Land use change and food security: Has introduction of rice production in cotton zone in Benin met optimal allocation of resources by households?

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Biography

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Abstract

Land use is one of major source of decrease of soil fertility and food insecurity. In Benin cotton is the main cash crop. The benefits derived from this crop become an opportunity for producers who changed their land use and invested a lot effort and resources in it. This caused a decline of the soil fertility and exposed farmers to food insecurity and to environmamntal damages.The introduction of rice production becomes an alternative for diversifying agriculture in order to face some of previous cited problems. Re-change the land use becomes one possibility and the farmers cultivates several crops in the year which enter in competition in terms of resources use.

This study carried out in Benin, analyses the rationality of farmers in the management of his farm and finds out the allocation of resources that allow him to maximise his profit.

The model built showed that rice is the most profitable crop while cotton gross margin is low. It reduces then the area of cotton for about 56%. It allows the production of maize, sorghum, peanut and the soy bean for ensuring the food security of the household whereas rice and the bean have an economic importance.

Key words: Land use, food security, rice, cotton, Benin

1. Introduction

The rural world faces nowadays several problems such as food insecurity, climate change, deforestation, decline of soil fertility etc. Food security is an issue of great and growing concern in many countries, particularly in Africa. Despite global pledges, the recent report of the United Nations Special Report on the Right to Food highlighted that the number of people suffering from hunger has increased every year since 1996 (UNCTAD, 2008). For the first time ever the number of hungry people passed the one-billion mark in 2009 (EED, 2010). All these problems compromise the rural development and put rural population into the situation of vulnerability and poverty.

Benin is confronted to food insecurity and the problem exists with acuteness. In order to tackle the situation a lot of agricultural policies were launched. One of the most famous is the diversification of the agriculture in order to vary the source of income and improve the food security by producing food crops.

In fact agricultural sector in Benin contributed to about 39% of GDP and employed about 80% of population in 2002 (UNDP, 2003). Cotton is the main cash crop in this sector which contributes to about to 64% of export income, 90% of agricultural revenue and 24% of state revenue (OBEPAB, 2002). The farmers found its cultivation as an opportunity and changed the land use in its favor in order to increase the production with intensive use of chemicals. This situation causes a decline of the soil fertility and exposed farmers to food insecurity and to environmamntal risks and damages. The production of food decreased and made farmers vulnerable to food security. This situation was worsened by the recent decrease of the cotton price on international market which lowers the cotton price offered to farmers. Farmers' life then was compromised and the food insecurity and poverty increase.

The agricultural policy in order to solve this problem proceeded to the introduction and the reinforcement of rice production in different regions of Benin. This introduction of rice has been done also in cotton production zone due to the fact that the cotton zone is rich of land and dregs appropriate for rice production which are not farmed or not properly.

In fact the department[1] of Alibori, big producer of cotton, is also one of the departments which produce a big quantity of rice (34 % of the national production). The municipality of Banikoara[2] is situated in this agro-ecological zone with important dregs of 4756 ha in 2006 (Sector CeCPA Banikoara on 2006) favorable to the cultivation of rice. However, the producers of this zone regularly complained about the low performance of their farm which

[1] Benin is divided into 12 regions or sub-states called departments (In French: department)
[2] First municipality producer of cotton in the Alibori region and the whole country.

has a negative impact on their income. The launch of rice production in this region is based on all these advantages it has for rice production. The possibility to re-change the land use becomes obvious and the farmers cultivate then several crops in the year which enter in competition in terms of resources use.

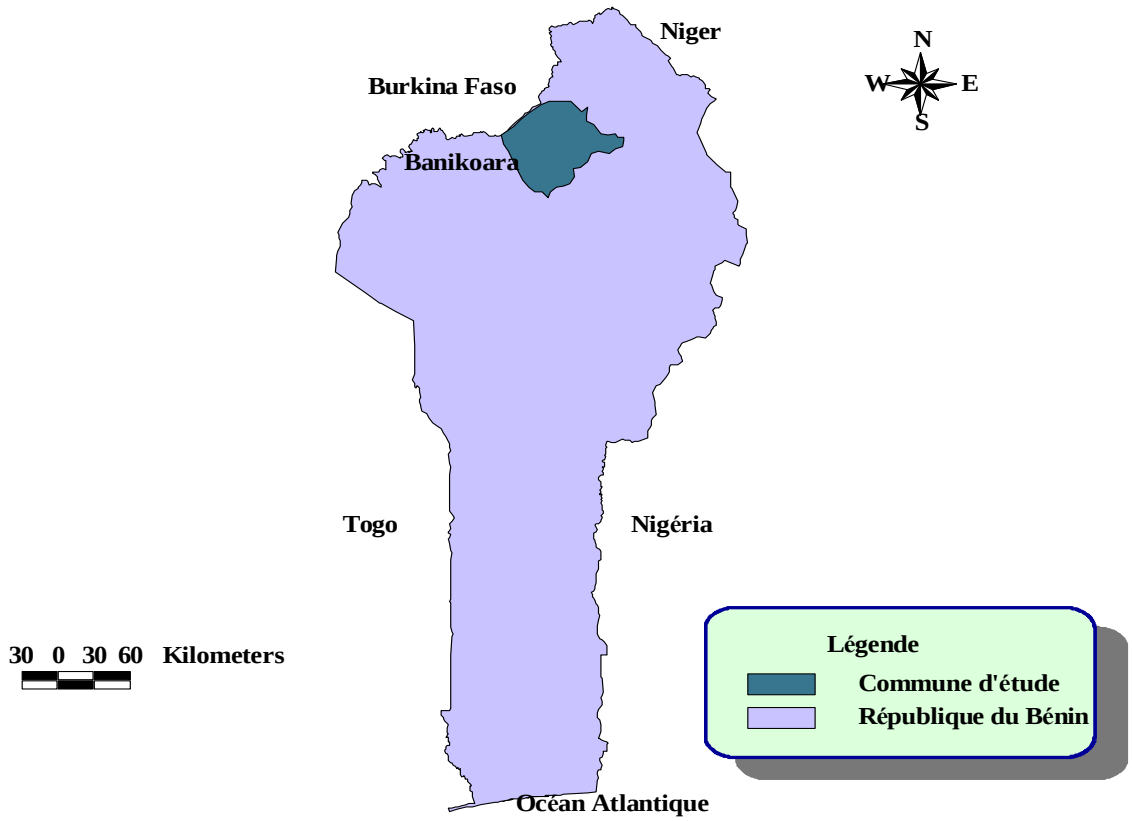
To manage better the cohabitation of rice and cotton in this zone and allow the farmers to increase their income to make more successful their farm, it is thus necessary to investigate in the North of Benin whether the farm is profitable, economically efficient and viable long-term to contribute not only to increase the income of the producers but also and especially to contribute to cover the national needs of the rice and to save currencies from import.

This study carried out in towship of Banikoara in Benin, by using the linear programming analyses the rationality that guide the producer in the management of his farm and finds out the allocation of resources that allow him to maximise his profit.

2. Study area

The municipality of Banikoara is situated in the Northwest of the department of Alibori, between in latitude 10°50 and 11°45 North and in longitude 2 ° and 2°55 East. It is bordered in the North by the municipality of Karimama, in the South by the municipalities of Kérou and Gogounou, in the East by the municipality of Kandi and in the West by Burkina Faso. It covers 4.383 km² among which approximately 49 % of arable land and 50 % of forests classified (National park " W " of the river Niger and upper Alibori).

Banikoara belongs to the second agro-ecological zone. This zone is a known zone under the name of "Cotton Zone of the North-Benin" because the economic life of the region is dominated, indeed, for the last three decades by cotton production. It covers, except from the municipality of Banikoara, the municipalities of Ségbana, Gogounou and Kandi in the department of Alibori and municipality of Kérou in the department of Atacora.



3. Methodology

Data were collected in two villages (Kokey and Kokiborou) in Banikoara. In all 71 households were surveyed. The approach used consists in determining a representative average farm which cultivates rice and cotton. Therefore the average farm is formed by five active persons among whom two men, two women and one permanent farm worker.

Seven activities (crops) were retained within the framework of the elaboration of the model. These activities correspond to the main crops cultivated by the farmers (rice, cotton, maize, some sorghum, bean, soya and groundnut)

C = {rice, cotton, maize, sorghum, bean, soya, groundnut}, with C the set of crops

- **Availability and constraints of land**

The available land is represented by the area of land effectively cultivated by the representative farm in 2006 and not the area of land it owns in all. Two types of land were distinguished by taking into account physical characteristics of the land. It is about dregs for the cultivation of rice and the dry land for cotton, maize, sorghum, bean, groundnut and soya.

Hence the available of land is limited to the average area of dregs and dry land cultivated by the average farm.

Table 1: Availability of land expressed in ha

Type of land	Availability (ha)
Dregs	0,515
Dry land	9,77

Source: Survey, 2007

The following constraints are formulated for land:

Sup (riz) ≤ dsps1 ;

∑sup(C-{riz}) ≤ dsps2.

Where dsps1 is the area of dregs available for rice cultivation.

Dsps2 is the total area available for the cultivation of cotton, maize, sorghum, bean, groundnut and soya.

- ☞ **Availability of and constraints of labor**

The labor is a major constraint and its management is one of the pillars of the production. Two types of labor were considered: family labor and paid workers. Regarding the family labor three periods were considered by taking into account the cultivation calendar:

Period 1(April to June): The activities of cleaning of land, plowing and sowing for maize, cotton, sorghum, soya, groundnut, rice and bean are done. The application of herbicide for cotton, maize and sorghum begins during this period.

Period 2(July-August): It is the period of weeding for rice. Most of the crops receive the fertilizers. The hoeing and the application of insecticides for the most part of the crops are also made during this period.

Period 3(September à January): it corresponds to the period of harvest of the crops.

The constraints of labor is: ∑ ∑mo (p, c) ≤ dspmo (p)

Where mo (p, c) labor required for cultivating 1 ha of crop c during the period p;

Dspmo (p): labor available during the period p

Regarding the paid workers the number is not a constraint but rather the money for acquiring is the constraint.

Table 2: Availability of family labor in man-day

Period	Availability(man-day)
Period 1	318
Period 2	219
Period 3	427,5
Total	964,5

Source: Survey, 2007

- **Constraints related to input-credit payments**

The cotton cultivation allows farmers to have access to the input credit. The farmers have the possibility to request for the quantity of inputs corresponding to their forecast of area to be cultivated. There is thus no limit in the wanted quantity. The most important thing is to be able to pay off from the revenue gained after cotton sale. If this revenue does not cover the inputs cost they should be able to pay from the other sources. The GV[3] is the local institution responsible for the collecting of the debts related to inputs. In this study it was supposed that only the revenue gained from the sale of the cotton allows paying off the inputs credits. Let us indicate that the inputs are supposed to be used only for cotton but it has been noticed that the farmers overestimate the quantity of inputs for cotton and use the surplus for the food crops. But this situation is not expressed in the model. The model considers that all credit is reimbursed by cotton revenue.

The constraints are as followed:

$\sum$ (prfum*qfum+prins*qins+prher*qher)*x(c) $\leq$ REC ;

REC = prv(cot)*prod(cot);

prfum= price of sale of 1kg of chemical manure in FCFA/kg;

qfum= quantity manure for 1ha of crop in Kg ;

prins= price of sale of 1L of insecticide in FCFA/L ;

qins= quantity of insecticide necessary for 1ha of crop in L ;

prher= price of sale of 1L of herbicide in FCFA/L ;

qher= quantity of herbicide requested for 1 ha of crop in L ;

REC= revenue from cotton in FCFA;

prv(cot)=price of sale of cotton in FCFA/Kg ;

prod(cot)=production of cotton in Kg.

[3] GV means "Groupement villageois", group of farmers

Table 3: Expenditures related to the purchase of manure, insecticide and herbicide (FCFA/ha).

Types of expenditures	Expenditures (FCFA/ha)						
	Rice	Cotton	Maize	Sorghum	Beans	Groundnut	Soya
Manure	42359,15	55902,39	32083,81	463,38	-	-	9212.44
Insecticides	-	34515.28	-		7937.84		404.35
Herbicides	28646.85	13044.05	10534.85	1885.72	1284.51	864.32	1539.31

Source: Survey, 2007

- **Use of stock for seeds**

Farmers often keep seeds for the next season from the available harvest for current year. Therefore a relationship between the quantity of seeds to be stocked and the area of production it has been stocked for is written as followed:

SMNCE(c) = sem(c)*sup(c)

sem(c) : Average quantity of crop c to be stocked for sowing 1 ha in kg ;

SMNCE(c): quantity of crop c to be stocked in kg;

rend(c) : yield of crop c in kg/ha ;

PRO(c): harvested production of crop in kg;

PRO(c) = rend(c)*sup(c).

PROD1(c): Harvest of crop *c* available for consumption in kg

STOCKO(c)*:* stock of crop c from previous season in kg

PROD1(c) = PRO (c) – SMNCE(c)

STOCKO(c) =0

- **Availability and constraint of capital**

The available funds in capital are the capital used by the producers to pay workers. These available funds are represented by a part of the income of harvest.

- **Constraint of self consumption**

These constraints are the minimal quantities of every food to be produced to satisfy the food needs of the household. To identify these needs, the parts of the production self consumed were considered. It would have been more interesting to take into account the energy and protein needs of the household to determine the consumptions in nutriments of the

household. But considering the limited time available it was not possible to estimate the energy and protein needs of the household. With regard to the declared consumptions, the households are supposed self-sufficient.

The needs of household are presented in table 4.

Table 4: Foods self consumption needs in Kg.

Crops	Self consumption needs
Rice	328,928
Maize	2723,512
Sorghum	1108,032
Bean	82,488
Groundnut	53,384
Soya	59,592

Source: survey, 2007

20 % rise was made for all the products because of the losses and the gifts as well as the food supplied to the occasional farm workers.

$sup(c)* rend(c) \geq P_0$

rend(c)= yield of crop c (kg/ha)

sup(c)= area of crop c (en ha)

P_0= self consumed production kg)

- **Model**

The objective function is written as followed:

Max $Z = \Sigma (prv(c)*Q(c)-sup(c)*C(c)) = \Sigma (sup(c)*prv(c)*rend(c)- sup(c)*C(c))$, with

- prv(c)= Price of one unit of product c ;
- Q(c) = Quantity of c produced in kg;
- C(c) = Cost related to the production of 1 ha of product c in FCFA;
- sup(c) = Area cultivated for crop c in ha;
- rend(c) = Yield of crop c in kg/ha.

PROD1(c) =PRO(c) – SMNCE (c)

PRO(c) = rend(c)*sup(c)

SMNCE(c) = sem(c)*sup(c)

$Sup(riz) \leq dsps1$

$Sup(C-\{riz\}) \leq dsps2$

REC = prv(“coton”)*PRO(“coton”)

$\sum$ (prfum*qfum+prins*qins+prher*qher)*sup(c) ≤ REC

mo (p)*sup(c) ≤ dspmo(p)

sup(c)* rend(c) ≥ P_0

sup(c)≥ 0

mo (p)≥ 0

5. Results and discussions

No particular condition was put for this model. It is about the first model executed with the collected data. This model constitutes the basic model.

- ***Area cultivated***

Table 5: Area cultivated in ha

	Observed results	**Results of model**
Rice	0,515	0,515
Total 1	0,515	0,515
Cotton	5,12	2,256
Maize	2,88	1,262
Sorghum	1,06	0,801
Beans	0,26	5,290
Groundnut	0,29	0,058
Soya	0,16	0,103
Total 2	9,77	9,77
Total	10,285	10,285

Total = total 1 + total 2

Source: Survey, 2007

The model gives a total area of available dry land which amounts to 9, 77 ha corresponding to the total dry land area available for the average farm. As for the dregs the total area proposed in the model was also completely consumed. The plan of optimal production used consequently all the area belonging to the average farm. This thus testifies of the importance granted to the agricultural activity in this zone. Land seems to be a major

constraint for agricultural production. Indeed the areas used are effective, which means that the producers in that case are capable to use more area, even if they should rent the land. The opportunity costs of land are respectively to 296.940 FCFA for the dregs and 75.488 FCFA for the dry land.

As for the allocation of the resource for each crop the results of the model appear as follows:

All the available area for rice (0,515 ha) is used by the optimal plan of production. It explains the current desire of farmers to cultivate this crop. Similar results are obtained by Adégbidi (2003) who noticed from a model of programming that all the available area (0,78ha) for the rice was completely used by the optimal plan of production. The model allocates a part of the production (just the quantity which is needed by the farm for self-sufficiency) in the consumption and the major part (3/4 of the production) in the marketing. Indeed the rice is a very profitable crop its marketing presents an economic interest not only for farms but also for the entire region.

The model proposes a decrease of about 50 % of the area of the cotton. This result demonstrates that in the current conditions of production, the cotton is not profitable for the farmers. This confirms the strong decrease that faces the production of the cotton and the crisis in the sector nowadays. Studies carried out in 2002 by the OBEPAB in the municipality of Glazoué showed that the cotton presented a negative gross margin, what justified the debts of the producers and the decrease of production. Similar results are obtained by Adidehou (2004) in the municipality of Glazoué who noticed that in the present state of production, the cotton is not a profitable speculation for the farmers.

Areas assigned to the crops such as maize, sorghum, groundnut and soya are lower than the observed reality. The produced quantities are only intended for the satisfaction of the needs of the household. While in the observed reality, the farmers market a part of these products, the model proposes that only the necessary quantities for the consumption should be produced. These crops do not thus present an economic importance for the region, at least in the current conditions of their production. If it had been allowed to buy maize, sorghum, groundnut and soya, the difference between the solution gave by the model and the reality regarding the areas of these speculations would have been big (marginal productivity maize = 15,350 FCFA, sorghum = 11,975 FCFA, groundnut = 21,236 FCFA, soya = - 41,120 FCFA).

As for the cultivation of bean the optimal solution is about 20 times superior to the observed situation. The model thus suggests the production of more beans for market. This situation is due to the fact that among the crops on dry land bean is the one which has high

gross margin. It is to say that apart from rice, bean is a profitable crop which can supply monetary resources for the household. The difference between the observed situation and the optimal solution can be explained by parasitic problems. Indeed bean is subject to a strong parasitic pressure which is difficult to manage. According to Adégbidi (2003) the yields of beans are good every two years, because of the parasitic problems. In spite of its important profitability the farmers assign it few areas because of the risks connected to the parasitic attacks. This risk not being included in the model, the beans benefits then from the reduction of area of maize, sorghum, groundnut and soya.

From the model it can be retained that the resources are mobilized first of all for the satisfaction of the needs of consumption, then, the available factors are used for the production of the crops which supply the biggest income for the farm by taking into account available resources and requirements of every crop. That is why rice and bean are the crops of which areas proposed by the model are superior or equal to those observed. Given that they present the best margins, the model is anxious to produce them within the limits of the available resources. Similar results are obtained by Madi (2000) in an entitled study: the prices of products and the productive system in the cotton zone of the north extreme of Cameroon. These results showed that since the production is sufficient for the consumption, the crops such as cotton, mouskwari and bean appear in the model because presenting the best economic opportunities.

- **Family and paid labor**

The model shows that there are effectively rush hours of activities during which the family labor constitutes a major constraint in the production. The concerned periods are: in July-August. The family constraints of labor relative to these periods are quite effective. They are thus periods during which the producer needs to hire labor force.

Table 6: Labor force in man-days

Period	Observed results		Results of model	
	Family labor	**Paid labor**	**Family labor**	**Paid labor**
Period 1	318	78	251,176	-
Period 2	219	52	219	39,831
Period 3	427,5	130	104,622	133,693
Total	964,5	260	574,798	173,524

Source: Survey, 2007

On 964, 5 men-days available family labor in the farm, the model gives a use of 574,798 men-days. As for paid labor, instead of 260 work days paid on average by a farm we have a request 173,524 days. In all a global work of 748,322 days would allow obtaining a better monetary income by keeping at the same time its independence towards the market of the food-producing. This surplus of labor force could be used for other activities as the extra-agricultural activities for varying income source for the household.

- **Capital**

Use of own capital

The use of the capital is the same in the observed situation and that of the model. The current assets are only intended for the labor force. The model thus used this capital in its just limit.

- **Credit**

The credit is only available for the cotton; however the farmer use this credit for others crops by overestimating the quantity of inputs. The revenue from the sale is thus used to pay off this credit. So the model uses this credit proportionally to the cultivated cotton area. The reduction of credit (from 375.627 to 695.954) is proportional to the decrease of the cotton area proposed by the model (2,256 ha instead of 5, 12 ha).

Table 7: Credit allocated to crops (FCFA).

	Observed results	**Results of model**
Credits		
Inputs rice	36568	36568
Inputs cotton	529724	233409
Inputs maize	122741	53784
Inputs sorghum	2490	1881
Inputs bean	2397	48786
Inputs groundnut	250	50
Inputs soya	1784	1149
Total	695954	375627

Source: Survey, 2007

- **Income**

The gross margin of the crops such as cotton, maize, sorghum, groundnut and soya decreased with regard to the observed average situation, because of the decrease of area used. Only gross margin of rice and bean increase and carry the agricultural gross margin from 706.143 FCFA to 831.790 FCFA, corresponding to 18 % increase (table.8). So with the same

total area and with less work, the model proposes an increase of the income of 18 % with a complete independence towards the market of the food-producing basic products regarding the consumption of the household. In this situation we can ask the question to know why the farm does not choose to work less and to gain more money. The answer to this question is that the farmer who knows his business knows well that he can gain more money by making for example less maize and enough of beans and rice with the resources which he has. The model does not allow the farm to produce more because the risk of a bad harvest is not taken into account here, what is against the farmer logic. Even if the maize is less profitable, the farmer wants to be assured that in case of insufficient rain or bad harvest due to insects, he can survive without going to the market. It is what justifies the strong diversification and the distribution of area in its farm which varies from one year to another.

Table 8: Gross margin of crop (FCFA).

Gross margin	**Observed results**	**Results of model**
Rice	149695	170823
Cotton	230121	100665
Maize	167514	79796
sorghum	68009	48120
Bean	36051	423217
Groundnut	39019	3275
Soya	15734	5894
Total gross margin	706143	831790

Source: Survey, 2007

The various results given by the model on the utilization of land, labor force and the capital then on the income show that the obtained basic model is optimal. Consequently, the hypothesis of this study to see whether allocation of the factors of production is not still optimal is confirmed. Indeed, the model presents a better use of the factors of production to optimize the income.

6. Conclusions

This study has investigated whether the introduction of rice for diversification of crop allow farmers to attain the optimal plan of production. The linear programming technique was used to achieve this objective. It has been found that rice is the profitable crop for farmers and is able to allow them to reach food security. The allocation of factor by farmers as showed by the model is not optimal. There is a need to re-allocate resource in order to attain the optimal solution as given by the model. A lot of attention needs to be given to farmers so that they can be able to achieve the optimal plan.

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