Article

Not peer-reviewed version

Irrigated Agriculture Facing the Challenge of Climate Change: What Adaptation Strategies for Farmers in the Irrigated Perimeters of Môle Saint-Nicolas, Haiti?

Frantz Mial * , Jean-François Bissonnette , Marc-André Bourgault * , Meryem Qacami *

Posted Date: 6 February 2024

doi: 10.20944/preprints202402.0306.v1

Keywords: climate change, perception, adaptation, agriculture, irrigated perimeter

Article

Irrigated Agriculture Facing the Challenge of Climate Change: What Adaptation Strategies for Farmers in the Irrigated Perimeters of Môle Saint-Nicolas, Haiti?

Frantz Mail [1,*], Jean-François Bissonnette [2], Marc-André Bourgault [3,*] and Meryem Qacami [4,*]

[1] Doctoral thesis student at Laval University, Quebec, Canada, author
[2] Department of Geography, Laval University in Quebec, Canada, associate professor, Jean-Francois.Bissonnette@ggr.ulaval.ca
[3] Department of Geography, Laval University in Quebec, Canada, assistant professor
[4] Doctoral thesis student at Laval University, Quebec, Canada, collaborator
* Correspondence: frantz.mial90@gmail.com (F.M.); Marc-Andre.Bourgault@ggr.ulaval.ca (M.-A.B.); meryem.qacami.1@ulaval.ca (M.Q.)

Abstract: Môle Saint-Nicolas, like all other communes in the Republic of Haiti, faces increasing climate variability, impacting agricultural production and water resources. Consequently, there is a pressing need for adaptation to these climatic changes. This research aims to showcase the adaptation strategies deployed by farmers to cope with the increasing climate variability. Surveys were conducted through group and individual discussions with a randomly selected cohort of 150 farmers. Two types of analysis were performed: quantitative and qualitative. The quantitative data analysis was conducted using SPSS software. The findings reveal that farmers have perceived changes in rainfall patterns, temperature, wind, and their environment. These changes manifest as irregular rainfall, higher temperatures, prolonged drought periods, violent winds accompanied by rain, premature cessation of rains, and reduced flow from water sources. In response, the most common adaptation strategies developed include selecting new cultivars, early-maturing varieties, crop rotation and diversification, canal dredging, new soil preparation methods, upstream water source protection, and micro-watershed management. The significance of this research lies in its contribution to enhancing farmers' adaptive capacities by alerting stakeholders in the irrigated perimeters about the consequences of climate change, thereby incorporating the real needs of farmers in future projects.

Keywords: climate change; perception; adaptation; agriculture; irrigated perimeter

1. Introduction

The latest World Bank report (2020) identifies Haiti as the poorest country in the Western Hemisphere and ranks it among the top 10 countries most affected by climate change. The report also estimates that damages related to climate change could reach $3 billion USD by 2025 without effective intervention. Thus, climate change poses a significant threat to Haiti, which contributes minimally to the greenhouse gas emissions phenomenon. Like other Latin American and Caribbean countries, Haiti has been experiencing the adverse effects of global changes for years, including disruptions in rainfall patterns and prolonged drought periods (Saint-Louis et al. 2019). Furthermore, generally, the poorest countries and individuals are the most vulnerable to the impacts of climate change, disproportionately affecting the less affluent (Guivarch et al. 2010). These impacts are already threatening development progress, especially in poor rural communities and in the agricultural sector, which sustains the economies of many low-income countries (Ryan et al. 2018). Additionally, agriculture has seen a decline in productivity along with an accelerated process of capital depletion among farming households (Beaucejour P., 2016).

In 2012, the agricultural sector was hit by several extreme weather events, including droughts causing an estimated $80 million USD in damages to agriculture, and Hurricane Sandy, which

Preprints.org (www.preprints.org) | NOT PEER-REVIEWED | Posted: 6 February 2024 doi:10.20944/preprints202402.0306.v1

resulted in agricultural losses of about $52 million USD (CNSA[1], 2013; CIAT[2], 2014). According to the United Nations Food and Agriculture Organization-FAO (2022), rural Haitian communities facing high risks of crop losses lack the necessary resources to cope with climate variability. Warmer temperatures will harm plant crops, irrigation canals will receive less water, and pests like giant ants will appear in the Central Plateau and the Northwest, where the irrigated perimeters[3] are located. Consequently, irrigated agriculture has emerged as a means of adaptation in response to climate change. It has developed through the construction of large dams, particularly in developing countries, where the number of dams in 2000 accounted for two thirds of the global total (Tapsoba et al 2018). Improving water management for more resilient agriculture allows producers to adapt to climatic constraints, enabling them to diversify their crops in the irrigated perimeters and promote better crop rotation (Azar S., 2017).

Irrigated agriculture can provide the necessary water quantities for crops through various artificial irrigation methods. This type of agriculture requires capital investment and infrastructure for water transport, such as irrigation canals, sprinklers, water reservoirs, necessitating advanced technical developments in turn[4]. In Haiti, the development of the irrigation sector is a significant asset for the agricultural sector to address the impacts caused by the January 12, 2010 earthquake, serving as a crucial determinant in improving agricultural productivity and income, and job creation (MARNDR, 2012). It is noteworthy that the Republic of Haiti has about 250 irrigation systems, covering an estimated 135,000 to 150,000 hectares of land, which constitute areas with high agricultural potential (MARNDR[5], 2012). The practice of irrigation in Haiti is longstanding. At the end of the colonial period, the irrigated areas accounted for some 58,000 hectares. After a period of collapse due to the degradation of facilities and their operating conditions, the development of irrigated areas resumed at the beginning of the century[6]**.** The Ministry of Agriculture is making efforts

---

[1] National Coordination of Food Security (CNSA), which aims to influence public policies designed to sustainably improve the food security conditions of the Haitian population under the supervision of the Ministry of Agriculture, Natural Resources and Rural Development (MARNDR).

[2] The Interministerial Committee for Territorial Planning (CIAT) has the mission to define the government's policy on territorial planning, watershed protection and management, water management, sanitation, urban planning, and equipment. This institution was created in response to an alarming observation and the need for coherent and coordinated actions in the field of territorial planning.

[3] Ramons Claude Jean-Philippe, climate change: the need to manage the inevitable, master in environmental economics and natural resources.

[4] Irrigated land: definition, explanations, Aqua Portail

[5] The Ministry of Agriculture, Natural Resources and Rural Development (MARNDR) addresses the issue of irrigation in Haiti through the Directorate of Agricultural Infrastructure (DIA).

[6] Haiti, National Plan for Agricultural Investment - Development of Rural Infrastructures, Annex 2 of MARNDR: The majority of irrigation systems in Haiti are gravity systems, fed from spring and river waters (diversion capture). They are generally small in size.

to improve irrigation systems; however, there is no policy aimed at adapting agriculture and irrigation canal management to climate change (Singh et al. 2014). Climate change poses considerable challenges that Haitian farmers must urgently adapt to. The challenge is to identify this threat, assess it, and develop targeted adaptation measures[7]. The adoption of adaptation measures by a farmer depends on their perception of climate change and its causes, its negative impacts on the environment, and the means available to provide solutions (Kabore et al. 2019). Moreover, the capacity to adapt, or the ability of a system to adjust to climate change, allows for coping with the potential consequences of climate change damages (GIEC[8], 2017; Bissonnette et al. 2017). According to Madisson (2007), perceiving climate change is a prerequisite for adaptation; one must perceive before adapting. According to this author, adaptation is the combined result of populations' perceptions of climate evolution and their demographic and socio-economic characteristics.

The commune of Môle Saint-Nicolas is one of the 146 communes in the country's most vulnerable to climate change. It is primarily an agricultural commune, but its crops have been subject to drought and scarce rainfall for many years. According to Rainer Schmidt (2011), the lower Northwest of Haiti, where the irrigated perimeters are located, is a dry region with difficult access to water. More than 180,000 people suffer from food insecurity and try to increase their income by cutting wood to make charcoal since agriculture, with insufficient yields, cannot meet families' needs.

This research aims to show the adaptation strategies deployed by farmers in the irrigated perimeters of Môle Saint-Nicolas to face meteorological variability and extreme weather events. The interest of this study is to contribute to strengthening farmers' adaptive capacities by alerting stakeholders in the irrigated perimeters to take into account the real needs of farmers in future projects. The central question addressed in this research is as follows: What are the adaptation strategies deployed by farmers in the irrigation perimeters of Môle Saint-Nicolas to face the increase in variability and extreme climatic events? To achieve this objective, the methodological approach used was both qualitative and quantitative. SPSS[9] software was used for processing quantitative data. In this article, we analyze how farmers perceive the decline in agricultural production and water resources in the rehabilitated irrigated perimeters in a context of climate change. Then, we present and discuss the main results in terms of farmers' perceptions of climate variability, deployed adaptation strategies, and the vulnerability of farmers to climate change.

2. Theoretical Framework

In the context of combating climate change[10], adaptation encompasses a category of thought and action. It brings together all practices aimed at acknowledging and addressing the consequences of climate change (Garcia P., 2015). The classical concept of adaptation is the idea that there exists a pre-

---

[7] Adaptation to climate change: a challenge for family farming, news flash N°2, authors: Markus Giger, Udo Hoeggel, Centre for Development and Environment (CDE), 2011

[8] The Intergovernmental Panel on Climate Change was established in 1988 to provide detailed assessments of the state of scientific, technical, and socio-economic knowledge on climate change, its causes, potential impacts, and response strategies.

[9] Statistical Package for the Social Sciences (SPSS), it is software used for statistical analysis.

[10] The United Nations Framework Convention on Climate Change defines climate change as changes in climate that are attributed directly or indirectly to human activity that alters the composition of the global atmosphere and that are in addition to the natural variability of the climate observed over comparable periods.

existing problem that an organism resolves by adapting to it (Godard O., 2010). Adaptation is defined as all the organizational, locational, and technical evolutions that societies must undertake to limit the negative impacts of these changes and maximize their beneficial effects (De Perthuis, 2009). The most commonly used definition of adaptation is that of the IPCC, which is an adjustment process to current or expected climate and its effects, to mitigate harmful effects and exploit beneficial opportunities (IPCC, 2018). Thus, adaptation to climate change refers to all strategies, initiatives, and measures specifically aimed at dealing with the evolving climate and its consequences. Adaptation actions are generally intended to address the major risks induced by climate change but can also stimulate innovation (Walthall et al. 2013; Janowiak et al. 2016; Pascal Pepin P., 2020). It is fundamentally local, as the direct impacts of climate change are and will be felt locally (Van Gameren et al., 2014).

However, several factors influence the adaptation capacity of producers, such as their socio-economic, environmental conditions, and access to information and technology[11] (IPCC, 2007; Fabre C., 2010). Adaptation seeks to limit vulnerabilities to reduce the impact of climate change. Farmers already have numerous technical adaptation options for marginal changes in existing systems. These autonomous adaptations are part of strategies to manage climate risk, which still require research efforts, especially in developing countries (Soussana J-F, 2013). In these theoretical considerations, Fishbein and Ajzen (1975) propose the basic hypothesis that producers' adaptation to stimuli such as climate change is coherent only in light of their conception and, therefore, their perception. According to these authors, since the perception of climate change is the interpretation of the observed stimulus, the producers' decision to adapt would be a reasoned process. For the agricultural sector, adaptation to climate change translates into an adjustment of activities and practices to mitigate the harmful effects of climate change and to seize new opportunities that may arise from climate evolution (FAO, 2012; Ouranos 2015; Pepin P., 2020). Moreover, irrigation is a key adaptation strategy to boost agricultural production where water is available (CNEDD, 2020). It has become necessary to ensure continuous growth and guarantee product quality[12]. According to Renoux (2011), at the farm level, irrigation allows for the diversification of crops, balance between winter and summer crops, thus providing security against climatic hazards. It also aims to increase and stabilize agricultural yields, especially in the face of droughts expected to intensify due to global warming (Ducharne et al. 2022).

At this level, the primary goal is to mobilize broad agronomic expertise to adapt to altered climatic conditions. This begins with the use of appropriate genetic material better suited to higher temperatures and more effectively utilizing increased photosynthesis and water efficiency, while minimizing the effect of shortened growth cycles (Bernard Seguin B., 2003).Documented studies on adaptation strategies indicate that the use of drought-resistant seeds, adjusting sowing and irrigation dates (Abid et al. 2015; Sarr et al., 2015; Ofuoku, 2011), efficient water and fertilizer management (Bagula et al. 2013), and crop diversification are among the most favored adaptation methods in agriculture worldwide (Torquebiau, 2017; Makate et al. 2016; Bele et al. 2014).

3. Materials and Methods

3.1. Study Area and Justification for Site Selection

This study was conducted in five irrigated perimeters located in the commune of Môle Saint-Nicolas, Haiti. The selection of this commune was based on its agricultural potential in the past. Môle Saint-Nicolas, through its irrigated perimeters, has historically contributed to supplying local and regional markets with agricultural products. It was known as one of the communes in the lower Northwest with significant agricultural potential due to its irrigated perimeters, and the non-irrigated areas were also known for producing peanuts, roots, and tubers, as well as for ruminant livestock.

[11] https://www.ipcc.ch/site/assets/uploads/sites/2/2019/10/SR15_Glossary_french.pdf

[12] Irrigation, a Response to Climate Change by Pierre Sauriol, Horticultural Consultant Agronomist.

 doi:10.20944/preprints202402.0306.v1

From the 1960s, farmers from other regions of the country came to find an irrigated plot, which at that time were difficult to find.

Observing the decline in agricultural production since 2000, local authorities have lobbied national authorities and international NGOs to address this situation. According to testimonies from some local actors, local and international NGOs, in concert with the Haitian state, have implemented projects to strengthen agricultural sectors in the irrigated zones of the commune. These NGOs have invested thousands of dollars through humanitarian projects to rehabilitate the irrigated perimeters with the goal of reviving agricultural production, yet the socio-economic situation of the farmers remains unchanged and even deteriorated. During natural disasters, agricultural plots are completely destroyed, and livestock, which represent a guaranteed source of income, especially ruminants, die and disappear. Given the agricultural potential of this commune from the 1960s and its decline since 2000, scientific interests have led us to choose this theme to conduct this research and demonstrate the causes of the deterioration of agricultural production in the rehabilitated irrigated perimeters to make better decisions.

3.2. Presentation of the Commune of Môle Saint-Nicolas

Môle Saint-Nicolas is a commune in Haiti located at the extreme western tip of the peninsula, in the north of the country. The commune covers an area of 227 km² with a population of 30,795 inhabitants in 2009 according to the latest IHSI[13] census. It is one of the coastal communes of the Northwest department. The distribution across the territory is very uneven, with two main urban centers: the town of Môle Saint-Nicolas, located in the first section, and the agglomeration of Mare-Rouge, at the center of the 2nd section. The latter often claims the status of a commune, with a geographical and economic environment very different from that of the town of Môle Saint-Nicolas. The eastern part, covered by the first section and overlooking the Windward Passage, is almost uninhabited due to a challenging environment, while habitats are found along the main roads first leaving Mare-Rouge towards Côtes-de-Fer. The rainfall in Môle Saint-Nicolas varies between 1000 and 1200 mm of rain on average per year, and the average annual temperature is 26.9°C (CNIGS[14], 2014). This commune has two rainy seasons: one starts in April to May, and the other from September to December. It has two rivers: the La Gorge river, which originates in the commune of Bombardopolis and flows into the vicinity of the town of Môle Saint-Nicolas, where it supplies the town's drinking water network, and also the Lema river (CNIGS, 2014).

---

[13] The Haitian Institute of Statistics and Informatics (IHSI) is the institution responsible for collecting quantitative information on the social, economic, and demographic aspects in Haiti. It was established by the law of September 4, 1951. About four decades later, a new decree, dated July 1, 2020, came to renovate and reorganize the Haitian Institute of Statistics and Informatics.

[14] The National Center for Geo-Spatial Information is a public reference organization for the production, exploitation, archiving, and dissemination of specialized data on the Haitian territory using modern geo-scientific methods and tools.

Preprints.org (www.preprints.org) | NOT PEER-REVIEWED | Posted: 6 February 2024 doi:10.20944/preprints202402.0306.v1

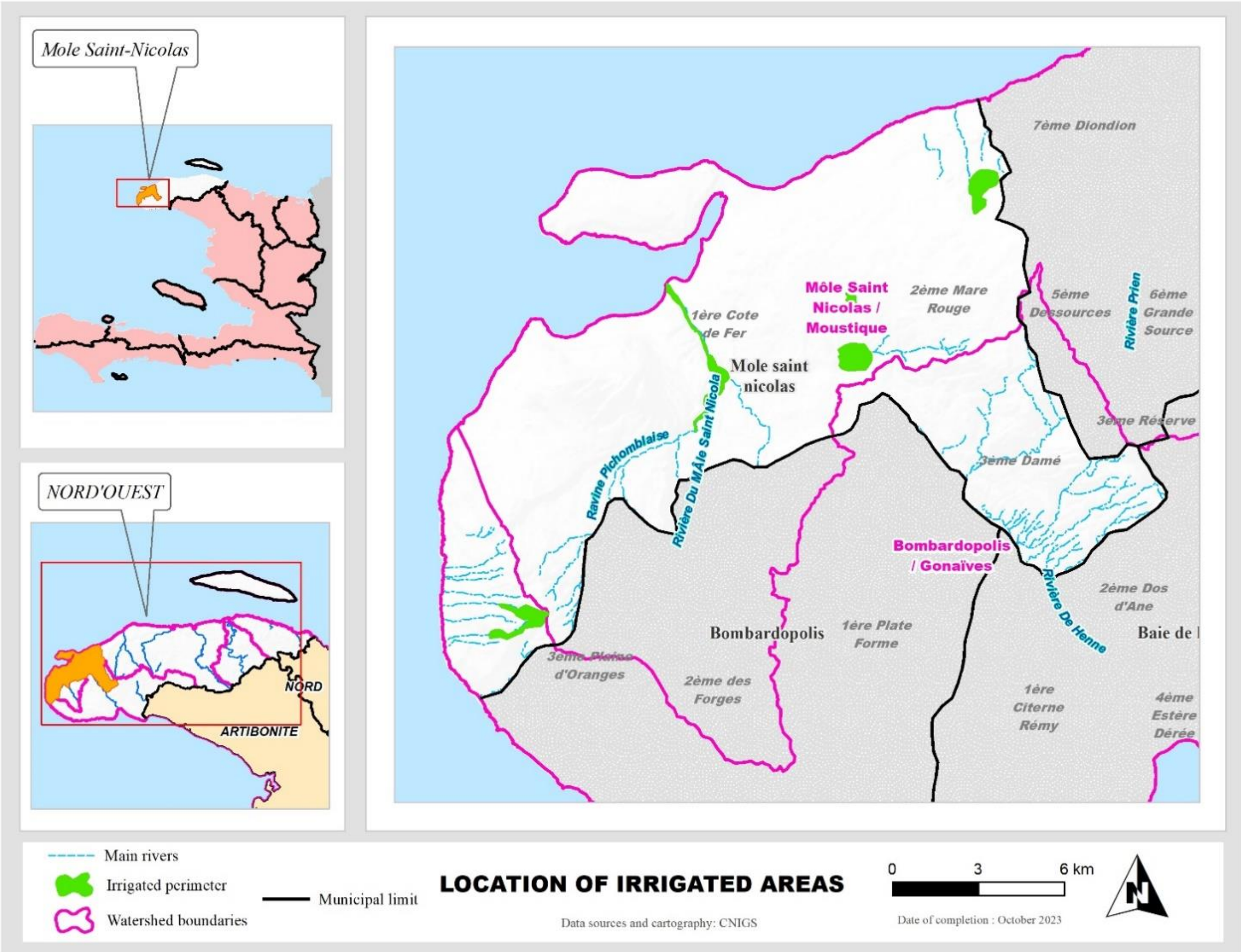

Figure 1. Geographic map of the commune of Môle Saint-Nicolas.

3.4. Data Collection and Analysis

Data collection was carried out in the five irrigated perimeters of Môle Saint-Nicolas, namely the Nan Trou, Polvo, Digotrie, Lavaltière, and La Gorge irrigated perimeters. In each irrigated perimeter, 30 farmers were randomly selected by the irrigators' associations, resulting in a total of 150 farmers responding to an individual questionnaire and some to a group questionnaire that included both closed and open-ended questions. Focus groups varied between 8 and 12 participants and included both male and female users of the irrigated perimeters. This number was chosen following Baribeau (2009), who noted that the number of people typically ranges from 8 to 10 for a focus group. Additionally, observation visits were conducted in collaboration with the stakeholders of the perimeters to assess the condition of the physical infrastructure of the irrigated perimeters, water sources, micro-watersheds, and agricultural plots.

The farmers considered in this study were at least 18 years old. This age criterion is justified by the fact that climate change occurs very slowly, and it is the adult individuals who may have experienced it (Kabore et al. 2019). The main data collected from the farmers in the irrigated agricultural perimeters were based on the following themes: the socio-economic characteristics of the farmers, the various changes observed, the perception of climate change, the adopted adaptation strategies, and local knowledge. The collected data were processed and analyzed according to the objectives set by this research. Nevertheless, two types of analysis were performed: quantitative and qualitative. The quantitative data were analyzed using SPSS software for descriptive analyses

Preprints.org (www.preprints.org) | NOT PEER-REVIEWED | Posted: 6 February 2024 doi:10.20944/preprints202402.0306.v1

(frequency and percentage). As for the qualitative data, the processing was based on narrative documents from the irrigators' associations and NGOs[15] active in the irrigated perimeters.

Table 1. Presentation of the irrigated perimeters.

Irrigated perimeter	*Number of developed hectares*	*Number of farmers*	*Sample size*	*Sampling rate*
Polvo	78	129	30	23,25%
Nan Trou	54	197	30	15,22%
Digotrie	68	225	30	13,33%
Lavaltière	75	215	30	13,95%
La Gorge	80	286	30	10,48%

Source: Author's survey, 2023.

4. Results

4.1. Socio-Economic Characteristics of Farmers

The study of the socio-economic characteristics of farmers in the irrigated perimeters was based on a sample of 150 farmers presented in Table 2 below. Among the 150 surveyed farmers, 33 of them, or 22%, are women, and 117, or 78%, are men. The average age of the farmers is about 50 years, with the youngest farmer being 23 years old and the oldest 76 years old. Younger individuals are more engaged in non-agricultural activities and have migrated to urban areas within the country or abroad in search of a better life (Dameus et al. 2022). The educational level of the farmers is generally low. There are 22 farmers, or 14.7% of those surveyed, who are illiterate. The majority of the farmers have primary level education, accounting for 52.7% of the surveyed population. Only two individuals have a university-level education, representing 1.3% of the total sample. The land tenure modes in the irrigated perimeters include purchase, leasing, and inheritance from grandparents. The leasing term for lands varies between 2 and 5 years across the perimeters, and access to this land, upon the owner's approval, confers full rights of exploitation throughout the leasing period. In fact, agriculture is the main activity for 100% of the surveyed farmers. These farmers supplement their agricultural production with non-agricultural activities to support their families' survival. Through their agricultural activities and the establishment of social and solidarity economy structures, they have been able to save a portion of their income, which is then transformed into credit among the members.

Table 2. Number of interviewed farmers.

Characteristics	*Number (150)*	*Percentage %*
Sex		
Female	33	22 %
Male	117	78 %
Age group		
18 to 29 years	10	6.7 %
30 to 39 years	18	12 %

15 Ayiti Gouvènans (AG) is a local NGO that actively works in micro-watersheds to protect hydro-agricultural infrastructures against water erosion and also to enable the replenishment of groundwater linked to water sources that feed irrigated areas.

Welt Hunger Hilfe (WHH) is a German non-governmental organization that works in constructing physical infrastructures of irrigated perimeters and in strengthening the agricultural sector.

40 to 49 years	55	29.3 %
50 years and over	77	51.3 %
Education level		
Illiteracy	22	14.7 %
Primary	79	52.7 %
Secondary	47	31.3 %

Source : Author's survey, 2023.

4.2. Farmers' Perception of Climate Change

An irrigator's ability to adapt to water resource scarcity depends on their perception of the observed phenomenon (Mahdhi et al. 2019). Therefore, the climatic parameters investigated in this study to determine farmers' perceptions are rainfall, temperature, and wind speed. These parameters are considered the most significant climatic variables for determining the perception of farmers in the irrigated perimeters regarding climate change. Furthermore, Table 3 below lists the indicators of the climatic variables perceived by farmers. Understanding these variables at the regional level helps to prevent risk, plan, and optimize farming operations (Gommes R., 2011). All 150 farmers from the irrigated agricultural perimeters perceive changes in rainfall patterns. These changes in rainfall have direct repercussions on irrigated agricultural production. The main changes observed by farmers include decreased and irregular rainfall, extended dry seasons, high intensity of rainfall accompanied by violent winds, and reduced flow rates of water sources feeding the irrigated perimeters.

Table 3. Indicators of climatic parameters perceived by farmers in the irrigated perimeters.

Climatic parameters	Indicators of changes
Rainfall	Decrease in rainfall patterns ; Delayed onset and early cessation of rains ; Lengthening of drought periods ; High intensity of cyclonic rains ; Reduction in water source flow ; Irregular rainfall patterns.
Temperature	Increased temperatures ; Very strong heatwaves ; Increase in the number of hot days.
Wind	Stronger winds ; Rain accompanied by violent winds.
Environmental changes	Emergence of pest insects ; Appearance of diseases in crops ; Reduction and disappearance of certain plant.

Source: Author's survey, 2023.

Accordingly, 44.7% of the interviewed farmers state that the dry season varies between 3 and 7 months in the areas and zones surrounding the irrigated perimeters. Following the drought period, 55.3% of the farmers report that the rain always comes in a cyclonic form, causing floods that destroy the physical infrastructure of the perimeters and agricultural plots. Indeed, the irregularity of rainfall leads to a total reduction in the cultivated plots and also challenges the local knowledge of farmers about their environment. Predominantly, the rain is always accompanied by violent winds lasting several days over the irrigated perimeter. During interviews, a group of 132 farmers, which constitutes 88% of those surveyed, declare that the rainy seasons always start late and end early. Often, this premature cessation in the irrigated perimeters occurs during the vegetative growth phase, leaving plants without the water they need, which frequently results in decreased agricultural yields.

Regarding temperature, 139 farmers, or 93%, perceive an increase in temperature with very strong heatwaves. According to them, both days and nights are getting warmer, and this increase in temperature causes evapotranspiration. Consequently, the reduction in water source flows and the drying up of certain water points are outcomes of this extreme temperature. Besides temperature, violent winds contribute to the decrease in agricultural production by causing the destruction of crops, young fruits of fruit trees, and soil drying after rainfall. The interviewed farmers unanimously declare that there is an environmental change in the irrigated perimeters, including the emergence of pest insects that destroy irrigated crops. Additionally, it is noted that certain plants are disappearing, such as citrus, coconut trees, and taro mazombèle in their environment.

4.3. Adaptation Strategies of Farmers in the Irrigated Agricultural Perimeters

In response to the increasing climate variability, farmers in the irrigated perimeters of Môle Saint-Nicolas have adopted new strategies to combat climate change. They have introduced short-cycle cultivars adapted to drought periods. The introduction of crops in the areas of the irrigated perimeters completely alters the traditional agricultural calendar by prioritizing new technical pathways adapted to climate variability. Through their experience and observed changes, they make specific choices and varieties for each season. They have given up (89%) certain water-intensive and high-maintenance crops in favor of others that can withstand water stress, and they also practice crop rotation. Thus, from September to November, 84.6% of farmers produce onions, leeks, and carrots in sufficient quantities due to water availability. However, they unanimously cultivate shallots throughout the year due to their drought resistance and yield potential. After harvesting these crops, they replace them with cereal and leguminous crops. Moreover, farmers diversify their agricultural production to minimize the risks of total yield loss by practicing polycultures in the irrigated perimeters.

According to Arsène and allies (2021), diversification and choosing less maintenance-intensive crops are strategies used to reduce the risk of crop losses due to climatic uncertainties. In the spring season, when water resources in the irrigated perimeters start to diminish, off-season irrigation is applied by about 72% of farmers by carrying out small-scale productions, i.e., reducing the cultivated area. They divide their production plots into two, one part for vegetable production and the other for cereals and legumes. During drought periods, some farmers use water storage containers for manual watering of vegetable crops. This practice is more widespread in the Nan Trou irrigated perimeter because, during this period, the water source flows significantly decreases. Farmers organize community activities after floods to dredge irrigation canals and repair some damaged infrastructure.

Facing soil fertility loss due to water erosion, farmers develop soil and water conservation methods following techniques taught by NGOs and Haitian state officials. Furthermore, the maintenance of irrigation canals, the protection of the upstream water sources that feed the agricultural perimeters, and the establishment of anti-erosion structures in the micro-watersheds are adaptation means implemented by farmers to combat water scarcity in the face of climate variability. The main types of structures built in the plots are thresholds, stone bunds, and living and non-living ramps. These anti-erosion structures contribute to adapting to rainfall variability by reducing water erosion and increasing water infiltration into the soil to recharge aquifers, which helps reduce crop water stress during drought periods.

Some farmers build rectangular ridges with furrows inside. This method not only allows for better water management but also facilitates weeding in the plots. During soil preparation, farmers use organic matter composed of domestic animal manure to increase soil fertility. Very few farmers practice fallowing. They exploit the irrigated agricultural plots throughout the year. Ruminant farming is a very profitable activity for farmers in the irrigated perimeters. In case of agricultural season losses, they rely on cattle and goat farming. Grazing is the first and last activity undertaken by farmers in a day before working on the irrigated perimeters. Moreover, they organize themselves through social and solidarity economy structures, named AVEC (Village Savings and Loan Association) and Mutual Solidarity. According to them, these structures allow them access to credits adapted to their socio-economic reality to improve their living conditions. Table 4 below shows the different local strategies adopted by farmers in the irrigated perimeters to face climate variability.

Table 4. Farmers' adaptation strategies to climate variability.

Adaptation strategies	Effectif	Percentage (%)
New technical pathways	144	96
Selection of new cultivars	150	100
Crop diversification	145	96.6
Crop rotation	140	93.3
Abandonment of certain crops	133	88.7
Off-season irrigation	108	72
Reduction of plots in the spring	101	67.3
Anti-erosion structures in plots	146	97.3
Fallow practices	61	40.7
Membership in savings and credit groups	150	100
Storage and manual watering of crops	32	21.3

Source : Author's survey, 2023.

4.4. Impacts of Climate Variability on Irrigated Perimeters

Due to climate change, farmers in the five irrigated perimeters of Môle Saint-Nicolas are increasingly vulnerable. Faced with this vulnerability, they have developed adaptation means based on their socio-economic capacity. However, extreme weather events continue to create uncertainties among them despite their efforts. These extreme events manifest as prolonged drought periods ranging from 3 to 6 months, rains accompanied by violent winds that destroy irrigated crops, and increased temperatures causing rapid evapotranspiration. During drought episodes, water source flows decrease significantly, and farmers are forced to turn to other income-generating activities. Furthermore, not only are farmers unable to meet their families' basic needs, but their children under five also suffer from malnutrition related to food insecurity, predominantly experiencing acute and moderate malnutrition. Over the past two decades, water resources have become increasingly limited and scarce during certain times of the year (from January through April and from May to September), leading to conflicts among users. Moreover, conflicts related to water resources in the irrigated perimeters are likely to increase due to the high demand for irrigation water by farmers. Additionally, climate variability causes forced displacement of farmers seeking other economic activities. They migrate to other cities in the country in search of a better life because the yield from irrigated agricultural production is not profitable.

4.5. Farmers' Vulnerability to Climate Change

The irrigated perimeter of Môle Saint-Nicolas remains vulnerable to the consequences of climate change. Hazards such as drought episodes, changes in rainfall patterns, cyclones, and floods negatively impact farmers' livelihoods. The level of vulnerability of farmers to climate shocks is high on several fronts. Socio-economically, access to certain basic services and their economic means to cope with extreme events are limited. Agriculturally, the productivity of the irrigated perimeters decreases, and farmers experience yield losses due to a lack of water resources. Consequently, the loss of agricultural yields has become a normal and acceptable fact across the five irrigated perimeters. In fact, the study of farmers' vulnerability was conducted based on the exposure of the four elements mentioned in the table below to climate risks. Vulnerability factors and their levels were identified and analyzed during group interviews with farmers who were part of the study sample.

Table 6. Consequences of climate change on water resources and production.

Vulnerability	Vulnerability factors	Level
Water Resources	• Major drought episodes; • Extreme temperature;	High

	• Degradation of micro watersheds and exploitation of trees upstream of water sources; • Poorly fed aquifers and increased runoff; • Surface water evaporation; • Increased water demand.	
Agricultural Production	• Variations in rainfall patterns; • Violent winds with rain; • Shifting sowing seasons; • Rapid/accelerated evapotranspiration; • Soil erosion and loss of arable layers; • Emergence of pest insects and diseases in crops; • Abandonment of certain crops; • Inability to find quality and suitable seeds during sowing; • Decrease in yields.	High
Socioeconomic	• Decapitalization of farmers; • High production costs; • High prices of agricultural inputs during sowing and lowered during harvests; • Exclusion from the conventional banking system and limited access to credit; • Migration of labor to other income-generating activities; • Limited access to basic needs: education for their children, quality healthcare, quality food; • Food insecurity (acute malnutrition in children under five); • Seasonal parasitic diseases; • Aging of farmers.	High

Source : Author's survey, 2023.

4.6. Discussion

The findings of this research indicate that farmers in the irrigated perimeters perceive climate change as phenomena contributing to the reduction of farmer income. Climate change induces extreme weather events that negatively impact the irrigated agricultural production of Môle Saint-Nicolas. Furthermore, climatic variables such as decreased rainfall, extended dry seasons, increased temperature, and violent winds are perceptions confirmed by farmers across the five irrigated perimeters. This perception by the farmers is due to the direct influence of these climatic variables on agricultural production, which can determine a good or bad agricultural season (Sanou et al. 2018). During dry periods, the water sources feeding the irrigated perimeters are unable to meet the water needs of vegetable crops, which are highly water-demanding and sensitive.

Bationon (2009), in his research thesis presented at the University of Ouagadougou, mentions that vegetable crops, unlike rainfed crops, have specific water and temperature requirements. When these requirements are not met, either the plants do not reproduce, or the production is of poor quality. Farmers in the irrigated perimeters often record a decrease or total loss of yields due to a sudden cessation of rains during the vegetative growth phase of crops. When the rains are insufficient, the consequences are reflected in the crops through poor development, wilting of leaves, crop burn due to increased temperature, lack of water for domestic needs, etc., similar to peasant perceptions identified in surveys conducted in the cotton zone of Northern Benin (Guilbert et al., 2010; Bambara et al., 2013; Sanou et al., 2018).

The irrigated perimeters of Môle Saint-Nicolas are managed by projects from non-governmental organizations (NGOs) in collaboration with the Haitian state through the Ministry of Agriculture.

The construction of hydro-agricultural infrastructure was aimed at increasing water resources and agricultural sectors in the irrigated perimeters. However, this goal has not been achieved to date, and the agricultural situation is deteriorating. Mostly, these NGOs do not take into account the socio-economic reality of the farmers. During the project lifecycle, adaptation capacity is improved, i.e., more progress is recorded due to the distribution of agricultural inputs and the development of micro-basins located upstream of the perimeters. During project implementation, there are always labor-intensive activities by distributing cash to workers. Moreover, some NGOs often used "food for work" as a payment method for building dry walls and contour canals (Smucker G., 2012). It was always a public works approach using mechanical structures on farmers' private lands. For these NGOs, it was a matter of mobilizing volunteer work with some encouragement, while for the farmers, the in-kind payment was a real salary that far exceeded the current price of agricultural labor (Smucker G., 2012). However, once the project ends, farmers receive no support to continue facing climate shocks.

The local adaptation strategies developed by farmers in Môle Saint-Nicolas are linked firstly to their perception and secondly to their economic means. Their perception is based on the different changes observed in the areas of the irrigated perimeters related to climate variability, and their economic means allow them to anticipate and better adapt to climate change. To cope with the increase in climate variability, the implemented strategy is focused on water resources, which, according to them, are cross-cutting both to ensure the profitability of agricultural production and to carry out domestic activities. Faye and colleagues (2015), in a research conducted in Senegal, mention that "in the agricultural sector, the implemented adaptation strategies consist of seeking more water-efficient cropping systems, better aligning the cropping cycle by using animal traction and choosing early-maturing varieties, and developing techniques that allow concentrating rainwater where it is most useful." Similarly, in Haiti, farmers in the irrigated perimeters often consider early-maturing varieties as a good response to delayed rains and better adaptation. Despite these efforts to cope with increased climate variability, the degradation of hydro-agricultural infrastructure in the irrigated perimeters is an obstacle for the agricultural sector. However, farmers do not have sufficient financial means to maintain the damaged canals. Their economic means merely allow for canal dredging through community activities. In this situation, the agricultural sector offers low yields due to the degradation of hydro-agricultural infrastructure, and food needs are not met, as confirmed by Abdoul-Kader and collaborator (2022) in their research in the urban commune of Konni in Niger.

In terms of capacity building on the use of climate data and understanding the challenges of climate change, farmers remain vulnerable. No stakeholder in the perimeters participates in the mobilization of knowledge on adaptation to climate change. Moreover, few scientific studies have been conducted on the irrigated perimeters of Môle Saint-Nicolas, which is why climate data remains limited for conducting scientific work. In line with the research of Mushagalusa Balasha and colleagues (2019) conducted in South Kivu in the eastern Democratic Republic of Congo, the results of this study can guide public authorities and agricultural development actors in defining a program to strengthen adaptation capacities to climate change by formulating new strategies based on existing indigenous knowledge. Furthermore, one of the biggest problems of the irrigated perimeters is the unavailability of labor due to the migration of some farmers. Additionally, the cost of soil preparation and plot maintenance is very high. Farmers are forced to do this work themselves over several days. Ahodode's work in Northern Benin on farmers' adaptation strategies shows the same reality as Haiti in terms of labor, stating: to mobilize labor, one must have an effective social network and sufficient financial and material resources. Even when calling for mutual aid, the mobilized workers must be fed, and one must be available to help them in return.

5. Conclusions and Perspectives

The objective of this study was to analyze the impact of rainfall variability on irrigated agricultural production as well as the perceptions and adaptation strategies of farmers to climate change in the commune of Môle Saint-Nicolas, Haiti. The results clearly show that farmers in the irrigated agricultural perimeters perceive climate change through the increase in extreme weather

 doi:10.20944/preprints202402.0306.v1

events. The irrigated agricultural production of this commune is exposed to extreme climatic conditions, which consequently have a negative impact on the farmers' standard of living. Furthermore, these extreme events lead to a decrease in water resources feeding the irrigated perimeters, yet the exploitation of trees upstream of the water sources and in the micro-watersheds continues to increase for commercial purposes. Farmers develop several types of strategies to mitigate the consequences of climate variability.

The adaptation strategies implemented to cope with increased climate variability include the introduction of new cultivars, modification of the agricultural calendar, diversification and rotation of crops, early-maturing varieties, soil management, canal dredging, and development of micro-basins. These strategies have allowed farmers to significantly increase the yield of irrigated agricultural production in the perimeters. However, the adaptation capacity of farmers depends on their socio-economic characteristics. Farmers with low adaptation capacity are those with generally low education levels and aged over 50 years. They have no other activities besides agriculture, and their incomes are primarily derived from the irrigated perimeters. This category of farmers incurs huge losses during natural disasters. Therefore, there is a need to strengthen the adaptation capacity of farmers in the irrigated perimeters by establishing regular programs and training on vulnerability, natural disasters, and climate change. Hence the need for capacity building because the impacts of change on the perimeters are and will be increasingly severe. In fact, scientific work must be developed not only in the 146 communes in Haiti to obtain data that can help stakeholders master climate challenges but also to establish a national research center on climate variability involving researchers in the climatic field. There is a lack of scientific data in this field that is available not only to train and inform the Haitian population but also to conduct scientific research. Moreover, decision-support tools adopting such approaches would be highly useful for assessing the adaptation measures to be considered to improve the adaptation capacity of the most vulnerable living in rural areas of Haiti.

References

1. Abdoul-Kader M. and Dambo L., 2022: Land pressure and new standards of access to land in the urban commune of KONNI: Issues and perspectives, Geographical space and Moroccan Society, 62 pages
2. Abid M., Scheffran J., Schneider U. and Ashfaq M., 2015: Farmers perceptions of and adaptation strategies to climate change and their determinants: the case of Punjab province, Pakistan, EarthSyst. Dynam, pages 225-243
3. DOI: https://doi.org/10.5194/esd-6-225-2015DOI
4. Azar S., 2017: Environmental and social management framework, as part of the RESEPAG II Project, financed by the World Bank, 144 pages
5. Bagula E., Mapatano K., Katcho and Nacigera G., 2013: Efficiency of water management and soil fertility techniques on corn yield in semi-arid regions: case of the Ruzizi plain (South Kivu, Democratic Republic of Congo)
6. Bationon Y., 2009: Climate change and issues of irrigated crops: Case of market gardening, master's thesis, natural resources management option, University of Ouagadougou
7. Beaucejour P., 2016 : Agriculture in Haïti, Port-au-Prince, edition 2016, 17 pages
8. Bernard Seguin B., 2003 : Adaptation of agricultural production systems to climate change, external geophysics, climate and environment (Climate), Agroclim unit, Inra, Agroparc site, domaine Saint-Paul, 84914 Avignon cedex 9, France, 7 pages
9. Bissonnette J-F., Dupras J., Doyon F., Chion C. and Tardif J., 2017: Perceptions of small private forest owner's vulnerability and adaptive capacity to environmental disturbances and climate change: views from a heterogeneous population in southern Quebec, Canada
10. Dameus Al. and Joseph Kendy Jules 2022: Agricultural labor crisis and business opportunities in the Haitian agriculture, a case study of vallée de Jacmel municipality
11. https://doi.org/10.4000/etudescaribeennes.24624
12. Faye C. and Sané T., 2015: Climate change in the casamance watershed: climate evolution and trends, impacts on water resources and adaptation strategies, 22 pages
13. Fishbein M. and Ajzen I., 1975: Belief, attitude, intention, and behavior: an introduction to theory and research. Reading (MA, USA): Addison-wesley pub
14. Flore D., 2021: Putting life back among us, experiences of hunger and peasant organization in the Lower North-West of Haiti", plots, human sciences review.

15. https://doi.org/10.4000/
16. Fréguin S. and Devienne S., 2006: Economic liberalization and marginalization of the peasantry in Haiti: the case of Arcahaie, third world review, pages 621-642
17. Garcia O., 2015: Under adaptation, immunity: study on the discourse of adaptation to climate change, Grenoble Alpes University
18. https://tel.archives-ouvertes.fr/tel-01470390/document
19. Godard O., 2010 : Adaptation aux changements climatiques, cette ambiguë adaptation au changement climatique, dans natures sciences sociétés 2010/3 (Vol.18), pages 287 à 297 Éditions EDP Sciences ISSN 1240-1307
20. Godard O., 2010 : Dossier «adaptation aux changements climatiques», cette ambiguë adaptation au changement climatique. Natures, Sciences, Sociétés, pages 287-297
21. Guivarch C. and Taconet N., 2010: Global inequalities and climate change, in OFCE review 2020/1 (No. 165), pages 35 to 70
22. Hallegatte S., Lecocq F. and Perthuis D., 2010: Economics of adaptation to climate change, Ministry of Ecology, Energy, Sustainable Development and the Sea. 2010, 89 p. ffhal-01189449
23. IPCC, 2001a: Climate Change 2001: The scientific basis, report of IPCC, working group I, IPCC, Geneva, http://www.ipcc.ch.
24. IPCC, 2018: global warming of 1.5°C, special report of the IPCC on the consequences of global warming of 1.5°C compared to pre-industrial levels and associated trajectories of global greenhouse gas emissions, in the context of strengthening of the global parade against climate change, sustainable development and the fight against poverty [Published under the direction of V. Masson-Delmotte, P. Zhai, H. O. Pörtner, D. Roberts, J. Sake, P.R. Shukla, A. Pirani, W. Moufouma-Okia, C. Péan, R. Pidcock, S. Connors, J.B.R. Matthews, Y. Chen, X. Zhou, M.I. Gomis, E. Lonnoy, T. Maycock, M. Tignor and T. Waterfield]. In press.
25. Kabore P., Barbier B., Ouoba P., Kiema A., Some L and Ouedrago A., 2009 : Perceptions du changement climatique, impacts environnementaux et stratégies endogènes d'adaptation par les producteurs du Centre-nord du Burkina Faso », VertigO - la revue électronique en sciences de l'environnement, volume 19 numéro DOI : https://doi.org/10.4000/vertigo.24637
26. Maddison D., 2007: The perception and adaptation to climate change in Africa, policy research working paper wps4308. Washington (DC): The World Bank, Development Research Group, Sustainable Rural and Urban Development Team; www-wds.worldbank.org/servlet/WDS
27. Mahdhi N., Sghaier M., Fouzai A. and Kadri N, 2019: Water and climate change: what adaptation strategies for the management of irrigation water in south-eastern Tunisia, 15 pages
28. Makate C., Rongchang W., Makate M. and Mango N., 2016: Crop diversification and livelihoods ofsmallholder farmers in Zimbabwe: adaptive management for environmental change, springer plus: 1135, DOI: 10.1186/s40064-016-2802-4
29. MARNDR, 2012 : Politique d'irrigation 2012-2016 du MARNDR, 49 pages
30. MDE et PNUD, 2015 : Estimation des coûts des impacts du changement climatique en Haïti, 93 pages
31. Ministère de l'Agriculture des Ressources Naturelles et du Développement Rural, 2013 : Rapport basé sur les résultats du sous-secteur de l'irrigation Juillet 2012 - Juin 2013, 34 pages
32. Ofuoku A., 2011: Rural farmer's perception of climate change in central agricultural zone of deltastate, Nigeria, Indonesian journal of agricultural, 12 pages 63-69
33. Pelling M., 2011: Adaptation to climate change, from resilience to transformation, 274 pages ISBN 0-203-88904-5 Master e-book ISBN
34. Pepin P., 2020 : L'adaptation aux changements climatiques en agriculture : identification des pratiques et des technologies permettant d'augmenter la résilience des productions végétales du Québec, maîtrise en environnement Université de Sherbrooke, 111 pages
35. Pierre-Olivier G., 2015 : Sous l'adaptation, l'immunité : étude sur le discours de l'adaptation au changement climatique, géographie, Université Grenoble Alpes, 2015. Français. FfNNT: 2015GREAH025ff. Fftel-01470390f
36. Renaud J-P, 2011: Irrigation for sustainable agriculture, foundation for policy innovation, foundation for policy innovation, 44 pages
37. Ryan H. and Damassa T., 2018: Tackling poverty and climate change: how reducing short-lived climate pollutants can drive sustainable, pro-poor development, Oxfam Research Briefing Series (2018), 67 pages
38. Saint-Louis D., Michel D., Millien M. and Balthazard-Accou K., 2019: Impact of climate change on the occurrence of emerging and re-emerging vector-borne disease, 40 pages
39. Sanou K., Amadou S., Adjegan S. and Tsatsu K.D., 2018: Perceptions and adaptation strategies of agricultural producers to climate change in the northwest of the savannah region of Togo, 11 pages
40. Sarr, B., Atta S., Ly M., Salack S., Ourback T., S. Subsol and D. George, 2015: Adaptating to climate variability and change in smallholder farming communities : a case study from Burkinafaso , chadand Niger , Journal of agricultural extension and rural development ,1, pp. 418-429

41. Simonet G., 2015: A brief history of adaptation: conceptual evolution throughout the IPCC reports (1990-2014), Natures Sciences Societies pages 52-64
42. Singh B. and Cohen M, 2014: Adaptation to climate change: the case of Haiti, Oxfam research reports, 52 pages
43. Smucker G., 2012: The Haitian farmer and the fight against erosion for 50 years: an assessment. In. Anti-erosion control, rehabilitation of tropical soils and protection against exceptional rainfall, 19 pages
44. Soussana J-F, 2013: Adapting to climate change: agriculture, ecosystems and territories, Quae editions, RD10, 78026 Versailles Cedex
45. Torquebiau, E., 2017 : Climate-smart agriculture: for climate-compatible agriculture, Cahiers-Agricultures, 26 pages : 66001.DOI : 10.1051/cagri/2017048
46. Van Gameren, Weikmans R et Zaccai E., 2014 : L'adaptation au changement climatique, Éditions La Découverte, Paris, 2014
47. Weissenberger S., 2018 : Haïti: vulnérabilité, résilience et changements climatiques, Haïti Perspectives Vol. 6 No. 3 - Pages 19-26
48. Yegbemey R., Yabi J. and Aïhounton A., 2014: Simultaneous modeling of perception and adaptation to climate change: case of corn producers in Northern Benin (West Africa) doi: 10.1684/agr.2014.0697