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Farm Management Practices and Health Outcomes in Kourtheye District, Niger: A Focus on Climate Variability Impacts

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Abstract

Climate change is becoming a major issue for agriculture and the well-being of farmers. The objective of this article is to identify and analyze the production factors that may influence the competitiveness level of agricultural operations, as well as to establish a structural and functional typology of these farms. Using Principal component analysis (PCA) combined with hierarchical ascending classification (HAC) on 250 farmers, the study was able to set farms typology. Furthermore, variance analysis and econometric models (linear et quadratic) were also used for in-depth analysis. The results show the existence of three groups of farm (G_A, G_B, G_C): G_A (19.7%), G_B (65.3%), and G_C (15%). Drought spells and flood are the main climatic risks affecting rainfed farm operations. For irrigated crops such as rice, the major constraints remain bird attacks, the invasion of pests and nematodes. Climate variability significantly increases the prevalence of morbidities in the region by raising the number of inactive individuals. This significantly and differentially affects the outcomes of these assets. Health expenditures represent a significant share (G_B: 12% and G_C: 11%) and a non-negligible share (G_A: 8.4%). However, larger participations (G_C) show better economic performance due to economies of scale, but all categories would benefit from adopting appropriate strategies to reduce losses and increase their resilience.

Keywords

Farm, Management, Kourtheye, Climate Change

1. Introduction

In 2018, agriculture accounted for about 4% of the global gross domestic product (GDP), with shares exceeding 25% of GDP in some developing countries [1]. The total area of agricultural land worldwide is approximately 4.74 billion hectares, although this figure has decreased by 3% since 2000. Despite this decline, cereal production increased from three to six million tons between 2000 and 2021, representing an annual growth of 2.8% [2]. As of 2021, approximately 27% of the global workforce was engaged in agriculture, which translates to around 866 million people employed in this sector according to the FAO [3]. With 70% of Africans dependent on agriculture for livelihoods, the sector is critical to the economies of all African countries [4]. It employs more than a billion people in developing countries. In low- and middle-income countries, the agricultural sector tends to be the primary source of employment [5] [6]. This leads us to the concept of farming, a fundamental production structure in rural economies. The term itself is multifaceted. In simple terms, an agricultural exploitation, or farm, is a collection of land, buildings, and animals. However, economists often see farms as businesses focused on maximizing profits. They define farm management as the skill of combining resources to achieve this goal. While this profit-oriented view is common, it doesn't always fit the reality of African agriculture. Many African farms, particularly family farms, prioritize food production for family and community needs over profit maximization. These family farms are crucial for rural economies, providing essential food, income, and employment [7]. According to [8], not all farms are the same. They vary in size, resource access, and management experience. Family farms, which make up nearly 80% of farms in sub-Saharan Africa in general and Niger in particular , employ 75% of the workforce [9]. Due to climate change, farms are facing more and more unpredictable weather conditions. These include droughts, floods, extreme heat irregular rainfall [10]. Additionally, new pests and diseases are threatening crops. However, climate is considered by [11] as an exogenous agricultural input that is beyond the farmer's control. In general, climate simulation models for the future in Southern countries do not allow for solid hypotheses, and many local climate variations are likely. The prevalent poverty in these countries further exacerbates the uncertainty that research must confront. According to projections, by 2050, most African countries will experience climates currently unknown over more than half of their arable land [12]. For example, a study indicates that in rice cultivation, temperature increases lead to sterility [13]. This complicates the effective recognition of the various agricultural operations of households even further. Therefore, recognizing family farms as partners first involves understanding their practices and objectives, followed by their organizational dynamics and functioning in this new environment marked by degradation due to climatic variability. This will make it possible to define development strategies that include family farms. Furthermore, in line with earlier studies, it has been noted that climatic variability has an indirect impact on agricultural activities in the form of additional detrimental health

effects. Thus, the question of whether farmer health could play a significant role in the growth of these farms emerges. If yes, do these effects vary depending on the agricultural operation? Because family farms vary greatly in terms of their socioeconomic traits, organizational structures, and modes of operation based on agro-ecological zones, it is crucial to review and update the body of information on these farms [14].

Among the many difficulties facing the municipality of Kourthèye, which is situated in the Tillabéri department and is home to a variety of farms, are "the negative effects of variability and climate change. In the study area, agriculture is the main economic activity of the population, whose production is carried out in rain for some speculations and in irrigation for others [15]. The main activity of rural Nigeriens, it faces recurring issues of declining yields, leading to the impoverishment and food insecurity of the households engaged in it" [16]. Furthermore, the decline in farmers' health has a substantial and adverse influence on the efficiency of farms management, in addition to having an effect on the health of farmers and their homes. According to [17], the majority of low-yielding farmers (82.3%) in the department of Tillaberi face crippling medical costs. The relationship between the amount of production and the amount of expenditures is then clearly visible. Today, it is not enough to defend these agricultural activities; we also need to encourage their change. The variety of agricultural operations can affect how climate elements are perceived. To control food insecurity and ensure the success of rural research and development operations for sustainable agricultural development, it is imperative to create a typology of these agricultural operations. This will serve as a starting point for all the different political actions aimed at revitalizing them.

Establishing a structural and functional typology of agricultural operations in relation to climate variability and health, as well as identifying and analyzing the production elements that may affect this agriculture's level of competitiveness, are the goals of this work. It will also be beneficial to comprehend how reasoning about the effects of climate change and variability on farming households and their operations can be aided by understanding of agricultural operations.

2. Methodology

2.1. Study Area

The rural municipality of Kourthèye is situated between 13˚45' and 14˚27' North latitude and 1˚30' and 1˚52' East longitude, in the southwest section of the Tillabéri Department. Geographically, the urban municipality of Tillabéri borders this municipality to the north; the rural municipality of Karma borders it to the south; Namaro borders it to the southwest; the rural and urban municipalities of Simiri and Ouallam border it to the east; and the rural municipality of Gothèye borders it to the west (**Figure 1**).

A variety of socio-economic infrastructures, including educational, health, hydraulic, agricultural, pastoral, and road infrastructures; a diverse human capital that includes the population, municipal services, decentralized state services, and

development partners; and social capital composed of community organizations primarily composed of farmers, herders, and fishermen are the foundations of the economic potential. Other socio-economic infrastructures include agricultural production (through rain-fed, irrigated, and recession systems), pastoral activities, fishing/aquaculture, commerce, and crafts. The natural aspects of relief, soils, climate, vegetation, fauna, and water resources are all part of the physical environment. Understanding these essential components will help place the municipality in its proper context. The Sahelian climate has a precipitation gradient that is negative from south to north. In fact, from north to south, the average annual rainfall totals vary between 250 and 400 mm. Even at their lowest, temperatures are still rather high, averaging between 18˚C and 45˚C all year round. There are two different kinds of watercourses in the municipality of Kourthèye: permanent and semi-permanent ponds, as well as the Niger River and its seasonal tributaries on the left bank. In the municipality's far west, the Niger River runs 55 kilometers across it [18].

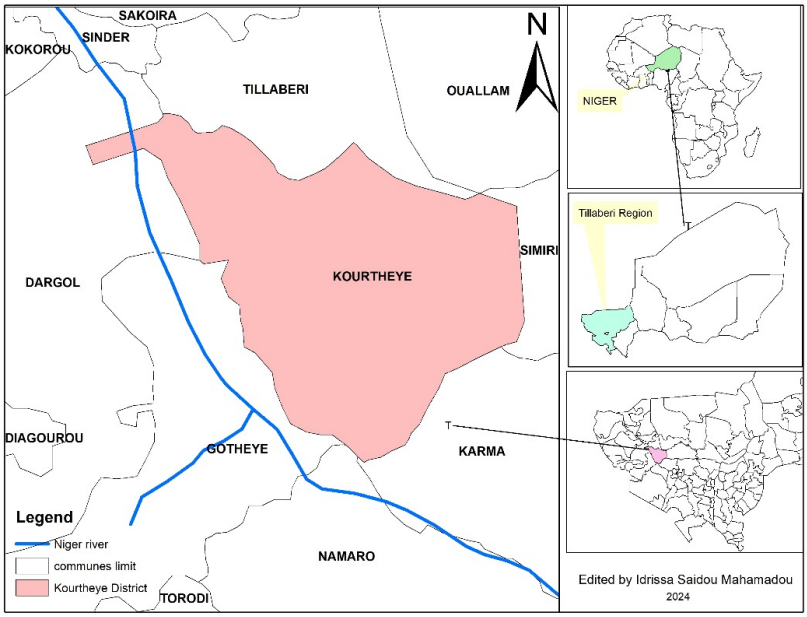

Figure 1. Study area.

2.2. Data Collection Steps

To achieve its objectives, three survey devices (SD) were implemented. The first involves "observing the landscape" (I), which means conducting a field mission initially to observe the various agricultural operations. This phase aims to discern how family farms (EA) are organized (geographical situation, potential climate risks that could affect the farms, observing the landscape, and household behaviors regarding the farms), but mainly to prepare the ground for subsequent activities: focus groups and household surveys. This first phase is purely qualitative. The second survey device allows for discussions with farmers in "focus groups" (II) to gain an overview

of their operations and the constraints they face. In this sense, it seeks to understand their perceptions of climate change, its impacts on the farms, and on household well-being, particularly the health of farmers. The selection of participants for the focus group was facilitated by the leaders of the various villages in the commune, who proposed participants based on their experience in agriculture. However, this does not prevent the participation of other farmers who may not have significant experience. Finally, the last device involves a questionnaire that enabled the collection of individual data from farmers (III) regarding production factors, the effects of climate change, and their health status in relation to climate.

The following Table 1 provides the main components and indicators considered during the individual survey, along with their descriptions and measurements.

Table 1. Descriptions and measurements of the main components and indicators.

Components	Description	Measurement of indicators
Production factors and agricultural productions		
Labor	Represents family and hired labor	Number of people working on the farm and their associated costs in CFA francs
Capital	Represents the cost of investments in equipment and intermediate consumption	Cost of agricultural tools such as hand tools: Hoe, Hilarious, cutter plow, cut-cut, motor pump carts Cost of quantities of seeds, plant protection products, mineral fertilizer, irrigation water, fuel
Land	Represents the area cultivated by the farmer	• Here, most of the land is inherited for rainfed agricultural operations • For irrigated agricultural operations, the cost of the land lease has been considered
Agricultural productions	Represents in this study the productions obtained from rainfed crops and those from irrigated crops	Quantities of main crops: Millet, sorghum, rice, and cowpea
Farmer health		
Sick individuals (especially related to climate-sensitive diseases)	Represents the number of people unable to work due to the deterioration of their health condition	The number of agricultural workers who fell ill and were unable to work on the farms.
Medical care	Represents the care of sick individuals	Cost in CFA francs of caring for agricultural workers who fell ill.
Days of agricultural activities lost	Represents the days of agricultural work lost by a farmer	Number of days lost.
Climate risk and Farmer income		
Climate risk	Represents the climatic risk factors present or potentially present on the farm	Yes or No (Yes, if the farm was affected and No, if the farm was not affected)
Farmer income	Represents what the farmer earns from agricultural or non-agricultural activities	The amount earned per month from agricultural and non-agricultural activities.

2.3. Sampling

The sample size for the survey is set at 250 agricultural households. The following

mathematical formulas were used in three steps to determine the final sample size. The first step (1) involves determining the initial sample size (ISS). Its calculation formula is as follows:

where:

$$ISS = \frac{z^2 \cdot P(1-P)}{e^2}$$

- z is the security level regarding the representativeness of the population. A margin of error $e = 5\%$ was used, hence $z = 1.96$;
- P is the homogeneity of the population, found from previous studies, and $q = 1 - P$.

The second step (2), called adjustment of the sample size (ASS), takes into account the number of farmers. Its calculation formula is:

$$ASS = \frac{ISS \cdot N}{N + ISS}$$

where:

- N is the total number of farmers.

The third step (3) coincides with the adjustment for the response rate to determine the final sample size (FSS) to ensure a response rate (RR) of 90%. Its formula is written as:

$$FSS = \frac{ASS}{RR}$$

2.4. Systemic Approach

This is a purely qualitative method. It involves working with farmers and mobilizes multiple disciplines to understand the functioning and organization of agricultural operations. The study focused on aspects related to climate change, the health of farmers, and their agricultural households. This approach allowed for establishing a cause-and-effect relationship between these dimensions through an analytical framework.

2.5. Methods for Constructing and Analyzing Typologies of Agricultural Operations

According to the literature, several methods are used to create a typology of agricultural operations. The methods employed to realize these typologies depend on the objectives sought and the selected discriminating indicators. However, structural typologies and functional typologies can be distinguished based on the nature of the variables used [19]. The former uses multiple discriminating criteria simultaneously. Principal component analysis (PCA), correspondence factor analysis (CFA), and hierarchical ascending classification (HAC) are distinguished in this context. PCA and CFA are used to characterize operations concerning the selected variables, while HAC is used to group operations based on the weight of the considered variables [6]. PCA is a method from the family of data analysis, more generally from multivariate statistics, which involves transforming correlated

variables into new uncorrelated variables. These new variables are called "principal components" or main axes. It allows practitioners to reduce the number of variables and make information less redundant.

These new variables are referred to as "principal components" or main axes. This method allows practitioners to reduce the number of variables and make the information less redundant. It is important to specify that the choice of one of these methods depends on the nature of the researcher's data. For quantitative data, PCA is preferred, while for qualitative data, CFA is more suitable. In hierarchical ascending classification (HAC), the goal is for individuals grouped within the same class (intra-class homogeneity) to be as similar as possible, while the classes should be as dissimilar as possible (inter-class heterogeneity). Two identical observations will have a distance of zero. The more dissimilar the two observations are, the greater the distance will be. Based on a review of the literature, it appears that PCA is more commonly used in executing typologies of agricultural operations, as seen in studies by [20]-[22]. Given the quantitative nature of the data, PCA combined with HAC has been maintained in this study. For PCA, a total of 17 variables were used to construct the typologies of agricultural operations: age, household size, agricultural assets, wage labor, mil production in kg, sorghum production in kg, rice area in hectares, rice production in kg, area of dry crops, access to climate information, availability of modern agricultural materials, access to agricultural support, membership in a farmers' organization, access to agricultural credit, availability of non-agricultural income sources, income (both agricultural and non-agricultural), and capital factors (which include equipment and intermediate consumption). Access to agricultural credit is essential for allowing farming operations to invest in technological improvements, quality seeds, equipment, and sustainable farming practices. This has a direct impact on the productivity and profitability of the farm. This will help distinguish agricultural operations. HAC will then iteratively group individuals to produce a dendrogram or classification tree. The classification is ascending because it starts from individual observations; it is hierarchical because it produces increasingly larger classes or groups that include sub-groups within them.

Descriptive statistics, as well as analysis of variance (ANOVA) for structural and functional typologies is used. ANOVA tests the null hypothesis that all group means are equal against the alternative hypothesis that at least one group mean is different. The Chi-Square test for organizational and technical production typologies of agricultural operations, is used to analyze whether significant differences exist between categories.

Linear Models and Quadratic Models are fundamental concepts in statistics and data analysis, used to describe relationships between variables. The two models have been used to analyze the relationships between major diseases and the number of people who fell ill (chronic diseases and malaria).

Table 2 presents the description of the economic and financial indicators considered in this study. This allowed us to analyze the economic performance of

agricultural holdings.

Table 2. Description and formulas the economic indicators.

Profitability Indicators of Agricultural Operations	Description of indicators	Applied Indicator Formulas
Gross Agricultural Product (PBA)	The total value of agricultural production before deducting expenses.	**PBA = Σ(Quantity produced × Unit selling price) + Subsidies or production aid**
Variable Costs (CV)	Costs that depend directly on the level of production	**CV = Cost of inputs + variable labor + energy and fuel costs + external services + other variable costs.**
Fixed Costs (FC)	Fixed agricultural costs are expenses that do not vary directly with the level of production or sales in an agricultural operation.	**CF = Depreciation + Rent + Fixed salaries + Insurance + Taxes and duties + Maintenance and repairs + Other fixed costs.**
Production cost (PC)	expenses incurred by farmers to cultivate crops or raise livestock	$PC = VC + FC$
Margin on Variable Costs (MVC)	The amount that remains to cover fixed costs and generate profit once variable costs are paid.	• **MVC = Gross Agricultural Product (GAP) – Agricultural Variable Costs** • If the MVC > 0, the operation covers its variable costs and generates a margin that can be used to cover fixed costs. • If the MVC < 0, the operation does not generate enough revenue to cover its variable costs, and therefore the operation will be in financial difficulty.
Gross Value Added (GVA)	It represents the wealth created by agricultural operations over a given period.	Agricultural GVA = Value of Agricultural Production − Intermediate Consumption
Net Value Added (NVA)	It measures the wealth created by agricultural operations after subtracting the depreciation of the capital used in the production process.	Agricultural NVA = Agricultural GVA − Depreciation
Agricultural Profitability Index (API)	It measures the overall profitability of the operation, taking into account not only the revenues from agricultural activities but also financial charges and taxes.	API = Gross Operating Surplus (GOS)/Total Production Cost (TPC) × 100 • **Index > 100**: The operation is profitable. This means that the operation generates profits (GOS) that exceed its production costs. The higher the index, the more profitable the operation is. • **Index = 100:** The operation reaches the break-even point. Revenues exactly cover production costs, with no net profit generated. • **Index < 100:** The operation is not profitable. It generates profits that are lower than its production costs, which could indicate financial losses.

3. Results

3.1. Climate-Health-Agriculture Nexus

The systemic approach taken has established a link between various production factors, production systems, and the health impacts of climate change. Indeed, the agricultural operations of farming households in the municipality are facing

alarming climatic conditions that prevent them from ensuring sufficient and sustainable agricultural production. The effects of climate change (drought, flooding, soil degradation, locust invasions, temperature rise, etc.) have had consequences on household health, particularly affecting the workforce such as family labor and, at times, hired labor. In this context, certain agricultural expenditure items, such as intermediate consumption and equipment (very rarely), are used to cover healthcare costs for household members. Additionally, households have other sources of income outside agriculture. These activities include trade, daily labor, fishing, crafts, civil service jobs, migration, and others. These income sources significantly contribute to expenditure items related to agricultural operations (notably, capital factors represented here by equipment and consumption). Furthermore, this operation still retains an extensive character, primarily manual labor employing rudimentary tools (hoes, plows, etc.). The largest portion of agricultural production obtained is intended for self-consumption (Figure 2).

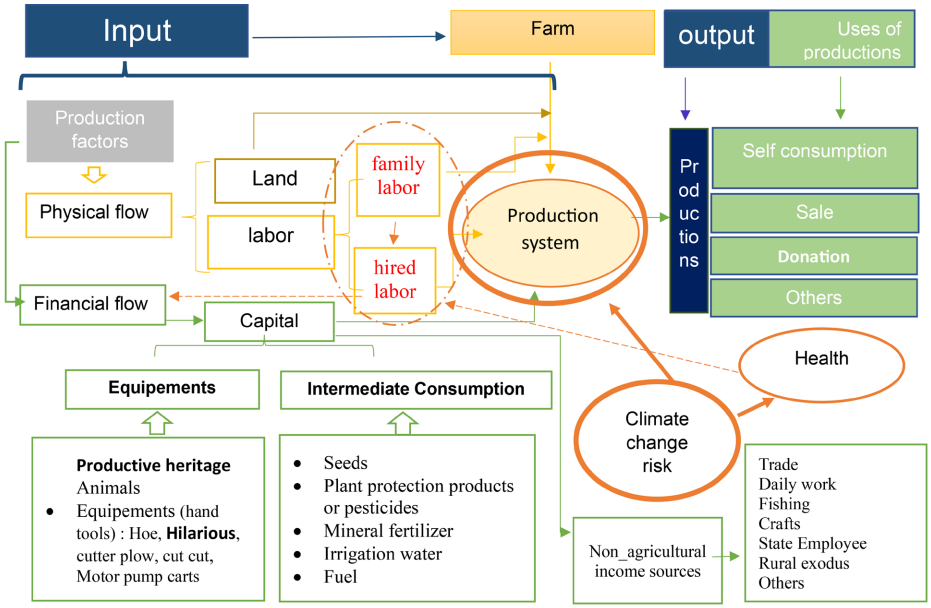

Figure 2. Climate-health-agriculture nexus analyst in the area context.

3.2. Typologies of Household Farm Operations

After analysis (PCA), three dimensions were retained. These dimensions explained a total of 65.97% of the variability. The three dimensions can group three categories of variables: one category related to services, a second related to technics of production, and a third concerning the socioeconomic factors of farming households. The results below indicate that most variables in category one are positively correlated with dimension 1. However, some variables from dimensions 2 and 3 are also linked to this factor. For example, access to agricultural credit (0.5) from axis 2 and income (0.3) from axis 3 are included. This gives this axis the power to hold most of the information and explain the interrelationships that exist among them in the agricultural production process. Axis 2, primarily composed of

variables from category 2, has an explanatory power of 15.848% (of variability). Regarding the third factor, it includes age (0.7), household size (0.8), agricultural assets (0.8), income, and capital factors (0.7) like shows the figure below (Figure 3).

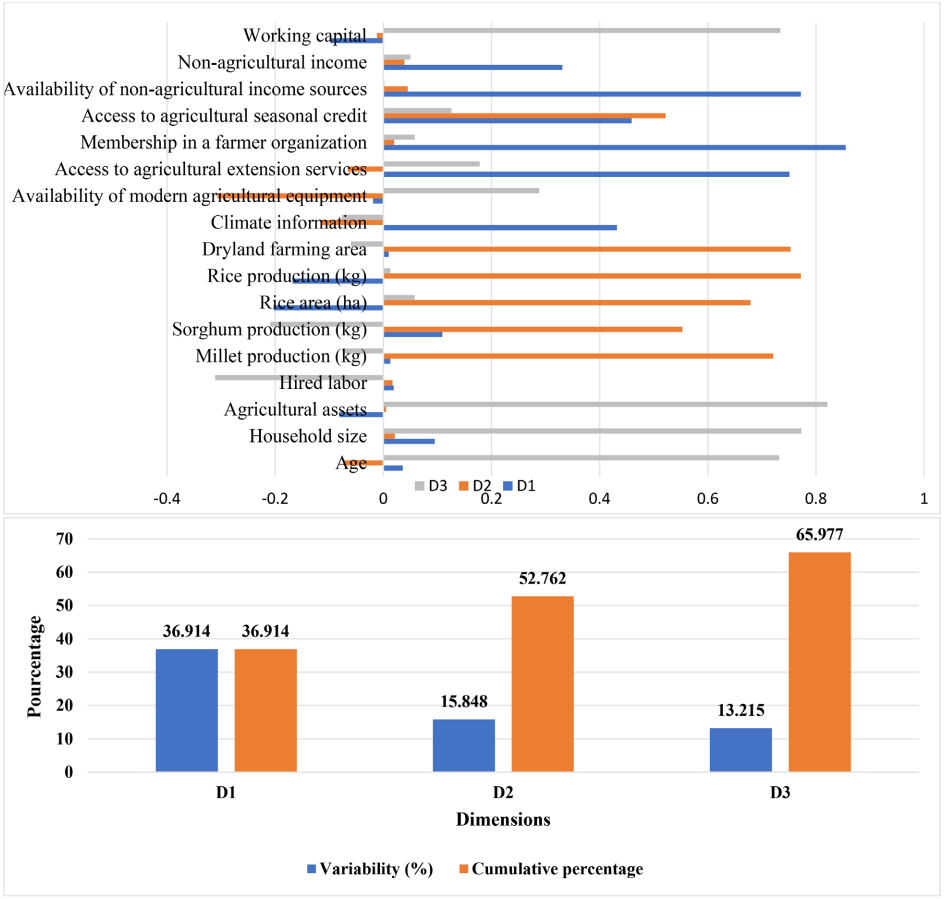

Figure 3. Analysis of variables and dimensions.

3.3. Categories of Agricultural Operations by Hierarchical Ascending Method Variance Decomposition for Optimal Classification

The variance decomposition indicates that the intra-group variance is 73.28%, while the inter-group variance (between groups) is 26.72%. The high proportion suggests that the groups created by the hierarchical method contain relatively heterogeneous operations. This could reflect significant differences among operations within the same group in terms of structure, resources, or resilience to climate change. Although the inter-group variance is lower than the intra-group variance, it is still significant. This indicates that the groups exhibit distinct characteristics regarding their response or vulnerability to climate change. The high intra-group variability (73.28%) may also reflect challenges in grouping operations into homogeneous sets. This can be explained by multiple factors, such as the diversity of agricultural practices within the same municipality, varying capacities

for adapting to climate change among operations in a single group, and the influence of unaccounted variables in the model, such as cultural or religious factors (Table 3).

Table 3. Within-group and between-group variance decomposition.

	Absolute	Percent
Within-class	601275131.651	73.28%
Between-classes	2492545646.981	26.72%
Total	3093820778.632	100.00%

3.4. Types of Agricultural Operations by Hierarchical Ascending Classification

The results of the hierarchical ascending classification have defined three types or groups of agricultural operations (G_A, G_B, and G_C), as represented in the figure below. There is an irregular progression between the groups, reflecting a diverse nature of operations according to the context (Figure 4). Based on the analysis

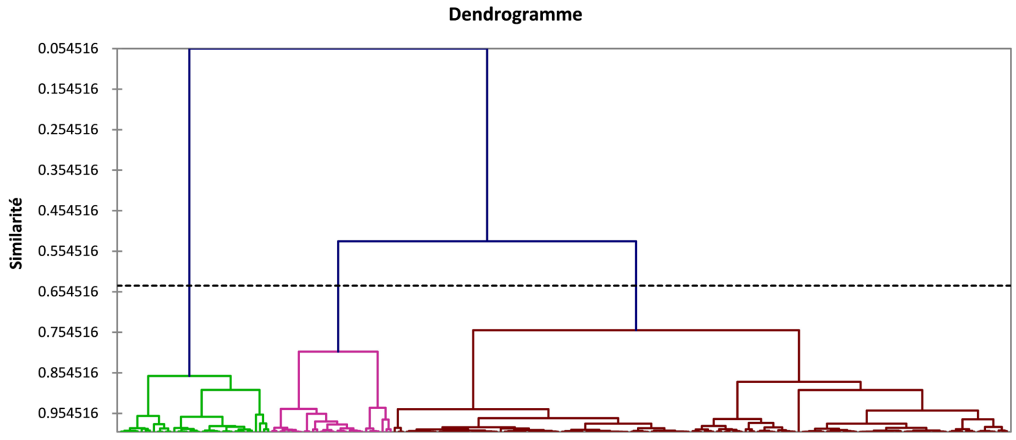

Figure 4. Hierarchical ascending classification.

from the PCA, agricultural operations can be categorized into three types or groups:

- **Smallholder Farmers (G_A)**: Representing 19.7% of producers, these farmers primarily rely on family labor as their workforce and practice rain-fed cultivation (millet, sorghum, cowpeas) as their main agricultural activity, with rice cultivation occurring only in small proportions.
- **Medium-Sized Farmers (G_B)**: Comprising 65.3% of producers, these farmers utilize both hired labor and family labor. The main crops grown by these farmers include millet, sorghum, cowpeas, and rice.
- **Large Farms (G_C)**: Making up 15% of the sample producers, these farms primarily depend on hired labor as their main agricultural workforce and invest heavily in intermediate consumption and equipment. This group places signi-

ficant importance on rice cultivation in addition to dry crops, whereas smallholder farmers focus more on rain-fed crops.

This classification suggests that the identified groups correspond to distinct typologies of operations based on their vulnerabilities to climate shocks and their health impacts.

- **Vulnerable Groups**: Operations with low adaptation capacity or heavily impacted by climate.
- **Resilient Groups**: Operations with adapted practices (irrigation, diversifi-cation).
- **Intermediate Groups**: Operations in transition, partially adapted.

3.5. Structural and Technical Analysis of Household Agricultural Operations

The analysis of the variance results recorded in Table 3 shows that there is no significant difference in the age of operators across different agricultural operations ($P > 0$). The average age is 57.65 years in G_A agricultural operations, 56.02 years in G_B, and 52.68 years in G_C. In terms of labor force, the difference is statistically significant ($P < 0.05$). G_A operations have an average of 4 agricultural workers, compared to 5 in G_B and 8 in G_C. The cropping systems are dominated by cereal cultivation (millet, sorghum, cowpeas) across all categories, with production results differing significantly at the 5% level. These productions are primarily intended for household self-consumption, especially for small and medium-sized farmers (Table 4). The practice of rice cultivation is more significant among farmers in the G_B and G_C groups.

Table 4. Structural and technical analysis.

Variables	Type of farms			Sig anov
	G_A (19.7%)	G_B (65.3%)	G_C G_A (15%)	
Age (years)	57.65	56.02	52.68	0.55
Average household size (number)	9	10	13	0.949
labor force (number)	4	5	8	0.037**
Rice production (kg)	1200	1200	1200	
Superficie riz (ha)	0.25	0.53	0.88	0.000***
Rendement (R) (kg/ha)	4800	4800	4800	

Significant at the level of: *** = 1%, ** = 5%, and * = 10%.

3.6. Analysis of Economic and Financial Results of Rice Farms

In an environment marked by climate change, rice farms face various challenges, including yield losses, rising costs, and economic vulnerabilities. The data reveals significant disparities among the three types of farms characterized by their sizes, performances, and expenses. High production losses for all three types (with

respective relative losses of 48%, 48%, and 43%) indicate potential impacts from climatic hazards (droughts, floods) and possible inefficiencies in adapting agricultural practices. Variable costs represent a substantial portion of total expenses, ranging from 37% to 38% depending on the type. Large farms (G_C) incur high fixed costs due to greater investments; however, these costs are proportionately well-managed compared to small (G_A) and medium-sized farms (G_B). G_C operations are more profitable, with a profitability index of 1.80 (very satisfactory profitability), attributed to better management of fixed costs and higher yields. In contrast, G_A farms remain less profitable with a marginal profitability index of 0.64 due to lower yields and significant losses. Health expenditures, often linked to climate-sensitive diseases such as malaria or malnutrition, diminish households' financial capacities to invest in agricultural activities. This directly impacts productivity and resilience against climate shocks. Health expenses constitute a notable share of total costs: 8.4% for G_A, 12% for G_B, and 11% for G_C (Table 5).

Table 5. Economic and financial results of rice farms.

Variables	Typologie des exploitations rizicoles					
	G_A		G_B		G_C	
	Percent	Costs	Percent	Costs	Percent	Costs
Intermediate consumption cost (%_Fcfa)	37%	100000.0	25%	102803.9	27%	153,660
Depreciation (%_Fcfa)	31%	85,509	27%	111,505	31%	179,253
Salaried workforce (%_Fcfa)	23%	61,246	23%	95,351	18%	100,296
Rice production quantity (%_kg)	52%	1200	40%	2000	**56.8%**	4543.25
Rice production quantity expected (in optimal condition) (%_kg)	100%	2300	-	5000	100%	8000
Production lost quantity (%_kg)	**48%**	**1100**	**60%**	**3000**	**43.2%**	**3456.75**
Redevance (%_Fcfa)	9%	25,000	12%	50,000	13%	73500.00
Health expenses to the setriment of cultural activities	8.4%	22,824	12%	47,913	11%	64,148
Gross Agricultural Product (PBA) (Frcfa)	-	360,000	-	600,000	-	1,362,975
Rendement (R) (kg/ha)	-	4800	-	3733	-	5148
Variables Cost (VC) (FCFA)	37%	100000.0	37%	150716.4	0.38	217808.2
fixes Cost (CF) (FCFA)	63%	171,755	63%	256,856	62%	353,049
Gross Value Added (GAV) (FCFA)	-	260000.0	-	497196.08	-	1209315.0
Net Value Added (NVA) (FCFA)	-	174491.1	−0.53	385690.82	−0.58	1030062.4
Production cost (PC) (FCFA)	100%	271,755	-	407572.4	-	570857.1
Margin on Variable Costs (MVC) (FCFA)	-	260000.00	-	449283.53	-	1145166.7
Agricultural Profitability Index (API)	-	**0.64**	-	**0.95**	-	**1.80**

3.7. Organizational Typology of Agricultural Production

Agricultural operations develop various types of relationships with certain public

or private structures to increase their productivity. However, disparities are observed among them. The unavailability of modern agricultural equipment, or its complete absence in production units, is noted in small (G_A) and medium-sized (G_B) farms. Only large farms (G_C) have access to such equipment, albeit in a relatively low proportion (30%). The majority of these farmers lack access to agricultural support due to a shortage of advisors. Nonetheless, a significant proportion across all categories belong to a peasant organization and have access to climate-related information through platforms such as community radio and WhatsApp. Additionally, farming households have other sources of income outside agriculture. The practice of these activities depends on the type of agricultural operation to which the household belongs. Activities such as crafts, fishing, daily labor, and rural exodus are more commonly practiced by those in G_A. For medium-sized farmers (G_B), daily labor, rural exodus, trade, and other activities are prevalent. In contrast, large agricultural operations (G_C) tend to engage more in trade, livestock farming, and fishing (Table 6).

Table 6. Organizational and economic analysis of farms.

Key variables	Options	G_A	G_B	G_C	Sig. Khi-deux
Modern agricultural material availability (%)	Yes	13.0	29.9	30.0	0.011***
	No	70.1	87.0	70.0	
access to agricultural guidance (%)	Access	13.0	20.4	50.0	0.609
	No Access	79.6	87.0	50.0	
Membership in a farmers' organization (%)	Yes	56.5	83.0	80.0	0.000***
	No	17.0	43.5	20.0	
Access to agricultural campaign credit	Access	68.0	43.5	50.0	0.000***
	No Access	32.0	56.5	50.0	
Available from non-agricultural income sources (%)	Yes	32.0	17.4	50.0	0.004***
	No	68.0	82.6	50.0	
Access to climate information (%)	No Access	1.20	5.60	33.30	0.032**
	Access	98.80	94.40	66.70	
Non-agricultural income sources (%)	Craftsmanship or Handicrafts	75.00	25.00	0.00	0.000***
	Trade	15.00	20.50	64.50	
	Animal husbandry	11.00	14.00	75.00	
	Others	25.00	65.00	10,00	
	Fishing	65.00	25.00	25,00	
	Daily labor or Day labo	50.00	50.00	0.00	
	Rural exodus	36.70	49.30	14.00	

Significant at the level of: *** = 1%, ** = 5%, and * = 10%.

3.8. Effects of Climate Change on Agricultural Operations

Drought remains the primary major climatic risk across all categories of rain-fed agricultural operations. No statistically significant difference was observed (P = 0.361) between the groups. Regarding irrigated crops, it is noted that flooding and the invasion of caterpillars or bird attacks remain the main major risks affecting all operations. However, this inter-category difference is significant at the 1% level (Table 7).

Table 7. Major climate factors in agricultural operations.

Climate risk Factors		Types of Agricultural Enterprises			Sig.
		G_A	G_B	G_C	
Case of agricultural enterprises of rainfed crops (%)	Soil degradation	21.00	31.20	47.80	0.361
	Flooding	62.70	24.30	13.00	
	Locust invasion	19.40	41.90	38.70	
	Caterpillar invasion	45.50	36.00	18.00	
	Drought	18.50	39.50	41.90	
Case of agricultural enterprises of irrigated crops (%)	Damage caused by hippopotamuses	44.40	50.60	4.50	0.000***
	Soil degradation	50.00	30.00	20.00	
	Flooding	46.70	35.00	18.30	
	Locust/bird invasion	33.33	43.3	33.33	
	Caterpillar invasion	45.90	44.30	9.80	
	Drought	43.20	0.432	13.60	

Significant at the level of: *** = 1%, ** = 5%, and * = 10%.

3.9. Health Effects of Climate Change on Agricultural Production: The Case of Malaria on Production

Figure 5(A) and Figure 5(B) illustrate the level of production (in irrigated and rain-fed/dry crops) according to the increase in the number of active individuals suffering from malaria. It is observed that rice production among households gradually declines as the number of sick individuals increases. In contrast, for rain-fed crops, the decline in production is minimal as the number of sick individuals rises (Figure 5).

The significance value of the F statistic is less than 0.05 for both models (logarithmic and linear). The results from both models are therefore statistically significant ($P < 0.05$), indicating that the variation explained by each model is not due to chance. The curve fitting graph provides a quick visual assessment of how well each model fits the data. The estimated parameters show negative results for the constant and b2 in the logarithmic model, while they are positive for the CS (Table 8). Consequently, the analysis indicates that the marginal effect of parameter b2 could reach—64.7 kg of production when there is one sick individual (especially among the heads of operations).

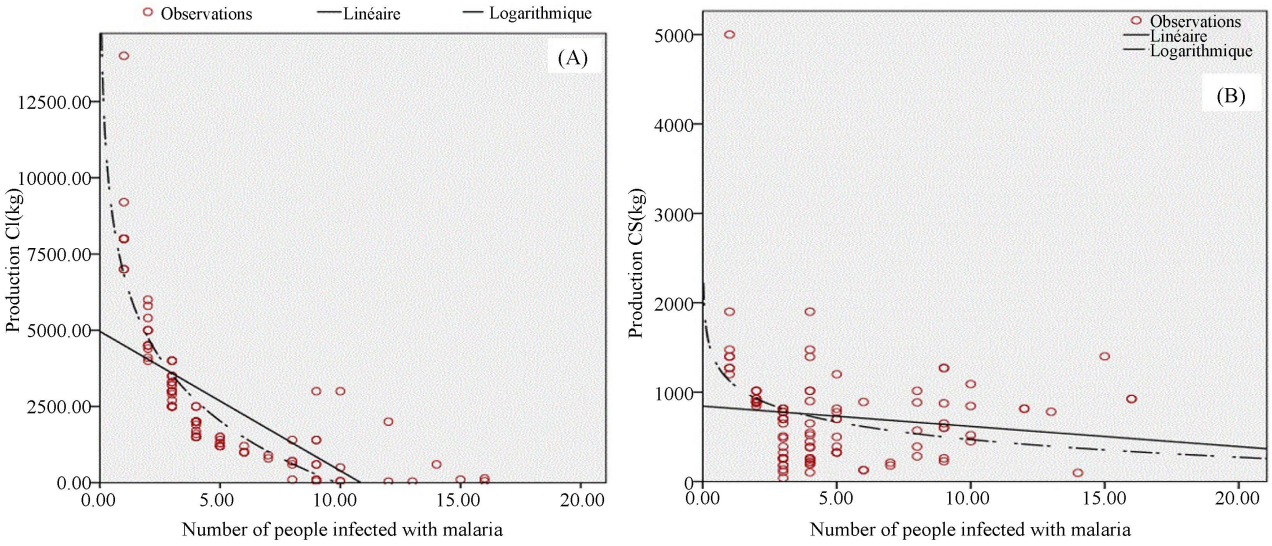

Figure 5. Influence of malaria on the production of irrigated crops (A) and rainfed crops (B).

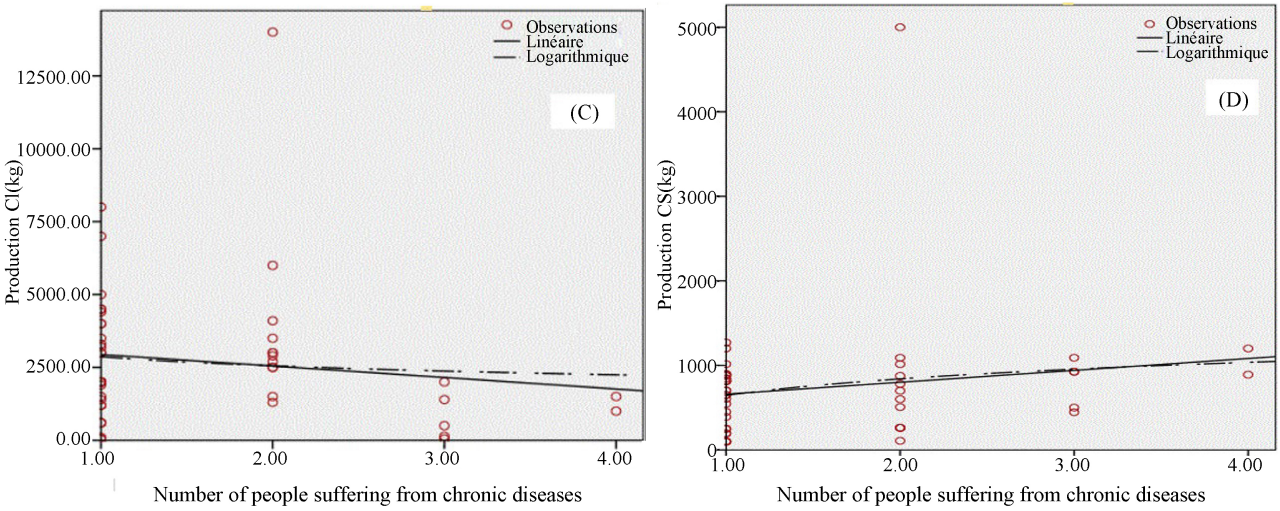

Figure 6. Influence of chronic diseases on the production of irrigated crops (C) and rainfed crops (D).

Table 8. Model and parameter estimates.

Summary of the model and parameter estimates										
Equation	Summary of the models				Parameter Estimates					
	R-squared		Significance level		Constante		b1		b2	
	RP	**IR**	**RP**	**IR**	**RP**	**IR**	**RP**	**IR**	**RP**	**IR**
Linear (F = 8.648)	0.051	0.087	0.020	0.00	394	1699	34	424	-	-
Quadratic (F = 8.397)	0.062	0.157	0.038	0.00	275	−1219	79	1511	−2.67	−64.7
The independent variable is the number of people sick with malaria. RP: Rainfed Crop, IR: Irrigated Crop.										

3.10. Case of Chronic Diseases Related to Climate Variability on Production

Regarding the impact of chronic diseases on production, the variation in the production level of households is not as significant, although it represents the second most prevalent illness among farming households (**Figure 6**). All estimated parameters are positive except for b1.

4. Discussion

Agriculture is the primary economic activity practiced by all surveyed farm operators [22]. The use of an analytical framework has enabled a better understanding of how agricultural operations function in the context of variability and climate change. The integration of economic, health, and environmental functions within agriculture and these farming operations will only be possible if agriculture returns to a path of diversity that responds to the distinctiveness of different environments. The results from the principal component analysis demonstrated a satisfactory level of explanation for the variability of information, with the first three axes accounting for 65.97% of the variance. Following these results, complemented by the hierarchical ascending classification method, three types of agricultural operations [7] are present in the area. These agricultural operations exhibit varied characteristics, particularly regarding cultivated areas, available labor force, intermediate consumption, agricultural equipment, and production outputs.

These factors have already been cited in the literature as a basis for differentiating agricultural operators [23] [24]. The predominance of medium-sized farms (G_B) is a general characteristic of agriculture in the municipality, characterized by limited means of production. Most individuals from small and medium farms do not have enough land to meet their essential needs. In contrast, large farms often ensure that these essential needs are largely met. Furthermore, given the saturation of agricultural space and the constant decline in soil fertility, the survival of small and medium farms is threatened in the medium to long term, unless a land reform occurs to reduce inequalities in land access. The overwhelming majority of agricultural operations are of the subsistence type, with the objective not only to satisfy basic needs but also to fulfill the duty of solidarity that binds people to one another.

The average age of farmers ranges from 52.68 to 57.65 years, slightly higher than those reported by [22] in the same area. There is a significant difference in household size among the different types of agricultural operations, with an average of 9 people in G_A farms, 10 in G_B farms, and 13 in G_C farms. Furthermore, a notable difference is observed in the agricultural workers among households at the 1% significance level [25]. These results are similar to those obtained by [26]. The low representation of agricultural workers in these operations can be attributed to rural exodus, which is not a new issue. This trend may reflect strategies adopted by farmers hoping to find better working and living conditions in urban areas. This transfer of labor from agriculture to other economic sectors is also a historical

phenomenon, often an unpleasant but inevitable stage [27]. The average area for rain-fed crops is 1.158 hectares for G_A farms, 2.25 hectares for G_B farms, and 3.5 hectares for G_C farms. These operations are characterized by a lack of support for producers due to insufficient agents on-site. This activity is threatened by several risks associated with variability and climate change. The impact of climatic hazards is particularly critical as it affects 90% of cultivated land that does not benefit from regular irrigation. It contributes to the over-indebtedness of farms and reduces their planning capacity. This impact is characterized by insufficient rainfall (leading to recurrent droughts) and soil degradation across all agricultural operations. G_A farms are particularly vulnerable to frequent flooding risks (such as rice farms, especially outside designated areas), leading to significant fluctuations in agricultural production.

The major climatic risk common to all rain-fed agricultural operations is drought. High production losses are reported for all three types of farms, with respective relative losses of 48%, 48%, and 43%, confirming the possible impacts of climatic hazards (droughts, floods) and potential inefficiencies in adapting agricultural practices. The difficulties faced by producers in accessing quality agricultural inputs, the limited or even nonexistent access to agricultural credit, and the absence of state subsidies are also indicators that hinder agricultural development in the area [20]. The majority of the production obtained from these agricultural operations is intended for household food consumption. However, a portion is sold in markets by producers who have transportation means, constrained by the need to cover certain expenses. Among these expenses, healthcare costs occupy a very significant place. Indeed, climate variability and change have had many negative effects on the health of farming households, as the areas involved in this study are characterized by several factors that promote the development of morbidities throughout the year (especially related to the geographical location of farming households in the area). According to [28], Heatwaves and climate variability increase the risks of dehydration, heatstroke, and illnesses related to heat stress. The costs of medical treatments and income losses weigh heavily on farming households, increasing their vulnerability to poverty [29].

This has resulted in an increase in the number of inactive individuals in agricultural activities, consequently affecting certain expenditure items in agriculture. According to [29] Malaria is a major cause of morbidity, particularly in rural areas. It reduces the workforce and directly impacts agricultural yields. However, sustainable agricultural operations necessarily require an economically viable, ecologically sound, and socially equitable approach [30]. In these contexts, proposing a model has become necessary to support policies aimed at the sustainable transformation of agricultural operations.

5. Conclusion

This study first established a comprehensive analytical framework for agricultural operations to understand their organization and management in the context of health impacts from climate change. In these contexts, a structural, technical-

economic, and functional typology of agricultural operations was developed. These agricultural operations can be grouped into three types: G_A farmers, who place more emphasis on rain-fed crops (millet, sorghum, cowpeas) and utilize family labor as their workforce; G_B farmers, who practice both rice cultivation and rain-fed crops; and G_C farmers, who prioritize rice cultivation in their agricultural arrangements. G_A and G_B farmers constitute the overwhelming majority in the area and are often disadvantaged by historical factors, with very limited material and financial resources. Droughts and floods are the main climatic risks affecting these operations. For rice fields, the primary constraint remains caterpillar infestations, with the emergence of a new species negatively impacting rice production. High production losses for all three types (with respective relative losses of 48%, 48%, and 43%) indicate possible impacts from climatic hazards (droughts, floods) and potential inefficiencies in adapting agricultural practices. Climate change is significantly increasing the prevalence of morbidities in the area, leading to a rise in inactive individuals among G_A and G_B farmers. In light of the analysis of results, it is important to formulate recommendations.

6. Recommendations for Policymakers and NGOs

- **Support for Agricultural Operations**: Provide significant subsidies to support farms classified as A and B, particularly by supplying modern agricultural production equipment and inputs (such as the production and dissemination of improved seeds that are adapted to local climatic conditions).
- **Encourage Cooperation**: Promote cooperation among farms to share equipment and reduce costs.
- **Healthcare Access**: Enhance access to healthcare services to lower health expenditures and their impact on agricultural incomes.
- **Sustainable Practices Awareness**: Raise awareness about sustainable agricultural practices to minimize health risks associated with chemical products.
- **Risk Management Measures**: Implement climate risk management measures, such as water-efficient irrigation systems and agroecological solutions.
- **Training for Resilience**: Train farmers in more resilient agricultural practices.
- **Increase Access to Agricultural Credit**: Improve access to agricultural credit to finance technological investments.
- **Develop Local Markets**: Foster the development of local markets to maximize income.
- **Support for Agricultural Organizations**: It is crucial to prioritize existing agricultural organizations in the area and support them through capacity-building initiatives, ensuring they have access to competent technical agents.
- **Climate Change Awareness**: Educate producers about climate change issues and their consequences on household health and agricultural operations.
- **Training for Phytosanitary Brigadiers**: Consider training, retraining, and equipping phytosanitary brigadiers, as well as methods for recovering degraded lands for agricultural purposes.

Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

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