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Sugar complex of Zuenoula (Central-West of Côte d'Ivoire), an example of a functional agro-ecosystem

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Abstract

The effects of climate change observed in Côte d'Ivoire are expressed dangerously on the production of sugar cane, the main source of existence of sugar structures like SUCRIVOIRE. So, SUCRIVOIRE decided to develop a policy to protect the immediate environment of sugarcane cultivation in an agro-ecosystem context. In order to clearly define the axes of this environmental policy, which aims at supporting and guaranteeing sugar production, it was important to evaluate all the ecosystem goods and services offered by the Zuénoula sugar estate, hence the initiation of this work. To carry out this work, a floristic inventory method based on the itinerant technique was carried out in the off-sugar plots. A socio-cultural and socio-economic survey was carried out among the living populations on the SUCRIVOIRE Zuénoula estate. The results of the work revealed the cohabitation of the sugar cane crop with seven (7) natural forest reserves of 120.54 ha and containing 471 species, including 11 species with special status and 17 species representing species exploitable in terms of timber artwork; thirteen (13) crops other than sugar cane occupying 392.28 ha and belonging to 324 farmers for whom the only cultivation of rice yields the sum of 433 822 500 FCFA per year. It emerges from this study that this agro-ecosystem in its operation, presents itself as a high natural value agriculture offering services such as: the supply of food, financial and genetic resources, that of support in primary production and habitat and that of microclimate control. These different services are guidelines for a sugarcane environmental protection policy that must be based on a program of planning, sustainable and participative management.

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Introduction

As part of the diversification of its agriculture, long based on the coffee/cocoa binomial since independence and also for the reduction of regional disparities as well as rural exodus, Côte d'Ivoire opted in 1971 for the establishment of agro-industrial structures such as SODESUCRE (State Corporation for the Development of Sugar Cane Plantations) (Brou, 2005). This structure, which led six (06) sugar complex, was replaced by SUCAFCI and SUCRIVOIRE (Borotou and Zuénoula) in 1997.Sugar cane culture, in Côte d'Ivoire as elsewhere where it is produced, has many advantages in terms of multifunctionality in the context of rural development: income creation, service delivery and other agricultural production (Kouassi *et al*, 2019). These many services offered by sugar complex result in a considerable human flow that exerts a high human pressure on the complex with its corolars in terms of economic and food needs (Kouassi *et al*., 2019).

At the Zuénoula sugar complex, where this phenomenon is very visible, the protection of the environment and biodiversity is an important part of SUCRIVOIRE's socio-environmental policy, which results in the protection of forest flaps, the reforestation of certain endangered tree species and the allocation of plots to populations for growing food crops. All these actions make these agro-industrial structures, true agro-ecosystems whose overall functioning is poorly known.In Côte d'Ivoire, there is very little work on agro-ecosystems and even less on those represented by sugar complexes; elsewhere, however, agro-ecosystems have been the subject of numerous studies worldwide, such as that of AUGUSTE (2010) in Haiti.

This work aims to provide information on the functioning of this agro-industrial structure as an agro-ecosystem. This research initiative has one main objective, that of characterizing the unregistered and unencrypted agricultural activities that are practiced in the SUCRIVOIRE perimeter in Zuénoula apart from the exploitation of sugar cane through an inventory of biological groups, a directory of all agricultural activities carried out and a definition of their economic value.

Materials and methods

Study area presentation

The sugar estate in Zuénoula is located in the west-central part of Côte d'Ivoire, in the Marahoué between latitude 7°25'45" North and longitude 6°02'35" West. The terrain is sparsely rugged and has an average altitude of 250 metres. Zuenoula is located in the Guinean mesophile sector (N'Brah *et al*., 2013) and represents a climatic transition zone between the southern half more watered (1200 to 1800 mm rains / year) and the north drier (1100 to 1600 mm rains / year). The climate is baoulean type and has a dry season and a rainy season. The dry season runs from November to February with average temperatures ranging from 25.8°C to 26.7°C and average rainfall ranging from 4 mm to 57.8 mm. The rainy season lasts from March to october with temperatures ranging from 25.6 to 28.9°C and average rainfall ranging from 100.3 to 212.7 mm (Fig.1). Most of the arable land consists of ferralitic soils, which have been modified and slightly desatured with a mosaic of forest and savannah (Kouassi *et al*., 2019) dominated by species such as *Cola laurifolia*, *Leptoderis cyclocarpa*, *Pterocarpus santalinodes*, *Imperata cylindrica*, *Panicum maximum*, *Rottboellia exaltata*,*Polygonum lanigerum*, and *Echinocloa pyramidalis* (MINEF, 2007). The current population of the Zuenoula Sugar Complex is 15,000 compared to 2,600 people in 1991 (N'Guessan, 2011) and more than 11,000 people live around this complex (Sifca, 2011).

Study strategy

The equipment used consisted of a camera for the taking of images, a GPS type Garmin Etrex 30 for the recording of geographical coordinates and a map of the sugar estate for orientation. For crops other than sugar cane, a survey of owners was carried out on the basis of a fact sheet which included surname and given names, level of education, age, gender, occupation, marital status, how the land was

acquired, the origin of the seed, the number of years of operation, the yield of each crop, the selling price of the crop. The inventory of plants other than sugarcane was made during several field visits.

It was done according to the tower-of-field method. During the inventory, the following parameters were taken into account: the location, the floristic composition, the area, the type of vegetation and the cycle for the case of crops.

The agro-economic approach focused on the economic value of the products from the different crops surveyed.

Thus, the discounted selling price of the unit of production expressed in kilograms was recorded on the market. For each crop, the average yield obtained for all producers was evaluated in financial terms on the basis of that of the unit of production.

Data processing and analysis

The identification of plant species was done with the forest guide of the flora of Côte d'Ivoire (Aké-Assi, 2002). Data processing was performed with Microsoft office 2016 (Word, Excel) software.

The mapping software ARCGIS 10.2.2 has enabled us to establish the location map of the listed plants.

Results

Zuénoula sugar complex covers a total area of 11750 ha with 7000 ha of sugar cane plantations or 59.57 pc of occupation.

The investigations carried out on site made it possible to name two (2) large vegetable groups, namely the wooded areas which include natural forest reserves (Fig. 2) and plots of reforestation (Fig.3) then the cultural groups. Fig.4 shows the distribution and location of these plants groups at the site.

Table 1. Floristic list of special species (1) and exploitable species (2).

floristic list			Natural forest reserves		
N°	species	families	FG	FR	FP
1	*Aframomum sceptrum* K. Schum. (1)	Zingiberaceae	x		x
2	*Albizia adianthifolia* (Schumach.) W.F. (2)	Mimosaceae	x	x	x
3	*Albizia ferruginea* (Guill. &Perr.) Benth. (2)	Mimosaceae	x	x	x
4	*Antiaris toxicaria* var. welwitschii (Engl.) (2)	Moraceae	x		x
5	*Baphia bancoensis* Aubrév. (1)	Fabaceae		x	x
6	*Ceiba pentandra* (Linn.) Gaerth. (2)	Bombacaceae	x	x	x
7	*Cola caricaefolia* G. Don (1)	Sterculiaceae	x		x
8	*Dalbergia oblongifolia* G. Don (1)	Fabaceae	x	x	x
9	*Dialium guineense* Willd. (1)	Caesalpiniaceae	x		x
10	*Dioscorea sansibarensis* Pax (1)	Dioscoreaceae	x		x
11	*Eriosema molle* Hutch. ex Mi Ine (1)	Fabaceae	x	x	x
12	*Erythrophleum suaveolens* (Guill. & Perr.) (2)	Caesalpiniaceae	x	x	x
13	*Hymenocardia acida* Tul. (1)	Euphorbiaceae	x		
14	*Lannea acida* A. Rich. (2)	Anacardiaceae	x		
15	*Lannea nigritana* (Sc. Elliot) Keay (2)	Anacardiaceae	x		x
16	*Mansonia altissima* (A. Chev.) A. Chev (2)	Sterculiaceae	x		x
17	*Parkia biglobosa* (Jacq.) Benth. (2)	Mimosaceae	x	x	
18	*Pouteria alnifolia* (Bak.) Roberty (2)	Sapotaceae	x	x	
19	*Premna hispida* Benth. (1)	Verbenaceae	x	x	x
20	*Sterculia setigera* Del. (2)	Sterculiaceae	x	x	
21	*Sterculia tragacantha* Lindl. (2)	Sterculiaceae	x	x	x
22	*Terminalia belerica* Roxb. (2)	Combretaceae	x		x
23	*Terminalia ivorensis* A. Chey. (1, 2)	Combretaceae	x		x
24	*Terminalia mentaly* H. Perrier (2)	Combretaceae	x	x	x
25	*Terminalia scimperiana* Hochst. (2)	Combretaceae	x	x	x
26	*Triplochiton scleroxylon* K. Schum. (1, 2)	Sterculiaceae	x	x	x

Wooded areas

There are seven (7) natural forest reserves covering a total area of 120, 54 ha. Floristic inventories carried out in these forest relics made it possible to count 471 species spread over 96 families and 179 genera. These forest relics are protected by SUCRIVOIRE, who has made them ecological sites where people are forbidden to make samples.

These reserves consist of a primary forest island (FP) of 5, 61 ha, 4 island forest galleries (FG) of 83, 15 ha and 2 islands of riparian forest (FR) 31, 78 ha.

Table 2. List of reforested species in Zuénoula SUCRIVOIRE.

N°	Reforested species	Common names
1	*Tectona grandis* L. f (Verbenaceae)	Teck
2	*Acacia mangium* Willd (Mimosaceae)	Acacia ou cachou
3	*Eucalyptus globulus* Labill (Myrtaceae)	Gommier bleu
4	*Entandrophragma angolense* (Welw.) C.DC	Tiama
5	*Mansonia altissima* A. Chev. (Sterculiaceae)	Bois Bete
6	*Gmelina arborea* Roxb. (Verbenaceae)	Melina
7	*Terminalia ivoriensis* A. Chev. (Combretaceae)	Framire
8	*Terminalia superba* (Engl. & Diels) (Combretaceae)	Frake
9	*Ricinodendron heudoletii* (Bail.) (Euphorbiaceae)	Akpi
10	*Pericopsis elata* (Harms) Meeuwen (Fabaceae)	Assamela

These forest relics are characterized by the presence of 11 species with special status and 17 species considered as exploitable species in terms of timber. Table 1 gives the floristic list of species with special status and species that can be exploited and present within the various natural forest reserves. The reforested plots cover 439.92 ha with ten (10) different species present in protected natural forest reserves and Table 2 gives the list.

Table 3. Most important crops and number of people practicing these crops and the areas occupied by each crop.

Most important crops	Yam	Cassava	Rice	Plantain banana
Number of people	67	88	268	30
Area in ha	12	13,51	321,35	3

Table 4. Economic value of the three major crops other than sugarcane grown at the Zuénoula complex.

Major crops	Number of farmers	Area (ha)	Production / ha / cycle (ton)	Production / year (ton)	Unit price (fcfa)	Economic value (fcfa)
Cashew	26	18,88	1,9	35,87	600	21 523 200
Cocoa	6	10,67	2,5	26,68	750	20 010 000
Rice	268	321,35	2,25	1446,075	300	433 822 500

Socio-economic value of crop sets

The investigations carried out include 13 crops other than sugar cane and occupying 392,28 ha on the complex. The crops are cocoa (*Theobroma cacao*), oil palm (*Elaeis guineensis*), cashew (*Anacardium occidentalis*), rice (*Oryza sativa*), eggplant (*Solanum aethiopicum* and *Solanum macrocarpon*), onion (*Allium cepa*), yam (*Dioscorea rotundata* and *Dioscorea alata*), cassava (*Manihot esculenta*), chili (*Capsicum annuum*), gumbo (*Abelmoschus*

esculentus), tomato (*Solanum lycopersicum*), plantain banana (*Musa spp*) and beans (*Phaseolus vulgaris*). Of these 13 inventoried crops, rice, cassava, yam and plantain banana are the most important and Table 3 shows the number of people practicing these crops and the areas occupied by each crop.

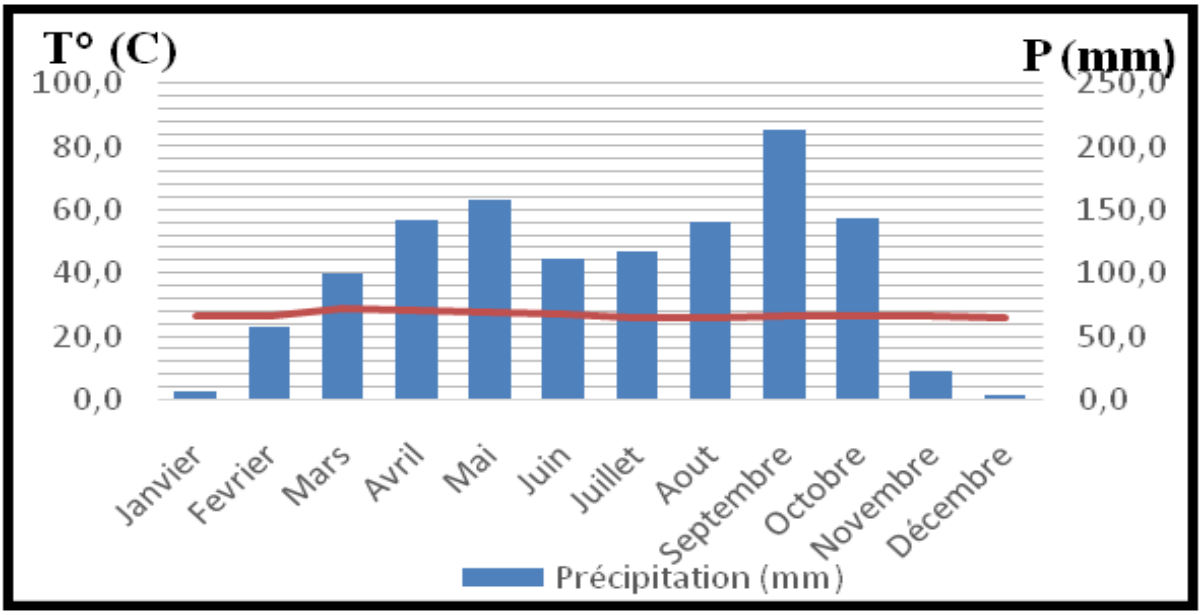

Fig. 1. Ombrothermal diagram of the Zuénoula department from 2007 to 2019 (sources: data from the study).

All these crops involve a total of 324 farmers, 80% of whom are the workers of SUCRIVOIRE and their production, for major crops such as cashew, cocoa and rice, are included in Table 4.

Fig. 2. Natural forest reserves

An economic approach to these productions has been adopted and the economic analysis is also reported in Table 4.

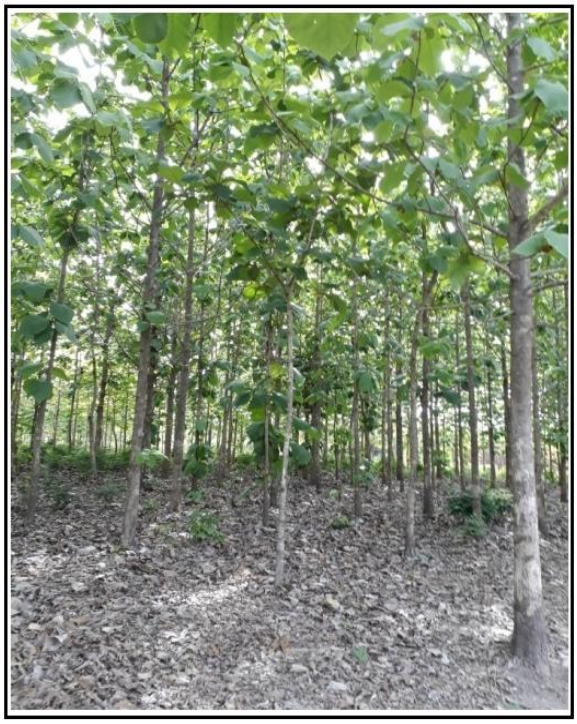

Fig. 3. Plot of reforestation.

The observation of the results shows that there is strong human pressure on the complex as to the

availability of land allocated to crops other than cane.Indeed, for all inventoried crops occupying 392,28 ha, 324 farmers are found;for cash crops and basic necessities, the supply-to-demand ratio is very low: 0,1 ha per person for plantain, 0,17 ha per person for yam, 0,15 ha per person for cassava, 1,2 ha per person for rice, 0,76 ha per person for carda and 1,78 ha/person for cocoa. The last three crops, which alone employ 300 farmers on the sugar complex and 350,9 ha, have an annual production of 475 355700 FCFA with 433 822500 FCFA for the only rice crop that remains the most practiced and extensive crop.

Discussion

The seven (07) forest relics and the reforested areas sampled for this work contain 250 plant species strictly protected by the Zuénoula sugar industry.

One of the characteristics of these plants is the presence of 11 species endemic to Côte d'Ivoire and 15 species representing species exploitable in terms of timber. The protection, creation and maintenance of woodlands by the sugar industry is in line with the environmental and biodiversity protection policy of the Ivorian State.

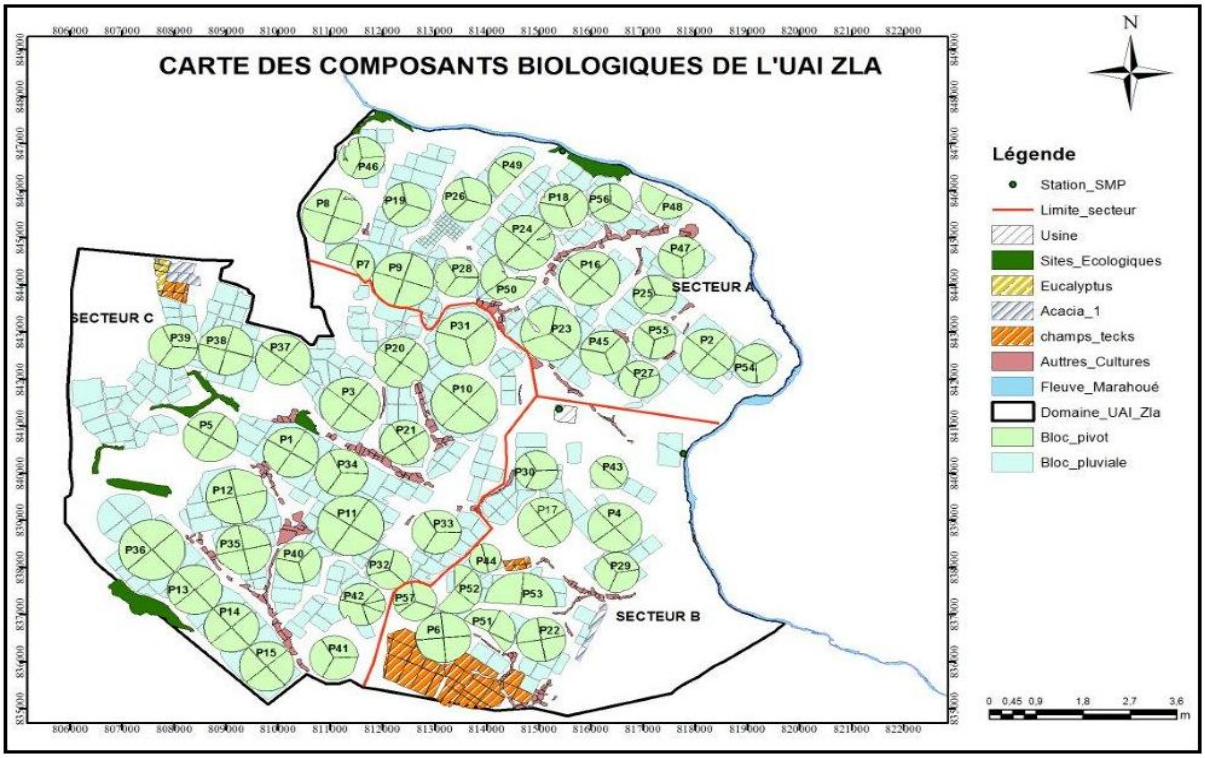

Fig. 4. Map of the plant assemblages of the UAI Zuénoula.

This policy of the sugar industry is thus an obstacle to the loss of biodiversity that Le Roux (2008) considered a negative effect of agriculture on the diversity of the environment.In fact, the homogeneity of sugar cane cultivation, the use of pesticides, the transformation of habitats, Nutrient inputs for crop use are the main negative effects of agriculture on environmental diversity (Auguste, 2010). These woodlands contain, according to Kouassi *et al.* (2012), 128 species of birds and 24 species of mammals. Their protection represents a major benefit for the preservation of the wildlife species in the area. These forest relics and reforested areas that can be considered as voluntary nature reserves integrated into the canning agricultural system constitute sub-agroecosystems having an ecological role to regulate and maintain the microclimate of the area (Dorcine, 2004;Auguste, 2010). This complex is thus a heterogeneous agro-ecosystem that Le Roux *et al.* (2008) considered to have positive effects and to play the role of biological reservoir.Indeed, agriculture is one of the main drivers of biodiversity loss but can contribute to the conservation and sustainable use of biodiversity (Gaudreau, 2012) as SUCRIVOIRE does

in Zuénoula. Apart from the protected wooded areas, the inventory also shows 13 different types of crops planted on 392,28 ha and involving 324 farmers on the same site. Consideration of thisreality gives the Zuénoula Sugar Complex the value of an agro-ecosystem that contributes to the well-being of populations by offering ecosystem goods and services. These farming systems can thus be regarded as sub-ecosystems of supply and support.It is therefore clear that this monoculture of cane performs various functions for the well-being of both humans and the environment, as CDB (2008) noted in his work on the link between agriculture and biodiversity in Quebec. At this stage, it is understandable that biodiversity and agriculture are interdependent on this complex and this agro-ecosystem provides key goods and services that may even have significant economic impacts, as shown by the results of the economic survey of the crops surveyed.

Services resulting from the functioning of this canning agro-ecosystem give it, according to Poux and Ramain (2009), the status of a “high natural value agriculture” characterised by a food and genetic resources supply service, a primary production and habitat support service and a microclimate control service.

Conclusion

This work made it possible to inventory various plant groups other than sugar cane with different characters. In fact, there are 560.46 ha of protected woodlands containing 471 different plant species with 11 species with special status and 17 species representing exploitable species in terms of timber. We also note the presence of 13 types of crops other than sugar cane established on 392.28 ha and belonging to 324 farmers, 80% of which are SUCRIVOIRE workers. The wooded complexes contain a diversity of plant and animal biodiversity and thus constitute a reservoir of biodiversity and provide an ecological role of regulation of the microclimate. The crop groups tha coexist with the cane are an Ancillary agricultural activity that does not depend on the sugar administration. They not only provide food to the in situ populations but also a fairly significant financial added value, with the sum of 433, 822,500 FCFA per year for rice cultivation alone. Overall, the operation of this agro-ecosystem demonstrates the perfect interdependence that can exist between agriculture and the immediate environment and then provides a variety of ecosystem goods and services such as food supply, financial and genetic resources, support for primary production and habitat, and microclimate control.

These different ecosystem services are self-guidance for a sugarcane environmental protection policy that must be based on a program of management, sustainable and participative management for the survival of the cane farm of which depend on many families.

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