CLIMATE RISKS OF IRRIGATION DEVELOPMENTS IN THE NARIARLE SUB-WATERSHED IN KOUBRI, NANKANBÉ BASIN, BURKINA FASO

Abstract :

Irrigation schemes in the Nariarlésub-watershed, Nankanbé basin in Burkina Faso are exposed to climaticrisks. These risks are accentuated by the combination of several natural, biophysical and anthropogenic factors. The objective of this study is to assess the climate risks of developments in Burkina Faso. The absence of a previous study assessing the risks of the basin highlights the originality of this article. Documentary research and the processing of satellite images served as methodology. This methodology is supported by field surveys with 155 farmers. The climatic analysis shows an evolution of minimum and maximum temperatures and a persistence of deficit years. Climate risk assessment provides decision support tools, guidance, effective adaptation practices and techniques.

Keywords : Burkina Faso, climate risks, Nariarlé

1. Introduction

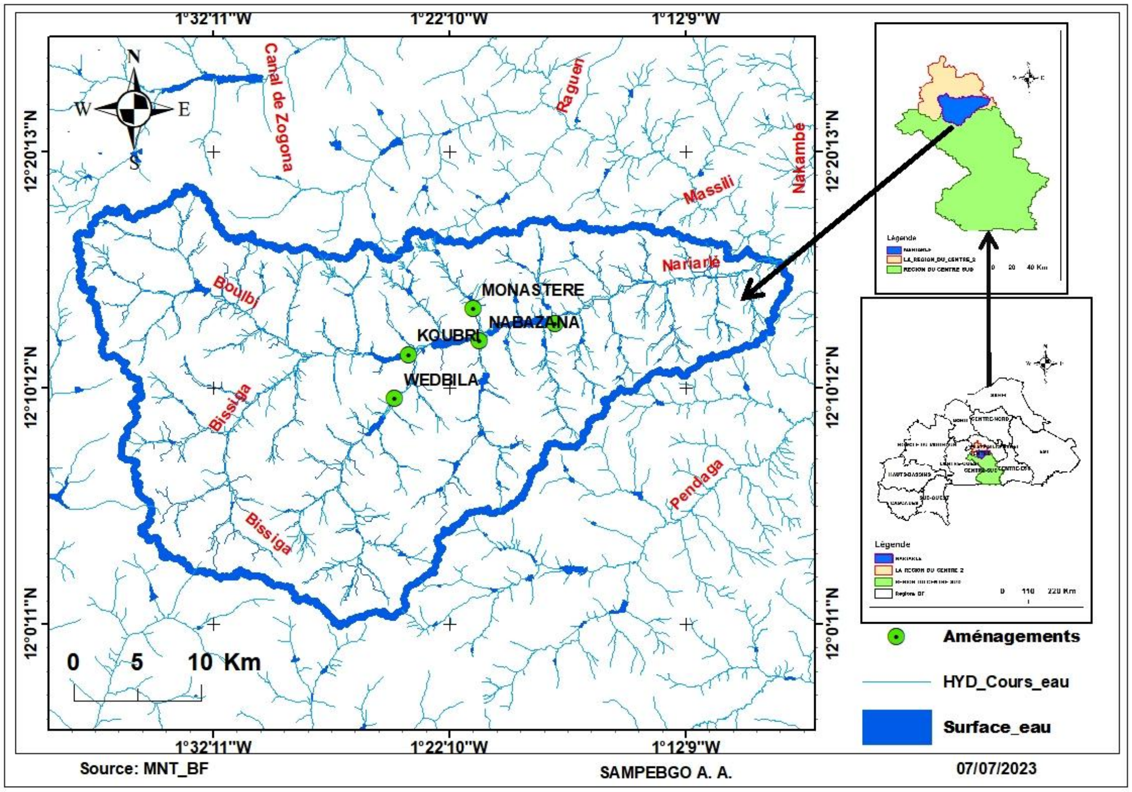
Climate change is a universal phenomenon, no country is spared, from the richest to the poorest. Its consequences are multiple and affect all areas of human and state life [1, p. 03], [2, p. 11] . From the melting of glaciers and ice in Greenland, to climate disorganization, including increased warming of the oceans, prolonged droughts, associated with forest fires of unprecedented scale as in the case of Australia (2019, 2 020), Siberia, 2019, 2023). In the opinion of several authors, climate change constitutes the greatest fundamental challenge of the 21stcentury [3, p. 10], [4, p. 03], [5, p. 10] . The year 2019 ended with an average global temperature 1.1°C higher than the pre-industrial averages of 0.1°C from 1850-1900 [6, p. 05] . More ambitious efforts must be made in the area of climate change mitigation to keep temperature rises to less than 2°C by the end of the century [7, p. 05], [8, p. 02], [9, p. 01] . The fight against climate change and its effects is everyone's business according to UN Secretary General Guterres A. [10, p. 06] . Margined, the ratifications of the various international conventions and protocols to combat climate change [11, p. 12], [12, p. 12], [13, p. 03], [14, p. 02], [15, p. 07], [16, p. 03] , multiple national sustainable development strategies implemented [17, p. 10], [18, p. 15], [19, p. 10], [20, p. 10] , Burkina Faso, like many African countries, remains extremely exposed to the risks linked to climate change [10, p. 04], [17, p. 36], [21, p. 41] . Studying the risks linked to climate change from irrigation developments is an opportunity for Africa to assess the risks linked to climate change from irrigation developments and to develop effective adaptation strategies in this area. Irrigation schemes are one of the alternatives to deal with climate change and food insecurity.

2. Material and methods

2.1. Presentation of the study area

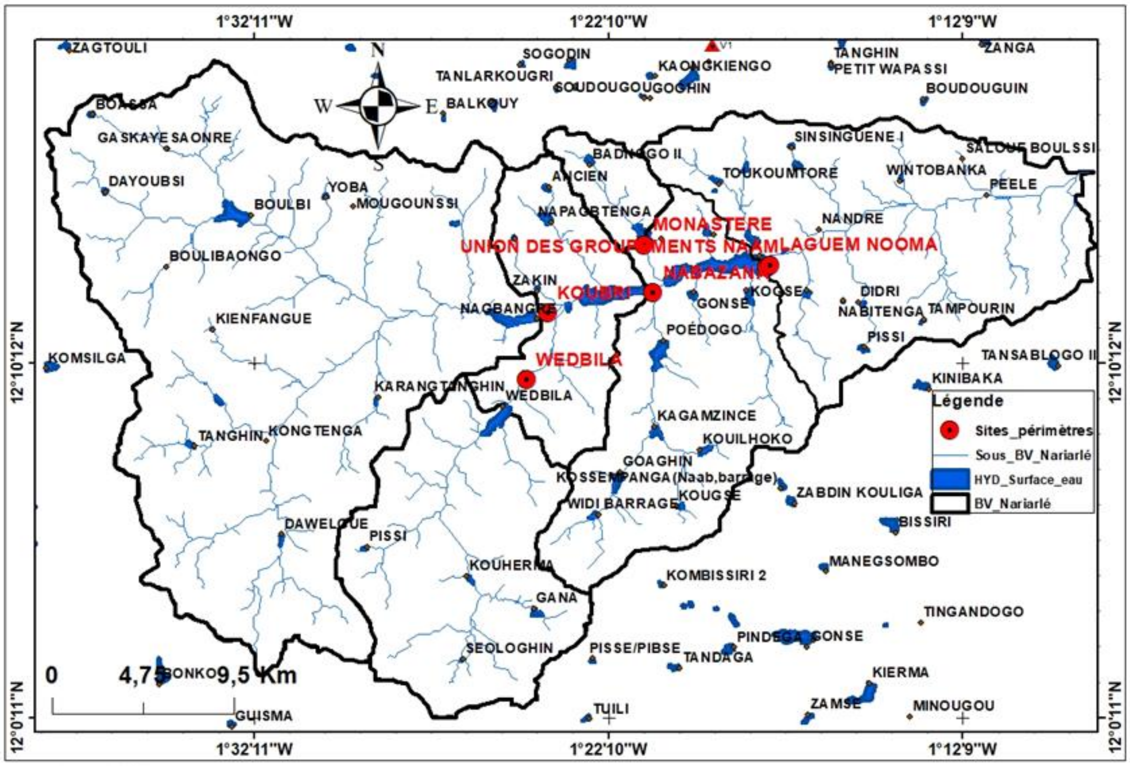
The Nariarlé watershed is located between latitude 12°12'54.03" north and 1°19'46.57" west of Burkina Faso (map1). It is defined as a global and coherent geographical entity for water resource management [22, p. 06] . The Nariarlé watershed is a sub-basin of the Nakanbé (one of the national basins of Burkina Faso). It covers seven (07) municipalities [23, p. 18] : four from the central region (Koubri, Saaba, Komsilga and Ouagadougou) and three from the south-central region, Bazèga province (Saponi , Kombissiri and Boulgou) **.**

Map 1: location of the Nariarlé sub-watershed



The irrigated areas are organized around the four sub-basins which are the areas of Wédbila, Koubri, Monastère and Nabazana (map 2).

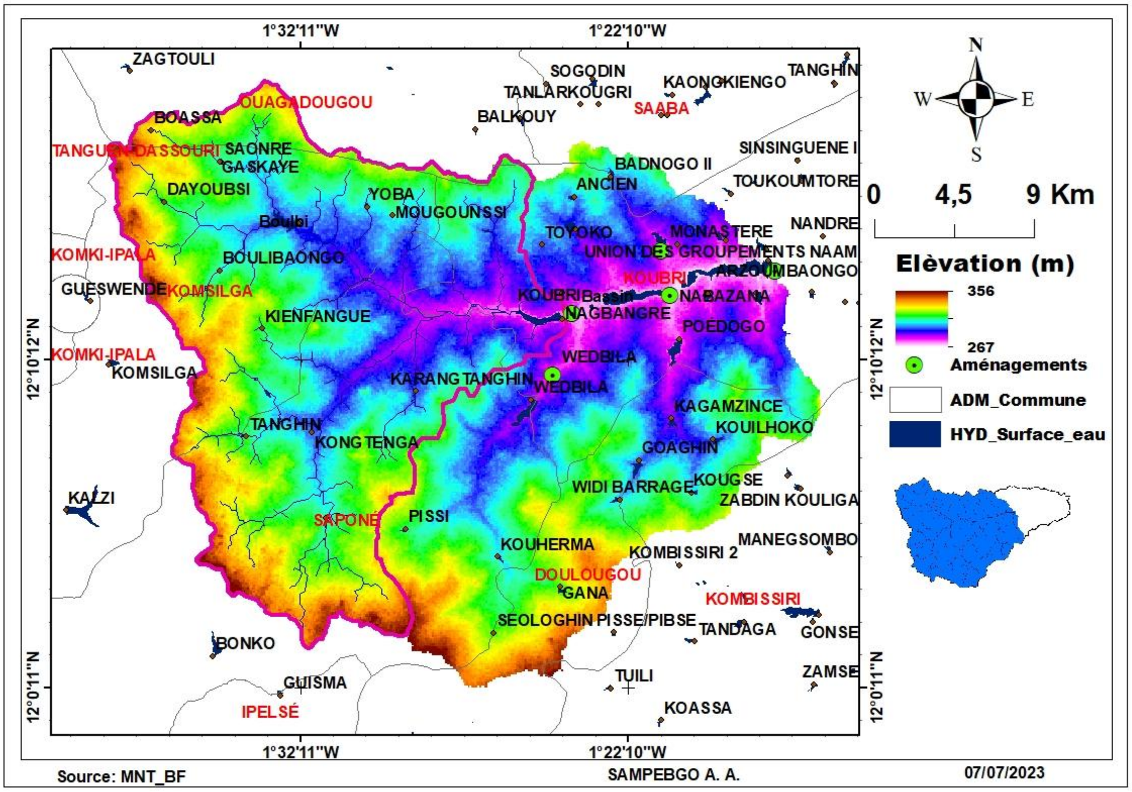
Map 2: irrigation schemes in the Nariarlé watershed



Source: MNT SAMPEBGO A. 13/02/2023

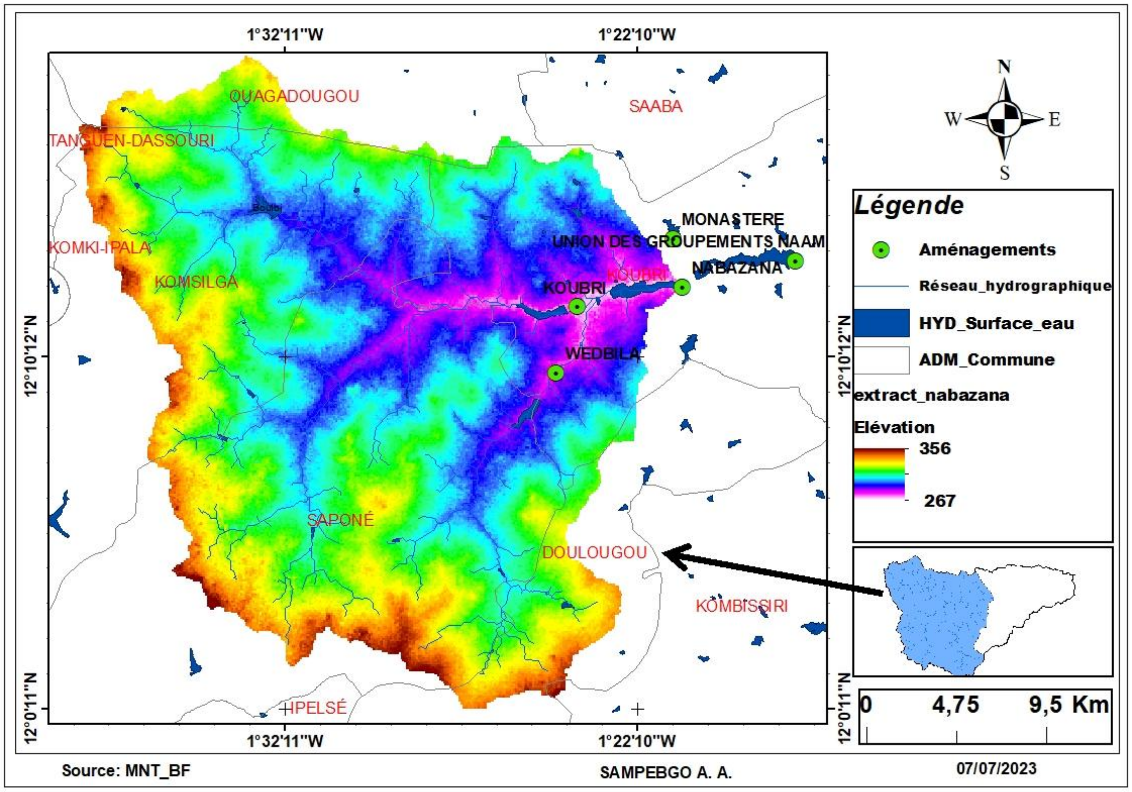
Boussouma irrigation schemesarelocated at 1°17'40.2'' East, 12°12'55.2'' North, 170 km from Ouagadougou. The Boussouma watershed (map 3) covers an area of 3.3 km^2 with an average slope of 0.01 according to technical studies. The hydrological balance deduced by analogy with the results of ORSTOM (1998, p. 50) indicated a maximum specific flow of 11.40 $m^3/s/km^2$, i.e. a maximum flood of 38m^3/s (Q= 3.3* 11.40) [25, p. 26] .

Map 3: Boussouma irrigation schemes



Nabazana irrigation schemeislocated at altitude 12°12'10.8'' north and longitude 1°20'52.2'' east. It has for an altitude between 270 m and 356 m developed and put intooperationin 1974, the basin (map 4) records 20 ha of developed area and a dam with a capacity of 380,000 m 3 of water.

Map4Nabazana irrigation schemes

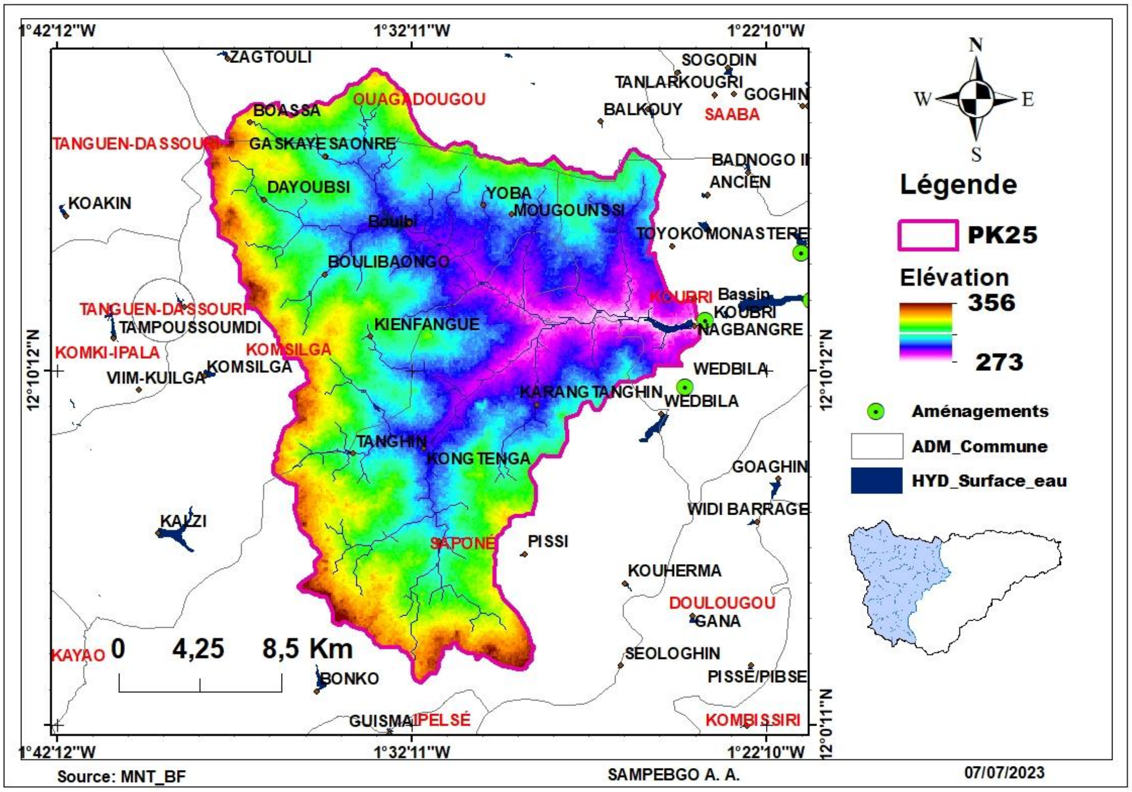


The developments of Koubri II . Financed by the Canadian fund (85,300,000 CFA), the Koubri II developments are located 674320.871 East and 1348480.929 North. Its altitude is between 273 m and 356 m (map 5). It is located in the village of Tanvi in the commune of Koubri, approximately 30km from Ouaga. Made in 1976 [26, p. 03] , rehabilitated in 1986, the Koubri dam is characterized by:

- A water retention dike three meters (3m) high and 360 m long
- A homogeneous dam (capacity 1960000m ^{3,} flow 2300000 m ^{3} /s,)
- A central spillway
- Two intake structures (upstream valve, right bank; downstream valve, left bank)

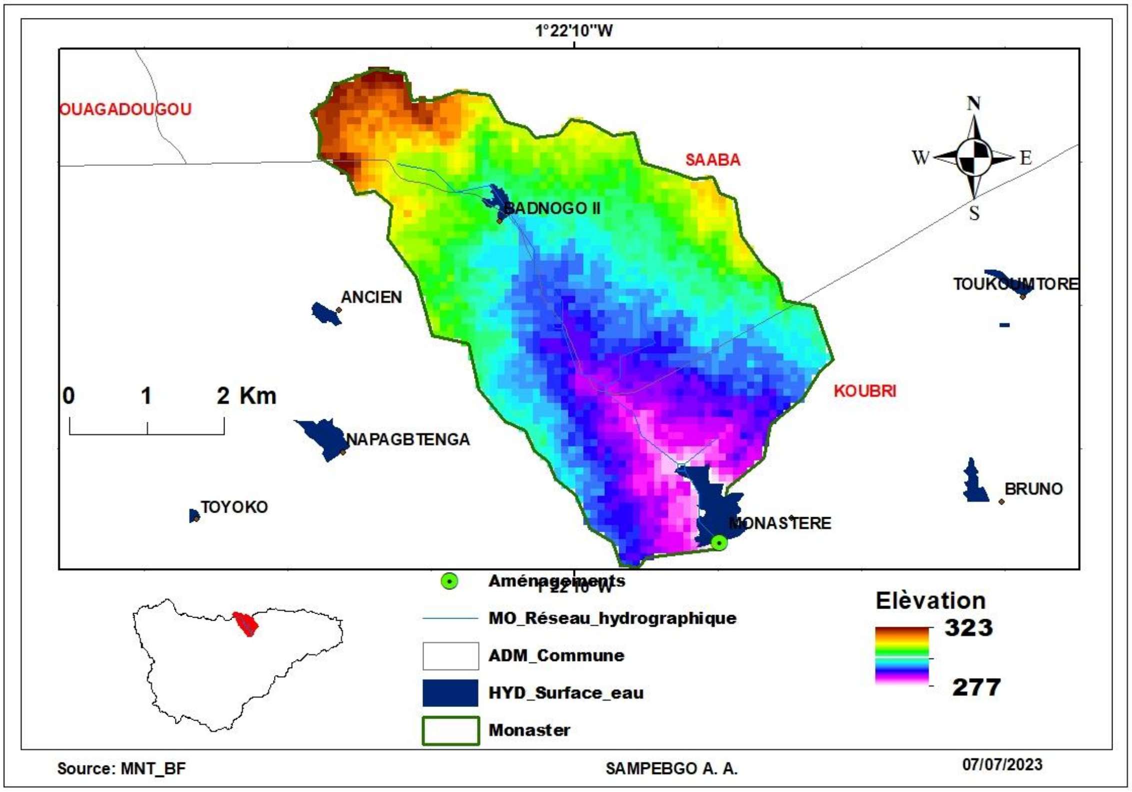
Volume of water stored 670,000 m ^{3} (water availability April-May).

Map 5: The irrigation facilities of Koubri II



The Monastery's developments (map 6) are organized over a 15ha irrigated area of gravity type. Water is taken by valve or by pumping, developed and made available to producers in 1989. Its geographical coordinates are 12°13'33.2" North latitude and 1°21'08.9" East longitude. Sold in 2018, the level of degradation of the dam remains average. It is located from 277m to 323m above sea level.

Map 6: The arrangements of the Monastery

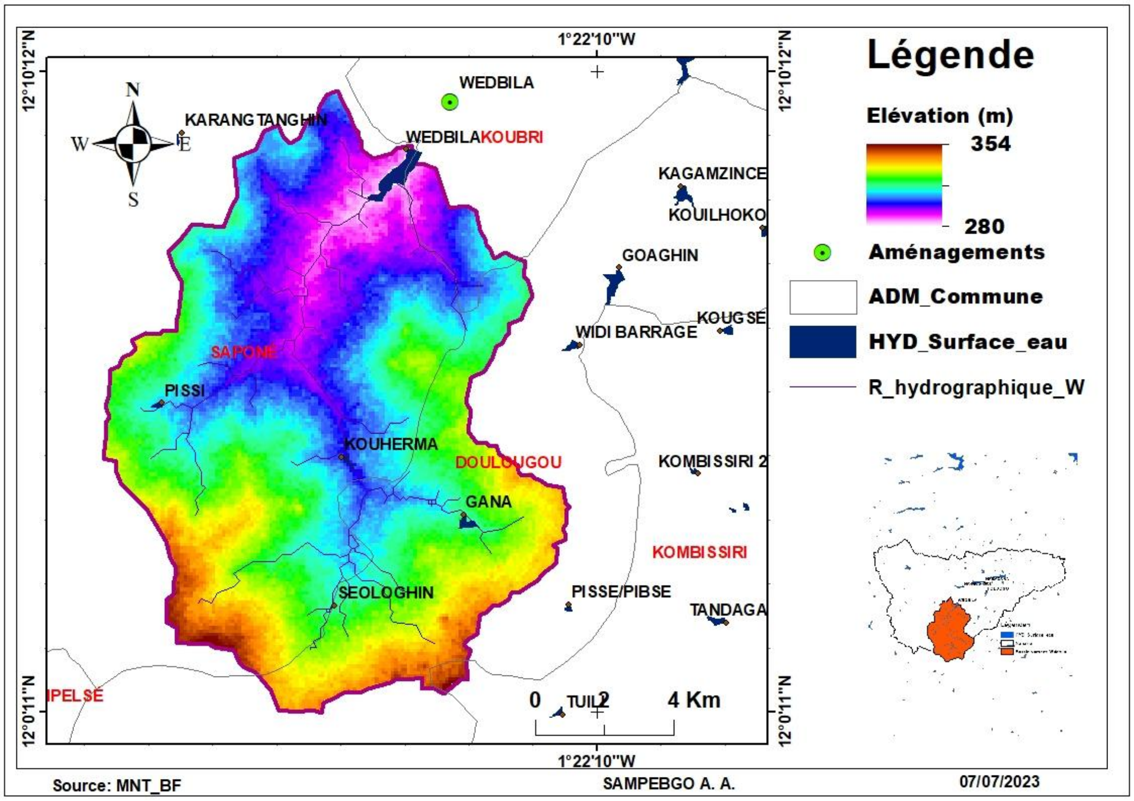


The Wèdbila dam was built in 1979 by the Oumarou KANAZOE company with financial assistance from the Federation of Evangelical Churches and Missions (FEME). Located southwest of the village Wèdbila (673262.07E, 1345008.523N) in the commune of Koubri, approximately 40 km from Ouaga, it was renovated at an estimated cost of 158,000,000 FCFA with an estimated ten-year flood at the dam spillway. 65 m3/s. its flow rate is estimated at 2,480,000 m^3/s. The Wèdbila dam is located between 280 m and 354 m above sea level. The existing arrangements are:

- 45 ha of landscaped area
- The primary canal, trapezoidal (long 2054 m, flow rate 225 l /s, Manning formula with Strickler coefficient equal to 60).
- 9 rectangular secondary channels 20 cm high (concrete blocks placed on a concrete slab 5 cm thick with a ceiling width of 30 cm.),
- Tertiary canals 1915 m long (1760 m earthen and 155 m lined)
- Four types of colatures contribute to perimeter drainage
- The belt collar has a total length of 1,2544 m, flow rate 8 m3/s
- The secondary colatures (except C5) collect water from the tertiary colatures, and sometimes water from 1 the belt colature (case of C3, C5, C7, C9, CIO, C11). This water is discharged into the central backwater, or directly outside the perimeter, by a control valve system.
- Main colature (former backwater, evacuates around 400 l/s via a pipe fitted with a cofferdam).
- Four protective dikes (eroded by rain).

The basin (map 7) records the following data: an area of 148.6 km^2, 58.95 km in perimeter, maximum altitudes vary between 354 m and 280 m and 74 tributaries.

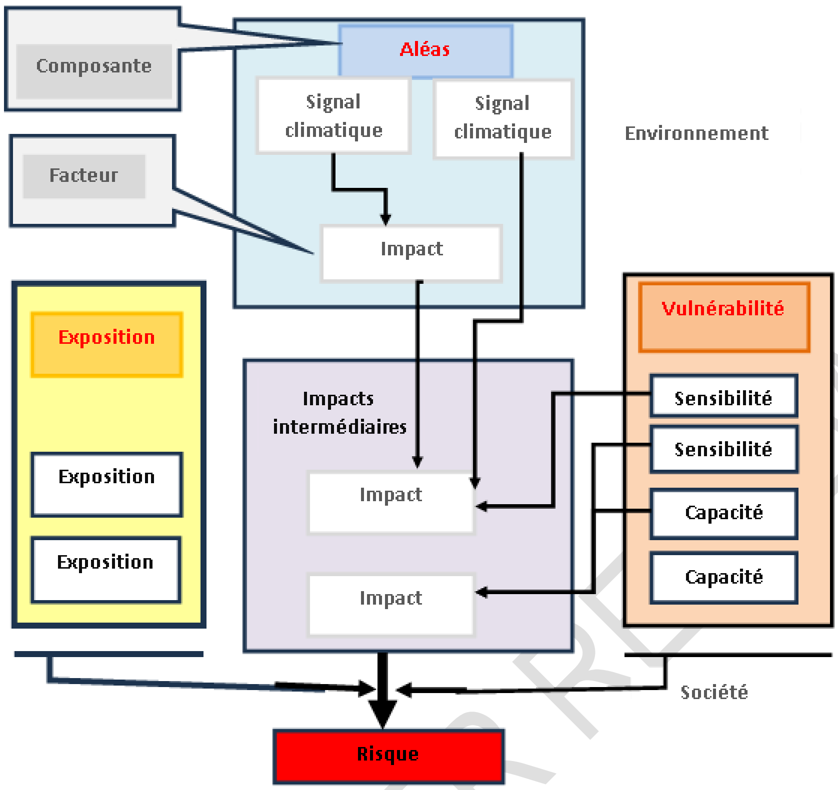
Map 7: Wédbila developments



2.2. Methodology

To assess the risks linked to climate change from irrigation schemes in the Nariarlé watershed, the structure of an impact chain (effects, consequences) developed according to the approach of assessment report 5 (AR5) was used.) of the IPCC. It makes it possible to analyze, systematize, better understand and prioritize the factors responsible for risks and its components (figure 1).These techniques are based on empirical observations, statistical approaches, descriptive models and the well-founded knowledge of stakeholders on climate risks (IGB, 2015).

Figure 1: Structure d'une chaine d'impact selon l'approche du RE5 du GIEC



The structure is organized around three (03) approaches according to the specific objectives of the study: climatic hazards, exposures and vulnerabilities. These approaches are evaluated as follows:

❖ The climatic or climatic hazards approach aims to identify and map the determining factors of climatic risks of Nariarlé irrigation schemes. The climate hazard map is obtained by superimposing the maximum daily temperature map and the maximum daily precipitation map using the " *weighted arithmetic aggregation* " method (Eq.1), recommended and described by the GIZ [27, p. 130], [28, p. 52], [29, p. 128] . The maximum daily temperatures and precipitation for irrigation schemes are obtained by interpolating the maximum temperatures and precipitation from the CORDEX project for the year 2022 (RCP 8.5). The spatial analysis points correspond to the coordinates of the irrigation schemes of the different watersheds of Nariarlé (table 1).

$Tn_{i,0/1} = \frac{X_i - X_{min}}{X_{max} - X_{min}}$(Eq. 1),

$IC = \frac{(I_1 \times W_1 + I_2 \times W_2 + I_3 \times W_3)}{\sum_1^n W}$(Eq. 2), IC:composite indicator . W: is the coefficient assigned to the indicator.

Table 1 : weighted arithmetic aggregation of climatic hazards

Extraction points	Latitude	Longitude	Tmax (°C)	Pmax (mm)	Normalized values	Level of hazards
V1	12.32	-1.32	46,103	65.46		
V2	11.88	-1.32	44,966	60,047		

V3	11.88	-1.76	44,657	112,474				
V4	12.32	-1.76	45,478	106,034	Tmax (°C)	Pmax (mm)	IC	
KOUBRI	*12.19363*	*-1.39769*	*45.75*	*98.7*	*0.6*	*1*	*0.8*	*Very high*
WEDBILA	*12.1623*	*-1.40761*	*45.52*	*79.5*	*0*	*0.38*	*0.19*	*Weak*
NABAZANA	*12.20314*	*-1.34797*	*45.63*	*69*	*0.28*	*0.04*	*0.16*	*Very weak*
MONASTERY	*12.22588*	*-1.35247*	*45.9*	*68.5*	*1*	*0.02*	*0.52*	*Pupil*
BOUSSOUMA I	*12.2154*	*-1.29457*	*45.8*	*67.7*	*0.73*	*0*	*0,36*	*Average*

Source: SAMPEBGO A., 2023

❖ The complementary approach or exposures, used for the identification and analysis of complementary practices and strategies at risk of irrigation developments in the Nariarlé watershed to climatic hazards. Exposures constitute complementary units for assessing the opportunities or threats they may present for adaptation strategies. They are based on an index system integrating *social, technological and economic indicators* (table 2). This constitutes a decision support tool in terms of choice and priority of intervention for more effective management of climate risks.

exhibitions :correspond to anthropogenic factors such as demographic pressure

For technology exhibitions: The method used is the weighted aggregation of the CO $_{2}$ rate on the ground according to the profilesBZB 54 , BZB 109 and BZB 127 and the technological level (the number and types of agricultural tools used on ten (10) developed areas visited).

Economic exhibitions: They are determined from the economic productivity cost of irrigation developments in millions of FCFA (CP) for the 2021-2022 dry season agricultural campaign of four types of production (tangelo, corn, rice and tomato).

$$CP = \sum_{n}^{1} Q_i \times P_i \quad (Eq.3)$$

Q_i = The quantity of products

$$P_i = Prix\ unitaire\ par\ production$$

Table 2: exposure level

Irrigation development sites	Social exhibitions	Technology exhibitions	Reverse economic exposures	Exposure aggregations	Level of exposures
Monastery	0.04	0.94	0.42	0.46	Average
Nabazana	0	0.50	0.27	0.25	Very weak
Wédbila	1	0.47	0	0.49	Pupil
Boussouma I	0.31	0.46	0.3	0.36	Weak
Koubri	0.2	0.43	1	0.54	Very high

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❖ The third subsection is based on **the vulnerabilities** which are organized into two (02) sub-indexes which are (table 3): vulnerability to erosion (the speed of alteration or friability of the basin, protection of the soil by vegetation) and vulnerabilities to water stress. Values 1-0 are given, 0 being a value for development with very low vulnerability and 1 for very vulnerable development.

Table 3: level of vulnerabilities

Irrigation development sites	Vulnerabilities		Aggregated value	Level of vulnerabilities
	Erodibility	Stress		
Boussouma 1	0.58	0.89	0.73	Very high
Monastery	0.03	1	0.51	Average
Nabazana	0.59	0.77	0.68	Pupil
Koubri	0.72	0.11	0.41	Weak
Wèdbila	0.57	0	0.28	Very weak

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The mapping of climate risks for irrigation schemes is illustrated by superimposing the map of hazards, exposures and vulnerabilities (table 4).

Table 4: level of risks

Irrigation development sites	Hazards	Exhibitions	Vulnerabilities	Risks	Risk level
Boussouma 1	1	0.36	0.73	0.69	Very high
Monastery	0.75	0.46	0.51	0.57	Pupil
Nabazana	0.50	0.25	0.68	0.46	Average
Koubri	0.27	0.54	0.41	0.39	Weak
Wédbila	0	0.49	0.28	0.25	Very weak

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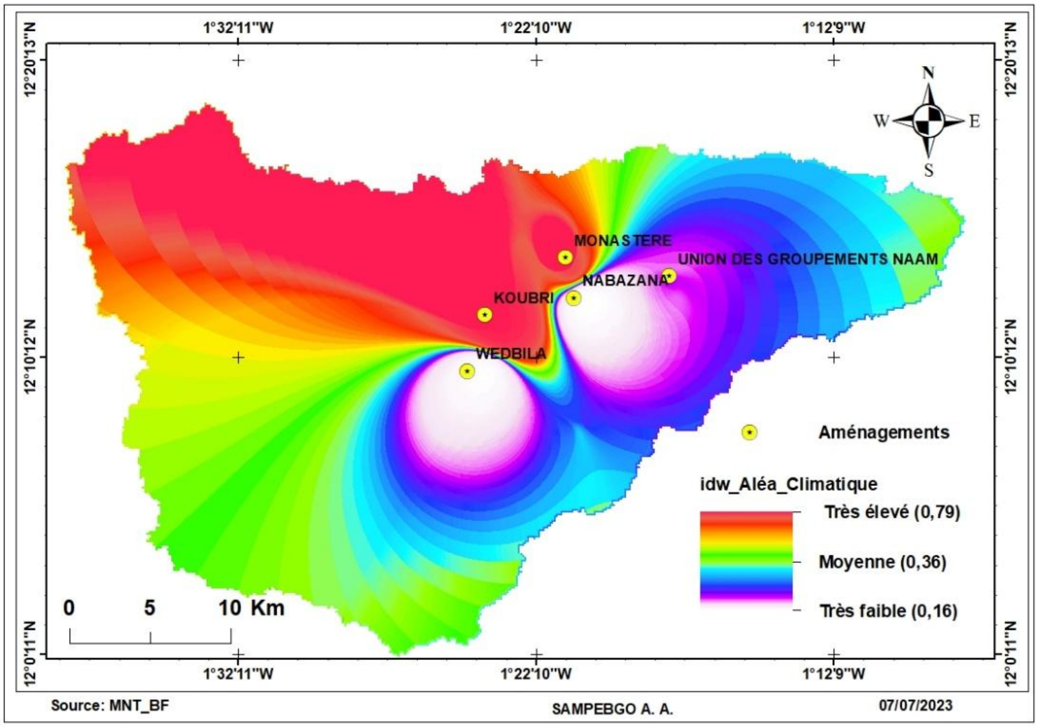
Practices and techniques for adapting to climate risks are assessed using the interview guide and a questionnaire. The data is analyzed by categorical indicators (low, moderate, high category , total absence) and binary indicators (the “yes” or “no” value which are quantified as “0” and “1”). Three (03) variables are used to analyze the practices and techniques of adaptation to climate risks of irrigation schemes in the Nariarlé watershed (Prevention or anticipation, reduction or resilience, monitoring-evaluation).

3. Results

3.1. <u>Climatic hazards:</u>

The climatic hazard map reveals a very high level for the Koubri developments, high for the Monastery, moderately for Boussouma I, low for the Wédbiladevelopment and verylow for the Nabazanairrigated areas (map 8).

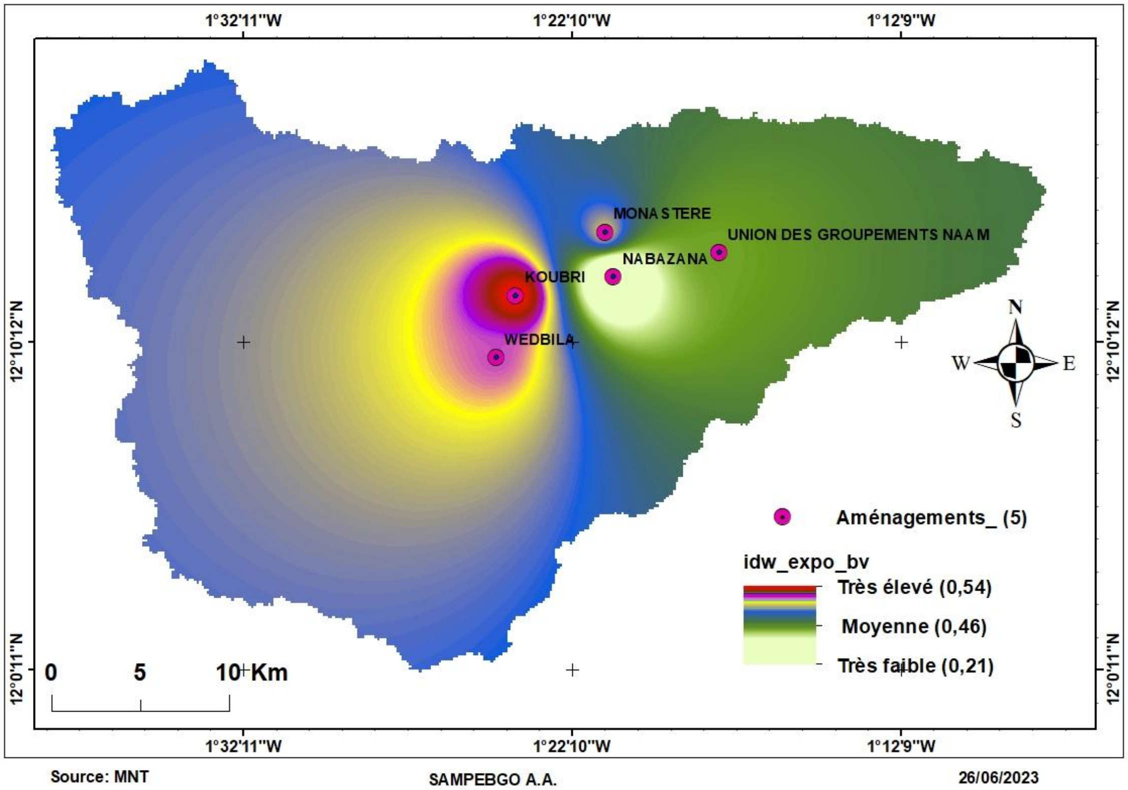
Map 8: climatic hazards



3.2. The exhibitions:

Exposure mapping reveals that the Koubri developments have very high exposure and those of Nabazana have verylowexposure. The Monastery facilities remain moderately exposed (map 9).

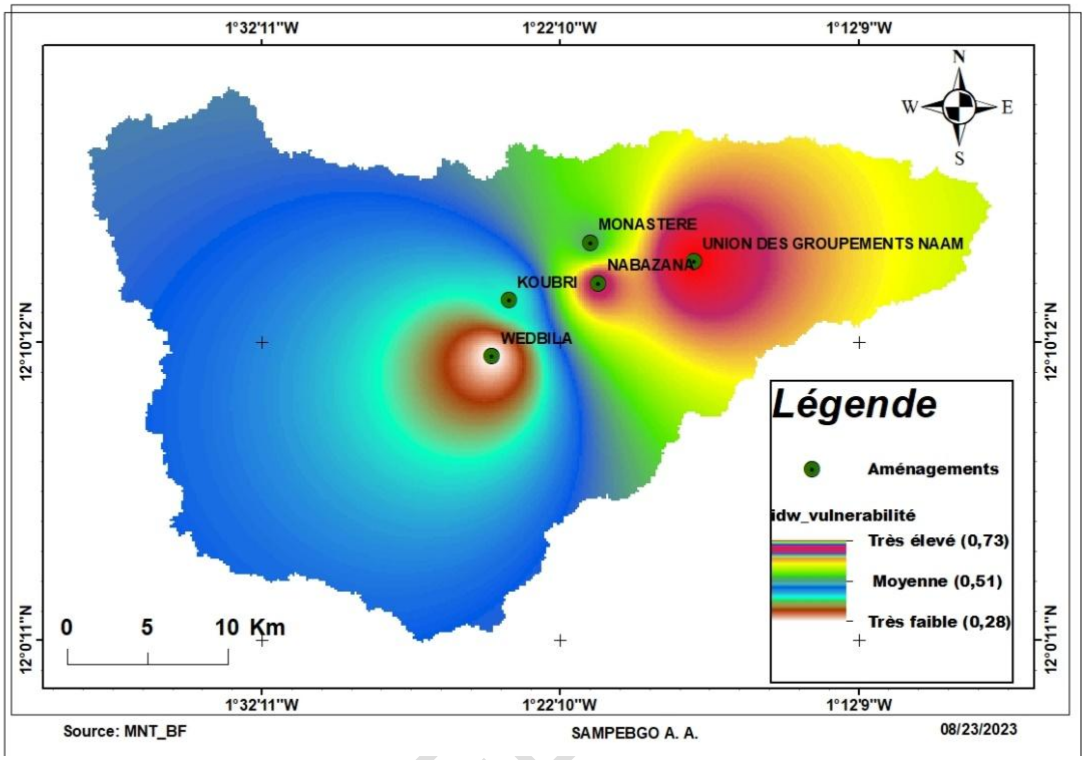
Map 9: exposure to climatic hazards



The results observed are (map 10):

- A very high level of vulnerabilities of the Boussouma developments
- A high level of vulnerabilities of Nabazanadevelopments
- An average level of vulnerability of Monastery developments
- A low level of vulnerabilities in Koubri or PK25
- A very low level of vulnerabilities in Wédbila

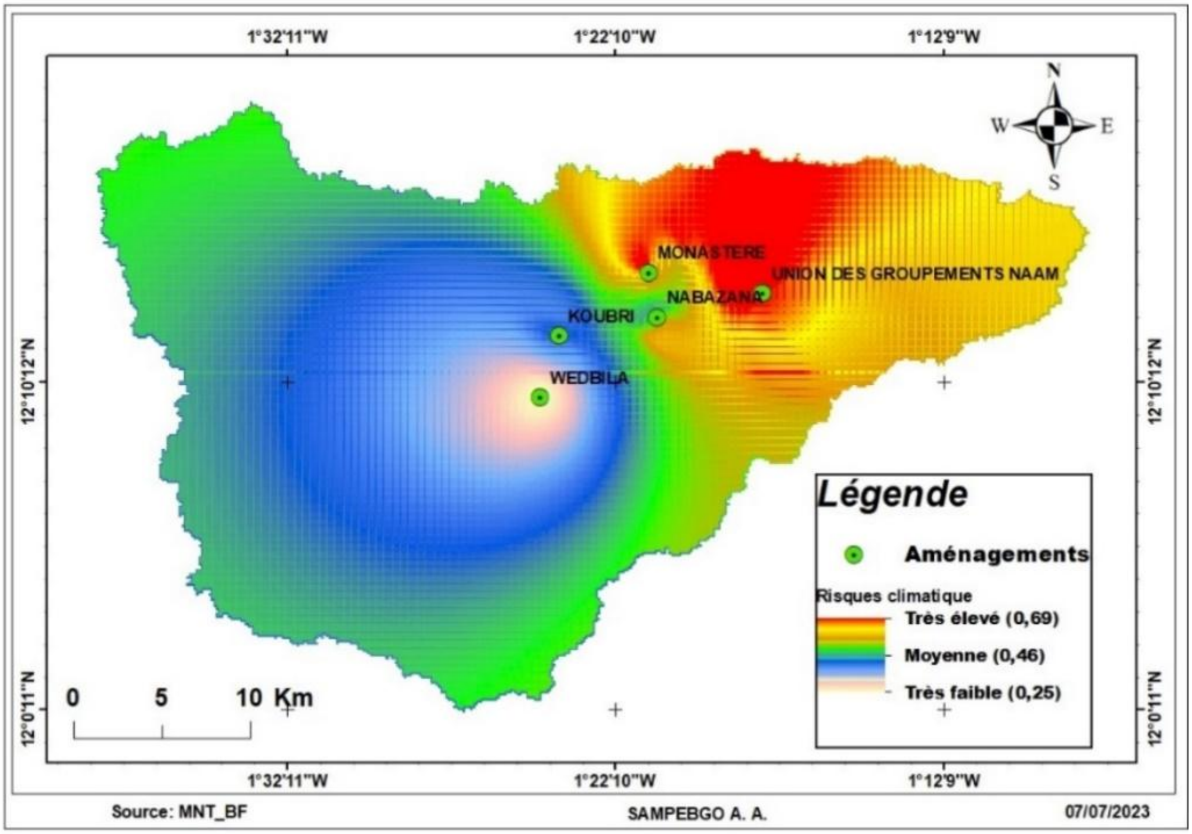
Map 10: climate vulnerabilities



Climate risks:

The level of risks remains very high in the irrigation schemes of Boussouma followed by those of the Monastery. The Nabazana developments remain moderately exposed to climate risks. The Koubri and Wédbila developments are respectively weakly and very weakly exposed to climate risks (map 11).

Map 11: climate risks



The perception of stakeholders on practices and techniques for adaptation to climate risks gives the following results (table 5):

- Total absence of practices and techniques for prevention or anticipation of climate risks (mechanisms for mobilizing resource actors, risky behaviors, technological tools, alert systems, acquisition and dissemination of information).
- Total absence of practices and techniques for monitoring and evaluating climate risks (resilience effort, exposures, vulnerabilities, hazards).
- Low practice of techniques for reduction or resilience to climatic risks (mulching in the event of high heat , abandonment of irrigated areas to flooding and water stress).

Table 5: perception of stakeholders on practices and techniques for adaptation to *climate risks*

Villages	Irrigated areas	Number of respondents	Risk adaptation practices and techniques		
			Prevention or anticipation (%)	*Reduction or resilience: mulching (%)*	*Monitoring and evaluation* (%)
NABAZANA	NABAZANA	15	0	43	0
WEDBILA	WEDBILA	65	0	85	0
KOUBRI	PK 25	25	0	76	0

	DOWNSTREAM				
NAKAMTINGA	MONASTERY	15	0	65	0
BOUSSOUMA	SOUGRI NOOMA	30	0	56	0

Source: SAMPEBGO AA 2023

4. Discussion

The study of the climatic hazards of the Nariarlé watershed shows that irrigation developments are subject to the effects of climate change as a whole. These results are in line withthose of AP Ouoba , (2013) whosestudies on climate change and vegetation dynamics, carried out in the Burkinabè sahel as well as Le Barbé &Tapsoba , (1994) in the characterization of fluctuations interannual rainfall in the Sahel. The period 1950-2020 is marked by a very high level of vulnerabilities to temperatures (45.75°C) and precipitation (98.7mm). The temperature of each decade (1980) has been warmer than all those which preceded it since 1850. These results are in conformity with the work of [30, p. 07] ; of [27, p. 28] ; of report five of [31, p. 07] and the World Meteorological Organization ([10, p. 06] . The analysis of complementary risky practices and strategies reveals that the developments are very exposed to additional risks. Piping or collection of aggregates (sand , gravel) on the dikes and nest of dams and the growth in the $CO_{2\ level}$ on the ground demonstrates the threats to adaptation strategies. The irrigation schemes of the Nariarlé watershed constitute a set of systems vulnerable to erosion and water stress[32, p. 112], [33, p. 106], [34, p. 13] . The protection of the soil by vegetation depends on the nature of the land use and the density of cover.

5. Conclusion

The analysis of hazards, exposures and vulnerabilities of irrigation schemes in the Nariarlé watershed reveals that irrigation schemes in the watershed are exposed to climatic risks. The watershed is experiencing strong population growth. Measures for management, acquisition and dissemination of information related to climate change remain weak overall. Risky behaviors are accentuated with incivism. External support (project/program) for risk and exposure management is limited to mulching techniques (during high heat) or the simple abandonment of irrigated areas to the vulnerabilities of climatic hazards (floods, water stress). In the short term, the assessment of risks linked to changes implies an improvement of the system and mechanisms for monitoring and evaluating studies of risks linked to climate change of developments, mobilization (actors-resources), availability of material means resilience and alert systems (mechanisms, tools, equipment, monitoring, etc.). In the long term, this study constitutes a decision support tool in terms of choice and priority of intervention for more effective management of climate risks and attacks on food security in Africa.[35, p. 26], [36, p. 06], [37, p. 10], [38, p. 04], [39, p. 22], [40, p. 06] .

DECLARATIONS

ACCESSIBILITY OF CLIMATE DATA : “The authors declare that the data underlying the work are accessible. These data are accessible to the national meteorological agency of Burkina Faso (ANAM-BF). Order number 2022/65”.

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