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**THE EVOLUTION OF FARMING SYSTEMS IN  
NORTHERN COTE D'IVOIRE: BOSERUP VERSUS MALTHUS AND  
COMPETITION VERSUS COMPLEMENTARITY**

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## **Abstract**

A socio-economic analysis of a sample of farms in Northern Côte d'Ivoire revisits two debates about the evolution of farming systems in sub-Saharan Africa. Taking into account the diversity of farming systems, the debates “Boserup vs. Malthus” and “competition vs. complementarity” between cotton and food crops become better informed and less straightforward.

## **Introduction**

In the literature on the evolution of farming systems in sub-Saharan Africa two debates are often cited. The debate “Boserup vs. Malthus” is structured around the question whether population density is the independent or the dependent variable in the relationship between population pressure and agricultural development (Boserup, 1965). In the debate “competition vs. complementarity” the role of export crops (cotton) in agricultural development is discussed (Bassett, 1988). The competition or “food first” thesis considers the introduction of cotton to be the main cause of food crises, as this export crop competes with traditional food crops. The complementarity thesis contends that food production will benefit from the promotion of export crops through “trickle down” effects.

However, these general theories do not take into account the diversity of farming systems and their evolutionary dynamics. Therefore this paper combines a typology of the farming systems with a socio-economic analysis of their functioning and performance. Only such a combination can give insights in the short-run dynamics and long-term evolution path of farming systems. For this we used survey data and participatory rural appraisal inquiries over a four-year period in four villages of the Dikodougou region (Northern Côte d’Ivoire) with different population densities to (1) assess the influence of population pressure, (2) construct a typology of the prevailing farming systems, and (3) compare the economic performance of these systems.

## Data

During the period 1995 – 1998, the project IDESSA-KULeuven<sup>1</sup> has carried out surveys and did participatory rural appraisal inquiries in four villages of the Dikodougou region (Stessens and Doumbia, 1996). As a result, a comprehensive database at two levels is available. The first level is the village agro-ecosystem<sup>2</sup>. Historical factors (ethnic conflicts) have left their print on the demographic pattern of Northern Côte d'Ivoire. As a result, our village sample in the Dikodougou region shows a high diversity. In Table 1 we rank the villages according to their population density. The Northern villages of the sample (Tapéré and Tiégana) are ancient villages, slightly depopulating due to decreasing global soil fertility levels and a strong social control system limiting any personal enrichment. The Southern villages (Ouattaradougou and Farakoro) are recently founded and are still being colonized by immigrating Northern farmers.

The second level is the level of the production system. In each village a representative sample of farms was surveyed during three years. Depending on the technology and the importance of cotton, five farm types can be distinguished. The *YRG-system* is based on the manual cultivation of yam, rainfed rice and groundnut. Analogous with Le Roy this traditional system prevails in sparsely populated areas. When adopting cotton, the farmer can just “try” this cash crop (*YRGC*), accord it a more important place in his production system ( $CR^+(MF)$ ) or adopt animal traction ( $CR^+(AT)$ ). Unlike the high diversity of crops we encounter in the latter two systems, a small group of large mechanized farms can be observed, specialized in two crops: cotton and rainfed rice (*CR*). Finally, besides these prevailing production systems, other systems occur based on maize (*MR*, *CRM*) or other crops.

## Methodology

To compare the economic performance of these production systems, we first calculate the annual Net Value-Added (*NVA*) of the surveyed farms:  $NVA = \text{Gross Production } (p) - \text{Intermediate Consumption } (c) - \text{Amortization}$ . All these terms have to be standardized, i.e. divided by the total labor force used in Annual Work Units (*AWU*). To obtain annual gross production  $p$ , crop yields are multiplied by the surface sown and the market price. Annual intermediate consumption  $c$  consists of seed costs (based on the market price), fertilizer and pesticide costs. Annual amortization is calculated by dividing the purchase price by the lifespan of the equipment. While  $c$  is proportional to the cultivated agricultural area  $S$ , annual amortization can be divided in a proportional part  $\alpha$  (hoes and small equipment) and a non-proportional part  $\beta$  (oxen, ploughs, sprayers, carts, ...):

$$NVA = \underbrace{\left(\frac{p}{S} - \frac{c}{S} - \frac{a}{S}\right)}_{\text{Proportional part} = \alpha} \times S - \underbrace{A}_{\text{Non-proportional part} = \beta} \quad (1)$$

Proportional part =  $\alpha$  Non-proportional part =  $\beta$

$$NVA = \alpha \times S - \beta \quad (2)$$

Dufumier and Mazoyer simplify the conventional theoretical assumption of a concave production function (Varian, 1997) to the first linear approximation (equation 2). Their methodology is oriented towards the comparison of different production systems within a homogeneous region and the analysis of the economic conditions of a switch from one system to another. By estimating the upper and lower limit for the slope  $\alpha$  of this function, the minimal reproduction threshold  $R$  and the maximal area that is cultivable by one *AWU*, within the actual production system, the theoretical area of existence of the production system is defined. A production unit can renew its

production factors only if  $NVA > R$ . Within a homogeneous region this threshold varies from one farm to another for objective and subjective reasons, but in the long run it converges to the wage rate on the labor market. The parameters  $\alpha$  and  $\beta$  represent respectively the profitability and the degree of investment of the production system. For each farm and each year of the sample these parameters are calculated. Averages are taken for each production system and compared using a Tukey HSD (Honest Significant Difference) test for unequal sample sizes and a level of significance of 10 % (Table 3). Finally the production systems are visualized by drawing the linear function based on the averages of  $\alpha$  and  $\beta$  and defining it by the 95 % confidence interval limits of the observed cultivated agricultural areas  $S$  (Figure 1 and Figure 2). For the region of Dikodougou, we estimated a reproduction threshold  $R$  of 100,000 FCFA per  $AWU$ .

In a second stage, technical efficiency of the farms is measured. Measurement of technical efficiency requires firstly the specification of a frontier production function, and secondly the measurement of the deviation or distance of the farms from the frontier, which is then a measure of technical inefficiency. For this, we will use the technique of Data Envelopment Analysis (DEA), that constructs a convex hull around the observed data (Charnes, Cooper, and Rhodes, 1978). A farm displays total technical efficiency if it produces on the boundary of the production possibility set, i.e. it maximizes output with given inputs and after having chosen the technology. This boundary or frontier is defined as the best practice observed assuming constant returns to scale (CRS). Total technical efficiency can be further decomposed into pure technical efficiency and scale efficiency. To calculate pure technical efficiency, the production technology is assumed to display variable returns to scale (VRS).



Scale efficiency is then the residual between total and pure technical efficiency. As a result, a farm that displays pure technical efficiency may not operate at an optimal scale, that is, its input-output combination may not correspond to the combination that would arise from a zero-profit long-run competitive equilibrium situation (Färe, Grosskopf, and Lovell, 1985). We follow the approach suggested by Coelli, Prasada and Battese who contend that in a VRS model an inefficient farm is benchmarked against firms of similar size. In a CRS model a firm may be benchmarked against firms which are substantially larger (smaller) than it.

## Results and Discussion

In Table 3 we represent the results of the Tukey HSD test for the parameters  $\alpha$  and  $\beta$  based on a level of significance of 10 %. Only production systems with sufficient observations (Table 2) have been taken into account. Profitability ( $\alpha$ ) of the traditional *YRG-system* is highest due to the high Value-Added of yam, the most consumed food crop of the Dikodougou region. With the exception of the specialized *CR-system*, this system outperforms significantly the other production systems. The traditional system is also characterized by a low level of investment ( $\beta$ ), significantly lower than the mechanized production systems. The highly specialized and mechanized *CRM* and *CR-systems* show significantly higher investment requirements than the more diversified *CR<sup>+</sup>-systems* and the traditional *YRG-system*. The data show that the two extreme production systems using a completely different technology are characterized by a comparable performance, despite the investment lag between them.

In Figure 1 we visualize the production systems by drawing the linear function based on the averages of  $\alpha$  and  $\beta$  and defining it by the 95 % confidence interval limits of the observed cultivated agricultural areas  $S$ . The estimated reproduction threshold ( $R$ ) of 100,000 FCFA per  $AWU$  has been indicated by a horizontal dotted line.

In the remainder of the paper we present our hypothesis regarding the evolution of the production systems in the Dikodougou region. All farms face a minimal reproduction threshold  $R$ . Farms creating an amount of wealth ( $NVA$ ) superior to this threshold can renew their production factors and in addition have a net investment capacity per  $AWU$  of  $I = NVA - R$  at their disposal. The accumulation of this financial surplus creates opportunities to switch to a more capital-using and land-using production system. Farms not reaching this threshold cannot fully renew their production factors and will disappear in the long run.

Figure 1 shows that the traditional *YRG-system* is capable to surpass the reproduction threshold with a low land-to-man ratio and a superior profitability (Table 3). This observation opposes the popular view that traditional production systems are land-consuming and characterized by low economic performance. However, this system can only be durably renewed year after year if certain conditions are fulfilled. Firstly, the natural fallow period has to exceed 21 years (De Rouw, 1991) to control weeds and completely restore the natural fertility level of the plot. A reduction of this critical fallow period results in higher weed levels and a lower production of biomass. Secondly, the cultivation period cannot be extended too long to prevent the accumulation of a weed seed bank in the soil and the exhaustion and erosion of the soil. Only in the most sparsely populated village Tapéré are these conditions fulfilled.

A pure form of the traditional *YRG-system*, based on average fallow and cultivation periods of respectively 22 and 3 years, persists durably. Figure 2 shows how this traditional cropping mix has been gradually diversified as population pressure increases. Yam production declines, due to declining yields, and is substituted by cotton.

Population density has a direct effect on fallow and cultivation periods (Table 1). This can be visualized by the *R-factor* or “degree of residence” (Ruthenberg, 1980), representing the proportion of cultivated land per unit utilizable land (fallow + cultivated land), which seems closely related to population density (Table 1). While the cultivated area per Family Work Unit (*FWU*) remains relatively constant, utilizable land declines sharply (Figure 3).

The combined effect of decreasing fallow and increasing cultivation periods leads to an unbalance of the bio-physical environment. Forest vegetation is gradually replaced by savanna. Weeding bottlenecks exacerbate and the utilization of herbicides becomes necessary. In addition, longer cultivation fosters the development and accumulation of pests stimulating the demand for pesticides. Finally, demand for fertilizers develops as yields decrease due to the declining fertility levels. The combination of all these effects (Figure 4) erodes the profitability of the traditional system, translated into a decline of the slope of the *YRG-curve* (Figure 1).

A possibility to escape this vicious circle is to diversify the cropping mix with cotton. The resulting hybrid system is composed of the juxtaposition of a traditional food cropping system and a modern cash cropping system. This export crop is not an

innovation *in se* in Northern Côte d'Ivoire, where it has been cultivated for a long time. The innovation consists of new farming practices exogeneously introduced, diffused and subsidized (fixed price and access to credit) by the CIDT (Compagnie Ivoirienne de Développement des Textiles) since 1974: monoculture, sowing in rows, mechanization and use of fertilizers, insecticides and herbicides. The switch from the *YRG* to the  $CR^+(MF)$ -system results in a significant decline of the profitability (Table 3). The complementarity thesis contends that food crops are benefiting from cotton via trickle-down effects, summarized and questioned by Bassett. Our data show that the competition thesis prevails in manual production systems adopting cotton. The labor bottlenecks of cotton coincide with those of food crops, i.e. in the period September – November. The technical limit of the system is reduced as cotton competes with food crops for labor. The combination of an exacerbating labor bottleneck and a decline of global profitability pushes farmers towards and below the reproduction threshold (Figure 1). Effectively, the lowest incomes in our sample are generated by  $CR^+(MF)$ -systems, especially in densely populated villages like Tiégana.

Inspired by the law of decreasing marginal returns, Malthus argues that population, if not controlled, increases by a geometric ratio while agricultural production expands following an arithmetic ratio. In the first phase of the evolution of the production systems, i.e. the alteration of the traditional system, Malthusian arguments are solidly underpinned: competition for exhausting resources leads to degradation of the bio-physical environment, poverty and conflicts. However, two arguments contend that the switch from the traditional to the hybrid system should not be considered as a simple decline of profitability. Firstly, it also constitutes an attempt to prevent a further decline of the latter. The timely synergism of increasing population and

declining soil fertility levels at one side and facilitated access to inputs provided by the CIDT (by adopting cotton) at the other side, offers an extra argument in favor of the complementarity thesis in the first phase of the evolution process (Figure 4). Secondly, the pessimistic view in Figure 1 is based on a Malthusian interpretation of farm size, i.e. in terms of cultivated agricultural surface (Mounier, 1992). Boserup includes an important production factor in her analysis, ignored by Malthus: fallow. Incorporating this element into the analysis and comparing the production systems in terms of their utilizable agricultural area (*UAA*) clearly changes the picture (Figure 5). Demographic pressure decreases the utilizable land-to-man ratio (Figure 3) so that farmers are forced to increase their farming intensity (*R-factor*). As a consequence, yields per unit cultivated land decrease but profitability measured per unit *UAA* increases. This demographically induced Boserupian intensification clearly opposes the popular Malthusian view. In reality however, one rather observes migration of people instead of such intensification.

Moreover, Malthus' thesis ignores the possibility of technological innovations and the latter are precisely the dependent variables in the model of Boserup. These variables depend on their turn on a series of independent variables like population pressure and market access. Remember the weeding bottleneck induced by the combined effect of decreasing fallow and increasing cultivation periods. Breaking up this constraint induces a strong demand for supplemental labor (typically female), exceeding the labor surplus created by population pressure (Pingali, Bigot, and Binswanger, 1987). At the same time, the reduction of the forest cover leads to a gradual disappearance of the major obstacle of cattle breeding: the Tsé-Tsé fly (*Glossina palpalis*, *Glossina morsitans*). This important effect, combined with the progressive thinning out of tree

stumps and the development of grasslands, create favorable conditions for the development of cattle breeding and animal traction. Due to its capacity to combine bedding and weeding, this innovation breaks up the labor bottleneck of the manual production system. Adoption of equipment for animal traction is the main reason why average invested capital per *AWU* increases according to population density (Figure 6), an argument in favor of Boserup's thesis.

By growing cotton, the hybrid  $CR^+(MF)$ -system accumulates the necessary financial capital to switch to animal traction. From now on, the farm is able to surmount the labor bottleneck and to increase farm revenue above the reproduction threshold, just by extending cultivated area (Figure 7). It's clear that in the second phase of the evolution process, land access becomes a crucial factor. Analogous with Pingali et al., we observe that households who dispose of abundant utilizable land resources and a substantial labor force pool more easily adopt animal traction.

In the third phase of the evolution process, land access becomes even more important. The highly specialized *CR* and *CRM*-systems are characterized by significantly higher investment levels (Table 3), visualized by the increasing intercept of the linear curves. It's clear that only a privileged minority of farmers is able to reach this expansion phase. Moreover, these production systems only occur in the Southern migration villages where cultivated agricultural areas per *FWU* are higher due to anticipation strategies (Figure 3). Cultivation of land implies appropriation of the land. Moreover, in the Northern villages these production systems would be discouraged by the strong social control system, limiting any personal enrichment. The emergence of these systems exacerbates the pre-existing social polarization. A new social class of landowners appears, recruiting external agricultural labor.

While the thesis of competition prevails in the first phase of the evolution process, Figure 7 advances that in the second and third phase, valid arguments for the complementarity thesis are underpinned. Thanks to the accumulation of financial revenue generated by the cultivation of cotton, the access to credit and technical know-how by the CIDT, the farmer is able to surmount the labor bottleneck and to increase farm revenue above the reproduction threshold. Increasing cultivated areas push further the *R-factor* resulting in a higher demand for inputs, advanced by the CIDT. Inquiries show that these inputs, normally only reserved for cotton, are also largely used on food crops (Figure 4). Areas under food crops increase resulting in higher food security. Maybe the competition thesis doesn't apply *in* the production system, it certainly applies *between* production systems. Expansion exacerbates pre-existing land access inequalities and leads to social polarization. Thus, development of cotton can endanger food security of the least land endowed households.

Up to here, we showed how population pressure affects farm revenues inducing Malthusian (decline of profitability, exacerbation of labor bottlenecks and reduction of the technical limit of the production system) as well as Boserupian mechanisms (induced intensification and production system switch). But what is the global effect of population density on total factor productivity of the farm? To answer this question, we calculate total, technical and scale efficiencies of the farms via a DEA-analysis that calculates the relative distance of the observations from a frontier production function ranging from 0 % (inefficient) to 100 % (on the frontier). In a second stage, these efficiency results are compared via a Tukey HSD test for unequal sample sizes.

By comparing the production systems mutually, no significant discrimination can be made. All systems can be practiced in an efficient as well as an inefficient way, without one system consequently outperforming the other systems. Only by comparing the two technologies, significant differences emerge. While total efficiency is almost equal, manual farming is characterized by a significantly<sup>3</sup> higher technical efficiency and a significantly<sup>4</sup> lower scale efficiency.

The effect of population density on farm efficiency is expressed in Figure 8. Each arrow represents a significant difference at a significance level of 5 %. While scale efficiency slightly but not significantly decreases, a significant change in technical efficiency is observed between Ouattaradougou and Tiégana. The combination of the two effects leads to a significant picture of total efficiency declines correlated with increasing population density. Farms operating in scarcely populated villages have a comparative advantage relative to those of densely populated areas. The latter have to compensate the fertility loss and weed proliferation with an increasing use of chemical inputs and labor resulting in lower technical efficiency levels. The figure shows also that the traditional *YRG-system* in his purest form, i.e. in Tapéré, not only achieves the highest profitability per unit cultivated land (Table 3), but also manages to combine its few inputs (Figure 4 and Figure 6) in the most efficient way.



## **Conclusions**

In this paper we showed how two polarized debates about the evolution of farming systems in sub-Saharan Africa can be put in perspective by taking into account the diversity of farming systems and their evolutionary dynamics.

In literature, Boserup is often opposed to Malthus. Our analysis shows that these theories are complements rather than opposites. Demographic pressure causes indeed Malthusian mechanisms leading to important farm efficiency losses. But at the same time, changes in the bio-physical environment generate favorable conditions for the adoption of animal traction. The intensification of the cropping cycles and the switch from manual farming to animal traction illustrates well the Boserupian response to the changing village agro-ecosystem. However, as long as land resources are available, one rather observes migration of people instead of such intensification.

The analysis of the competition and complementarity debate about the relation between cotton and food crops shows that neither of both applies simultaneously on all farm categories. Adoption of cotton alleviates partially the Malthusian effects via trickle-down effects generated by the CIDT: a timely synergism. But despite this valid argument for the complementarity thesis, farm level data show that the adoption of cotton in manual production systems is associated with strong labor bottlenecks due to competition between cotton and food crops, reduction of the technical limit and low incomes. Thus, the competition thesis is a more realistic representation for the first phase of the evolution process. Moreover, it consists of an additional stimulus for the adoption of animal traction.

In the second and third phase of the evolution process however, the arguments in favor of the complementarity thesis are underpinned. Thanks to the accumulation of financial revenue generated by the cultivation of cotton, the access to credit and technical know-how by the CIDT, the farmer is able to surmount the labor bottleneck and to increase farm revenue above the reproduction threshold. Despite the fact that the competition thesis doesn't apply within the production system, it certainly applies between production systems. Expansion of mechanized production systems exacerbates pre-existing land access inequalities and leads to social polarization, endangering food security of the least land endowed households.

Which lessons can we draw from this analysis? The evolution of the farming systems in the Dikodougou region has shown to be a complex system requiring a systemic and multidisciplinary approach. An important component of this approach is the analysis in different levels. The level of the village agro-ecosystem is especially adapted to the case of sub-Saharan Africa, but is often neglected in literature. Knowing the underlying laws of this system is essential to tune agricultural development projects in order to be coherent with the specific features of each type of village agro-ecosystem. The sparsely populated village of Tapéré is often referred to as “traditional” or “backward”. Nevertheless, our survey data show that the production systems are characterized by the highest profitability per unit cultivated land and the highest total technical efficiency. As a result, this village will react differently to agricultural intensification propositions than a village like Tiégana, where Malthusian effects are clearly perceived by all farmers.

**Table 1: Typology of the production systems in the Dikodougou region**

	Absence of cotton	Presence of cotton	
Systems based on manual farming ( <i>MF</i> )	<i>YRG</i> (51), <i>MR</i> (6), <i>other systems</i> (5)	Adoption phase <i>YRGC</i> (4)	Diversification <i>CR</i> <sup>+</sup> ( <i>MF</i> ) (9)
Systems based on animal traction ( <i>AT</i> )	-	Diversification <i>CR</i> <sup>+</sup> ( <i>AT</i> ) (30), <i>CRM</i> (9)	Specialization <i>CR</i> (12)

MF = manual farming; AT = animal traction; Y = yam; R = rainfed rice; G = groundnut; M = maize; C = cotton

**Table 2: Major characteristics of the four village agro-ecosystems**

Village	Tapéré	Ouattaradougou	Farakoro	Tiéghana
	ancient (before end 19 <sup>th</sup> century)	recent (sixties)	recent (sixties)	ancient (before end 19 <sup>th</sup> century)
Genesis				
Population density (inhabitants/km <sup>2</sup> )	14 <sup>a</sup>	17 <sup>a</sup>	28 <sup>a</sup> (31 <sup>b</sup> )	40 <sup>a</sup> (38 <sup>c</sup> )
Average annual population growth	- 2.5 % <sup>d</sup>	28.1 % <sup>d</sup>	9.5 % <sup>d</sup>	- 1.3 % <sup>d</sup>
<i>R-factor</i> = <i>C/(C+F)</i>	12	24	27	31 (32 <sup>c</sup> )
Fallow <i>F</i> (years)	22	18	16	21
Cultivation <i>C</i> (years)	3	6	6	9
<i>F/C</i>	7.2	3.2	2.6	2.2 (2.1 <sup>c</sup> )

<sup>a</sup> estimation for 1997 based on the survey data of the project IDESSA-KULeuven

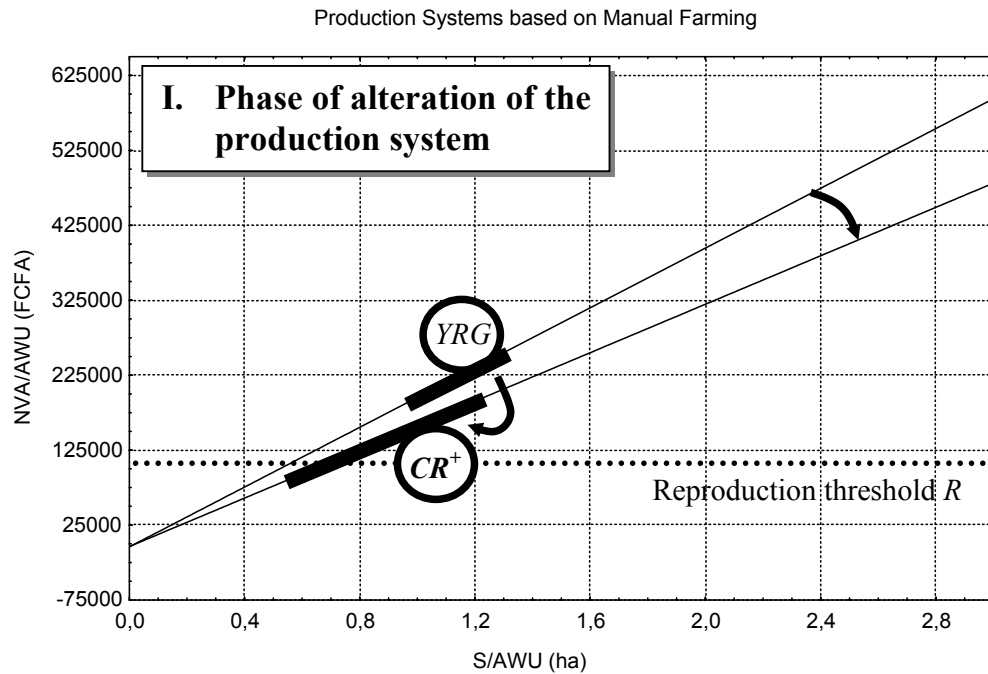
<sup>b</sup> estimation for 1997 carried out by Poppe through a demographic census and air photos

<sup>c</sup> estimation for 1998 based on a study carried out by the “Plan Foncier Rural” in Korhogo, Côte d’Ivoire

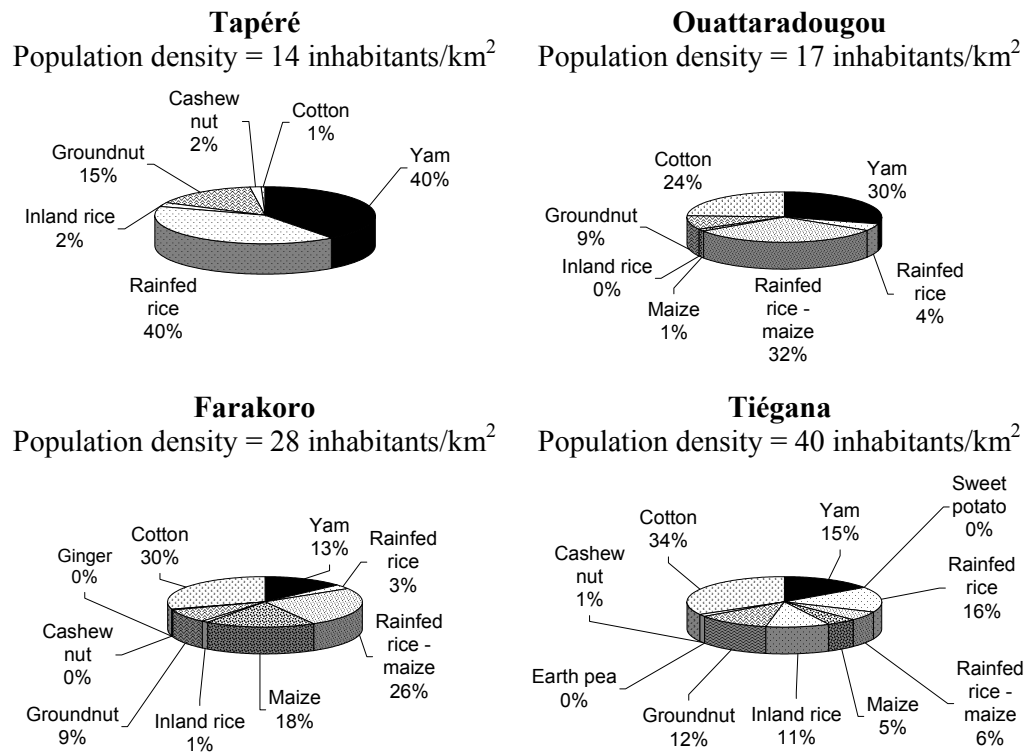
<sup>d</sup> average based on demographic censuses during the period 1975 - 1990, carried out by the “sous-préfecture de Dikodougou” in Côte d’Ivoire

**Table 3 : Results of the Tukey HSD test for  $\alpha$  and  $\beta$  (level of significance = 10 %)**

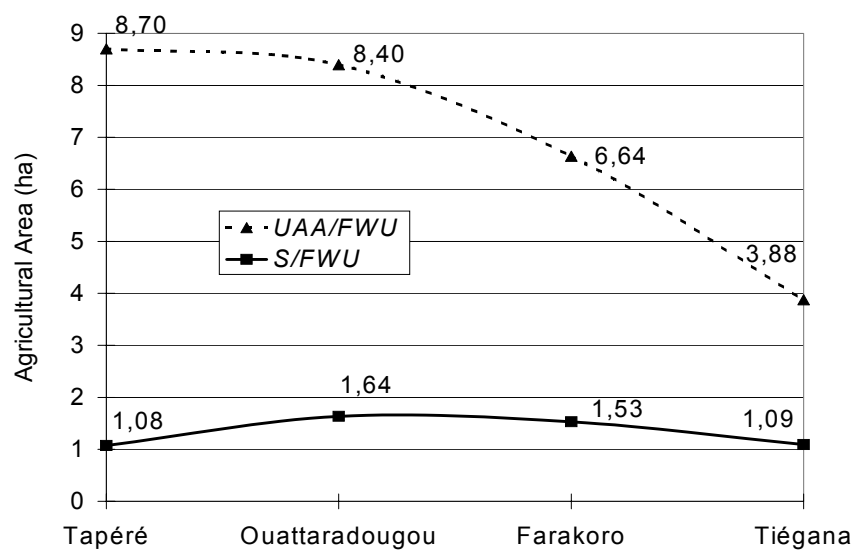
Parameter $\alpha$			Parameter $\beta$		
Production System	$\alpha$	Tukey Test	Production System	$\beta$	Tukey Test
1 <i>CRM</i>	94,407	1 2 3 4	1 <i>CR</i> <sup>+</sup> ( <i>MF</i> )	3,677	1 2 3 4
2 <i>CR</i> <sup>+</sup> ( <i>MF</i> )	157,616	1 2 3 4	2 <i>YRG</i>	4,063	1 2
3 <i>CR</i> <sup>+</sup> ( <i>AT</i> )	172,629	1 2 3 4	3 <i>CR</i> <sup>+</sup> ( <i>AT</i> )	16,728	1 3
4 <i>CR</i>	186,596	1 2 3 4 5	4 <i>CRM</i>	23,987	3 4 5
5 <i>YRG</i>	228,139	5	5 <i>CR</i>	29,710	4 5



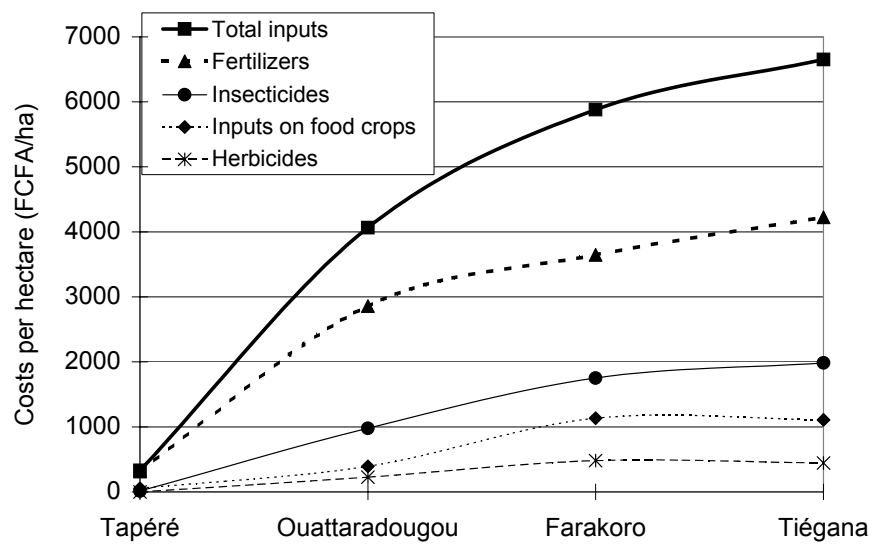
**Figure 1: The evolution of the production systems in the Dikodougou region according to the point of view of Malthus**



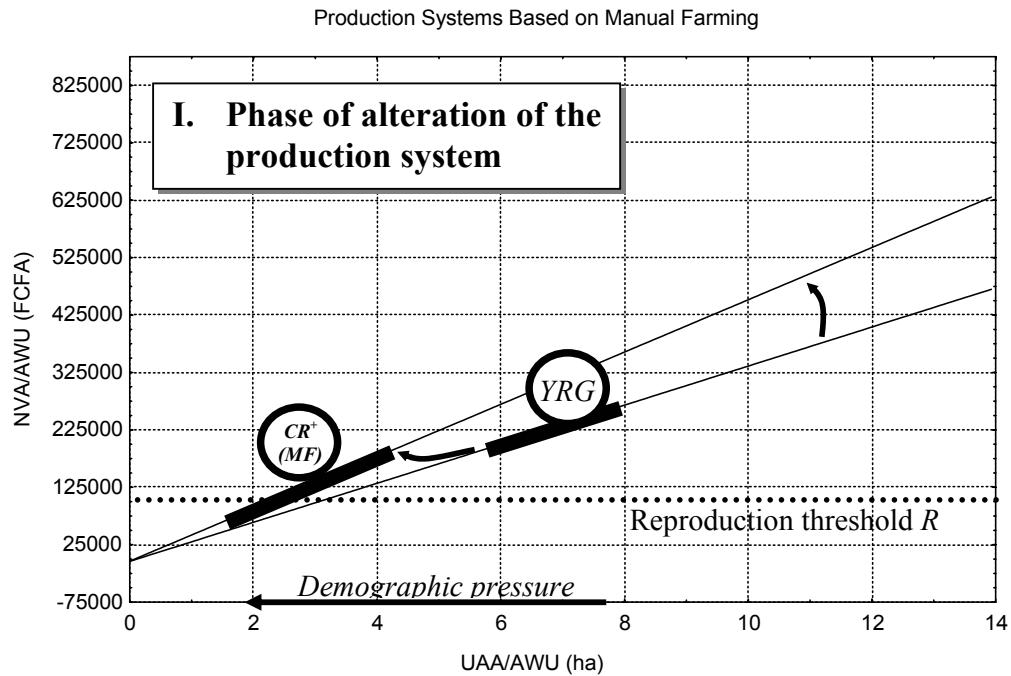
**Figure 2: Average cropping mix of the farms**



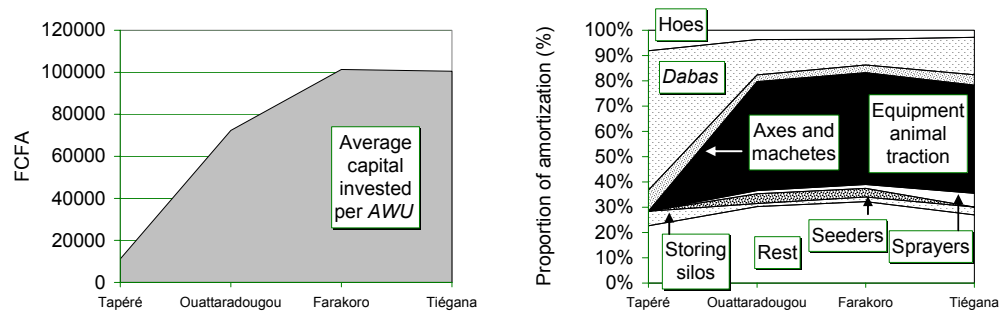
**Figure 3: Average Cultivated (*S*) and Utilizable Agricultural Area (*UAA*) per Family Work Unit (*FWU*)**



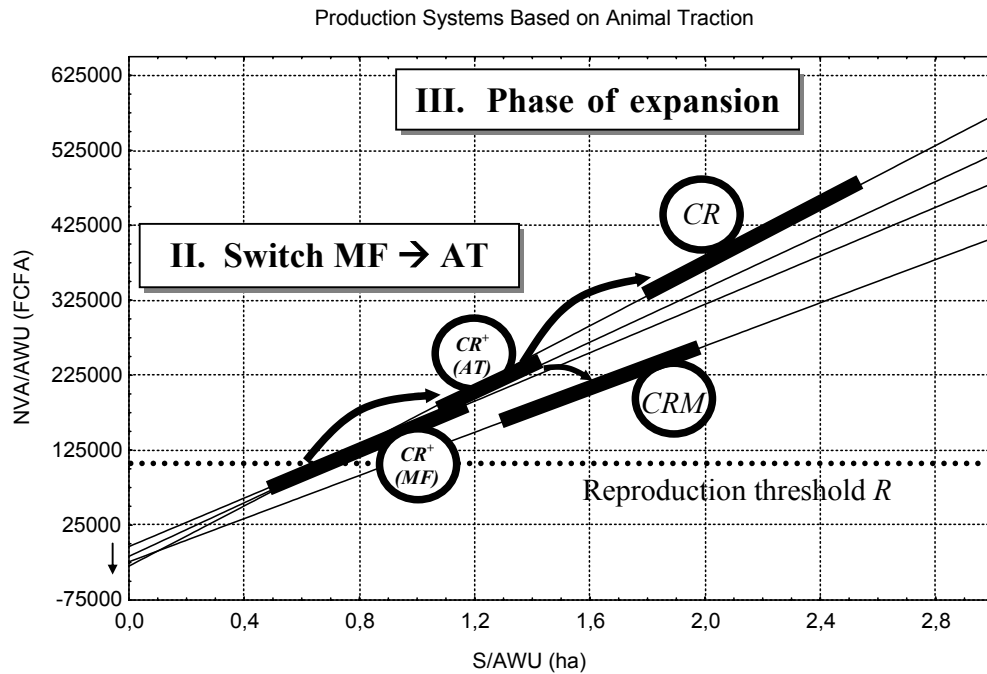
**Figure 4: Average variable costs per unit cultivated land**



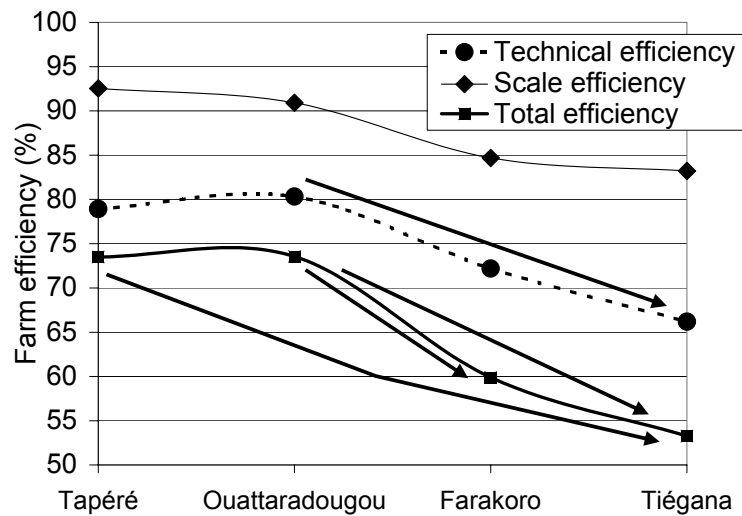
**Figure 5: The first phase of the evolution of the production systems in the Dikodougou region according to the point of view of Boserup**



**Figure 6: Average capital invested per *AWU* and share-out of total amortization costs among different farming tools**



**Figure 7: The second and third phase of the evolution of the production systems in the Dikodougou region**



**Figure 8: Total, technical and scale efficiency of the farms in the Dikodougou region**

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<sup>1</sup> IDESSA (Institut DES Savanes) is one of the precursors of the actual CNRA (Centre National de la Recherche Agronomique) in Côte d'Ivoire. KULeuven (Katholieke Universiteit Leuven) is the Belgian project partner.

<sup>2</sup> Typically in sparsely populated sub-Saharan areas, the village behaves as a territorial and human entity characterized by its own identity and coherence: the village agro-ecosystem (Jouve and Tallec, 1996).

<sup>3</sup> with a significance level of 1 %

<sup>4</sup> with a significance level of 0,1 %

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