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Tentative prediction of cocoa yield (*Theobroma cocoa* L.) in farmer's field in Cameroon

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ABSTRACT

The study aims to identify the explanatory factors of the commercial cocoa yield farmer's fields in 9 villages located in 4 agro-ecological zones of Cameroon. The method of analysis statistical of segmentation CART was used to explain the variables of the output according to all the explanatory variables available. The test was carried out starting from the data of two years diagnosis, in 36 farmer's plots where the observations related to 30 cocoa trees, that is a total of 1080 trees. The genetic Type, the vigour off the tree (section), flowering (flowers cushion), the bios attackers (stings pods rate and rotted pods rate) and the climate factors (the monthly average temperature and monthly rainfall) were the parameters measured to try to explain the variables of production (the number and the weight of harvested cocoa pods). The results obtained show that the hybrid genetic type have rate of trees in farmer's field is more than 33%, predicted 250% increase production in pods number and weight. Moreover, it was observed that the rate of stings and rotted pods was reduced by 2% when the temperature lied between 24 and 27°C and the mean annual rainfall equal gold less than 1775mm. Moreover the rate of things pods fruits was reduced by 2/3 (two thirds) the number of flowering when this one is lower than 2066. The rate rotted pods was reduced by 40% when the section of the cacao-trees is higher than 138 mm ².

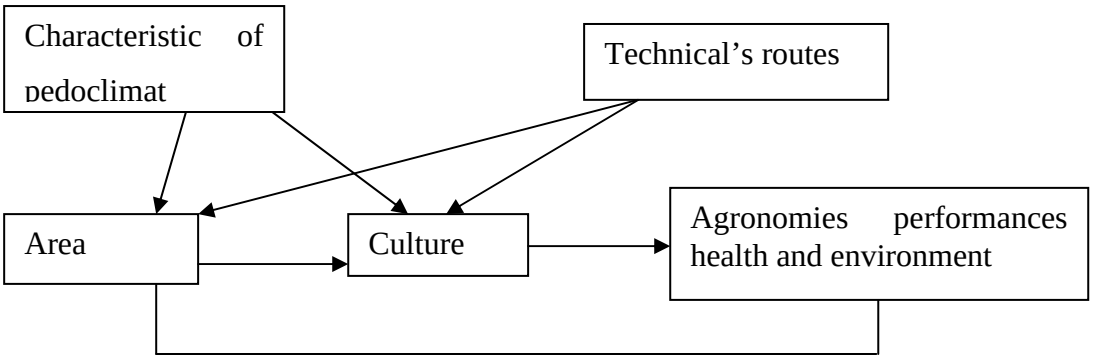
Keywords: Predict yield, Farmer' S studs, CART segmentation, Cocoa tree.

INTRODUCTION

The cocoa-tree (*Theobroma cocoa* L.) is a plant originating in tropical America [7] cultivated in Cameroun, in the forest belt of the Center, South-west and Littoral. This zone has a hot and wet climate whereas the high plateau of the West and the North-west with cold climate are the almost exclusive field of the culture of the coffee-tree. The cacao-tree is cultivated for the cocoa beans which is an importance source of income for many peasants.

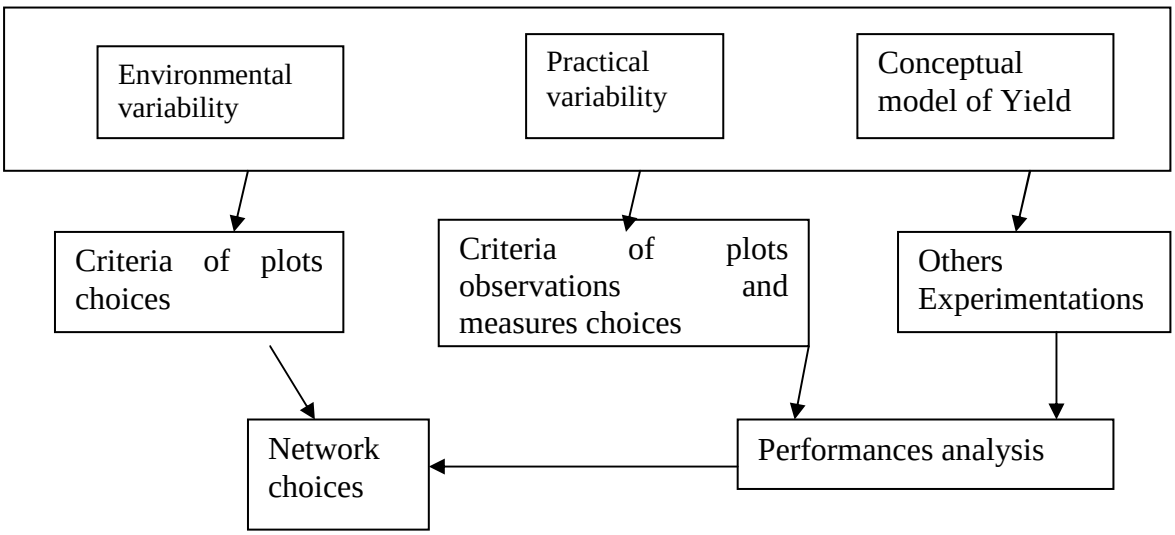
In agronomy of the cacao-tree, a recurring problem posed with research is the establishment of technical routes having really physiological justifications. At the frequent request of the farmers, it is important to be able to diagnose the "operation" of the plots in order to really identify the "unproductive" plots, to understand the causes of the encountered problems and to bring, if possible, the corrective measures to the adopted technical routes. That could be carried out thanks to the development (or by the adaptation to the cacao-plantations) of a relatively simple "model" explaining the compartmental production using a minimum of parameters.
A general step of agronomic diagnosis exists and was developed and formalized in agronomy in the case, mainly of the field crops of the North of France [6]. The following diagram recalls the broad outline of them and could be adapted to cocoa-culture. They are in fact a diagram analysis the relations of culture and areas.

Diagram 1: Relationships between culture and area (T. Dorée and al. 1997)



This step is based on the quantification of the parameters of the environment (pedoclimat), the cultivation methods, and then agronomic performances of a network of representative plots, to inquire and observe. Analysis of the performances (to be chosen: output, quality of the product, behavior in the various risks, etc) must lead to a hierarchisation factors of variation of performances. And so only the knowledge of the output of the cacao-tree is wished, the weight of pods is well correlated with the commercial cocoa weight [8].

Diagram 2: Hierarchisation factors of variation of performances of many years



The tools and the methods for statistical analysis were develop in agronomy to contribute to the decision-making [1,2]. The goal is not to find a solution optimal of model but to explain in a farmer's field the variable to be explained according to all the explanatory variables. To predict the observations in field of the behavior of the cacao-tree in the pieces, the segmentation CART, method of discriminating statistical analysis reliable and is standardized. In this study the method of segmentation CART is used to highlight the genetic type, the strength of the tree (the section), flowering (floral bearings), the bio attackers (rate of fruits stings and rotted fruit rate) and the factors climatic (the monthly temperature average and monthly pluviometry), which is the parameters measured to try to explain the variables of production (the number and the weight of pods collected) on the one hand and the bio attackers, in particular, the mirides [3] and it *Phytophthora* spp [12] in addition, in optics to propose the technical routes for an increase in the productivity cacao-plantation in farmer's fields [10]. The knowledge of these factors would have contributes to improve it the production in the plot cacao-plantations and the income of the peasants.

MATERIALS AND METHODS

Data observations

It is about the two years diagnosis, in 36 farmer's fields of cacao-tree distributed in 9 villages located in 4 agro-ecological zones at Cameroun. The observations related to 30 cocoa trees by plot, that is to say a total of 1080 cocoa trees. The variables observed or measured are:

On the level of the villages we measured: the average temperature day (in °C) and pluviometry (in mm) day. On the level of each cocoa tree, the circumference of the stems to 50 cm height [8], the number of the floral bearings enter to 150cm height, the varieties of the cacao-tree (standard genetics), the number of fruits stings, the number of fruits rotted, the number and the Weight of pods collected.

For these data, the genetic Type (Amelonado, Hybrid, Trinitario), the strength of the tree (the section in cm ^{2}), flowering (the number of floral bearings), the bios attackers (fruit stings rate and rotted fruit rate) and the factors climatic (the average temperature per year in °C and pluviometry per year in mm) were the parameters measured to try to explain the variables of production (the number and the weight of dent collected). Indeed on the 4 zones of study, 2 are with rather young plantations (Talba and Bokito) and 2 others with old plantations (Ngomedzap and Obala).

The numerical photographs take the general form of the type of vegetable material of the trees, their sheets and of their pods are realized. The identification of material was done with the CIRAD by Geneticist of the cacao-tree.

Method of segmentation CART

The software used is the SPSS Answer Tree [15]. It is based on the squares of the probabilities of appearance to each category of the node, and is reached its minimum (zero) when all the observations of the node are included in only one target category.

Construction of maximum tree $T_{Max:}$

- Sample base t_0.
- Of one predictor X_j, we search a dichotomy modalities X_j we have two segments decreasing t_g and t_d maximizing $\Delta(t_g,t_d)$.
- If X is nominal, the dichotomy is no defined.

- If X is ordinal, the dichotomy is $\{[X \leq i],[X > i]\}$
- Of ith procedure of one segment decreasing the procedure is stopped how we defined low of segmentation.

The pruning of the tree is based on the rule of the standard error, i.e. the selected program smallest under tree to which the risk is close to that to under tree having the minimum risk. Algorithme CART pruning is :

$$T_{\max} = T_1 \supset T_2 \supset T_3 \supset \ldots \supset T_{\text{racine}}$$

Where T_{Max} is the same as T_{racine} and help to construct the generation of tree by $T_k = T_{(\alpha k)}$, *The generation complexes penalties* α_k *are:*

$$0 = \alpha_1 \leq \alpha_2 \leq \alpha_3 \leq \ldots$$

The choice of Tree T_j of minimum number of pruning need t calculate:

$$C(T_{\max}) = C(T_1) \leq C(T_2) \leq \ldots \leq C(T_{\text{racine}})$$

$$\text{Ecart-type}\left[C(T_{\max})\right] = \sqrt{\frac{C(T_{\max}) \times \left[1 - C(T_{\max})\right]}{n}}$$

$$C(T_j) \leq C(T_{\max}) + \lambda * \text{Ecart-type}\left[C(T_{\max})\right]$$

And λ=1

The risk is calculated by taking the proportion of observations of the sample incorrectly classified by the tree. The error count standard used is by defect 1. The maximum number of levels of the tree is 5. The minimum number of observation in a node relative is 8. The nodes including/understanding less observation will not be divided. The minimum number of observations in a node child is fixed at 4. If the scission of a node has as a result a node child of which the number of observations is lower than this value, the node will not be divided. These two values were fixed compared to the number of observations which is relatively weak. The segmentation is carried out on each variable to explain according to all the explanatory variables. The rate error and best under tree are estimated using the method of re-substitution and cross validation [11]. The use of the technique of segmentation, rather recent makes it possible to take into account the interactions between the explanatory variables [4,5].

Data Analysis

The data collected on a tree scale were gathered to use them on a compartmental plot. The factors affecting the number and the weight of pods collected, the fruits stings and rotted fruits were identified with the assistance of a model of regression per tree of segmentation CART with version 3.1 of SPSS Answer Tree. Moreover, the correlations were carried out with software SAS version 9.1 [14] to the threshold of 5%.

RESULTS AND DISCUSSION

Table 1 presents the variable numbers pods and emphasizes that the hybrid factor of the genetic type can explain it in second year with an average value of prediction of 259 dent and this when more than 33% of the hybrids are present in each farmer's field with an increase on average of 225% of the number of pods collected.

Table 1: Variable numbers Pods collected

Period	Average of the variable	Explanatory factors	Characteristic value	Predicted average value
1st year	139			
2nd year	115	Hybrid	>33%	259
2 years	254			

Table 2 presents the variable weight of pods collected. In second year and for the two years of study, the hybrid factor of the genetic type seeks to explain the weight of pods collected with average values of prediction of 93170 grams in second year and 230660 grams for the two years, that is to say, respectively an increase on average of 258% and 246% of the weight of pods collected at the compartmental level.

Table 2: Variable "Weight of pods collected"

Period	Average of the variable	Explanatory factors	Characteristic value	Predicted average value
1st year	57507			
2nd year	36149	Hybrid	>33	93170
2 years	93656	Hybrid	>33	230660

Of these two measured variables of the development of the output to knowing the number and the weight of pods, the presence of the Hybrids when they are with more than 33%, will increase the production in farmer's field with the double and half.

Table 3 presents the variable "fruits stings". For the first year of study, factors, pluviometry and bearing explained state of punctures of pods being able to involve a loss of production. With more 938mm of rains, the rate of punctures is predicted of 21% and with a value lower or equal to 2598 of the bearings, it is 15%. For the 2nd year, of 25% initial of rate of punctures, we will be able to predict 15% with a characteristic value lower or equalizes with 1794 bearings per plot of 30 trees. And for the 2 years always at the rate of stings of 25% and the same value characteristic of the number of bearings as in 2nd year, the predicted value is de17% of the rate of punctures. The plot having a number of floral bearings lower on average than 2066 will reduce the rate of pods stings rate of 40%. The presence of the heterogeneous cacao fields, having Several genetic groups a choice would offer to the attacks of the stings of the insects as a private individual of the mirides [3,13].

Table 3: Variable "fruits stings"

Period	Average of the variable	Explanatory factors	Characteristic value	Predicted average value
1st year	26%	- Pluviometry - Bearing	>938 ≤ 2598	21% 15%
2nd year	25%	Bearing	≤ 1794	15%
2 years	25%	Bearing	≤ 1794	17%

Table 4 presents the variable "fruits rotted". For the 1era year of study, factors, average temperature, pluviometry and section explained state of the fruits rotted of pods being able to

involve a loss of production. With a value inferior or equalizes with 27°C, the rate of rot of pods is predicted of 4%, with a value lower or equal to 1547mm of rains, it is 3% and when the section with a characteristic value higher than 138mm ², the predicted value is 2%. For the 2 years, of 5% of initial rate of rot, the factors of climate which are the average temperature and pluviometry explain the rate of rotted of pods with characteristic values superior with 24 for the temperature and lower or equalizes with 2840mm rains having a predicted value of 3%. Largest sections (> 138mm ²) having a great number of pods will reduce the rot of pods rate of two thirds.

Table 4: Variable "rotted fruits"

Period	Average of the variable	Explanatory factors	Characteristic value	Predicted average value
1st year	6%	- T° average - Pluviometry - Section	≤ 27 ≤ 1547 >138	4% 3% 2%
2nd year	3%	-	-	-
2 years	5%	- T° average - Pluviometry	>24 ≤ 2840	3% 3%

The coefficient of correlation of the various variables used for this study is presented at table 5 and emphasizes that the variables of development of output which are the number pods and the weight of dent have a significant correlation by report/ratio of the genetic type and their of relation is equal to or higher than 50%. We note also a significant relation of 37% between the rate fruits stings and the genetic type Amelonado. The average temperature is as well correlated with an opposite relation of 61% of the variable rate of rotted fruits.

Table 5: Correlation Coefficients of variables in two years.

	Numbers pods	Weight pods (Pdca)	Section	Bearing	Rate fruits stings (Tfpiq)	Rate rotted fruits (Tfpou)
Pdca	0,96***	-0,01	-0,15	0,29	-0,03	0,05
Section	-0,06	0,45**	0,16	-0,11	0,37*	-0,25
Bearing	0,52**	-0,17	-0,19	0,03	-0,12	-0,14
Tfpiq	-0,16	-0,30	0,08	0,36*	-0,05	-0,61***
Tfpou	-0,15	-0,61***	-0,05	0,34*	0,15	0,02
Amelonado	-0,57**	0,80***	-0,05	0,18	-0,08	
Hybrid	0,72***	0,55**	-0,29	0,13		
Trinitario	0,50**	-0,18	0,07			
Average T°	-0,01	-0,13				
Pluviometry	-0,08					

***, **, * *threshold of significance to α=5%*

The age of the trees of cacao-tree in the plot plays an important part in the production as well as other factors such as the shade and the fertility of the ground [8].

CONCLUSION

The use of the technique of rather recent segmentation CART, made it possible to bring new elements on the factors influencing the development of the output and the bios attackers of the cacao-tree. For an increase of 250% the production pods some and in weight of the cacao-tree in the farmer's field, the piece must have more than 33% of the hybrid genetic type. This suggests in practice that the farmer's field cocoa-plantation can consist of two or of three genetic types with a strong percentage of hybrid. Moreover, pluviometry and the temperature influence the rotted fruit and fruit stings rate. Indeed, the reduction of the rotted fruit rate and stings are of at

least of 2% when the temperature lies between 24°C and 27°C, with a lower average pluviometry or equalize with 1775mm. This end product will make it possible to the technician of rural development to better popularize the seedlings of hybrid developed at the point by agricultural research with close to the producers of the cacao-trees and to suggest the effect of the climate on the means of fight which are in connection with the loss of pods.

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