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Community Adaptation Strategies to Extreme Hydroclimatic Events in the Nakambé Watershed (Burkina Faso)

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ABSTRACT

Rainfall is the most important climatic parameter, especially in Sahelian countries, as it conditions the dynamics of agricultural activities. However, excess or shortage of rainfall can lead to floods or droughts that are detrimental to human activities. The aim of this study is to analyze local communities' strategies for adapting to extreme hydroclimatic events in the Nakambé watershed. The methodology used is a qualitative approach based on surveys of 499 people, individual interviews and focus groups. CSPRO 7.5 software was used for data collection, and data processing was carried out using SPSS software. The results show that to mitigate the adverse effects of flooding, people have developed strategies such as building drainage channels (91% of respondents), while 79% practice ridge ploughing and intercropping (61% of respondents). As far as drought is concerned, the strategies adapted are the reorganization of the agricultural calendar, the construction of bunds, the use of short-cycle varieties, the use of inputs according to 89%, and gas-fired pump irrigation (4% of growers surveyed). According to 48% of growers surveyed, they make use of socio-anthropological aspects such as sacrifices and prayer sessions, as well as traditional meteorologists known as "rainmakers".

Keywords: Extreme hydroclimatic events, Adaptation strategies, Nakambé watershed, Burkina Faso

INTRODUCTION

The effects of climate change will have a much greater impact on rural populations in the South, particularly those in the Sahel, who are more vulnerable and dependent on natural resources (Zoungrana, 2010). Each nation must make this a matter of concern and develop its own strategies (at local and national level) to cope with the changes brought about by climate change (Dimon, 2008). Like other countries in sub-Saharan Africa, Burkina Faso's agro-sylvo-pastoral sector offers the greatest potential for accelerating economic growth and ensuring community food security. Around 80% of the population is engaged in agriculture. The Bagré dam has been set up as a growth pole. The growth pole is a strategic lever for accelerating growth and structurally transforming the national economy for sustainable development. According to the Ministry of Agriculture, Hydraulics and Halieutic Resources (MAHHR, 2004), 40% of Burkina Faso's population is concentrated in the large basin drained by the Nakambé River, which puts considerable pressure on natural resources (Thiombiano, 2010) for agricultural purposes. Agriculture is the main activity of the Burkinabè population, but a number of difficulties are hampering its development: lack of financial resources, poor supervision of producers, low soil potential and degradation of natural resources. These difficulties are compounded by the hazards of climate change. Populations are victims of the effects of climate disruption, leading to extreme hydro-climatic events, the most frequent of which are floods and droughts. Several strategies have therefore been implemented by local

populations to counteract the effects of extreme hydro-climatic events in the Nakambé watershed.

PRESENTATION OF THE STUDY AREA

The study area is the Nakambé watershed at the outlet of the Bagré dam. The Nakambé is one of Burkina Faso's major rivers. Hydraulic structures have been built along the Nakambé, bearing the names of the localities in which they are located (Bagré, Ziga, Loumbila, etc.). According to Ibrahim (2012), the 2001 inventory of water reservoirs in Burkina Faso identified more than 40% of the country's 1,479 structures in the watershed, where a number of agricultural activities are carried out, including market gardening, livestock breeding and rice cultivation. The population is projected to reach 867, 3368 by 2020. Map 1 below shows the location of the Nakambé watershed.

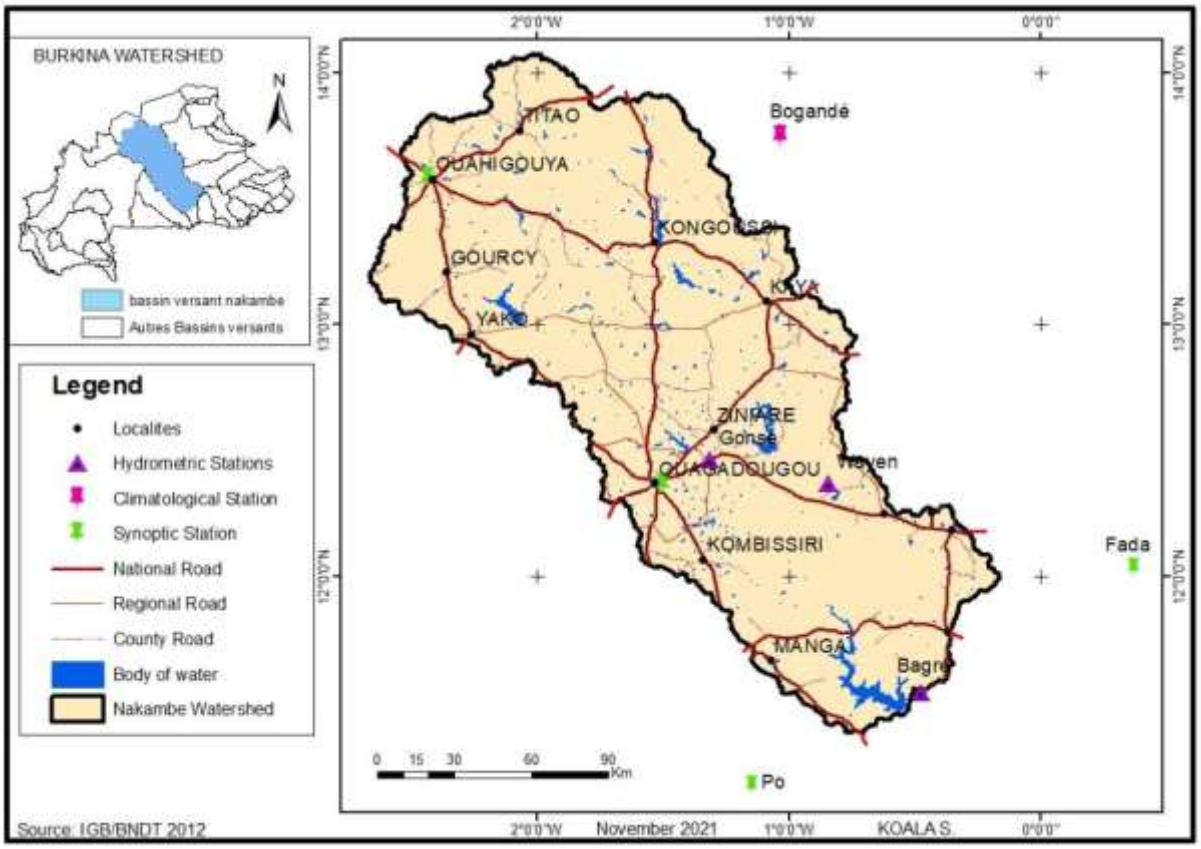

Figure 1: Localization of Nakambé watershed at Bagré outlet

MATERIALS AND METHODS

Sampling is based on the representative character of the various stakeholders concerned with the issues of hydro-climatic extremes and farmers' adaptation strategies in the Nakambé watershed.

In this study, the main variable of interest taken into account to determine the minimum necessary and optimal sample size is the proportion of the population engaged in agriculture (market gardening), livestock farming and fishing. Schwarzt's (1995) formula was used to determine the sample size:

$$n = \frac{\mu_\alpha^2 \times p \times (1-p) \times 1.1 \times e}{d^2}$$

Where:

- n is the minimum required sample size

- μ_α is a parameter/factor related to the confidence level;
- p is the proportion of the population engaged in agriculture, animal husbandry and fishing.
- d is the desired precision or margin of error;
- e is the parameter used to measure the cluster effect;
- is the correction factor to increase the sample size by 10% in order to take into account possible cases (rates) of non-response.

In calculating the minimum sample size:

- the confidence level used is 95% (in this case, $\mu_\alpha = 1.96$);
- Proportion of the population engaged in farming, livestock breeding and fishing "p" is 82%, according to the Ministry of Agriculture. Thus; 1 - p = 0.18;
- the margin "d" is 5%;
- the cluster effect (e) has been estimated at 2.

Applying this formula, we find a number of 499 households concerned by the collection of quantitative data. Villages were selected on the basis of their proximity to dams in the Nakambé watershed.

The CSPRO 7.5 software, downloaded from the CSEntry application, was used to collect data from the field surveys, which were then processed using SPSS and EXCEL spreadsheets.

RESULTS

The results showed producers' adaptation strategies to extreme hydroclimatic events (floods and droughts).

Farmers' Adaptation Strategies to Floods

To reduce their vulnerability to excess water during floods, farmers in the Nakambé watershed in Bagré adopt several strategies.

Building flood drainage channels

Water drainage systems are generally built into the fields. Collecting systems built along contour lines are more likely to avoid soil erosion and result in an even distribution of collected water over the cultivated area. These systems involve sloping drains to bring water onto a cultivated field to compensate for water deficit. When the field is flooded, they are also used to evacuate water as far as possible, to ensure good crop yields. This type of layout relies on the availability of surface water and slope systems to facilitate water drainage. In fact, this agricultural drainage system consists of evacuating water from plots when it is in excess. t is practised in soils that are mostly waterlogged due to a temporary perched water table. According to 91% of those surveyed, during periods of excess rainfall, land drainage reduces surface runoff and correspondingly increases rainwater infiltration. However, these drains sometimes serve as a passageway for water from the river to the fields during periods of flooding. This helps prevent water stress on crops, thereby improving yields. According to 87% of respondents, this system is not well developed in Bagré's Nakambé watershed. What's more, the market-gardeners affected by the disaster have limited means, so they make only rudimentary arrangements. The use of archaic tools makes this technique difficult. In the event of major flooding, these tools become ineffective for digging large gullies to evacuate the water. According to field studies, this system is recommended for good agricultural yields in Burkina Faso.

Adapted practices (mulch, rice cultivation)

Adapted practices are farming practices that protect plots from flooding or retain water in dry periods (earth bunds), or protect crops from drought and sun (zaï or mulch). These practices, sometimes referred to as "endogenous strategies for adapting to hydro-climatic

extremes", were observed among farmers supervised and trained as part of development projects or by agents of NGOs or structures involved in agricultural production and strategies for adapting to climate change. In the Nakambé watershed at Bagré, these practices have proved totally inadequate in the face of certain unforeseen hazards (for example, earthen bunds are not effective in protecting against flooding). In fact, rice growing is one of the activities moderately linked to hydro-climatic extremes. It is mainly developed in the form of flooded rice-growing in the watershed to meet the country's internal consumption needs; it is set up on unexploited land because it can be flooded, with the support of national or international agricultural projects.

According to 88% of those surveyed the rice plants are on soil that is well suited to flooding. Although this is not a specific response to hydro-climatic risks, rice growing is nonetheless becoming an adaptation strategy as the scale of flooding increases sharply in some regions. According to 84% of those surveyed, land that can no longer be used for the traditional crops of maize, millet and sorghum is being developed through rice cultivation. Despite this, rice cultivation has sometimes been developed on land that is now much more affected by flooding. The flooding phenomena favor the development of these crops and constitute an adaptation measure for farming activities in the Nakambé watershed at Bagré.

Ridge ploughing

Ridge ploughing is a technique that consists in cutting out a portion of land and turning it over on its pivot using a hoe. In fact, growers develop strategies by creating a cordon of sand at the ends of the ridges to encourage infiltration of water before it runs off, so that crops can benefit from the little water they receive from rainfall. When runoff is very strong (after heavy rains), the sand cordon breaks. This strategy prevents flooding in the fields. Photo 1 shows ridge ploughing in the village of Ouonon in Toécé.

Photo 1: Field ridge in the village of Ouonon in Toécé
Shot: Koala, December 2020

Photo 1 shows the ridge ploughing of a field in the Nakambé watershed at Bagré. Ridges are made at a certain height, depending on the crop (87% of respondents). For example, for maize, millet and sorghum, ridges are 15 to 20 cm thick, while groundnut ridges are at least 25 cm thick. This technique is used by at least 79% of the growers surveyed. The latter sometimes plough the ridges perpendicular to the slope, to allow water to settle between them. Ridges are

often used because of their ability to retain soil moisture for longer (up to two months), until the plants germinate, according to fieldwork.

Abandoning submersible fields

The abandonment of submersible fields is adopted by 62% of the populations surveyed, especially those located in areas that flood very often. For farmers, this strategy enables them to bypass flooding and avoid crop losses caused by hydro-climatic extremes. According to field studies, the abandonment of submersible plots consists in abandoning highly submersible fields in favor of those that are consequently less submersible.

The abandonment of submersible fields is very restrictive and can only be implemented by farmers with extensive arable land. What's more, it does not solve the problem of water shortage for crops, and contributes to the destruction of biodiversity. According to 82% of the people surveyed, this strategy is used to reduce the effects of flooding in the Nakambé watershed in Bagré.

Early crop harvesting

According to 74% of growers interviewed, early crop harvesting is a widely used practice in the Nakambé watershed at Bagré. Thus, when crops have already reached maturity before flooding occurs, growers press ahead with harvesting. In this case, they manage to recover part of their production. A few cobs of maize, millet and sorghum that fall into the water are collected and used to feed animals. Crops that are lucky enough to complete their vegetative cycle before the floods arrive are stored in granaries. Those that are still fresh, in the absence of conservation techniques, are sold immediately after harvest. This practice enables farmers to avoid the rotting of produce, and to meet their special needs. For 73% of respondents, this strategy reduces the impact of flooding on agricultural production in the research area.

Intercropping

Intercropping is the practice of growing two crops side by side. It offers protection to one or both vegetable crops against the effects of hydro-climatic extremes and pests. This practice involves growing several different species simultaneously on the same plot. Crop cycles are either parallel or overlapping. Complementarity of species is sought to make the system more resilient to bio-aggressors. According to 61% of those surveyed, intercropping helps market gardeners to make efficient use of small plots and increase their total yield or the value of their produce, particularly during periods of flooding. This involves growing lettuce next to tomatoes, or lettuce next to peppers on the same bed. This technique requires a great deal of calculation. The most resistant plants must be allowed to grow for a few days before sowing the most sensitive ones and watching over their growth. This technique consists of alternating different crops in rows or beds, so that they complement each other. Several factors are taken into account when setting up a market garden crop association. These include

- the length of the vegetable growing cycle between sowing and harvesting;
- vegetable rooting depth;
- the plant's need for fertilization;

Market gardeners combine crops so as not to lose all their harvests in the event of flooding. Photo 2 shows a plot where a market gardener has combined three crops: chilli, eggplant and maize in the village of Tangaye.

Photo 2: Combination of chilli, eggplant and maize in Tangaye village in Bam
Shot: Koala, September 2020

Photo 2 shows the association of chillies, eggplants and maize for adaptation purposes in the Nakambé watershed at Bagré. According to 93% of respondents, the association is also made between crops such as: aubergine-carrot; cabbage-chilli; lettuce-carrot; cucumber-tomato; onion-carrot, etc.

Cultivation favours the balance of environmental resources when the species used in association have complementary characteristics (root system, vegetative development, length of cycles). In association, plants exchange various services (fertilization, repellent or toxic action on specific insects or weeds, etc.). The most easily observed is the repellent effect a plant (its emanations) can have on a pest. When several species are grown in association, they necessarily compete for access to water, light and nutrients. Technical choices limit this competition and develop the complementarity of the species used in association.

Producers' Drought Adaptation Strategies

The high degree of crop exposure in the Nakambé watershed at Bagré has compromised the future of rain-fed agriculture in recent years. Severe droughts are forcing the adoption of water management strategies aimed at improving agricultural productivity and enhancing the value of irrigated agriculture. People (farmers, market gardeners, fishermen and herders) develop a variety of strategies to find water for crops, animals, etc. during phases or droughts. Adaptive technologies developed by these populations include the construction of water reservoirs. In the research sector, it requires the implementation of facilities (reservoirs, irrigation) for regular water supply, water being one of the key determinants of this mode of agricultural, market gardening and animal production.

Reorganizing the agricultural calendar

Farmers in the Nakambé watershed at Bagré, like other rural communities in Burkina Faso, have developed pragmatic knowledge of the succession of local seasons. Despite the non-existence of a coherent and efficient system for disseminating agrometeorological information produced by the relevant national services, farmers have been able to establish their work calendars each year (field preparation, sowing/re-sowing, ploughing, harvesting, etc.) according to the type of crop they choose. Indeed, recurrent droughts since the 1970s and the spatio-temporal variability of rainfall have made it difficult to use the traditional agricultural calendar. Having acquired the knowledge that the rainy season really begins in the period from

June to September, the growers in their entirety abandoned the empirical agricultural calendar, which proved non-operational in the face of hydro-climatic risks, in favor of a new cultivation calendar. As a result, the agricultural calendar was reorganized from 2010 onwards, due to the late and irregular rains.

The staggered sowing technique involves sowing two fields at different times. According to 87% of those surveyed, the chances of harvesting remain intact in the event of a false start to the rainy season or a break in rainfall during the pre-wet or wet period. Repeated sowing or multiple sowing consists in sowing the same land after each rain or rain sequence indicating a normal recovery following a false start. The aim is to prevent the water deficit from affecting all seed generations. According to 88% of growers, this gives the grower the chance of an acceptable yield at the end of the season, if not the best. Clearly, the reduction in area per household in a continuing family farming system does not guarantee the survival of the staggered sowing technique; in the same context, current seed subsidies are unsustainable in the long term. However, this technique will remain important for adaptability as long as climate information systems remain deficient in alerting farmers in good time.

Construction of bunds

Dykes are strategies for conserving water in fields. They are small compacted earth structures used to form basins in which market garden produce and other products are grown (Photos 3 and 4).

Photo 3: Earthen cages in the village of Rikiba in the Nakambé watershed
Shot: Koala, December 2020

Photo 4: Earthen cages in the village of Rikiba in the Nakambé watershed
Shot: Koala, December 2020

Photo 3 shows an earthen bund used to irrigate a banana field, while Photo 4 illustrates an earthen bund in use to irrigate an onion field in the Nakambé watershed, ensuring good crop yields. Earthen bunds help channel and distribute irrigated water in the absence of rain. Depending on their size and type, they also serve to collect runoff water, according to 91% of respondents. Built so that the base of one is level with the top of the other, dikes are the most widespread traditional method of lowland development. But they remain highly vulnerable and require regular maintenance.

Abandonment of long-cycle varieties and use of short-cycle varieties

In order to respond to the current climatic context and meet demand, growers have adopted new crop varieties. As a result, some crop varieties that are essentially long-cycle are being abandoned. Short-cycle varieties such as maize and millet (75 days and 65 days, respectively) have the advantage of reaching the end of their development cycle before the onset of climatic phenomena. The shortening of the plant cycle has been the determining factor in the acceptance of new varieties, according to fieldwork. According to Ministry of Agriculture officials, apart from maize, millet and 75-day sorghum, which are currently being tested, a large proportion of farmers (88%) have adopted 90-day maize to replace local maize, which has a 120-day cycle. The same applies to local millet and sorghum, which are increasingly being replaced by millet and improved sorghum in the Nakambé watershed. According to 79% of those interviewed, the abandonment of long-cycle varieties is due to the deterioration in rainfall over the last two decades. Indeed, these long-cycle varieties require water and good rainfall distribution. These varieties have been replaced by short-cycle, high-yielding varieties, such as the "cherry" tomato variety replaced by the "rama" tomato. The compatibility between the water and temperature requirements of these new crop varieties and the new ecological conditions resulting from climate dynamics are the reasons behind their adoption, according to growers.

Use of inputs

In the Nakambé watershed, 94% of farmers surveyed confirmed that it is difficult to achieve good yields without using fertilizers or pesticides. Hydro-climatic events have an additive effect on the problems of declining fertility faced by farmers. In order to fertilize the soil to facilitate plant growth and ensure an acceptable harvest before the rains stop, 88% of

growers surveyed use urea and organic fertilizers. The proliferation of weeds and heavy attacks on plants by pests have led to heavy use of pesticides (Photo 5).

Photo 5: Types of pesticides used in the Nakambé watershed
Shot: Koala, September 2021

Photo 5 shows a pesticide used in the Nakambé watershed. According to 89% of respondents, these products are used to achieve good crop yields. The types of products used depend on the grower's financial capacity. However, the use of inputs is justified in farming circles (60% of farmers questioned) by the concern to limit the drop in yield following climatic hazards.

Hydro-agricultural development for pump irrigation

Hydro-agricultural management for pump irrigation consists in organizing space to bring water from an underground source or borehole to a field that lacks it. When the water source is relatively far from the field, the motor-driven pump is used to bring water to the crops. This is done for crops where there is a water shortage. The pumped water can be discharged directly onto the plot, where the soil has hardened to facilitate ploughing. When the field is flooded, pumping is also used to evacuate the water (Photos 6 and 7).

Photos 6 and 7 show pump irrigation systems in the Nakambé watershed in Bagré, using a gas-powered motor pump. This strategy is used by 4% of growers surveyed. According to 67% of growers surveyed, the measures developed by growers to cope with low water availability are a function of their means (technical and financial). Thus, pump irrigation systems are much better suited to land with poor surface water resources and a shallow water table.

According to 67% of those surveyed, this strategy makes it possible to manage the risks of drought and repeated dry spells during the rainy season. Pumped irrigation allows partial or total control of water for agricultural purposes. These irrigation systems therefore represent an excellent strategy for reducing vulnerability and adapting agriculture to hydro-climatic extremes in the Nakambé watershed at Bagré.

Photo 6: Pump irrigation system at Toécé in the Nakambé watershed
Shot: Koala, December 2020

Photo 7: Pumped irrigation system at Dourou in the Nakambé watershed
Shot: Koala, December 2020

Socio-anthropological aspects

Extreme hydro-climatic events such as floods and drought are phenomena that have a negative impact on the population, according to fieldwork. The various farming communities in the Nakambé watershed at Bagré organize religious ceremonies (sacrifices, prayer sessions) to ask the favor of the "gods" or "God", depending on their conceptions. According to 48% of those surveyed, these widespread practices concern both followers of traditional religions and practitioners of non-native monotheistic religions (Muslims and Christians). What's more,

when faced with certain difficult climatic situations, such as a delayed rainy season or a false start, 43% of the farmers surveyed turn to the traditional meteorologist (rainmaker), a person reputed to have paranormal abilities enabling him/her to provoke rain; he/she could also stop the rain in the event of excess, even if in the opinion of the respondents the probability of success is lower. According to fieldwork, 60% of respondents believe that it is easier to cause rain than to stop it. Nevertheless, 38% of those surveyed considered this practice to be credible and effective. According to these people, provoked rain always has a localized influence (on the scale of the terroir, farm) and meets the objectives pursued by the applicants. In fact, magico-religious beliefs and practices relating to the climate may well constitute a psychological barrier that is almost impervious to the spread of a new perception of the challenges of hydro-climatic events within farming communities in the Nakambé watershed in Bagré.

DISCUSSION

This research also enabled us to analyze people's adaptation strategies in the face of extreme hydro-climatic events in the Nakambé watershed in Bagré, such as: early crop harvesting, practices, use of inputs, abandonment of submersible plots, adoption of new crop varieties, ridge ploughing, crop association and rearrangement of the agricultural calendar to counteract the water deficits and excesses encountered by their crops. The results obtained seem to correspond well with those of Ibrahim, (2012) and Ouédraogo (2012) respectively in the Nakambé and Yakouta watersheds in Burkina Faso.

Ouoba (2013), in his research on climate change, vegetation dynamics and farmer perception in the Burkinabe Sahel showed that the adaptation strategies developed by farmers to reduce the effects of climate change are early crop harvesting, the use of inputs, the abandonment of long-cycle varieties and the use of short-cycle varieties, ridge cropping, crop association and the installation of irrigation systems to counteract the water deficits and excesses encountered by their crops. This confirms the research work of Thiombiano (2010) and Yanogo (2012), obtained respectively in Nakanbé and around Lake Bagré (Burkina Faso). According to Deguenon (2021), short-cycle seeds are adapted to hot, humid conditions, with good tolerance to bacterial wilt. The use of drains to evacuate floodwater is also noted. This result is similar to that of Pereira (2012), who identifies the modification of sowing dates and the improvement of water use efficiency as strategies to be promoted in the municipality of São Domingos-Cap Vert. He follows the same logic as Chédé (2012), who identifies the use of early and drought-resistant varieties, the development of new cropping techniques, agroforestry, the development of irrigation techniques and assisted natural regeneration as measures to be prioritized in the municipality of Savè.

These results also confirm those obtained by Zongo (2016), who focused on innovative strategies for adapting to climate variability and change in the Sahel. The latter showed that the yields of producers who cultivate in hydroagricultural schemes are significantly higher than those who resort to summary schemes.

According to Saré (2018), to make better use of water, most growers have replaced the traditional irrigation system with the drip system. According to all those who have adopted this technology, productivity is vastly superior, both in quantity and quality compared with the traditional system. This corroborates the findings of an FAO study (2008), which underlines that the drip irrigation system is twice as profitable as traditional irrigated gardens, and that labor yields are around three times higher than for the traditional system. This is why the gravity-fed irrigation system is proposed in this work for flood plots.

Research by Ogouwalé (2006) has shown that developing countries need to prepare for and anticipate climate risks in order to reduce their vulnerability. In Benin in general, to develop production systems adapted to climate change, it is envisaged to update the agricultural

calendar by production zone, intensify extension and research into improved crop varieties, develop and disseminate technical itineraries adapted to the new climatic risks, and facilitate access to suitable agricultural inputs (Second National Communication of Benin, 2011). In the same vein, Newborne and Gansaonré (2017) have shown that in the face of climatic hazards, peasant communities in Burkina Faso develop strategies that take the form of ritual ceremonies to tutelary deities and ancestors, or animal sacrifices in honor of fetishes in order to implore their clemency.

Seydou (2016) has shown that during drought, surface water points dry up and water availability for market gardening becomes problematic for growers. Thus, during the dry period, market gardeners are cruelly short of water for their activity. They then turn to groundwater resources to provide water for their crops. Wells and boreholes are the underground water sources used by market gardeners to bring water to their crops. These market gardening wells are built by stakeholders or projects.

CONCLUSION

This work, carried out in the Nakambé watershed in Burkina Faso, shows that the adverse effects of extreme hydro-climatic events do not spare Burkina Faso. The country is facing changes in rainfall patterns (shorter rainy seasons and poorly distributed rainfall). The most frequent climate extremes are floods and droughts. The country is all the more vulnerable as it is located in a Sahelian zone. The sectors most affected by climate change are agriculture, livestock breeding and fishing, which employ around 80% of the country's population. To cope with these difficulties and increase their yields, populations have adopted several endogenous and modern adaptation strategies. The use of these strategies depends largely on the producer's financial situation, as they can be costly. These coping strategies can be summed up as the construction of drainage channels, ridge ploughing, the abandonment of submersible fields, early crop harvesting and intercropping to cope with flooding. In the case of drought, reorganizing the agricultural calendar, building bunds, abandoning long-cycle varieties in favor of short-cycle varieties, using inputs and pump irrigation are just some of the adapted strategies. Some growers resort to socio-anthropological aspects such as religious ceremonies to ask the 'gods' for favor. Others call on traditional meteorologists, also known as "rainmakers".

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