices during cocoa production such as bad shade control and weed control, low fertilizer and pesticide application, have led to degradation of cocoa farms (Assiri *et al*., 2009). Cocoa farming has thus become one of the main environmental threats (Higonnet *et al*., 2017). Yet, the cocoa sector provides livelihood to nearly six million people in Côte d'Ivoire (Tano, 2012). It is therefore, necessary to improve the sustainability of production. To achieve this, the Ivorian state has to make a transition to "Cocoa zero deforestation" to reverse the deforestation curve.

However, this operational policy is yet to be fully implemented (Ruf and Varlet, 2017). Agroforestry, as a science and technique of land use which consist in the cultivation of trees and shrubs for the benefit of smallholders (Torquebiau, 2000), appears to be one of the most important solutions for restoring the balance of ecosystems and agrosystems. This production model has been proposed in several countries as a strategy to reduce the effects of climate change (Asase and Tetteh, 2010; Cerda *et al*., 2014). It could help to break the negative spiral of environmental degradation, drop in production and food insecurity through its integration in the cocoa plantations. Although introduced in Côte d'Ivoire (Cissé, 2016) agroforestry innovation faces reluctance from farmers (Brou and Chaléard, 2007). The fact is that agroforestry is not always the first concern of the farmer and the appropriate technology is not made available to them (Brou and Chaléard, 2007).

The implementation of agroforestry systems can succeed without the consent of the rural world in which it will profoundly change the way of life through new farming practices. In such a context, it would be necessary to determine factors likely to influence the adoption of agroforestry by peasants, and perception of agroforestry in agroecological zones that have long been different of cocoa farming. The objective of this study is therefore, to analyze the farmer's perception of agroforestry as well as to identify the adaptation strategies to tackle climate change effect specifically to different agroecological zones.

Material and Methods

Study areas

The study area covered four departments and the surrounding villages: Agnibilekro (Kongodia (Lon -3.641137 ; Lat 6.903695) and Abengourou (Koitienkro (Lon -3.641137; Lat 6.903695), Amelekia (Lon -3.57522 ; Lat 6.83036)) in the Est, Divo (Ahouaty (Lon -5.163842 ; Lat 5.876386), Ogoudou (Lon -5.16052 ; Lat 5.902762), Tata (Lon -5.157794 ; Lat 5.892417), Djidjidou (Lon -5.055269 ; Lat 5.770795), Kouamekro (Lon -5.080672 ; Lat 5.768135)) in the Centre and Soubré (,Kragui (Lon -6.632916 ; Lat 5.436463), Touih (Lon -6.533522 ; Lat 5.788351), Adamankro (Lon -6.584642; Lat 5.360985) in the South-West of Côte d'Ivoire (Figure 1).

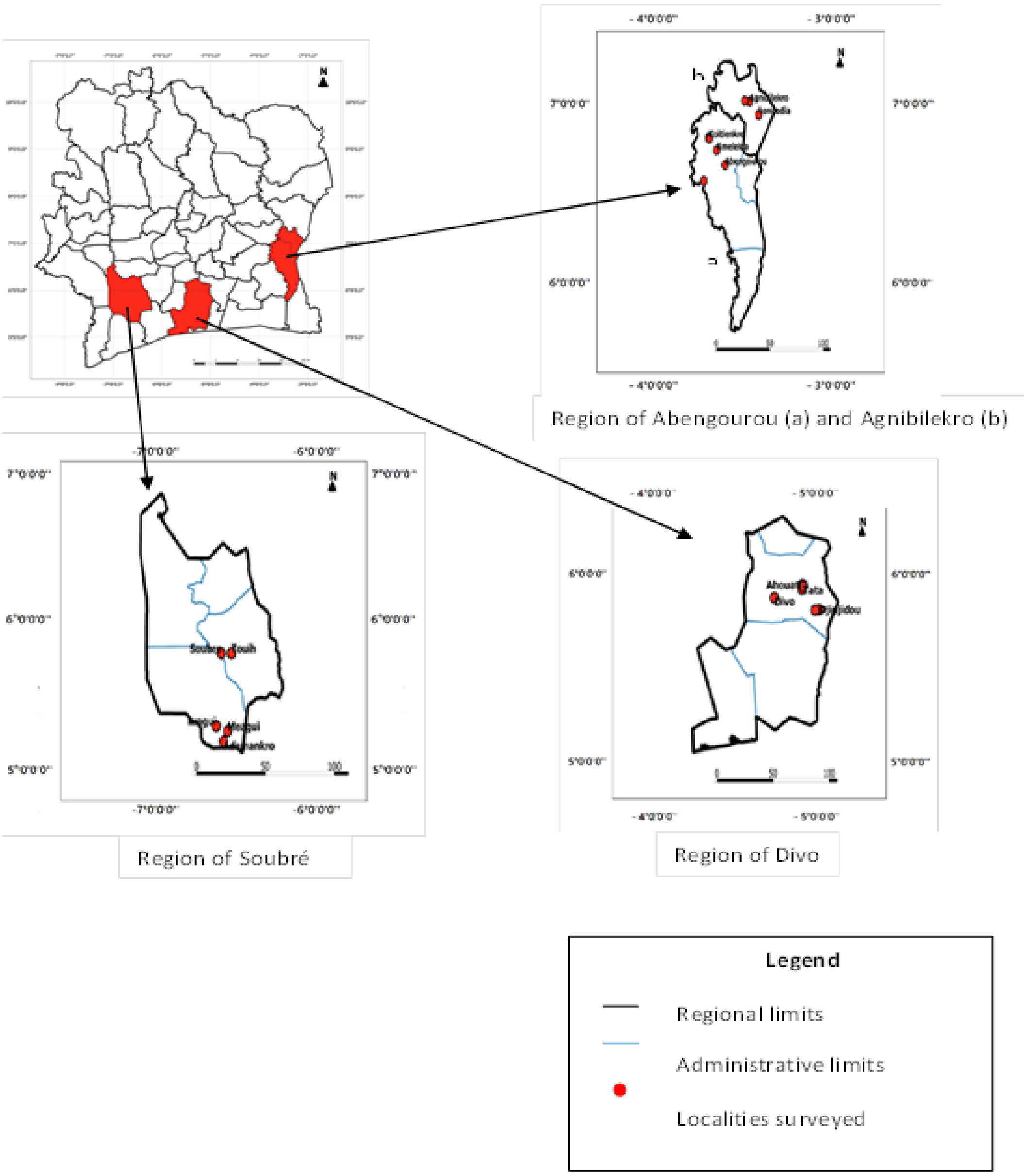

Figure 1: Map showing study site

In Agnibilekro and Abengourou, the rainfall varies between 1200 and 1400 mm per year. The vegetation consists of degraded forests and evergreen semi-deciduous forests. The soils are dystric and eutricferralsols. Divo records an average rainfall of 1605 mm/year. The vegetation is a mosaic of Guinean savannahs and semi-deciduous evergreen moist forests belonging to the mesophilic sector of the Guinean domain (Guillaumet and Adjanohoun, 1971). The annual average annual rainfall ranges from 1600 to 1800 mm (Brou, 2010). The average annual rainfall in Soubré is 1700 mm. The soils are lateritic and very sensitive to leaching. The vegetation is composed of an evergreen moist forest belonging to the Guinea-Congo basin (Kouamé and Zoro, 2010).

Methodology of survey

A semi-open and participatory questionnaire (Lançon, 2004) structured around four parts was used to collect the data. The study was stratified according to the three main cocoa successive production zones in Côte d'Ivoire. These are the East (Agnibilekro) and South-East (Abengourou), the former cocoa-growing zones characterised by old cocoa plantations; the Centre-West (Divo), marked by the cessation of cocoa expansion, the ageing of orchards and the decline in soil fertility; and finally, the West (Soubré), the current cocoa-growing zone where cocoa production developed rapidly. A total of 316 farmers were interviewed between February and june 2019, including 63 women. The information was collected on the socio-demographic characterization of the farmers and their cocoa orchards. The age and origin of the farmers and plantation age were recorded. Farmer's coping strategies to climate change were analysed. The questions submitted for this purpose provided information about the main climate change effects observed at the farm since its creation, the adaptation strategies implemented by the farmer to mitigate these effects, involving companion trees. The preferences of producers in terms of companion trees and the reasons for their choices were recorded. Specific questions were asked to know the compatible and undesirable trees in cocoa orchards, their roles, uses, advantages, disadvantages, field effect and production of cocoa trees. The list of trees was based on the experience of farmers. The trees were registered using local names. Their scientific names were later identified using "Nomenclature of Ivorian Species" and the "Flora Forest of Côte d'Ivoire" (Aubréville, 1959; Durand, 1985). The names of the families have been revised to the APG IV classification. The producer's perception of agroforestry was analyzed. The producer's perception of agroforestry was analyzed. The sources of information for the producer, the level of knowledge and supervision of techniques, the level of acceptance and implementation of agroforestry technologies, the factors limiting or motivating the practice, and producer suggestions for the success of agroforestry initiatives. Producers opinion on ten ecosystem services advocated by agroforestry was also included, namely the ability of the tree to regulate the climate, reduce weed control, increase yield, improve soil texture, fertilize the soil, maintain soil moisture, reduce pest and diseases incidence and extend the lifespan cocoa farms.

Data analysis

The data collected were entered on SPHINX plus² software (Version 5.0.0.82). The analysis was carried using the "PivotTables" wizard. Statistical analysis was carried with STATISTICA 7.1 software. The Newman-Keuls test was used to compare the means at the probability threshold of 5%.

Results

Socio-demographic characterization of cocoa farmers and characterization of cocoa orchards

The age of farmers varied from 18 to 76 years with an average of 46 years. In Abengourou and Agnibilekrou, two generations of farmers are represented, against 3 generations in Divo and 4 in Soubré. Producers aged 25-49 are the most important, followed by producers aged 50-75. The level of education in the three zones was 47.48%. Generally, the farmers have primary (29.18%) and secondary (18.3%) class levels. In Abengourou, Agnibilekrou and Divo, more than half of the producers are natives. In Soubré, 55.32% of the producers are mostly foreign migrant and national migrant (32.5%). Most farmers have fields of 2 to 5 ha established between 1960 and 2018. The size of orchards is statistically identical from one region to another. In Soubré, the average age of the orchards is 31 years (1988) and differs from the orchards in Abengourou, Agnibilekro and Divo, which have an average age of 22 years.

Farmers' coping strategies to climate change

In the areas surveyed, six main changes were observed by more than 80% of farmers. Those are, drop in rainfall, a rise in temperature, a drop in production, parasite pressure from cocoa swollen shoot virus (CSSV), a drop in soil fertility and a shift in seasons. More than 85% of producers by area noted that the drop in production is the main change. The rise in temperature and the decline in soil fertility are more felt in Agnibilékro. The drop in rain levels and the seasonal shifts were cited mainly in Divo and Soubré. The pest pressure was strongly felt in Soubré. To adapt to these changes, in Abengourou and Agnibilekro, the main strategy implemented by the producers is to associate *Anacardium occidentale* with cocoa. Farmers are considered the *Anacardium occidentale* as a soil improvement plant, with ideal shade, not favouring the parasites and making it possible to diversify the financial incomes. In Divo, *Ficus capensis* Hort.Berol*.* *Cola nitida* Schott & Endl., *Persea americana Mill.* and *Ricinodendron heudelotii* (Baill.) Pierre ex Heckel are found in numerous farms. In Soubré, the coping strategy was to keep a companion trees in the farm to ensure food and financial income. Fruit trees such as *Cocos nucifera, Ricinodendron heudelotii, Citrus capensis, Cola nitida* and *Persea americana* are found in cocoa farms (Figure 2).

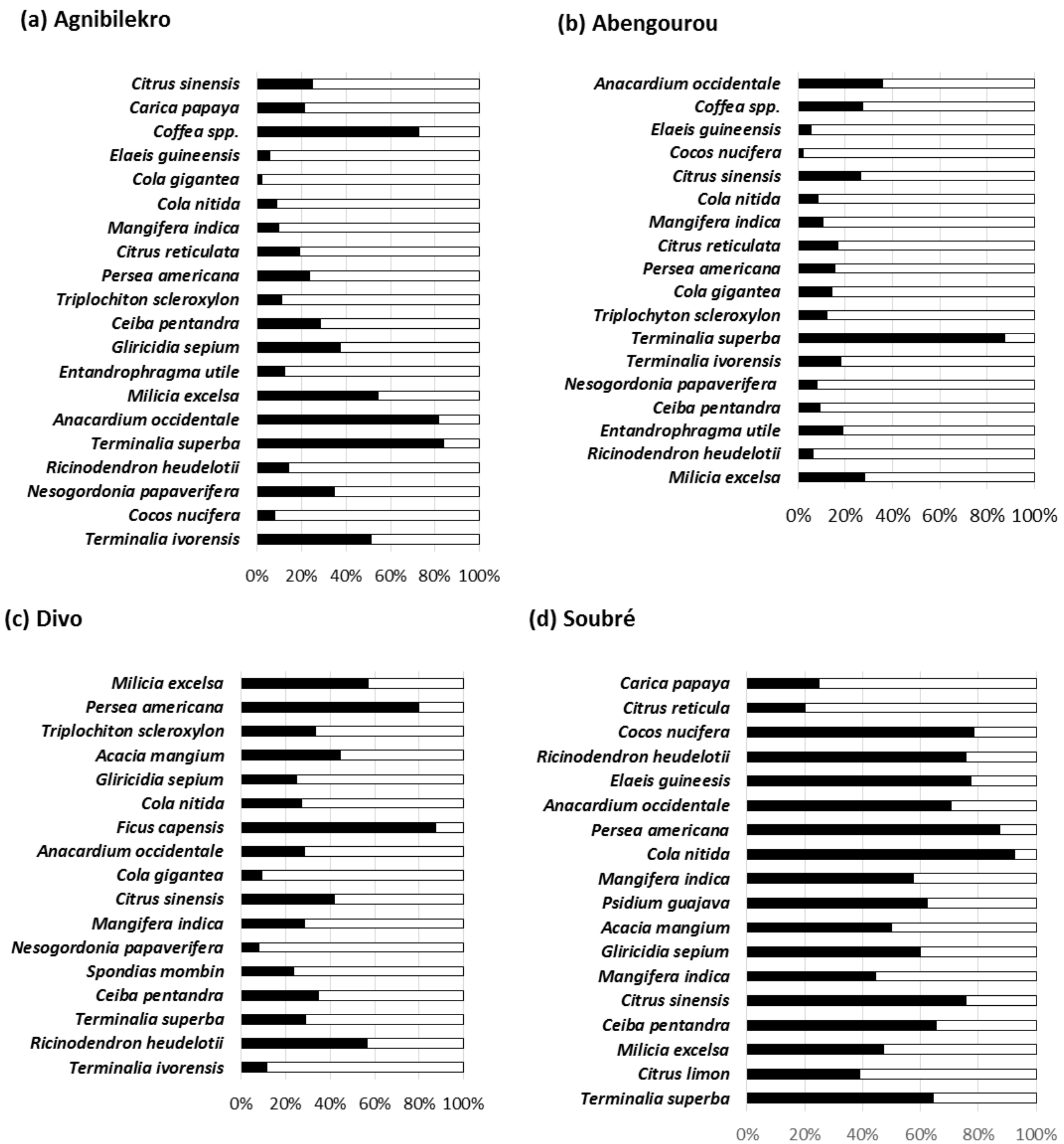

Figure 2: Preferred trees in the field in Agnibilekro, Abengourou, Divo and Soubré

In order to control pest pressure and the decline in soil fertility, farmer's strategies consisted using fertilizer and phytosanitary products to reduce parasite pressure. Another coping strategy was to maintain some trees in cocoa farm to reduce the sun's effects. The number of species required by farmers varied from one region to another. According to farmers (77.1%), the number of trees influences production conditions, as well as the growth of cocoa trees and excessive shading promotes brown rot, causes a drop-in production, excessive growth of cocoa and a production delay. But, the lack of tree induces decrease of the strength of cocoa and reducing production. In Agnibilekro, producers (30%) suggest 15 to 19 trees/ha. In Soubré and Abengourou, 10 to 14 trees/ha. In Divo, 31.97% producers recommend 5 to 9 trees/ha. In the survey areas, more than 2/3 of the cocoa farmers do not attribute to the ability of the tree to reduce parasite pressure. Indeed, according to the farmers, the trees are hosts of diseases and insects harmful to the cocoa tree. Also, some trees are designated to be able to limit parasite pressure in the plantations. These are *Colvillea racemosa, Terminalia superba, Anacardium occidentale, Milicia excelsa* in *Abengourou*, in Agnibilekro and Soubré, *Ceiba pentandra* and in Divo, *Terminalia superba* and *Terminalia ivoriensis*.

Farmers' preferences of cocoa companion trees

A vast majority of farmers (97.2%) have companion trees within their plantation. Thirteen advantages were grouped into four categories which justified the trees in the field. These included supply services (consumption, sale, pharmacopoeia, construction, and wood energy), support productivity (production increase, vigor of cocoa, soil fertilization), regulation services (shading, rain, farm sustainability) and finally cultural services (marking of territory, divine). Overall, one hundred and fifteen trees belonging to 25 botanical families are used in cocoa orchards. In Agnibilékro, 21 main compatible trees were been identified among which two were cited by more than 80% of producers. These are *Terminalia superba* (84%) and *Anacardium occidentale* (81.81%) (Figure 2a). In Abengourou, eighteen trees were considered compatible among which, *Terminalia superba* is designated by farmers (Figure 2b). In these two localities, trees are preferred for the shade and as lumber. The trees maintained within the plantations came from natural regeneration and those planted as cash crops such as *Anacardium occidentale* and Coffea spp. In Divo, 17 main trees were preferred. *Ficus capensis* and *Persea americana* are cited by the farmer (Figure 2c). In Soubré, 18 main trees are identified to be compatible with cocoa were *Cola nitida* (92.72%) and *Persea americana* (87.5%). These were also the most desired (Figure 2d). In Soubré and Divo, fruit trees or forest leguminous trees provided by cooperatives are preferred. These trees were associated with cocoa at the beginning, or in young plantations. In these regions, there was a high diversity of fruit species associated with cocoa compared to the eastern orchard. Forest species, mainly *Terminalia superba*, *Ceiba pentandra* and *Milicia excelsa*, were present in the plots before cocoa and are maintained to provide shade. Moreover, in Agnibilekro and Abengourou, and the production delays. In Divo, half of the producers opined that trees favor brown rot and deplete the soil. In Soubré, the drawbacks are linked to the drop-in production and cocoa pests, mainly rodents (squirrels) (Table 1).

Table 1: Benefits and drawbacks of companion trees in Abengourou, Agnibolekro, Divo and Soubré

Benefits	Locality (%)				Drawbacks	Locality (%)			
	Agnibilekro	Abengourou	Divo	Soubré		Agnibilekro	Abengourou	Divo	Soubré
Food	22.64	10.37	47.74	60.30	Occupies a large space	42	20	38.46	38.88
Economic value (Sale)	28.57	12	40.74	55.20	Excess shade favouring *Phytophthora* spp,	62.5	33.33	48.14	33.33
Medicinal value	31.29	19.6	33.33		production delay	40	87.5	5	2.5
Shade	57.14	33.33	43.47	87.5	Concurrence (water/ nutritional)	36	8	36	38.46
Cultural value	11.11	14.28	12.5	54.54	Pests of the cocoa tree (insects/mistletoes)	23.07	1.31	36	59.25
Increase of production	12.5	-	62.5	50	Production decline	34.37	3.125	22.58	68.42
Soil improvement		-	1.40	42.85	Branches falling	31.57	2.85	42.85	43.75
Construction	85.71	18.30	-	-	Prevents the development of cocoa trees	16.21	5.40	39.72	50.87
Sustainability	55.55	1.40	-	-	Deplete the soil	22.22	5.55	44.44	46.15
Brings rain	-	1.40	-	-	Woodcutter	9.09	9.09	36.36	87.5

Among the undesirable species, *Cola gigantea* was cited by more than half of the producers as the main undesirable species in the orchards of Abengourou, Agnibilekro and Divo (Figure 3). In Soubré, *Acacia mangium*, *Elaeis guinneensis* and *Mangifera indica* were the main undesirable. A list of the 25 main companion trees desired and 22 trees judged to be harmful is apparent from these observations Table 2 and 3.

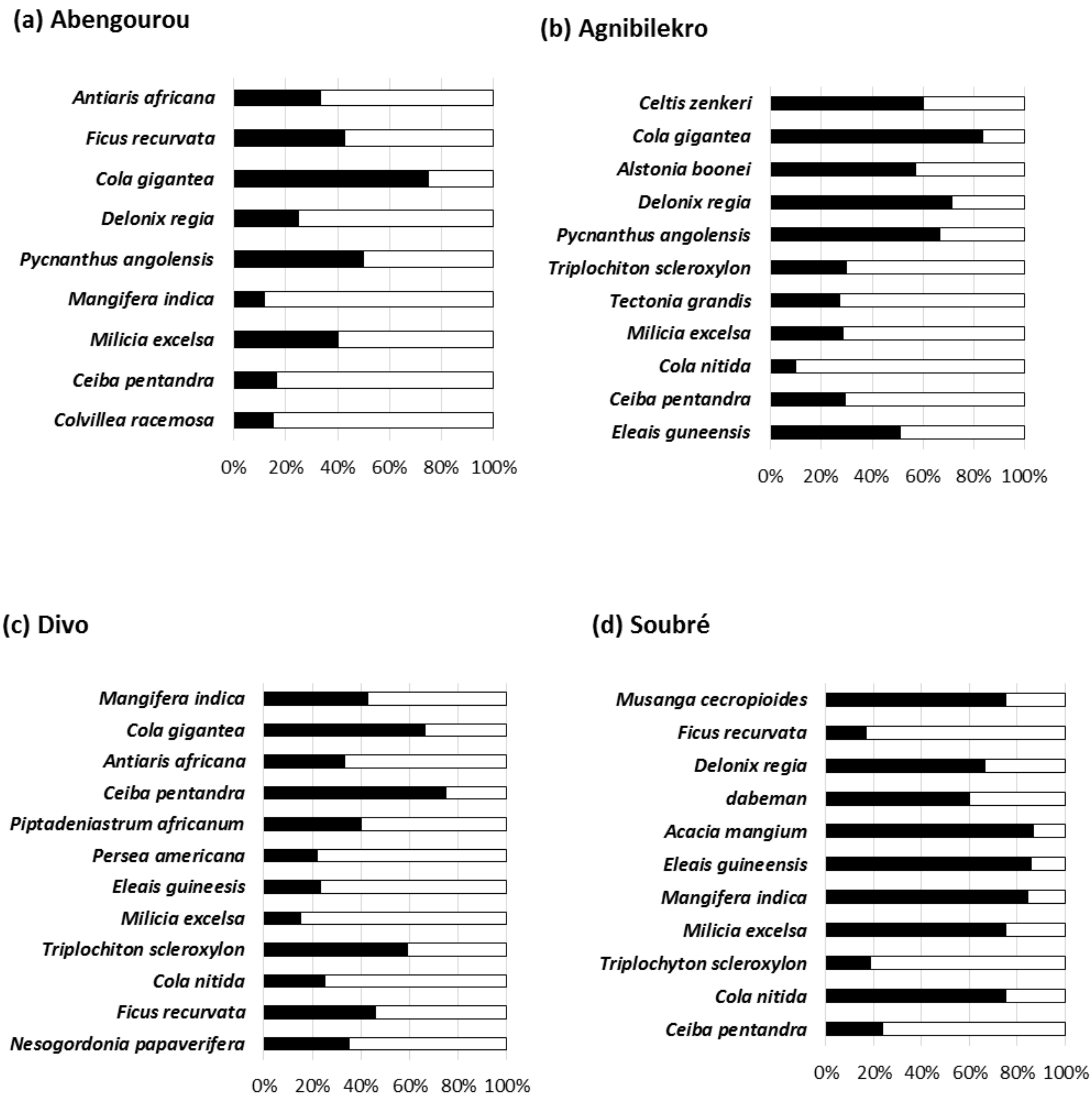

Figure 3: Undesirable trees in the field in Abengourou, Agnibilekro, Divo and Soubré

Table 2: Species compatibles with the cocoa tree, their origin and use, listed in Abengourou, Agnibilekro, Divo and Soubré

Scientific name	Family	Origin		Usage							
		Planted	Natural regeneration	Food	Medicine	Income	Bundle / energy	Timber	Shade	Delimitation / Location	Fertilization
Terminalia superba	Combretaceae		*					*	*		*
Ricinodendron heudelotii	Euphorbiaceae	*	*	Nut	Bark	*			*		*
Milicia excelsa	Moraceae		*					*	*		*
Ceiba pentandra	Malvaceae		*	leaf, root			*	*	*		*
Nesogordonia papaverifera	Malvaceae		*					*	*		*
Anacardium occidentale	Anacardiaceae	*				*					*
Terminalia ivorensis	Combretaceae		*					*	*		*
Entandrophragma utile	Meliaceae		*						*		*
adinan	*		*		Bark				*		
Gliricidia sepium	Fabaceae	*							*		*
Cola gigantea	Malvaceae		*						*		
Triplochiton scleroxylon	Malvaceae		*		Bark			*	*		
Persea americana	Lauraceae	*		Fruit		*	*		*		*
Citrus sinensis	Rutaceae	*		Fruit		*				*	
Mangifera indica	Anacardiaceae	*		Fruit	Bark				*	*	
Cola nitida	Malvaceae	*	*			*				*	
Cocos nucifera	Arecaceae	*		Fruit		*				*	
Elaeis guineesis	Arecaceae	*	*	Nut		*				*	
Coffea spp.	Gentianales	*				*				*	*
Citrus reticulata	Rutaceae	*		Fruit		*				*	
Carica papaya	Brassicales	*		Fruit	Bark						
Acacia mangium	Fabaceae	*							*		*
Psidium guajava	Myrtaceae	*		Fruit	Bark					*	
Citrus limon	Rutaceae	*		Fruit	Bark	*				*	
Ficus capensis	Moraceae		*						*		*
Spondias mombin	Anacardiaceae		*	Fruit	Bark					*	*

Table 3: Companion trees harmful to cocoa trees in Agnibilekro (Ag), Abengourou (Ab), Divo (D) and Soubré (S)

Scientific name	Family	Favors pod rot	Promotes pests	Attracts rodents	Competition (dries / impoverishes the soil	Causes physical damage	harm development of the cocoa tree	Excessive shading
Acacia mangium	Fabaceae	-	-	-	-	-	S	
Alstonia boonei	Apocynaceae	-	-	-	Ag	-	-	Ag
Antiaris africana	Moraceae						Ab, D	
Bombax buonopozense	Malvaceae	Ag	-	-	-	Ag, D	Ag, D	
Ceiba pentandra	Malvaceae	-	-	S	-	Ag, Ab, D, S	Ag,	-
Celtis zenkeri	Cannabaceae	Ag	-	-	Ag	-	-	-
Cola gigantea	Malvaceae	-	Ag, Ab, D	-	Ag	-	D	Ag, Ab
Cola nitida	Malvaceae	Ag, D, S	S	-	-	-	-	-
Colvillea racemosa	Fabaceae	-	-	-	Ab	-	-	-
Delonix regia	Fabaceae	Ag	-	-	Ag, S	-	Ag	-
Elaeis guineesis	Arecaceae	-	-	Ag, S, D	S	-	-	-
Ficus recurvata	Moraceae	-	-	-	Ab, D, S	-	-	-
Mangifera indica	Anacardiaceae	-	-	-	-	-	Ab, S, D	-
Milicia excelsa	Moraceae	-	Ag, Ab, D, S	-	-	-	-	-
Musanga cropioides	Urticaceae	-	-	-	-	-	S	
Nesogordonia papaverifera	Malvaceae	-	-	-	-	-	-	D
Persea americana	Lauraceae	-	-	D	-	-	-	-
Piptadeniastrum africanum	Fabaceae	-	-	-	D	-	-	-
Pycnanthus angolensis	Myristicaceae	Ag, Ab	-	-	Ab	-	-	-
Tectona grandis	Lamiaceae	-	-	-	Ag	-	-	-
Triplochitons cleroxylon	Malvaceae	-	-	-	Ag, S, D	-	Ag	-

Perception of agroforestry practice

Among farmers, 70.3% have already received incentives for agroforestry. About sixty-seven percent (67.39%) of the incentives came from agricultural cooperatives which taking care of 77.5% of the supervision of producers through "school farm" programs. However, in Abengourou, Agnibilekro and Divo, less than 25% of producers were trained and approximately 15% applied agroforestry techniques (Figure 4). In Soubré, more than half of the producers received training in agroforestry and 50% of the producers practice at least one of the techniques. Producers found it difficult to implement some of these practices. However, 80% of the producers were in favour of agroforestry (Figure 5). The motivating factor is increased income. The main limiting factor is excess shade. Most farmers were unanimous on the trees' ability to improve soil fertility, moisten and extend the life of orchards. However, the ability of trees to control diseases and insects was challenged by a large majority of farmers. In addition, the main suggestions from producers for the adoption of agroforestry innovations were raising awareness, increasing the purchase price of cocoa beans and the payment of premiums linked to agroforestry.

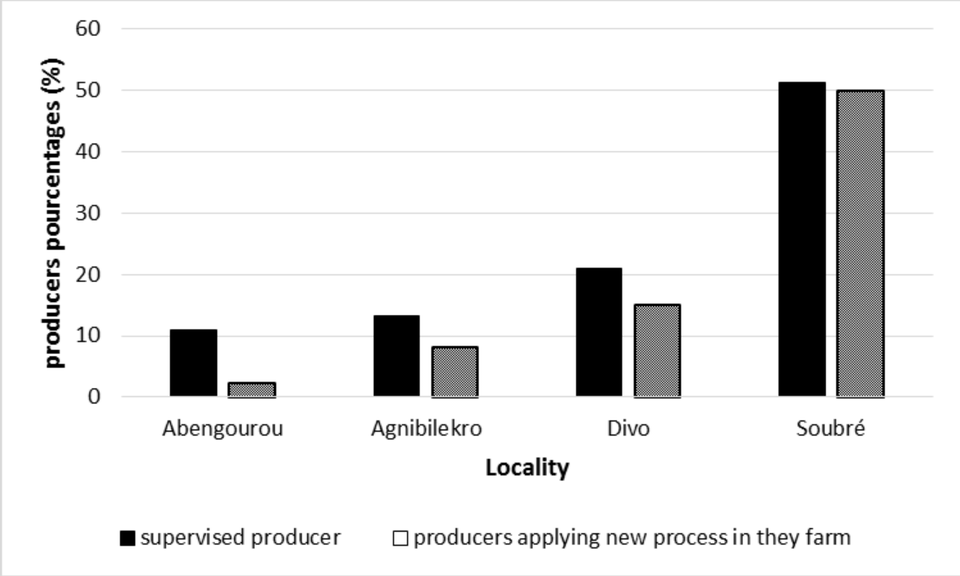

Figure 4: Rate of trained producers and rate of producers applying agroforestry techniques in Agnibilikro, Abengourou, Divo and Soubré

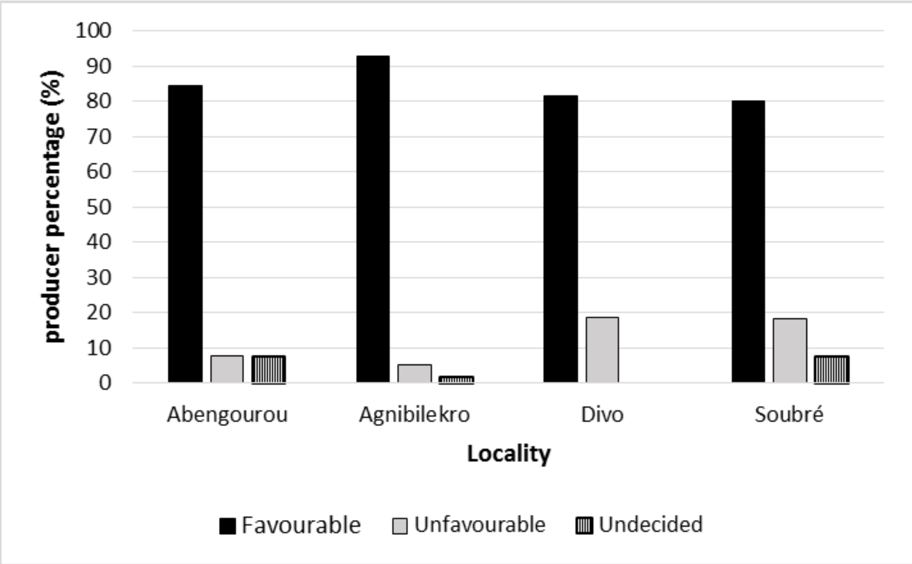

Figure 5: Level of agroforestry acceptance Agnibilekro, Abengourou, Divo and Soubré

Discussion

Socio-demographic characterization of farmers and characterization of cocoa orchards

Farmers between the ages of 18 and 40 were most interested by agroforestry initiatives. Our results are consistent with those of Gyau *et al*. (2014) and are explained by the curiosity of young people, who are more open to new agricultural practices. Moreover, the experience of older people regarding the difficulties related to the sustainability of cocoa production is a motivating factor in the practice of agroforestry. Our results mention older orchards in Agnibilekro, Abengourou and Divo (22 years) compared to those in Soubré (31 years). This suggests that cocoa farmers in these regions are in a phase of replanting orchards following the effects of the cocoa swollen shoot virus (Assiri *et al*., 2009; Koffie, 2014). In order to preserve their orchards, farmers, based on their experience, are interested in the companion tree species such as *Terminalia superba, Ficus capensis, Anacardium occidentale, Coffea* spp. and *Persea americana* which provide additional income and are capable to slow down the spread of Cacao swollen shoot virus.

Adaptation strategies and place of trees in the development strategies

The main effects of climatic change felt are the drop in cocoa production and to cope with these changes, the number of trees desired by farmers is between 10 to 19 trees/ha in Agnibilekro, Abengourou and Soubré. These results agree with those of Sanial, 2015 which stipulates that producers advocating this level of companion tree, considers the tree as an opportunity. Indeed, producers assimilate a high number of trees to the protection of cocoa trees against thermal stress. This suggests that the perception of the number of trees in the field, would result from a compromise coming from certification programs which recommend at least 18 trees per/ha and those from research according to which the cocoa reaches its maximum yield without shade. The trees wanted by farmers in cocoa farm is between 5 to 9 which, corresponds to the number of species previously listed by Ruf *et al*. (2019). This number of trees can be explained by the effective presence of trees in cocoa plantations and the lack of information for farmers on the benefits of the tree according to Gyau *et al*. (2014).

Farmer preferences in terms of companion trees

Low incomes and rising production costs have led producers to initiate innovations to increase their financial income and improve production conditions. They introduce new companion trees or maintain some whose shade is considered favourable. In Abengourou and Agnibilekro, light shade timber for construction is the most popular, as well as cash crops likes *Anacardium occidentale* and *Coffea* sp, while in Divo and Soubré, fruit trees such as *Persea americana, Cola nitida* and *Ricinodendron heudelotii* with real economic potentials are conserved. Adou-Yao *et al.* (2016) and Ruf *et al* (2019) also noted a selection of companion trees oriented towards earning additional income to that of cocoa trees. The maintenance of shade is based on the farmer's experience, variety cultivated and the economic value of the associated species (Adou-Yao and N'Guessan, 2006). The choice of *Anacardium occidentale* is explained by its resistance to drought (Ruf *et al*., 2019). Cocoa in the eastern zones (Agnibilekro and Abengourou) is affected by drought and could be replaced by *Anacardium occidentale* and *Cola nitida*. These practices appear to be a diversification option to promote cultural and economic exchanges between farmers. The aging of plantations and diseases led to a decrease in cocoa income and has favoured crop diversification. Furthermore, the reluctance observed in our study is due to that producers do not recognize in the tree the ability to reduce the high parasite pressure. In Divo and Soubré, the bad experience with *Acacia mangium* and *Gliricidia sepium* influenced the adoption of agroforestry by the farmers. However, *Colvillea racemosa, Terminalia superba, Milicia excelsa* and *Terminalia Ivoriensis* are designated to affect pest pressure in orchards. In addition to the specific species in each region, *Citrus sinensis, Anacardium occidentale, Mangifera indica, Gliricidia sepium, Terminalia superba, Ricinodendron heudelotii, Persea americana* and *Milicia excelsa* were preferred (Ruf *et al*., 2015; Adou-Yao *et al* , 2016). According to these authors, the choice of these species responds to a need to protect cocoa trees against heat stress, especially during the dry season, to maintain cocoa production and to diversify livelihoods, food security and soil fertility. *Triplochyton scleroxylon* and *Ceiba pentandra* in are designated as bad because of their negative influence on the soil and the cocoa. These trees have already been identified as causing damage to plantations by Koko-Kan and Snoeck (2013), Smith-Dumont *et al*. 2014, Adou-Yao *et al*., 2016 due to the fall of the branches, excessive shade and hydric and nutritional competition with cocoa.

Perception on the practice of agroforestry

Cooperatives have incited 70% of producers to agroforestry. Engagement with cooperatives is clearly an important source of advice on shade trees to protect cocoa during the dry season (Ruf *et al.*, 2015; Sanial, 2015). However, although the incentives for agroforestry are important, the level of supervision of producers remains relatively low in Abengourou and Agnibilekro department. This could be explained by the training programs which are directed towards of the Soubré producers. It would be advisable to balance training programs for all production areas. Most farmers want more trees on their farms, both to maintain their cocoa production and to diversify their livelihoods, particularly about their food and financial security. Finding mechanisms to receive financial benefits could facilitate the implementation of agroforestry technologies.

Conclusion

Farming practices and farmers' knowledge differ depending on the production areas and the origin of the farmers. Farmers maintain and preserve various local species, cash crops and fruit crops in their cocoa plantation to maintain production and diversify income. However, the choice of agroforestry is strongly linked to the effect of trees on cocoa production and especially on their ability to fight or not against diseases and pests present in the field. However, although a large majority of producers are ready for agroforestry, the implementation of agroforestry techniques remains weak due to the lack of supervision of producers and the poor understanding of the techniques taught. In order to ensure the sustainability of cocoa production in Côte d'Ivoire, it is therefore necessary to bridge the gap between local knowledge and research findings. By intensifying knowledge transfer and creating a link between farmers and scientists it will be possible. In-depth research is also necessary to determine precisely on the potential of companion trees designated by planters as compatible with cocoa, and in particular their impact on soil fertility, increased yield, and disease control in particular the CSSV so that region specific recommendations can be made with respect to companion trees.

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References

Adou-Yao CY, Kpangui KB, Vroh BT, Ouattara D (2016). Pratiques culturales, valeurs d'usage et perception des paysans des espèces compagnes du cacaoyer dans des agroforêts traditionnelles au centre de la Côte d'Ivoire. Revue d'ethnoécologie, 9, mis en ligne le 1er juillet 2016. https://doi.org/10.4000/ethnoecologie.2474

Adou-Yao CY, N'Guessan EK (2006). Spontaneous floristic diversity of cocoa and coffee plantations in the classified forest of Monogaga, Côte d'Ivoire. Schweizerische Zeitschrift für Forstwessen 157:31-36. https://doi.org/10.3188/szf.2006.0031.

Asase A, Tetteh DA (2010). The role of complex agroforestry systems in the conservation of forest tree diversity and structure in southeastern Ghana. Agroforest Syst 79:355–368. https://doi.org/10.1007/s10457-010-9311-1.

Assiri A, Yoro G, Deheuvels O, Kebe BI, Keli ZJ, Adiko A, Assa A (2009). Les caractéristiques agronomiques des vergers de cacaoyer (*Theobroma cacao* L.) en Côte d'Ivoire. J Anim Plant Sci 2:55–66.

Aubréville A (1959) La flore forestière de la Côte d'Ivoire. Centre Technique Forestier Tropical. Nogentsur-Marne, 3 vol, 372 p, 342 p, 334 p.

Brou TY, Chaléard JL (2007). Peasant visions of environment in Ivory Coast. Annales de géographie 653:65-87. https://doi.org/10.3917/ag.653.0065

Cerda R, Deheuvels O, Calvache D, Niehaus LA, Saenz Y, Kent J, Vilchez S, Villota A, Martínez C, Somarriba E (2014). Contribution of cocoa agroforestry systems to family income and domestic consumption: looking toward intensification. Agroforestry Systems 88:957-981. https://doi.org/10.1007/s10457-014-9691-8

Cissé A, Aka JCK, Koumé D, Vroh BTA, Adou Yao CY, N'guessan KE (2016). Characterization of cocoa-based agroforestry practices in areas of dense semi-deciduous forest: case of the locality of lakota (centre-west, Côte d'Ivoire). European Scientific Journal 12:50-69. https://doi.org/10.19044/esj.2016.v12n21p50

Durand PY (1985). Nomenclature des essences ivoiriennes: noms vernaculaires, noms commerciaux, noms scientifiques. Nogent-sur-Marne : CIRAD-CTFT, 20 p.

Guillaumet JL, Adjanohoun E (1971). Végétation in de la Côte d'Ivoire. In : Avenard JM, Eldin M, Girard, Sircoulon J, Touchebeuf de Lussigny P, Guillaumet JL, Adjanohoun EP, Perraud A. Mémoires ORSTOM, Environment naturel de la Côte d'Ivoire. Paris, 50:161-263.

Gyau A, Smooth K, Kouame C, Diby L, Kahia J, Daniel O, Tchoundjeu Z (2014). Farmer attitudes and intentions towards trees in cocoa (Theobroma cacao L.) farms in Côte d'Ivoire. Agrofor Syst. https://doi.org/10.1007/s10457-014-9677-6

Higonnet E, Bellantonio M, Hurowitz G (2017). Chocolate's Dark Secret: How the cocoa industry destroys national parks, Washington, Mighty Earth, 24 p.

Jagoret P, Kwesseu J, Messie C, Michel-Dounias I, Malézieux E (2014). Farmers' assessment of the use value of agrobiodiversity in complex cocoa agroforestry systems in central Cameroon, Agroforestry Systems 88: 983-1000.

Koffie K (2014) Diversité moléculaire du CSSV (*Cocoa swollen shoot virus*) et épidémiologie de la maladie du swollen shoot du cacaoyer (*Theobroma cacao* L.) en Côte d'Ivoire. Thèse de doctorat, Université Félix Houphouët Boigny.

Koko Kan L, Snoeck D (2013). Cacao-Fruit Tree Intercropping Effects on Cocoa Yield, Plant Vigour and Light Interception in Côte d'Ivoire. Agroforestry Systems 87: 1043–1052. DOI:10.1007/s10457-013-9619-8.

Koné M, Kouadio YL, Neuba DFR, Malan DF, Coulibaly L (2014) Evolution of the forest cover in Coted'Ivoire since 1960 to the beginning of the 21st century. International Journal of Innovation and Applied Studies, 7:782–794.

Kouamé NF, Zoro BIA (2010). Nouveau découpage de la zone de forêt dense humide de la Côte d'Ivoire. African journals online (AJOL). Sciences & Nature 7:177-194. https://doi.org/10.4314/scinat.v7i2.59962

Läderach P, Martinez AV, Schroth G, Castro N (2013). Predicting the future climatic suitability for cocoa farming of the world's leading producer countries, Ghana and Côte d'Ivoire. Climatic Change. 119:841–854. DOI 10.1007/s10584-013-0774-8.

Lançon J, Lewicki S, Floquet A, Sêkloka E, Djaboutou M (2004). Participatory evaluation of cotton lines created by the Producer-Selectors of Benin: Workshop proceedings (16-17 November 2004, Parakou, Benin), Montpellier: CIRAD, 12 p. Workshop for the evaluation of the material resulting from participatory cotton selection in Benin, Parakou, Benin.

Ruf F, Kone S, Bebo B (2019). Côte d'Ivoire's cashew nut boom: A social and ecological transition of the cotton and cocoa systems. Cah. Agric. 28:21. https://doi.org/10.1051/cagri/2019019

Ruf F, Schroth G, Doffangui K (2015). Climate change, cocoa migrations and deforestation in West Africa: What does the past tell us about the future? Sustain Sci 10:101–111. https://doi.org/10.1007/s11625-014-0282-4

Ruf F, Varlet F (2017). The myth of zero deforestation cocoa in Côte d'Ivoire. In: Pasiecznik N, Savenije H (eds.). (2017). Zero deforestation: A commitment to change. Tropenbos International, Wageningen, the Netherlands, pp 86-92.

Sanial E (2015). À la recherche de l'ombre : analyse du retour des arbres associés dans les plantations de cacao ivoiriennes. Mémoire de Master, Université Jean Moulin Lyon 3. https://doi.org/10.13140/RG.2.1.1341.6723

Schroth G, Laderach P, Dempewolf J, Philpott S, Haggar J, Eakin H, Castillejos T, Moreno JG, Soto Pinto L, Hernandez R, Eitzinger A, Ramirez-Villegas J (2009). Towards a climate change adaptation strategy for coffee communities and ecosystems in the Sierra Madre de Chiapas, Mexico. Mitig Adapt Strateg Glob Change 14:605–625.

Smith-Dumont E, Gnahoua GM, Ohouo L, Sinclair FL, Vaast P (2014). Farmers in Cote d'Ivoire value integrating tree diversity in cocoa for the provision of ecosystem services. Agrofor Syst. doi:10.1007/s10457-014-9679-4.

Tano AM (2012). Crise cacaoyère et stratégies des producteurs de la sous-préfecture de Méadji au Sud-Ouest ivoirien. Thèse de doctorat, Université Toulouse 2 Le Mirail.

Torquebiau EF (2000). A renewed perspective on agroforestry concepts and classification. Comptes rendus de l'Académie des sciences, série III, Sciences de la vie 323 : 1009- 1017.