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THE CORRELATION BETWEEN PRODUCTIVITY AND THE POLYCULTURE SYSTEM DEVELOPED IN THE KORSIMORO HYDRO-AGRICULTURAL PERIMETER

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ABSTRACT

Various initiatives are being undertaken to combat poverty in rural areas. These include the establishment of cooperatives and the construction of water infrastructure. This study had the privilege of focusing on an econometric model based on the hypothesis that there is a correlation between productivity and the cropping system developed in the hydro-agricultural perimeter of the commune of Korsimoro. To do this, producers' cooperatives were targeted. The sample was made up of 33.53% male farmers and 66.47% female farmers, of whom 56.73% owned plots of land and 43.27% did not. The aim was to identify the link between productivity and the type of cropping system practised within the developed perimeter.The results show that mixed farming is the main cropping system practised in the developed area. It evolves according to a seasonal calendar, local consumption and marketing. Productivity and polyculture are strongly correlated in terms of the coefficient of determination. The level of equipment remains relatively low ; the use of phytosanitary products is real ; the assistance of technical staff is insufficient ; the lack of financial means for the purchase of inputs are determining factors that negatively influence agricultural productivity in the Korsimoro hydro-agricultural perimeter.

INTRODUCTION

Real geographical phenomena are sometimes the result of four forms of complexity in geography. Structural complexity, complexity of scale, complexity of levels and the non-linearity of agricultural dynamics constitute these four forms of complexity in geography (A Dauphine, 2003, p.48). All forms of agriculture are the result of a combination of biological and social phenomena (C Tafani, 2010, p.17). In Burkina Faso, a development strategy to give rural households access to basic social services was launched in 2000. These include health and education services to boost agricultural productivity and reduce poverty (K Savadogo and *al*. 2016, p.154). Agricultural yields are lower, which can be explained by the difficulties farmers have in understanding the cropping calendar on the one hand, and extreme rainfall events on the other (A Ouédraogo, 2018, p.11).In the Massili catchment, multi-criteria analysis has made it possible to identify areas where farmers' strategies for adapting to climate variability are effective. The weighting of these different variables showed that stone barriers are the most dominant factor (25) and half-moons have a low weighting of 05 (P. I Yanogo, 2023, p.10). Agropastoral activities in the Centre-Nord region are not immune to these adversities. The Centre-Nord region is drained by the Nakambè watershed and the Niger sub-watershed and their tributaries. The region's water bodies (96) are made up of lakes, dams, ponds and boulis (W. O Nikièma and *al*. 2022, p.283). In the rural commune of Korsimoro, the dam plays a major role in pastoral and fish farming activities.There has been an explosion of uncontrolled market gardening around the perimeter of the basin. These practices are responsible for silting up the dam (Nakambè Water Agency, 2015, p.6). The increase in market-gardening areas goes hand in hand with the intensity of cultivation. An area of 232 ha mapped around the Korsimoro dam corresponds to a cropping intensity of 133%. With a view to increasing their income and maximising their cropping intensity, farmers grow dry-season crops (K. G Ndanga, 2011, p.44). In geography, a developed perimeter that has both connotations (productivity and cropping system) is a multidimensional perimeter. This is why the people of the commune of Korsimoro are interested in market gardening. The polyculture system has an influence on productivity, which raises the question of its effectiveness via agricultural yields in the Korsimoro hydro-agricultural perimeter. The aim of this study is to analyse the correlation between productivity and the type of cropping system developed around the Korsimoro hydro-agricultural scheme. The hypothesis of this work is that the cropping system typology developed around the Korsimoro hydro-agricultural perimeter has a strong influence on agricultural productivity yields.

This research focuses on three areas : the methodological approach used, analysis of the correlation between the mixed cropping system and agricultural productivity, and discussion of the results.

Presntation of the study environment and methodological approach

Presentation of the study environment : The rural commune of Korsimoro is the study site. It is located in the Centre-Nord region, more specifically in the province of Sanmatenga (Map 1). It is 30 km from Kaya, the regional capital, and 70 km from Ouagadougou (the capital of Burkina Faso).Korsimoro covers an area of 674.1 km² and has geographical coordinates of 12o 49' 27" north latitude and 1o 04' 05" west longitude. Administratively, the commune comprises 31 villages. The population is estimated at 64,349. The commune of Korsimoro is located in the Sudano-Sahelian climate zone. It has an alternating dry and rainy season. The dry season runs from October to May. It is influenced by dry, cool winds and the dry, hot harmattan winds. The rainy season runs from June to September. This season is dominated by cool, rainy monsoon winds. Between 1991 and 2020, average annual rainfall in Korsimoro was estimated at 669 mm/year.
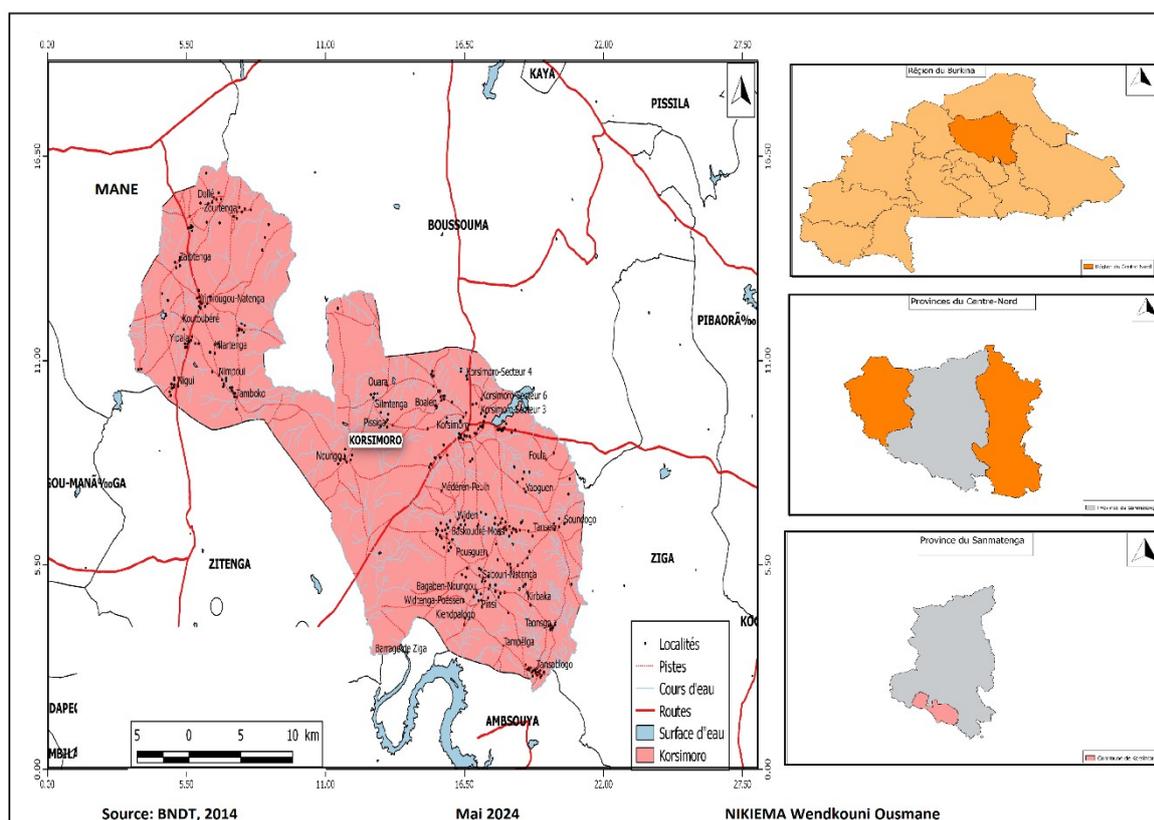
Map 1. Location of the commune of Korsimoro

METHODOLOGICAL

This study focused on primary and secondary data collection. Pre-existing information on the use of hydro-agricultural schemes was used to collect secondary data. Primary data was collected through field surveys of farmers. A total of 104 people were surveyed.These people range in age from 19 to 60 and over. The survey collected information on the cropping system, cropping equipment and techniques, factors influencing the correlation between agricultural productivity and the mixed cropping system, and income from agricultural products. Direct observation, an essential factor, was taken into account in data collection. It enabled a better understanding of the activities developed around the developed site. The hydro-agricultural perimeter site was considered as a spatial sample. Data processing and analysis were made possible by the use of technological tools. XLSTAT, 2024 software was used for statistical production. Text entry was carried out using a computer. Cartographic representations were possible using GIS software (ArcGis10.4). KoboToolbox software was used for data collection, processing and analysis. Other types of parameters such as the production function and the probabilistic approach were taken into account in data processing :

The production function

This is based on the quantity of speculation produced in kilograms and the quantity of inputs used. This gives the following formula :

$Q = F (K ; L) = L^{\alpha} K_1^{\beta 1} K_2^{\beta 2} .... K_n^{\beta n}$

K is the vector made up of all factors other than labour ;

L represents labour ;

α and β are the productivity parameters with respect to the various factors.

In addition to these physical factors, this model includes a dummy variable that takes into account the type of farm. Thus, the productivity obtained by the yield at 0.25 hectare is dependent on the quality of work and the use of phytosanitary products. This made it possible to establish the following formula : Yield = $\alpha_0 + \alpha_1 engrais + \alpha_2 herbicide + \alpha_3 \hat{a}ge + \alpha_4 \hat{a}ge^2 + \beta type + \varepsilon$

ε is the error of the hypothesis being tested. The sign of the variable is necessarily taken into account.

The probabilistic approach : This approach looks at the social status of producers, knowing their productivity capacity, the size of their farm plots and their age. In other words, it is a question of determining the probability of a farmer owning farm plots and practising mixed farming. This is a binary variability that is equal to 1 if the farmer owns the farm plots and practises mixed farming, and 0 otherwise.

$$Type = \begin{cases} 1 \; if \; the \; producer is \; a \; holder \; and \; pratises \; mixed \; farming \\ 0 \; oyherwise \end{cases}$$

The probability of holding and practising mixed farming is between 0 and 1 and is expressed by prob *(type = 1) = p*. The aim here is to detect the link between this probability and the other variables in the model, i.e. productivity, the size of the farm plots and the age of the producers. Hence : *p = F (Xβ)* with *X* the vector of explanatory variables.

F (Xβ) is the distribution function defined on an interval [0 ;1]. To better transpose the function *F (Xβ),* probability distributions can be used. These are the exponential law, the normal law, the logistic law and the gamma law. The logistic law is applied in view of the complexity of the dependent variables. This has made it possible to redefine the dependent variability :

$$Type = \begin{cases} 1 \; with \; probability \; \wedge(X\beta) \\ 0 \; with \; probability \; 1 - \wedge(X\beta) \end{cases} with \; \wedge(X\beta) = \frac{e^{x\beta}}{1+ e^{x\beta}} = \frac{1}{1+ e^{-x\beta}}$$

This gives a Bernouilli distribution whose density function is expressed by :

f(type) = $[\wedge(X\beta)]^{type}[1 - \wedge(X\beta)]^{(1-type)}$

The maximum likelihood function is given by :

$L(\beta) = \prod_{i=1}^{n} [\wedge(X\beta)]^{type \; i} [1 - \wedge(X\beta)]^{(1-type \; i)}$
$L(\beta) = \prod_{i=1}^{n1} [\wedge(X\beta)]^{type \; i} \; si \; type = 1$
$L(\beta) = \prod_{i=1}^{n2} [\wedge(X\beta)]^{type \; i} \; si \; type = 0$

By applying the logarithm function, the following expression is obtained :

$ln \; L(\beta) = \sum_{i=1}^{n1} type \; i \; ln \; [\wedge(X\beta)] + \sum_{i=2}^{n2} (1 - type)ln[1 - \wedge(X\beta)]$

By deriving the logarithm function partially as a function of *β,* this is equivalent to :

$$\frac{\partial \ln L(\beta)}{\beta} = \sum_{type=1} \frac{\lambda(X\beta)}{\wedge(X\beta)} X + \sum_{type=2} \frac{-\lambda(X\beta)}{[1-\wedge(X\beta)]} X = 0 \; avec \; \lambda(X\beta) = \frac{e^{x\beta}}{(1+ e^{x\beta})^2}$$

The density function of the logistic law *(λ(Xβ) = $\wedge'$(Xβ))*; *n_1* and *n_2* are respectively the numbers of producers who own plots of land and practise mixed farming and producers who do not own plots of land and practise mixed farming. The choice of this model is justified by the fact that in the implementation of activities in the hydro-agricultural perimeter, producers use endogenous knowledge to make their productivity profitable. This model was also used by (M. B Sangaré and *al.* 2020, p.113) in a study on land tenure and productivity in Mali. According to the authors, "in practice, interpretation of the parameters associated with the explanatory variables in this model is easier than in other models. Similarly, this model is an approximation of the probit model, i.e. the reduced centred normal distribution".

The results

The Korsimoro hydro-agricultural perimeter: In the commune of Korsimorro, there is only one type of cropping system. This type of cropping is polyculture. It is generally practised during the dry season. During the winter, farmers work in the fields growing food crops (millet, maize, sorghum) and cash crops (groundnuts, sesame). In order to gain a better understanding of the link between production and the cropping system developed in the hydro-agricultural perimeter, the econometric model was adopted. This model is based on theoretical analysis and a statistical database. It is based on two approaches : the production function and the probabilistic approach.

Analysis of the cropping system developed in the hydro-agricultural perimeter: The cropping system used is mixed cropping. To this should be added the cultivation techniques and the marketing of market garden produce. Sampling of male and female producers was carried out on a reasoned basis according to membership of cooperatives and producers not affiliated to cooperatives who practise mixed farming (Table 1). This table shows that the number of producers surveyed was 104. There were more plot holders than non-plot holders (59 plot holders compared with 45 non-plot holders). This gives an estimated 56.73% of plot holders compared with 43.27% of non-plot holders. Of the producers who own plots, those aged between 45 and 54 outnumber those who do not (23 producers). This could be explained by the fact that this age range corresponds to an age when these people are no longer interested in adventure. They are responsible for their families. Those aged 60 and over are outnumbered (2 producers).This age group corresponds to a time when these people no longer have sufficient physical strength to carry out work within the managed perimeter. For non-holders, the numerical superiority is observed in the 35 to 44 age bracket. This corresponds to the time when young people are eager for purchasing power. However, there is no headcount for producers aged 60 and over. At this age, older people no longer want to take the risk of investing in entrepreneurship by renting out plots of land. In addition, a link was established between

the status of producers and the size of their farm plots (Table 2). The data in this table show that the number of producers who do not own farm plots (64 producers or 61.54% of producers) is higher than the number of producers who own farm plots (40 producers or 38.46% of producers). This could be justified by the fact that producers who do not own farm plots are more involved in work on the hydro-agricultural perimeter than producers who own farm plots. Among producers with plots, those with a surface area of one hectare are the most represented (18 producers). This is followed by areas of 0.25 hectares (11 growers), 0.5 hectares (9 growers) and 0.75 hectares (2 growers) respectively. With regard to producers who do not own plots of land, the largest number of producers is found in the 0.25 hectare area (32 producers). The 0.5 hectare area has 21 growers. The 0.75 hectare area has 10 growers. The one-hectare area has one grower. As the size of the farm plot increases, the number of producers decreases.This could be explained by the fact that producers who do not own plots of land do not have sufficient financial resources to rent plots of land. Similarly, they do not have adequate material resources to maintain their plots.

Table 1. Distribution of producer status according to age in the Korsimoro hydro-agricultural area

Status of producers / age group (years)	Plot holders	No plot holders	Total
19-34	6	14	20
35-44	9	15	24
45-54	23	8	31
55-60	19	8	27
60 et plus	2	0	2
Total	59	45	104
Estimate (%)	56,73	43,27	100

Table 2. The link between the status of producers and the size of farm plots

| Surface area of farm plots (in hectares)	Plot holders	No plot holders	Total
0,25	11	32	43
0,5	9	21	30
0,75	2	10	12
1	18	1	19
Total	40	64	104
Estimate (%)	38,46	61,54	100

Source: Field survey, 2023

In addition, the use of phytosanitary products by producers in the hydro-agricultural perimeter is spreading. In order to increase crop yields, farmers are resorting to the use of certain plant protection products. Both farm plot holders and non-farm plot holders use them (Table 3). The data in this table provide information on the quantities and types of crop protection products used by growers. In terms of quantity, chemical fertiliser made up of NPK and urea (175 kg) is used by 37.5% of growers (39 growers) to make their crops profitable. Next, organic manure (100 kg) is used by 24.04% of farmers (25 farmers) on their plots. Chicken droppings (75 kg) are grafted onto row 3. It is used by 7 producers (6.73% of producers). After hen droppings come fungicides (50 kg). A total of 11 growers (10.58% of growers) use them on their plots. Herbicides (25 kg) came next to last. Eight growers (7.69% of growers) use it on their plots. Pesticides came last (10 kg). The percentage of growers who use pesticides is 13.46%, or 14 growers. In addition, on average, growers use 70.67 kg of plant protection products per 0.25 hectare.It should be understood here that growers use plant protection products without any means of protection. They put their health at risk, and the use of these products has far-reaching repercussions for the environment. This results in the degradation of plant cover, the poisoning of aquatic animals and the infection of groundwater through infiltration. Producers can contract illnesses such as eye and skin irritations, headaches, cancer, neurological diseases, reproductive disorders, etc.

Table 3. Quantity of types of plant protection products used by producers

Quantity	Type of crop protection products	Number of producers	Estimate (%)
175 kg	Chemical fertiliser (NPK and urea)	39	37,5
50 kg	Fungicides	11	10,58
25 kg	Herbicides	8	7,69
10 kg	Pesticides	14	13,46
75 kg	Chicken droppings	7	6,73
100 kg	Organic manure	25	24,04
Total	-	104	100

Source: Field survey, 2023

Farming equipment and techniques: In the hydro-agricultural zone, human power remains the real driving force. Working equipment is rudimentary and not very mechanised. It consists of the daba, the manga hoe and picks. The plough is used in a few places (2 producers) in the section of farmers who do not own plots, to plough the plots. In the irrigation system, farmers use motor-driven pumps and PVC pipes. Sprayers are also used to treat farm plots against possible pest attacks. These motor-driven pumps are powered either by fuel (petrol or diesel) or gas (butane). The survey revealed that 68.26% of growers (71 growers) use butane gas to power their motor pumps.Fuel is used by 31.74% of growers (33 growers). Of these, 18 (54.55%) use petrol and 15 (45.45%) use diesel to power their pumps (Figure 1). The excessive use of butane gas to power motor pumps by producers is under the pretext that the consumption of butane gas is more economical than fuel. The use of butane gas to power motor pumps could cause enormous damage in the event of fire (or even loss of life). It is therefore preferable to minimise the use of butane gas and maximise the use of fuel to power motor pumps.
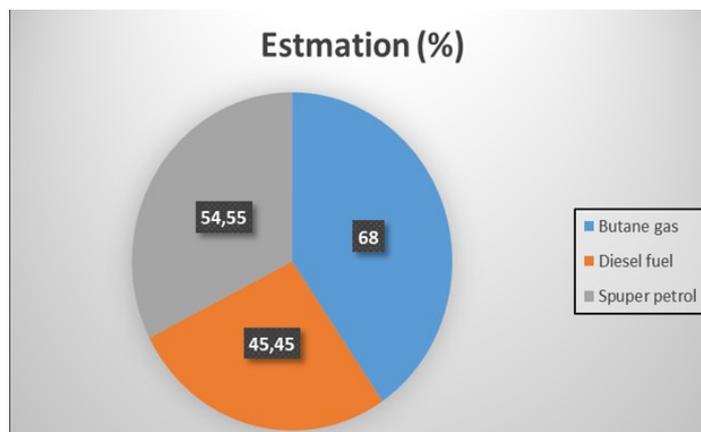
Figure 1. Estimated sources of power for motor-driven pumps

The illustrations below show the equipment used in the mixed farming system (Planche). In the Korsimoro hydro-agricultural perimeter, several methods are used to supply the plots of land farmed with water. These include small-scale village irrigation, small-scale individual irrigation and small contractors. The farm plots are located on the left bank, the right bank and upstream of the dam.

Plate Photographs illustrating the equipment used within the landscaped perimeter
Author : W. O NIKIEMA, 2023

Caption

1.   Motor-driven pump powered by butane gas
2.   Motor pump powered by fuel (super 91 petrol)
3.   10-litre sprayer and daba
4.   A pickaxe for plot work (weeding)

Small-scale village irrigation (P1): This type of irrigation is defined at the community management level. It is intended for the management of producer groups. When the group of producers does not have its own plots of land, each producer contributes towards the cost of renting the land and other expenses. Within the group, all producers have the same rights and duties. There are 8 groups.

Small-scale individual irrigation (P2): In this type of irrigation, the management method is determined by the owner of the motor pump or his family. Plots are between 0.25 and 5 hectares in size. Access to land and irrigation water is granted by the relevant authorities. The number of groups in this type of irrigation is equal to 9 groups.

Small entrepreneurs (P3) : These are individuals who own plots of between 0.25 and one hectare in size. To carry out work on their plots, they use local or foreign labour. The latter are not the owners of the plots. As a result, they make a considerable contribution (75,000 to 80,000 CFA francs/0.25 hectare/year) towards the rental of the plots.

Hydro-agricultural products in the Korsimorro perimeter: Depending on whether they belong to small-scale village irrigation, small-scale individual irrigation or small entrepreneurs, producers are involved in several production products. These include onions, tomatoes, rice, cabbages, lettuces, peppers, cucumbers, carrots, courgettes, etc. To do this, an operating account was drawn up. This operating account only took into account the main hydro-agricultural products such as onions, tomatoes and rice. The marketing of the production of these different products is given as a function of the sum of variable costs and fixed costs. The results are shown in Table 4.

Table 4 . The operating account for the main hydro-agricultural products

	P_1	P_2	P_3
Total variable costs	195 280	61 090	198 350
Production in bags of bulb onions (165 kg)	17	14	24
Selling price	935 000	301 000	504 000
Profit (F CFA)	739 720	239 910	305 650
Profit/kg (F CFA)	305		
	P_1	P_2	P_3
Total variable costs	404 600	210 000	345 600
Production in tomato crates (165 kg)	24	31	27
Selling price	533 330	373 330	501 200
Profit (F CFA)	128 730	76 920	155 600
Profit/kg (F CFA)	275		
	P_1	P_2	P_3
Total variable costs	38 500	38 520	46 270
Bagged rice production (in tonnes)	1,125	1,4	1,25
Selling price	234 000	135 000	121 500
Profit (F CFA)	285 500	96 480	75 230
Profit/kg (F CFA)	450		

Table 5. Productivities of the mixed farming system according to producers' status

Productivity	Plot holders	No plot holders	Total
Yield at 0.25 ha (kg/0.25 ha)	95,1	121,97	217,07
Production in kg	1474	2 683,5	4 157,5
Estimate (en %)	43,81	56,19	100

Source: Field survey, 2023

These figures show that rice marketing generates a profit of 450 F CFA/kg and is a major activity in the Krsimorro hydro-agricultural zone. Next, the marketing of onions provides a profit of 305 F CFA/kg and occupies second place. The last place is reserved for the marketing of tomatoes. This business makes a profit of 275 F CFA/kg. However, small village irrigation producers make more profit (739,720 F CFA) from the sale of onions. Next in line are producers of small-scale contractors, who made a profit of 305,600 F CFA. Producers of small-scale individual irrigation make around 290,910 F CFA. In short, onion productivity is more profitable than tomato and rice productivity in the Korsimoro hydro-agricultural perimeter.

Productivity of the polyculture system : Depending on the status of the producers (holders and non-holders of farm plots), the irrigation systems, the equipment and techniques used, and the use of plant protection products, it was possible to quantify the agricultural productivity yield. This yield was evaluated on an area of 0.25 hectares on the farm plots (Table 5). The data in this table suggest that agricultural productivity is a function of the use of plant protection products and the status of producers. The yield per 0.25 hectare of non-plot holders is higher (121.97 kg) than the yield per 0.25 hectare of plot holders (95.1 kg). This could be explained by the fact that non-plot holders have a greater incentive to be productive because their plots are rented out. For this reason, they are more involved in these activities.

Analysis of econometric data : This analysis briefly presents the results of the various estimates of the system equations for mixed farming and productivity. The interpretation and implication of policy are also taken into account.

Estimation of the equation for the mixed farming system: Using the Logit model as the reference system, it was possible to obtain the results shown in the table below.

Table 6. Proportionality of the estimates for the mixed farming system

Logit estimation				Number of producers = 104		
Log likelihood = -39,99937552				LR chi2(3) = Prob > chi2 = 0,000		
Type	Coefficient	Stantard error	z	P >|z|	[95 % Confidence. Interval]	
Age	.5042431,68	.1651343,2	6,344	0,00416	.1805858,08	.8279007,36
Productivity	-2,5389416	.7797585,12	-6,7808	0,00208	-4,06724032	-10106426,72
Area	-10,26196704	3,615352	-5,9072	0,0104	-17,34792592	-3,1600816

Source: Field survey, 2023

Analysis of this test of the joint hypothesis shows that logistic regression is compatible with probability. Already, the prediction of the probability of a producer practising mixed farming rhymes with productivity, the size of the farm plots and the age of the producers. As a result, it should be understood that the probability of practising mixed farming increases with age (0.00416). The probability of mixed cropping decreases with productivity (0.00208) and surface area (0.0104). Consequently, the older the farmers, the greater the probability that productivity is lower. On the other hand, the probability that a farmer owns plots of land is lower. It should also be noted that productivity has a very negative impact on the confidence interval [-4.06724032 ; -10106426.72]. What can we observe about marginal effects ?

Marginal effects : Focusing on variables such as age, productivity and area of farm plots, it is necessary to check whether there are any disturbances between these different variables (Table 7).

Table 7. Proportionality of marginal effects

Marginal effects after Logit y = Pro (Type) (prédiction) = .66607451,44							
Variable	dy/dx	Standard Error	Z	P > $|z|$	[95 % Confidence. Interval]		X
Age	.6097647,2	.3704,48	6,1568	0,00624	37163,36	.182366,08	41,36
Productivity	-.3526820	.16546,4	-6,9472	0,00208	-.877000,8	-.22836,32	6,1377 136
Area	-1,0338472	.77975,04	-5,9488	0,00832	-3,7621168	-.705575,52	.25

Source : Field survey, 2023

The figures in this table are more explicit. If a farmer's age increases by one notch, i.e. above the average (41.36 years), the probability that he or she owns farm plots and practises mixed farming increases by 0.060. When productivity increases by one kilogram, the probability of owning farm plots decreases by 0.35. When productivity increases by one kilogram, the probability of owning farm plots decreases by 0.35. In addition, the area farmed on 0.25 hectares has a negative impact on the probability of the producer owning plots, which is 1.03. How should these predictions be judged ?

Judging the relevance of the model: To gain a better understanding of the model, it is interesting to assess the quality of the model while agreeing on the prediction spreadsheet. This spreadsheet is a tool that helps to determine the best prediction ratio of the model (Table 8).

Table 8. Logit model ratio predictions

	True		
Classified	D	~D	Total
+	47	9	56
-	12	36	48
Total	59	45	104
Classified if predictive Pr (D) > = 0,5 True if D defined as Type = 0			
Sensitivity	Pr (+| D)	79,66 %	
Specific	Pr (-|~ D)	80,00 %	
Positive predictive assessment	Pr (D| +)	83,94 %	
Negative predictive assessment	Pr (~D| -)	75,00 %	
False + rate for true ~D Pr (+| ~D)		20,00 %	

The data shows that the positive predictive test ratio is higher (83.94%). Specificity was in second place at 80.00%. Sensitivity was in third place at 79.66%. The negative predictive test is in last place (75.00%). Also, for plot holders (59 producers), the model was able to predict 47 correct responses. In other words, from a certain rank given by the model (p > 0.5), false answers are equal to 12 and correct answers to 47 for plot holders. As for the non-plot holders, the model erred by 9 producers. In fact, nine producers were designated as plot holders even though they were renters. The exact prediction rate is calculated as follows : [((47 + 36) x 100) /104] = 79.80%. In short, this percentage means that the model's predictions appear to be accurate. Given the size of the populations studied (104), this score is acceptable overall.

Estimating the productivity equation : This involves applying the ordinary least squares method via the robust option. This method is more appropriate for objective correction of any heteroscedasticity. This resulted in the data shown in the table below. The power to explain this model is R2 = 92%, which is higher. By entering the data into XLSTAT, 2024, the result of the heteroscedasticity test gives the statistical value of Chi2(1) = 4.82 and the probability value (Prob > Chi2 = 0.0184). These results support the homoscedasticity hypothesis of the model. Variables such as NPK and urea, fungicides, herbicides, pesticides, hen droppings and organic manure and the status of producers did not give statistically significant values.

Table 9. Proportionality of the productivity estimate

Source	SS	Df	MS	Number of producers = 104	
Residual model	3220,105658	11	644,021131	F (11 ; 93) = 92,14	
	298,9333885	93	6,64296418	Prod > F = 0,0000	
Total	3519,0390465	104	650,66409518	R^2 = 0,9202 Adjustment of R^2 = 0,9102 MSE Racine =	
Performance	Coefficient	Standard error	T	P >|t|	[95 % Confidence. Interval]
NPK and Urea	.5538207		2,65	0,105	-.085175 .8708567
Fungicides	-.548631	.243037	1,05	0,002	-1.095621 .8945623
Herbicides	.609527	.372278	-1,89	0,003	-.9345890 -.1756325
Pesticides	-.730856	.373376	-2,12	0,004	-2,247527 -.2365548
Chicken droppings	.514789	.153148	-0,9	0,001	.1091868 .2685249
Organic manure	-.849740	.364259	-3,03	0,005	-2,359616 -.3398839
Age	.3010659	.0521908	8,19	0,000	.319060 .4848248
Age2	-.004523	.0008499	-5,73	0,000	-.0050122 -.002036
Type	-.3928538	.8812500	-0,47	0,827	-2,943015 2,370520

This could be explained by the fact that the quantity of plant protection products used has a positive influence on the yield on 0.25 hectares. Furthermore, the number of years of experience on the hydro-agricultural perimeter also has a positive influence on agricultural yield. Despite what is said above, productivity is not statistically significant.The negative value of this variable (type) contradicts what was said above (as a reminder, holders of farm plots are more involved in agricultural productivity and produce more than non-holders of plots). As a result, it is clear that holding plots is not a determining factor in productivity. On the other hand, those who do not own plots develop coping strategies to increase agricultural yields in production, because the plots can be withdrawn the following season. This is not the case with holders of farm plots, who will always own them.

Correlation between productivity and the mixed farming system : Analysis of these two tables allows us to identify the quintessence between the different variables. In other words, this analysis makes it possible to determine the correlation that exists between the estimates of the productivity equation and the estimates of the polyculture system equation. The polyculture system is developed on the farm plots. However, this mixed cropping practice gives different yields. For producers holding farm plots, the yield is numerically lower at 1474 kg/0.25 ha (i.e. 43.81% of production). On the other hand, in the case of growers who did not own plots, the yield was 2,683.5 kg/0.25 ha higher (i.e. 56.19% of production). The correlation coefficient for the two variables was 150.9048. Thus a positive value. This means that the estimates of productivity and the estimates of the polyculture system are moving in the same direction. Applying the formula for the coefficient of determination, which is calculated using covariance, gives an estimate of around 0.7516. By way of conclusion, variables such as productivity and the polyculture system are highly correlated (Figure 2).
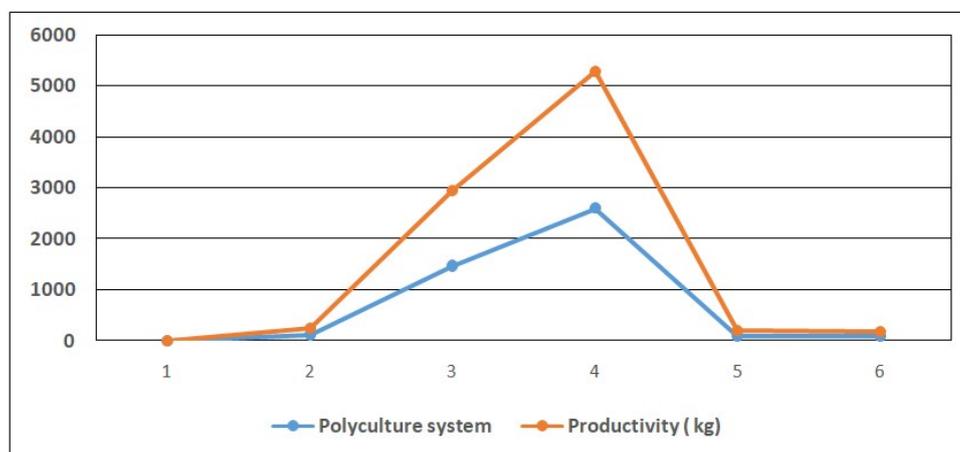

Figure 2. Changes in the correlation between productivity and the mixed farming system

DISCUSSION

The correlation between the cropping system and agricultural productivity has been the subject of study by contemporary researchers. In the Korsimoro hydro-agricultural perimeter, these two factors are highly correlated in terms of the coefficient of determination, which is 0.7516. There are 59 plot holders (56.73%). The majority of plot-holders are between 45 and 54 years old (23 farmers). The ratio of producers who do not own plots is 43.27%, or 45 producers. The greater number of non-plot-holding growers is found in the 35 to 44 age bracket. These results are in line with those of (P Jouve, 2003, p.581).In France, analysis of cropping systems practised in southern countries has shown that there is a spatial and social organisation of cropping systems at the level of rural communities. These different factors of differentiation of sub-constraints on a local scale show that these systems can correspond to varying levels of intensification. Similarly, the research findings of (J. P Dubois and *al*. 2001, p.406) corroborate the same results. Indeed, the adjustment of cultivated area to available labour is confirmed. It shows a good correlation between the area cultivated per farm and the number of man labour units. However, it should also be noted that the latter criterion only gives an approximate idea of the actual labour force on the farm. In this study, the production function was highlighted. It is based on the quantity of crop produced in kilograms and the quantity of inputs used. Thus, the productivity obtained by the yield per 0.25 hectare is specific to the amount of work and the use of sanitary products. It was used by (A Archer, 1979, p.232) in Quebec on the agricultural production function. Variables such as sample size, output per farm of unit i, inputs and labour were also used in this study. To better flesh out these results, the probabilistic approach was highlighted. This model was also used by (M. B Sangaré and *al*. 2020, p.113) in a study on land tenure and productivity in Mali. According to the authors, "in practice, interpretation of the parameters associated with the explanatory variables in this model is easier than in other models. Similarly, this model is an approximation of the probit model, i.e. the reduced centred normal distribution". The study showed that the average age of farm plot holders is between 45 and 54. The average age of those not holding plots was between 35 and 44. In the study site, the number of women producers outnumbered the number of men producers (66.47% compared with 33.53%). These results are contrary to those found by (FAO, 2014, p.2).These results showed that in the United States and other developed countries, the average age of producers is close to 60. In Africa, it is also around 60, despite the fact that 60% of the African population is under the age of 24. The results showed that the correlation coefficient of the two variables (polyculture and productivity) is 150.9048. In other words, a positive value. This means that estimates of productivity and estimates of the polyculture system are moving in the same direction. Applying the formula for the coefficient of determination, which is calculated using covariance, gives an estimate in the order of 0.7516. This value is close to 1. In conclusion, variables such as productivity and the polyculture system are highly correlated in the Korsimoro hydro-agricultural perimeter. The research work of (A Sanouna and *al*. 2020, p.469) attests to these results. The correlation between production factors and production is positive. It is significant at the 1% threshold in the Kourtheye zone in Niger. However, these results differ from those of (J. P Butault and *al*. 2005, p.58). The growth rate of farms has very little to do with their initial size : the relationship between this growth rate and the logarithm of the initial size is significant, but the coefficient of determination is almost zero. The regression coefficient is both close to zero and significantly positive. So there is no catching up, but rather a very slight accentuation of the disparities. In addition, in the Korsimoro hydro-agricultural perimeter, the type of cropping system developed is polyculture. Tomatoes, onions and rice are the main crops grown in the Korsimoro hydro-agricultural area. The same cropping system is developed in the Marne valley, where crops are diversified. It covers 65 hectares, including 2 ha of carrots, 13 ha of weeds, 40 ha of cereals and 10 ha of alfalfa (C Delfosse and *al*. 2020, p.4).These results are contrary to those found by (E Pinot and *al*. 2000, p.5). In Indonesia, more specifically in Malaysia and North Sumatra, rubber cultivation is more developed. Analysis of the marginal effects showed that if a farmer's age rises one notch, i.e. above the average (41.36 years), the probability that he or she will own plots of land and practise mixed cropping increases by 0.060. The area farmed on 0.25 hectare has a negative influence on the probability of the farmer owning a farm plot, which is 1.03. In the Konni area, the situation is quite different. There is a general trend towards smaller areas in the dry season than in the wet season. Similarly, the areas sown are smaller in the dry season than in the wet season, when water is not a limiting factor (A Saidou and *al*. 2023, p.13).Crop protection products are also used in the study area. In terms of quantity, chemical fertiliser made up of NPK and urea (175 kg) is used more by 37.5% of growers (39 growers) to make their crops profitable. Next, organic manure (100 kg) is used by 24.04% of farmers

(25 farmers) on their plots. Chicken droppings (75 kg) are grafted onto row 3. It is used by 7 producers (6.73% of producers). After hen droppings come fungicides (50 kg). A total of 11 growers (10.58% of growers) use them on their plots. Herbicides (25 kg) came next to last. Eight growers (7.69% of growers) use it on their plots. Pesticides came last (10 kg). The percentage of growers who use pesticides is 13.46%, or 14 growers. In addition, on average, growers use 70.67 kg of plant protection products per 0.25 hectare.It should be understood here that producers use plant protection products without any means of protection. This could have serious implications for their health. They can contract eye and skin irritations, headaches, cancers, neurological diseases, reproductive disorders, etc. The use of plant protection products has a harmful impact on the environment. Water pollution, leading to the destruction of aquatic animals. Infection of the water table through infiltration. Work carried out in the Republic and Canton of Geneva (2018, p.18) found similar results. The report refers to the negative effects associated with the use of plant protection products. The method of treatment is said to be a crucial factor. The use of plant protection products can cause immediate health problems (acute toxicity) or long-term problems (chronic toxicity). In the first case, the symptoms are neurological, allergic, respiratory or cutaneous effects. In the second case, the consequences are more dangerous. They include cancers, respiratory problems and nutritional disorders. A little further on, there is a link between the use of plant protection products and Parkinson's disease, as well as malignant haemopathies.Research by (N Nahon, 2012, p.238; M. M Robin, 2012, p.150; J. M Lescot and *al.* 2013, p.119; U Beck, 2008, p.60; J Delon, 2015, pp.10-11) corroborates the same results. The marginal effects of this study showed that if a farmer's age increases by one notch, i.e. above the average (41.36 years), the probability that he or she will be a holder of farm plots and practising the polyculture system increases by 0.060. When productivity increases by one kilogram, the probability of owning farm plots decreases by 0.35. In addition, the area farmed on 0.25 hectares has a negative impact on the probability that the farmer owns plots, which is 1.03. The same is true for the research results of (A. Y Sylla and *al.* 2014, p.10). The regression of bivariate probit estimates of the determinants of policy participation and producer status. Indeed, the probability that the coefficient is equal to zero ; the variable takes the value 1 if the farmer participates in the policy and 0 if not ; the status designates young people who take the value 0 and old people who take the value 1 ; the gender variable takes the value 0 for men and 1 for women.

CONCLUSION

The Korsimoro hydro-agricultural scheme is part of a mixed farming typology. The farm plots are irrigated by motor-driven pumps. These motor-driven pumps are powered either by fuel or by butane gas. At times, this could be very disastrous in the event of an incident. Agricultural techniques remain underdeveloped. The representation of women producers is numerically superior (69 women producers against 35 men producers). To increase agricultural productivity, plot holders (56.73%) and non-plot holders (43.27%) all resort to the use of phytosanitary products. The use of these phytosanitary products (100% of producers) is without any means of protection. This could inevitably lead to respiratory infections and the development of certain diseases (skin cancer, for example). Producers (80% of producers) also reported difficulties in marketing hydro-agricultural products. The study showed that the accurate prediction rate was 79.80%. The analysis of the correlation between the mixed farming system and agricultural productivity showed that the factors are highly correlated, with the coefficient of determination at around 0.7516.The water in the Korsimoro hydro-agricultural area is not permanent. This applies to the downstream section. From February onwards, this part dries up. Farmers dig wells to make up for the scarcity of water during this period. In order to make the Korsimoro hydro-agricultural area even more profitable, all the producers (both those who own plots and those who do not) need to be made aware of the issue, trained and financed. To make the water from the dam sustainable, the dam needs to be treated as a matter of urgency. Beacons should also be built downstream of the dam to prevent silting up and blocking the dam. Farmers should also considerably reduce the use of phytosanitary products and promote the use of organic fertiliser or compost.

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