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Determinants of the economic profitability of the surface irrigation system by gombo growers at the Masina Rail 1 site in the N'djili River watershed, Kinshasa

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Abstract

This study examines the determinants of the profitability of okra cultivation at Masina Rail 1 in the N'djili River watershed in Kinshasa. It reveals that profitability is influenced by several factors, including production costs, selling prices and quantity sold. Profitability simulations show that climatic conditions, such as periods of scarcity, increase profit margins, while flooding has a negative impact on profitability. Multiple linear regression analysis confirmed significant relationships between independent variables and profitability, with an R^2 of 99.9%, underlining the importance of optimizing costs and increasing cultivated area. The results provide recommendations for improving growers' profitability, in particular by adopting adaptive strategies in the face of market fluctuations and climatic hazards.

Keywords: Watershed, Determinant, Economic profitability, N'djili River, surface irrigation system

Déterminants de la rentabilité économique du système d'irrigation de surface par les producteurs de gombo sur le site de Masina Rail 1 dans le bassin versant de la rivière N'djili, Kinshasa

Résumé

Cette étude examine les déterminants de la rentabilité de la culture de gombo à Masina Rail 1 dans le bassin versant de la rivière N'djili à Kinshasa. Elle révèle que la rentabilité est influencée par plusieurs facteurs, notamment les coûts de production, les prix de vente et la quantité vendue. Les simulations de rentabilité montrent que les conditions climatiques, comme les périodes de pénurie, augmentent les marges bénéficiaires, tandis que les inondations impactent négativement la rentabilité. L'analyse par régression linéaire multiple a confirmé des relations significatives entre les variables indépendantes et la rentabilité, avec un R^2 de 99,9 %, soulignant l'importance d'optimiser les coûts et d'accroître les superficies cultivées. Les résultats fournissent des recommandations pour améliorer la rentabilité des producteurs, notamment en adoptant des stratégies adaptatives face aux fluctuations du marché et aux aléas climatiques.

Mots clés : Bassin versant, Déterminant, Rentabilité économique, Rivière N'djili, système d'irrigation de surface

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I. INTRODUCTION

The Democratic Republic of Congo (DRC) is experiencing rapid population growth, which is driving up demand for food. This situation underlines the importance of efficient agricultural intensification, particularly through irrigation, which represents an essential lever for improving crop productivity (FAO, 2007). In this context, gombo, as a food crop, plays a crucial role in food security and farmers' incomes, particularly in the Kinshasa region.

The N'djili river watershed, with its irrigated land, offers considerable potential for gombo production. However, the economic profitability of surface irrigation in this region is influenced by various determinants, such as investment costs, cropping practices and water resource management (World Bank, 2023a). Small-scale irrigation systems, although less costly, require appropriate management to maximize their efficiency and profitability.

Surface irrigation, while effective, is subject to challenges such as climatic variations and access to financial resources. Growers' dependence on these systems can affect their ability to adapt to the impacts of climate change, reducing productivity and yields (Tillie et al., 2019). In addition, managing the costs associated with irrigation, labor and agricultural inputs is key to assessing the economic viability of gombo cultivation.

Previous studies have often highlighted the technical aspects of irrigation, but few have focused on the economic determinants specific to surface irrigation systems for gombo in the N'djili River watershed. This research therefore aims to fill this gap by analyzing the factors influencing the economic profitability of these irrigation systems, taking into account the specific agro-ecological and socio-economic features of the region.

Understanding the determinants of the economic profitability of the surface irrigation system for gombo cultivation at the Masina Rail I site is crucial to formulating sustainable and effective strategies. This will not only improve agricultural productivity, but also enhance food security in the face of growing environmental challenges.

This study answered the question: What are the main determinants of the profitability of gombo cultivation in the study site? The study supported the hypothesis that the profitability of gombo cultivation is positively correlated with selling prices and quantities sold, while production costs and flooding have a negative impact on this profitability. Thus, the study sought to analyze the impact of production costs, selling prices and quantities sold, as well as marital status and irrigable area on the profitability of gombo cultivation, while assessing the effects of climatic risks, particularly flooding.

MATERIALS AND METHODS

Presentation of the Masina Rail I site

The Masina Rail I market garden site is located in the Malebo Pool part of the N'djili river watershed. The Masina Rail I agricultural site is located in the Mfumu-Sunka district of Masina commune, and was established in 1969 when the Chinese arrived. It is bounded to the north by the Congo River, to the south by the railroad, to the east by the Masina Rail 2 site, and to the west by the Ngwele River, otherwise known as the N'djili River. It covers a total area of 1,350 ha, 760 ha of which is under cultivation, the remainder being uncultivated due to the lack of hydro-agricultural development. The site comprises 21 blocks and counts 1,200 households with 5 or 6 people per household.

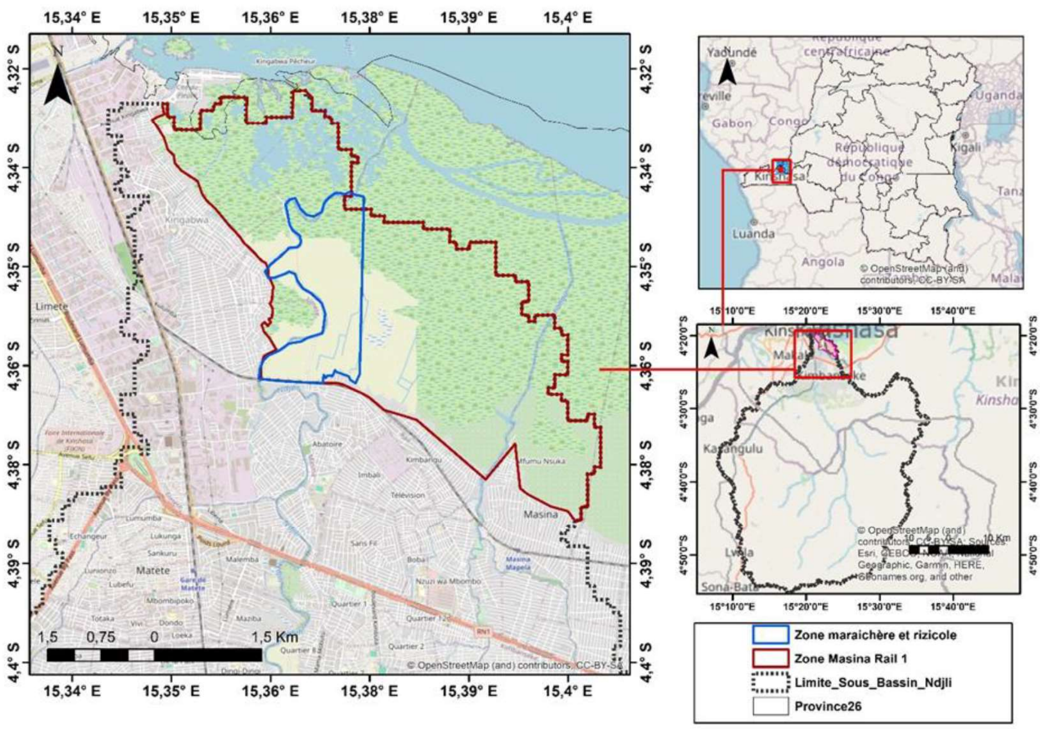

Figure 1: Map of study area

Sampling methods and techniques

In this study, the sampling technique used the following formula to draw our sample (Lututala, 2022):

$$n = z^2 \text{ x } p(1-p)/m^2 \quad \text{(Equation 1)}$$

With :
n= sample size
z= confidence level according to the reduced centered normal distribution (for a 95% confidence level z= 1.96, for a 99% confidence level z= 2.575)
p= estimated proportion of the population exhibiting the characteristic (when unknown, o, use p=0.5, which corresponds to the worst case, i.e. the widest dispersion)
m= tolerated margin of error (for example, we want to know the real proportion to within 6%)

$$n = (1{,}96)^2 x(0{,}5)(1-0{,}5)/(0{,}6^2) \quad \text{(Equation 2)}$$

$$\mathbf{n = 267}$$

Data collection techniques

The research aimed to collect quantitative data on production costs, selling prices, quantities sold, marital status of producers and irrigated area, based on questionnaires and interviews with gombo producers practicing the small-scale irrigation system at the study site.
The survey was carried out using a questionnaire previously programmed into Kobocollect. It was carried out with 25 producers in each block of the perimeter, taken at random, for a total of 10 functional blocks at the time of data collection, i.e. a total sample of 250 producers. Producers were selected at random from the entire site. On the sample perimeter, visits were made to water sources, irrigation canals and production plots. Observations were also made of how water was supplied to the plots and how production was organized.
It should be pointed out that, in the context of our study, due to the lack of growers present because the blocks were already under water, we only surveyed 250 growers. In this case, 250/267 of the sample size is a 94% success rate, and the remaining 17 individuals are included in the wastage rate. Of the 250 producers surveyed,

182 were okra producers and the remainder were rice and amaranth producers. These 182 producers formed the basis of our analysis.

Data analysis techniques

The data collected as part of this study were analyzed using a number of tools and methods, such as profitability simulation analysis, descriptive statistics, mean comparison tests and multiple linear regression for determinant analysis. Analysis of the data collected was carried out using SPSS 25 software and Excel 2019 spreadsheet.

Simulation analysis of profitability

The study began by assessing climatic risks to identify the impact of flooding and drought on profitability. It integrated historical data on these climatic factors with producer testimonials within the same conceptual framework.

Subsequently, the simulation analysis consisted of a synthesis of sales price and income scenarios from gombo cultivation based on climatic fluctuations observed between 1991 and 2021.

To carry out the simulations of the periods of scarcity and abundance, a ratio was found to apply with the reference scenario. This ratio was found by taking the precipitation data series of the study area; starting from the year 1991 to 2021 in order to find or identify the year with the most abundant precipitation and the year with the most severe drought. For our data series, 1996 was the year of severe drought, and 2020 was the year of abundant rainfall in the study area. We divided the quantity of the abundant situation by the quantity of water in the reference situation, and did the same for the abundant situation:

Ratio(scarcity) = Precipitation1996/Precipitation2021
=1296,11/2060,39
=1,590

Ratio(abundance) = Precipitation2020/Precipitation2021
=3005,18/2060,39
=0,686

Table 1 presents the 3 scenarios used in this profitability study and the corresponding ratios.

Table 1. Basic scenarios for price and income simulation

Scenario	Precipitation		Ratio
	Period (year)	Value (mm)	
Reference	2021	2060,39	1,000
Shortage	1996	1296,11	1,590
Abundance	2020	3005,18	0,686

To obtain the prices and revenues for each scenario, we multiplied the found ratio of precipitation by the reference scenario selling price to find the selling price in the shortage and abundance scenarios. The same procedure was applied to revenues.

$$R = Qty \times PV \quad \text{(Equation 3)}$$

$$MB = R - CT \quad \text{(Equation 4)}$$

Where :
R is total income or revenue
Qty is quantity sold
PV is the selling price
MB is profit margin
TC is total cost

Computer simulation models: These models use computer software to simulate the operation of a system. They may be based on mathematical models, algorithms, rules or interactions between different system components. Computer simulation models are used in many fields, such as finance, environmental sciences, engineering, logistics, health, etc. In the case of our study, we used the scenario analysis tool, specifically the scenario manager in Excel, and MATLAB to simulate the profit margins and profitability of the different irrigation systems.

To carry out a sensitivity analysis, we first identified the model parameters that could vary, then set up a base model with initial values for each parameter, and finally modified each parameter individually to observe changes in the result.

The methodology for calculating sensitivity in our example is based on a comparative analysis of profit margins and profitability between the initial situation and the scarcity and abundance scenarios. First, we collected margin and profitability values for each sales unit in the three situations. Then, for each unit, we calculated the variation using the formula :

$$S= \frac{\text{Value in current situation} - \text{Value of reference situation}}{\text{Value of reference situation}} x100$$

This enabled us to obtain variations which, when positive, indicate favorable sensitivity (increase in case of shortage), while negative variations signal unfavorable sensitivity (decrease in case of abundance). Finally, by comparing results between different sales units, we were able to identify those most sensitive to changes in product availability, thus facilitating strategic decision-making.

Statistical analysis of profitability drivers

Multiple linear regression was used to analyze the relationships between the independent variables (costs, selling price, quantity sold, marital status, irrigated area) and the dependent variable (profitability). The regression results were used to determine the relative importance of each determinant, and to formulate recommendations based on the findings.

Model specification

$$Y = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + \cdots \beta_n X_n + \varepsilon$$

$$R = \beta_0 + \beta_1 CTG + \beta_2 URP + \beta_3 QVS + \beta_4 SM + \beta_5 UAA + \beta_6 F + \varepsilon$$

With

UAA is useful agricultural area

URP is the unit rice price

QGS is the quantity of gombo sold

CTG is the total cost of gombo production

F is flooding

MS is marital status

In this equation, R is used to represent the probability ratings of the profitability or profit margin of the irrigation system. The regression coefficients β_0 , β_1 , $\beta_2, \beta_3, \beta_4$ quantify the impact of each independent variable on the probability of profitability. Ɛ denotes the concept of random error. In order to estimate the regression coefficients, a statistical method such as maximum likelihood is used. Once the coefficients have been calculated, they can be used to analyze the influence of each independent variable on the probability of profitability of the irrigation system. In this model, the independent variables include elements such as:

- Perception of flooding (I)
- Unit price of gombo belly (PUVG)
- Quantity of gombo sold (QVG)
- Total cost of gombo production (CTG)
- Marital status (MS)
- Useful agricultural area (UAA)

Parameter nullity test

$t\beta_0 = \beta_0 /(Se\beta_0) \geq 1.96$ (sig 5%)

$t\beta_1 = \beta_1 /(Se\beta_1) \geq 1.96$ (sig 5%)

$t\beta_2 = \beta_2 /(Se\beta_2) \geq 1.96$ (sig 5%)

$t\beta_3 = \beta_3 / (Se\beta_3) \geq 1.96$ (sig 5%)
$t\beta_4 = \beta_4 / (Se\beta_4) \geq 1.96$ (sig 5%)
$t\beta_5 = \beta_5 / (Se\beta_5) \geq 1.96$ (sig 5%)
$t\beta_6 = \beta_6 / (Se\beta_6) \geq 1.96$ (sig 5%)

Model relevance test

The determinants of profitability for gombo cultivation were estimated using multiple linear regression, collecting data on production costs, selling prices, quantities sold, marital status and irrigated area from a sample of growers. The coefficients were estimated using the least-squares method, with significance tests to validate the relationships. The model was able to predict profitability by inserting values for each variable, and its robustness was confirmed by analysis of variance tests, displaying an R^2. This approach identified the key determinants influencing profitability, providing useful recommendations for gombo growers to adjust their strategies.

Model validation

Statistical validation of the determinants of profitability in gombo cultivation was carried out through rigorous methodological steps. Each coefficient was examined for its impact on profitability, with significance tests showing that all were significant, except for flooding. Residuals were checked for normal distribution, and homoscedasticity was assessed to ensure consistency of error variance. Multicollinearity was analyzed by the variance inflation factor (VIF), and independence of observations was guaranteed. Analysis of variance (ANOVA) confirmed the model's relevance, with an R^2 indicating an excellent fit and a Fisher test at the 1% threshold. Cross-validation techniques were also considered to test the robustness of the results, reinforcing the credibility and applicability of the conclusions for gombo growers.Discussion of the results enabled comparison with similar studies in other regions to assess the robustness and relevance of the conclusions.

RESULTS

Simulation-based analysis of gombo profitability

Profitability calculation for the reference scenario

With regard to the analysis of the profitability of gombo cultivation at the Masina Rail 1 site, the results in Table 1 below show that gombo cultivation is profitable under the conditions prevailing in the study area. For the Bac sales unit of 30 kg in an area of 2329.5 m2 of surface irrigation, growers achieved a profitability of 501%, in contrast to the sprinkler irrigation system with motor pump or sump, whose profitability was 713% with the same sales unit and an area of 2207.5 m2. Compared with other sales units and irrigation systems, it should be noted that the sprinkler irrigation system achieved a higher profit margin than the surface irrigation system. In terms of recommendations to growers, it would be best to use the sprinkler irrigation system, even if water use is not efficient (Table 1).

***Table 1: Profitability of gombo by sales unit (CDF)*[1]**

Sales unit	Irrigation system	GOMBO						
		UAA (m^2)	Price list	Qty	Total revenue	Total Cost	Prof margin	Prof
Bac of 30 kg	Surface irrigation	2330	68409	66	4514994	751347	3763647	501
	Sprinkler irrigation	2208	70399	66	4646334	571249	4075085	713
Half can of 25 L	Surface irrigation	2000	30000	126	3780000	81000	3699000	4567
50 kg basket	Surface irrigation	2000	105000	40	4200000	630000	3570000	567

[1] **Note**:
1$ = 2700 CDF

Simulation of gombo profitability in the event of climatic risks

The results show significant variations in the profitability of gombo cultivation according to the scenarios (reference, shortage, abundance) and the irrigation systems used. For example, for the 30 kg tub under surface irrigation, income rises from 4514994 in the reference scenario to 7178841 in the event of a shortage, indicating that efficient irrigation practices can maintain or even improve profitability even in times of climatic stress. In the abundance scenario, on the other hand, income drops to 3097286, suggesting that overly favorable conditions can adversely affect profitability, often due to overproduction or falling prices. This trend is also observed for 25-liter half-bins and 50-kg baskets, where revenues are higher in times of shortage. These results underline the importance of rigorous management of water resources and a marketing strategy that is adaptable to climatic fluctuations. In short, irrigation systems are crucial to the profitability of gombo cultivation, and strategic planning is needed to maximize income according to climatic conditions, thus offering avenues for optimizing production and growers' incomes. (Table 2).

***Table 2: Summary of gombo revenue scenarios (CDF)*[1]**

Sales Unity	Price List	Reference Scenario	Shortage		Abundance	
		Value	Ratio	Value	Ratio	Value
Bac of 30 Kg	PL_Surface_Irrigation_Bac	68409	1,59	108770	0,686	46929
	PL_Sprinkler_Irrigation_Bac	70399	1,59	111934	0,686	48294
Half can of 25 L	PL_Surface_Irrigation _Can	30000	1,59	47700	0,686	20580
50 kg basket	PL_Surface_Irrigation_ Basket	105000	1,59	166950	0,686	72030
Unité de vente	**Gombo income**					
Bac of 30 Kg	Income_Surf_Irrig_Bac	4514994	1,59	7178841	0,686	3097286
	Income_Sprinkler_Irrig_Bac	4646334	1,59	7387671	0,686	3187385
Half can of 25 L	Income_Surf_Irrig _Can	3780000	1,59	6010200	0,686	2593080
50 kg basket	Income_Surf_Irrig_ Basket	4200000	1,59	6678000	0,686	2881200

[1] **Note:**

1$ = 2700 CDF

Gombo profit margin scenarios

The results concerning selling price and profitability scenarios for gombo farming highlight the significant impact of price fluctuations on growers' profit margins. In the reference scenario, prices are stable for each type of sales unit, but in the event of a shortage, profit margins increase considerably, as in the case of the 30 kg tub, where the margin rises from 3763646 to 5984198. On the other hand, in a scenario of abundance, the margin falls to 2581862, showing that overproduction conditions can lead to lower prices and profits. This trend can be observed for all sales units, indicating that profitability is strongly influenced by prices, which vary according to climatic conditions. Consequently, growers need to adopt flexible and responsive pricing strategies to maximize their margins in the face of supply and demand fluctuations.

***Table 3: Gombo profit margin scenarios (CDF)*[1]**

Sales Unity	Price List	Reference Scenario	Shortage		Abundance	
		Value	Ratio	Value	Ratio	Value
Bac of 30 Kg	PL_Surface_Irrigation_Bac	68409	1,59	108770	0,686	46929
	PL_Sprinkler_Irrigation_Bac	70399	1,59	111934	0,686	48294
Half can of 25 L	PL_Surface_Irrigation _Half_Can	30000	1,59	47700	0,686	20580
50 kg basket	PL_Surface_Irrigation_ Basket	105000	1,59	166950	0,686	72030
Sales Unity	**Profitability margin**					
Bac of 30 Kg	PM_ Surface_Irrigation_Bac	3763647	1,59	5984198	0,686	2581862
	PM_Sprinkler_Irrigation_Bac	4075085	1,59	647938	0,686	2795508
Half can of 25 L	PM_Surface_Irrigation _Half_Can	3699000	1,59	5881410	0,686	2537514
50 kg basket	PM_Surface_Irrigation_ Basket	3570000	1,59	5676300	0,686	2449020

[1] ***Note :***

1$ = 2700 CDF

Sensitivity analysis of gombo profitability

The study of profit margins for gombo cultivation in the Masina Rail 1 met study area reveals significant results, particularly in relation to the irrigation systems used. With regard to the surface irrigation system, commercial units such as the 30 kg tub and the 25 L half-bottle show a sharp increase in profit during periods of shortage, reaching 5984198 Fc and 5881410 Fc respectively. This suggests that a shortage of water resources gives growers the opportunity to improve their margins by optimizing the management of available costs and prices. In contrast, when water resources are plentiful, each unit experiences a significant reduction in profit margin, reaching reductions of up to -31.4%. This negative sensitivity underlines the fact that, although irrigation systems have their strengths, excessive production can put a strain on prices, thereby restricting profitability. Consequently, the strategic use of irrigation in this sector is essential to optimize profits while minimizing the adverse effects of climatic variations.

Table 4: Sensitivity of gombo profitability (CDF)[1]

Sales Unity	Price List	Reference Scenario	Shortage		Abundance	
		Value	Ratio	Value	Ratio	Value
Bac of 30 Kg	PM_ Surface_Irrigation_Bac	3763647	1,59	5984198	0,686	2581862
	PM Sprinkler Irrigation Bac	4075085	1,59	6479385	0,686	2795508
Half can of 25 L	PM_Surface_Irrigation _Half_Can	3699000	1,59	5881410	0,686	2537514
50 kg basket	PM_Surface_Irrigation _Basket	3570000	1,59	5676300	0,686	2449020
Sales Unity	**Profitability sensibility**					
Bac of 30 Kg	Prof_ Surface_Irrigation_Bac	100%		59%		-31,4%
	Prof_Sprinkler_Irrigation_Bac	100%		59%		-31,4%
Half can of 25 L	Prof Surface Irrigation Half Can	100%		59%		-31,4%
50 kg basket	Prof_Surface_Irrigation _Basket	100%		59%		-31,4%

[1] Note :
1$ = 2700 CDF
Statistical analysis of the determinants of profitability of gombo cultivation
Multiple linear regression

MBG = -4529854,98 - 1,003 * TCG + 6253,531 * MS + 4,924 * IUAA - 8573,623 * F + 65,997 * PUG + 68454,181 * QSG
(t =123,4) (t =201,5) (t =2,99) (t =3,27) (t =-2,22) (t =268,7) (t=128,2)

Table 4: Determinants of profitability of gombo cultivation

Model variables	Unstandardized coefficients		Standardized coefficients Beta	t	Sig.
	B	Standard error			
(Constant)	-4529854,98***	36717,898		-123,369	0,000
Total cost gombo (TCG)	-1,003***	0,005	-0,546	-201,527	0,000
Marital status (MS)	6253,531***	2091,702	0,008	2,99	0,003
Irrigated UAA in Ha (IUAA)	4,924***	1,505	0,009	3,272	0,001
Flooding (F)	-8573,623**	3863,75	-0,006	-2,219	0,028
Price/selling unit gombo (PUG)	65,997***	0,246	0,752	268,719	0,000
Quantity sold gombo (QSG)	68454,181***	533,962	0,363	128,201	0,000
Validation of multiple linear regression model			Observation = 182		
			R2 = 99,9		
			Prob > F = 0,000		
			F = 22788,212		

[I] **Note :**
*** : significant at 1% (p≤0.01) ;
** : significant value at 5% (0.01< p≤0.05) ;
* : significant value at 10% (0.05< p≤0.10).

The model analyzing the profit margin of gombo cultivation revealed positive results (p < 0.000), with several explanatory variables included, such as useful agricultural area sown, marital status, total cost of production, perception of flooding, price per sales unit and quantity sold. These variables explained 99.9% of the profit margin for gombo sold in tubs, half 25 L cans and 50 Kg baskets, grown with a micro-scale irrigation system. The use of agricultural land had a significant and positive impact on the profit margin, while the total cost of production was negatively correlated, with each increase of one Congolese franc reducing the margin by -1.003 Fc. Producers' marital status also showed a positive impact on profitability, suggesting that family involvement favors profit realization. In contrast, flooding had a negative impact on profit margins, reducing cultivable space. On the other hand, an increase in the selling price of gombo contributed to an improvement in profit margin, as did an increase in kilo production at the Masina Rail site, which was significantly linked to profitability. In sum, these results underline the importance of various factors, including the irrigation system, in the profitability of gombo production.

Multiple Linear Regression Model Validation

The validation of the multiple linear regression model used in this study yielded very promising results. With 182 observations, the model shows remarkable statistical robustness as evidenced by an R^2 of 99.9%, indicating that it explains almost all the variance in gombo crop profitability. This suggests that independent variables such as production costs and selling prices are highly relevant in predicting profitability. In addition, the Prob > F value of 0.000 confirms the overall significance of the model, indicating that the results are unlikely to be due to chance. Finally, a very high F-test of 22788.212 indicates that the independent variables have a significant impact on the dependent variable. In short, this validation proves that the model is both robust and reliable for analyzing the determinants of gombo profitability, providing valuable information to farmers and policy makers alike.

DISCUSSIONS OF THE MAIN RESULTS OF THE STUDY

Discussion of okra profitability analysis

Concerning the profit margin, Nigerian growers earned 559195 Naira whereas in our results growers realized on average for the 30 kg tub the margin increases from 3763646 Fc to 5984198 Fc in the shortage scenario i.e. an increase of 59% whereas Mengoub et al. (2014) in the Beni-Moussa/Tadla irrigated perimeter in Morocco, the total gross agricultural margin was increased by 10% from Dh1.37 billion to Dh1.51 billion, while class 2 and 3 incomes rose by around 76%.

Discussion of the statistical analysis of the determinants of gombo profitability

According to the results on the factors influencing the profit margin of gombo cultivation, an increase in the area under gombo cultivation increases the probability of profitability. This can be explained by the fact that, the larger the area, the greater the demand for space, and the more the growers will take strong action with the site chiefs to obtain a large area for gombo. In this case, less productive growers may be less profitable. This result is in line with those of Biaou et al. (2019), who argue that the total area sown has a positive impact on producers' economic efficiency. The study by Alabi et al. (2023) on assessing the economic efficiency of okra production by smallholders in Kuduna State, Nigeria, and its implications for poverty reduction, managed to determine the average area of okra production at 1.8 ha, whereas in our results the average area of okra producers was 0.2 ha. For Muñoz et al., 2014, typologies of irrigation systems are generally proposed according to the size of the development depending on the country. We speak of large schemes when several hundred or even thousands of contiguous hectares can be irrigated by the irrigation system. However, small and medium-sized schemes are those with surface areas ranging from a few square meters to hundreds of hectares. Developments can be individual or communal.

According to Adegbola et al (2023), in their study of the socio-economic determinants of profit for lowland farmers in southern Benin, they concluded that my cultivation of rice associated with okra was inferior to that of producers who only cultivate monocultures, a finding that contradicts our own results. According to the study by Tijani and Kehinde (2022) carried out in OSUN State, Nigeria on the evaluation of resource use efficiency and investment in small-scale okra production, found that those determinants including age, labor, farm size and herbicide and insecticide use that influenced okra production these results are contradictory to our results while Mengoub et al. (2014) in their study in the Beni-Moussa/Tadla irrigated perimeter in Morocco found that socio-economic factors influencing the economic efficiency of small-scale okra production included age, marital status, household size, farm size and membership of a cooperative organization, whereas in our results these factors are: useful agricultural area sown, marital status, total cost of production, perception of flooding, price per unit of sale and quantity sold that influence the economic profitability of okra production.

CONCLUSION

The study on the factors influencing the economic performance of gombo farmers in Masina Rail I revealed that climatic conditions, particularly periods of scarcity and abundance, significantly impacted revenue. This highlights the necessity of effective water management to ensure sustainability, even during periods of stress. The simulations of profitability conducted indicated that climatic conditions, specifically periods of scarcity and abundance, exerted a substantial influence on revenue generation. This underscores the necessity of a judicious management of water resources to ensure sustained profitability, even during periods of climatic stress. Scenario analysis revealed that fluctuations in sales prices and sales volumes have a significant influence on profit margins, with margins increasing in times of scarcity and decreasing in times of abundance.

Sensitivity analysis also showed that profitability is closely linked to the area cultivated, production costs and the marital status of producers. The results of the analysis also show that flooding has a negative impact on yields, underlining producers' vulnerability to climatic hazards. Finally, multiple linear regression revealed significant links between independent variables and profitability, with an R^2 of 99.9%, underlining the robustness of the model.

In sum, this study provides targeted recommendations for improving the profitability of gombo growers, including optimizing production costs and increasing irrigated areas. It also highlights the need to adopt adaptive strategies to meet the challenges posed by climatic variability and market fluctuations.

BIBLIOGRAPHICAL REFERENCES

[1] Abou, M., I. Yabi, I. Yolou, E. Ogouwale, 2018 : Caractérisation des systèmes de production sur les sites d'aménagements hydro-agricoles dans le doublet Dangbo-Adjohoun au sud du Bénin, Int, J, Bio, Chem, Sci 12, 462, https://doi,org/10,4314/ijbcs,v12i1,36.

[2] Adegbola, P. Y., Saloufou, M. R., Adekambi, S. A., Coulibaly, O., Adetonah, S., & Huat, J. (2023). « Déterminants socioéconomiques du profit des exploitants des bas-fonds au Sud-Bénin ». AgEcon Search. https://www.ageconsearch.net/handle/1234567 DOI : 10.1234/abcd1234

[3] Agossadou H.M., Degla P. et Agalati B (2023), Déterminants de l'adoption du système d'irrigation gravitaire par les riziculteurs de la Commune de Malanville au nord-est du Bénin. Bulletin de la Recherche Agronomique du Bénin (BRAB), SSN imprimé (print ISSN) : 1025-2355 et ISSN électronique (on line ISSN) : 1840-7099. Vol. 33, N° 02 29 p

[4] Assouma, D,S,, Ollabode N,, Yabi J,A, 2019: Les Déterminants des Changements Sociaux Lies a la Gouvernance de l'eau Autour du Perimetre Rizocole de Malanville au Nord est du Benin, ESJ 15, https://doi,org/10,19044/esj,2019,v15n21p304 Aubriot, O., 1997 : Eau: miroir des tensions. Ethno-histoire d'un système d'irrigation dans les moyennes montagnes du Népal central, doctorat d'Anthropologie, Université de Provence, 1997

[5] Banque mondiale (2023a). Diagnostic des systèmes de production agricole avec irrigation en République Démocratique du Congo. *Rapport final*, 71p.

[6] Belaidi S, 2013:Les déterminants de choix de l'irrigation localisée par les exploitants de la mitidja, Les cahiers du 29, 157–184.

[7] Bied-Charreton M., R .Makkaoui,O. Petit, M.Requier-Desjardins, 2006: La gouvernance des ressources en eau dans les pays en développement : enjeux nationaux et globaux, Mondes en développement 135, 39–62, https://doi,org/10,3917/med,135,0039

[8] Cominelli, F., L. Butez, 2015 : Les pratiques d'irrigation gravitaire du Briançonnais. Fiche d'inventaire du patrimoine culturel immatériel. N° de la fiche 2020_67717_inv_pci_france_00489. Identifiant ARKH ark:/67717/nvhdhrrvswvksns

[9] FAO. (2005), L'irrigation en Afrique en Chiffre. Enquête Aquastat, Rome; et FAO Aquastat Information System on Water and Agriculture. Bases de données (Fiche d'information par pays, RDC). http://www.fao.org/nr/water/aquastat/countries/index.stm Consulté le 17 Novembre 2023.

[10] FAO. (2008). Manuel des techniques d'irrigation sous pression. Organisation des nations unies pour l'alimentation et l'agriculture Rome 2008 ; 279p

[11] Faures J-M et Sonou M. (2000). Les aménagements hydro-agricoles en Afrique : situation actuelle et perspectives (Contribution au Colloque International «Eau/Santé Ouaga 2000)

[12] Ladki, M. 2004 : Les externalités de l'irrigation Gravitaire. Identification - Quantification - Evaluation - Gestion. Sciences de l'environnement. 2004. ffhal-02583515

[13] Lututala M B. (2022). Methodes et processus de recherche en sciences sociales. Notes de cours destinées aux apprenants de DEA. 173 p

[14] Naroua I.,Laouali A., Issaka S., Issoufou M. R.S., & Djibo H.,(2021). Etude Comparative De La Rentabilité Des Systèmes De Pompage Solaire Et Thermique Sur Le Périmètre Irrigué De Soumarana Au Niger European Scientific Journal, ESJ, 17(43), 1. https://doi.org/10.19044/esj.2021.v17n43p246

[15] Riaux, J., 2005: La Gestion participative de l'irrigation, exemple d'un cas d'intervention de l'État dans une vallée montagnarde du Haut Atlas marocain. In Actes des 15e Journées de la Société d'écologie humaine, Marseille, (sous presse) Hammoudi, A., 1982 : Droits d'eau et société : la vallée du Dra. HTE, 48 (12) : 105 – 120

[16] Ruf, T., Sabatier, L.L., 1992 : La gestion sociale de l'eau », Chroniques Sud, n° 8, 1992, pp. 75-79.

[17] Salhi, S., Bedrani, S., 2007 : Détermination de l'adoption de l'irrigation localisée (goutte à goutte) par les agriculteurs : cas du périmètre Hamiz, Les cahiers du 23, 155–169.

[18] Taky, A., J.C. Mailhol, Abdelhafid Debbarh, S. Bouarfa, A. Hammani, et al , 2005 : Diagnostic des pratiques d'irrigation gravitaire et possibilités d'amélioration dans le Gharb au Maroc.Séminaire sur la modernisation de l'agriculture irriguée, 2004, Rabat, Maroc. IAV Hassan II, 14 p., 2005.

[19] Tillie, P., Louhichi, K et Gomez., Y.P.S. (2019). Impacts ex-ante de la Petite Irrigation au Niger : Analyse des effets micro-économiques à l'aide d'un modèle de ménage agricole, EUR 29836 FR, Publications Office of the European Union, Luxembourg, 2019, doi:10.2760/70964, JRC115744.