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CONSEQUENCES OF PRECIPITATION VARIABILITY AND SOCIO-ECONOMIC ACTIVITY ON SURFACE WATER IN THE VRANSO WATER BASIN (BURKINA FASO)

Abstract: The aim of this study is to analyse rainfall variability and its impact on surface water in the Vranso catchment. To achieve this, the methodology consisted of collecting primary and secondary data. The primary data was acquired using a survey technique, while the secondary data was based on meteorological data (rainfall) and a literature review. Data processing was based on the standardised rainfall index (SPI), the Martonne aridity index and the standardised flow index. (SFI), and the frequency index (FI). The study shows that rainfall variability is significant over the period 1985-2014. This variability is reflected in alternating dry and wet periods. The study also shows that rainfall variability has an impact on flows in the Vranso catchment. Agricultural activities, gold panning and livestock farming contribute to the drying up of water bodies in the catchment. It would be useful for the regional authorities to tackle this problem by formulating conservation policies for these areas.

Key words: Burkina Faso, Vranso, Watershed, Rainfall variability, Surface water, flow

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Introduction

Catchments provide human societies with many goods and services such as clean water, biodiversity conservation, erosion control and carbon sequestration (Aglanu, 2014). This provides a strong incentive to understand the functioning of areas (Rezaie-Boroon et al., 2011; Gumma et al., 2016; Ibrahim et al., 2015; Diwediga et al., 2017; Rode et al., 2018; Bam & Bansah, 2020), management and ecosystem services provided by catchments (Kotri et al., 2016). However, few studies have focused on the impacts of climate variability on catchments (Faty, 2018). However, the presence of climate change in West Africa no longer needs to be demonstrated. Many authors, in Burkina Faso (Tirogo et al., 2016; Yanogo & Yameogo, 2023), Niger (Oguntunde et al., 2018). Diatta and Fink, 2014, Gbobaniyi, et al, 2014 note that the whole of West Africa is affected by climate variability. Given the role that surface water resources play in the livelihoods of West African populations. It would therefore be important to examine this issue in relation to anthropogenic actions. The aim of the study is to analyse the impacts of climatic and anthropogenic variability on water resources in the Vranso catchment in Burkina Faso. The aim is to characterise rainfall variability in the catchment. Then to determine the impacts of climate variability and anthropogenic actions on the catchment.

Data and Methods

The study area

The study area is located the Vranso sub-catchment in Burkina Faso. It is part of the lower Mouhoun basin. The Vranso watershed, which is the subject of this study, covers an area of 10,630 km2 (Monographie de la province du Boulkiemdé, 2001). It irrigates a large part of Boulkiemdé including Soaw, Imasgo, Nanoro, Ramongo and six (6) communes in Sanguié (Kordier, Didyr, Réo, Dassa, Kyon, Tenado), (Yameogo, 2011). Part of the province of Passoré (Bagaré, La-Todin, Yako, Samba, Pilimpikou, Arbolé), Zondoma (Boussou) and Kourwéogo (Niou, Boussé) are part of the study area. The Vranso catchment covers a total of 25 communes, including 3 urban communes (Koudougou, Réo, Yako) and 22 rural communes (Figure 1 below).

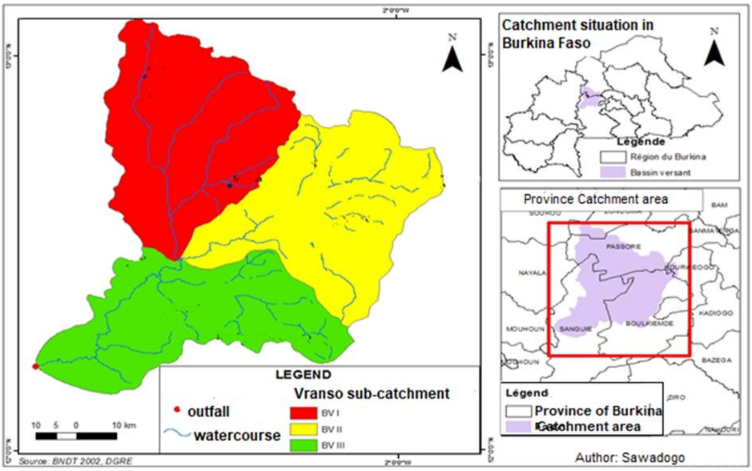

Fig. 1. Location of the study area

Data from the study

Secondary data

The climatic data are the annual and monthly averages of rainfall and temperature. These data were obtained from the National Meteorological Agency of Burkina Faso. The Saria station was used because of the availability of temperature data series. It is located at sub-basin level (BVIII, Figure 1). The period was chosen because of the lack of rainfall records and the desire to include periods of severe drought (1985) (Dipama, 2009) and wet weather (2014) (Yaméogo & Rouamba, 2023). This makes it possible to assess the contrasts in rainfall trends.

The hydrological data concerns annual and monthly river flows. They were obtained from the Direction Générale des Ressources en Eau (DGRE) and the Office Nationale de l'Eau et de l'Assainissement (ONEA). The agricultural statistics were collected on the AGRISAT-Burkina Faso website.

A literature review was carried out to take stock of work on climate variability and water resources. The libraries of the Ki-Zerbo and Norbert Zongo universities and the Internet were used for this purpose.

Primary data

The survey was used to collect the data. Purposive sampling based on two criteria, proximity to the catchment area and use of water resources from the catchment area, was used to collect the data. A total of 204 heads of households working in the agro-pastoral sector, market gardening and gold panning were contacted. The study covered 10 villages (see figure 2) and was surveyed from December 2022 to June 2023. Observation was also used in the study.

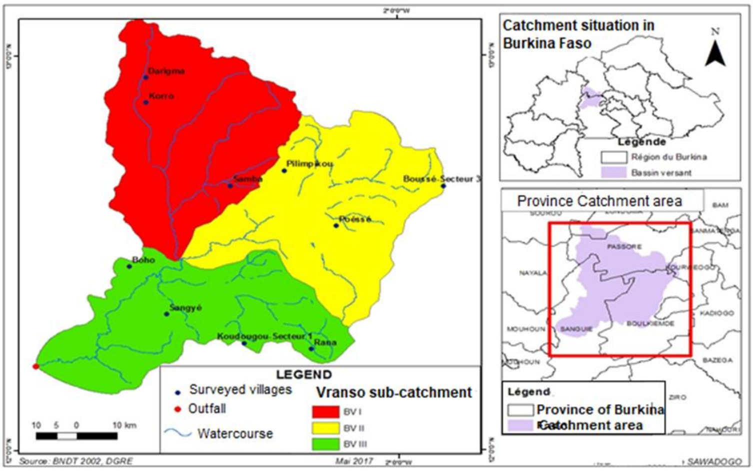

Fig. 2. location of study villages

Data processing and analysis methods

Secondary data

Rainfall and flow trends were studied using the standardised rainfall index (SPI), the Martonne aridity index and the standardised flow index. (SFI). The standardised rainfall index (SPI) is used to characterise rainfall deficits over a given period. It can be calculated to determine wet and dry periods in rainfall patterns. It is generally used by the AGRHYMET Regional Centre to characterise the climate of the Sahel regions. It is expressed using the following formula:

$$SPI=(AR-MAR)/\sigma \qquad (1)$$

where: AR is annual rainfall; MAR is mean annual rainfall and σ is standard deviation of the series considered.

The standardised flow index (SFI) is used to identify dry, deficit, normal, surplus and wet years in the flows observed over a given period (Kodja et al., 2017). The same formula was applied to flows. Thus, the Standardized Flow Rate Index (SFI) is as follows:

$$SFI=(AF-MAF)/\sigma \qquad (2)$$

where: AF is Annual flow rate; MAF is mean annual flow rate and σ: Standard deviation of the series considered.

In addition, the Martonne index was used to assess the climatic trend in the area. The Martonne aridity index is calculated using the following formula:

$$MI=TAR/(AT+10) \qquad (3)$$

where: TAR = Total Annual Rainfall/mm and AT = Average annual Temperature in degrees Celsius (°C);

The interpretation scale for the Martonne aridity index is summarised in table 1.

Tab. 1. Martonne Index (MI) and interpretation

Index	Climatic condition
MI >20	Sufficient humidity
MI < 10	Aridity
10 <MI< 20	Tendency to drought
MI< 5	Hyper aridity

Source: Piedallu et al., 2007

The trends in the indices were calculated using the linear adjustment formula:

$$Y=AX+B \qquad (4)$$

where: A is the directing coefficient, which represents the slope of the line, and B is a constant.

Thus, according to Kodja et al, 2013, if $A > 0$, there is an upward trend; $A<0$, there is a downward trend.

Primary data

The Frequency Index (FI) was used to process the primary data. It is used to classify respondents' answers according to their frequency. According to Bekr, 2015, its formula is:

$$FI=\sum a(n/N) \qquad (5)$$

where a is the constant expressing weight given to each response (range from 1 to 3), n is the frequency of the response and N is the total number of responses.

Results

Study on the variability of precipitation in the catchment area of the Vranso

Over the period 1985-2014, average rainfall was 776.93 mm. Above-average years are: 1991, 1993, 1994, 1998, 1999, 2003, 2008, 2009, 2010, 2012, 2013, 2014.Conversely, below-average years were: 1985, 1987,1988, 1989, 1990, 1992, 1995, 1996, 1997, 2000, 2001, 2002, 2004, 2005, 2006, 2007, 2011. Total annual precipitation also shows an upward trend in the Vranso watershed (Figure 3).

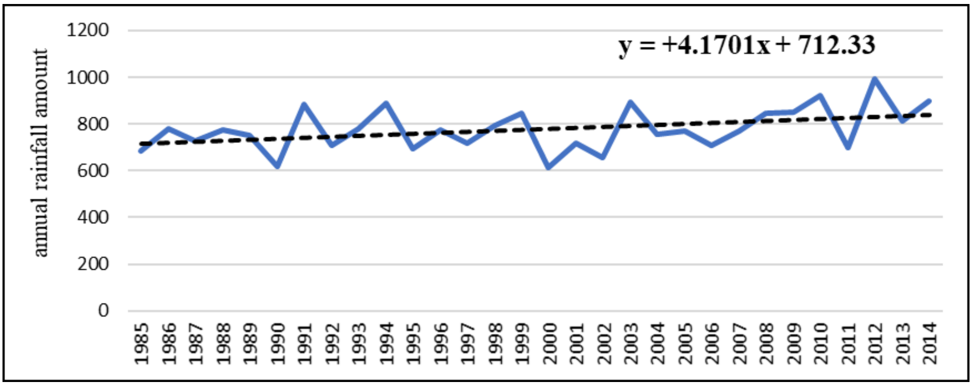

Fig. 3. Average annual rainfall between 1985 and 2014 (source: Burkina Faso National Meteorological Department, 1985-2014)

The climatic aridity index over the period 1985-2014 in the catchment area shows a long trend of drought (1985-2010), and a trend of sufficient humidity (2011-2014) (Figure 4).

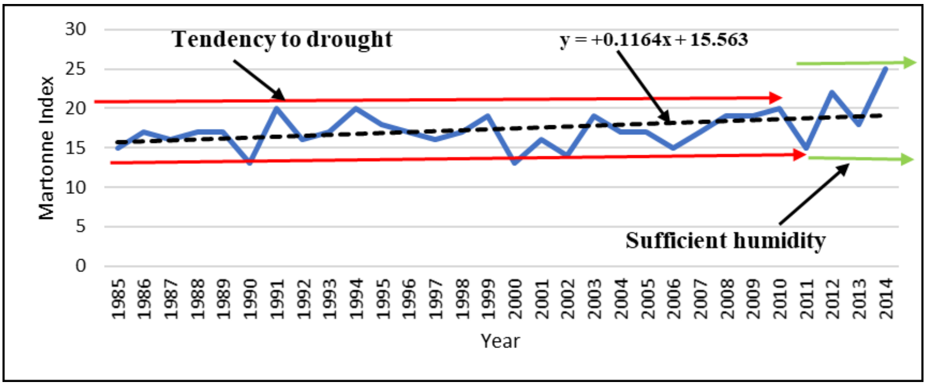

Fig. 4. Alternation of dry and wet periods in the period 1985-2014 (source: Burkina Faso National Meteorological Department, 1985-2014)

Figure 5 above shows that rainfall fluctuates in both dry and wet periods. The standardised rainfall index confirms the alternation of dry and wet periods over the period 1985-2014. The wet phase occurred in 2003. This difference between the two indices could be due to the implication of temperature in the Martonne index.

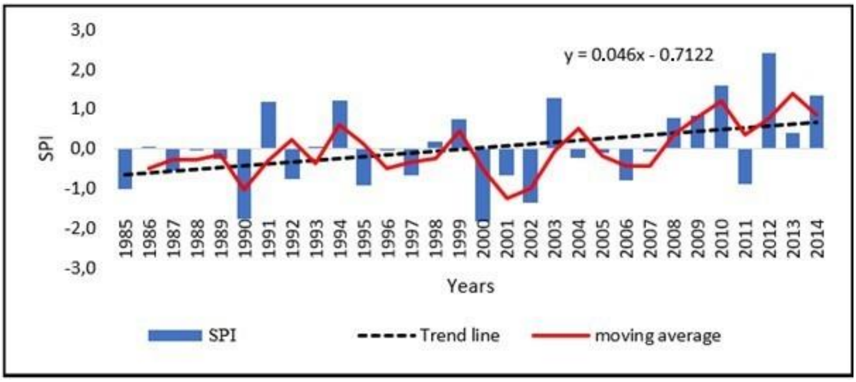

Fig. 5. Change in rainfall indices 1985 to 2014 (source: National Meteorological Directorate of Burkina Faso, 1985-2014)

The impact of rainfall variability on flow in the catchment area

Interannual variability of flows in the catchment area

Monthly and annual river flows are used to measure runoff, which is an index to quantify availability and measure the capacity of rivers to meet the water needs of populations and ecosystems. Therefore, it is important to choose this variable as an indicator. Figure 6 shows the high inter-annual variability of flows.

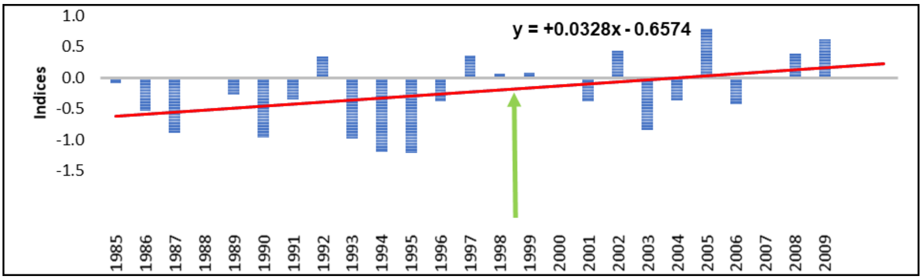

Fig. 6. Changes in flow indices from 1985 to 2009 (source: Direction Générale des Ressources en Eau, 2015)

Figure 6 shows three main evolutionary phases, marked by a succession of dry periods and wet periods. The first phase is characterized by a succession of dry periods from 1985 to 2001, with two inter-rainy years (1992 and 1997). The second phase was marked by alternating wet and dry years from 2002 to 2007. The third phase was characterized by a succession of wet years from 2008 to 2014.

Socio-economic activity and its effects on surface water in the Vranso catchment area

The intensity of the agro-sylvo-pastoral activities and their impact on the level of the surface water in the catchment area.

Land use varies according to the type of activity, as some practices, such as extensive livestock farming and agriculture, require a lot of space. In the five provinces covered by the study area (Boulkiemdé, Réo, Passoré, Zondoma, Kourwéogo), sedentary livestock farming dominates (90%). In the province of Kourwéogo, semi-sedentary livestock farming accounts for 55.4% of households, compared to 30.9% for "extensive sedentary livestock farming" (RGA, 2008). Figure 7 below shows the presence of herds and their pressure on surface water resources in the basin.

Fig. 7. Cattle herd in the minor bed of the catchment area in Réo (author Baouar Michel in 2023)

Agriculture and gold mining: factors putting pressure on surface water in the Vranso catchment area

Figure 8 below shows changes in the area used for rain-fed agriculture. The period 1985-1999 corresponds to below-average rainfall (776.93 mm). In contrast, the increase in rain-fed production corresponds to periods of above-average rainfall over the period 1984-2014. This means that pressure on land in the Vranso catchment is high when rainfall is relatively high. However, during periods of low rainfall, people continue to occupy the land on the edges of the catchment areas. All this slowly contributes to the silting up of the catchment.

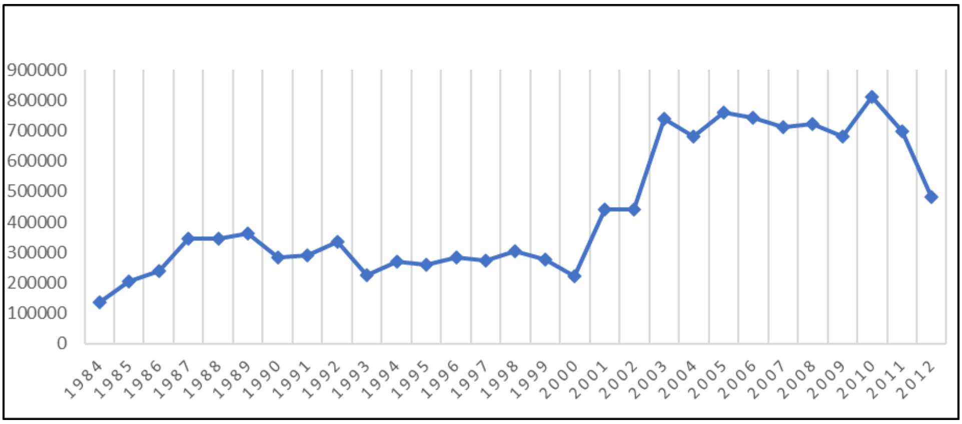

Fig. 8. Change in cultivated area per hectare according to rainfall from 1984 to 2012 (source: Agristat, Burkina Faso, 1984- 2013)

For the local population, agriculture, livestock farming and gold panning have an impact on the catchment. Drying out of stretch water, soil erosion and crusting of river banks are the main factors affecting the Vranso catchment (Table 2).

Tab. 2. The main factors affecting the catchment area

Impact of activities	3	2	1	FI	Rank
Early drying up of stretch water	**2.19**	**0.58**	**0**	**2.77**	1st
Soil erosion	2.19	0.52	0	2.71	2nd
Silting	1.47	0.48	0.26	2.21	4th
Water pollution	0.78	0.58	0.44	1.8	5th
Fish contaminated by cyanide	0.294	0.88	0.46	1.634	6th
Crusting of bank soil	1.53	0.38	0.29	2.2	3rd

Source: Field surveys, 2022-2023; 3: very high impact; 2: high impact; 1: low impact

This table shows that early drying up of stretch water is the most important, followed by soil erosion, then crusting of bank soil. Figure 9 below shows the drop in water levels in lakes Boulpon and Nazoanga in the Vranso catchment. The lower water level makes it easier for livestock to drink. This situation encourages soil crusting due to repeated trampling. The impact of agriculture and livestock farming is therefore clearly visible to the local populations in the catchment area.

Fig. 9. Drying up of stretch water in the Vranso catchment between 2008 and 2022 (source: Image Google earth pro, 2008-2023)

Discussion

Africa's pluviometric variability

The trend towards wetter periods observed in the study area between 2000 and 2014 has been noted by several authors in Burkina Faso. Karambiri et a.l (2019) in the Sourou valley, Rouamba et al. (2023) in the Mouhoun region and Yanogo and Yaméogo (2023) in the north and south-west of Burkina Faso report an increase in wet periods in Burkina Faso over the period 2000-2020. Kaboré et al. (2017) add that the increase in wet periods is more pronounced in the Sahelian zone than in the Sudano-Sahelian zone of north-central Burkina Faso. Other authors such as, Nouaceur & Murărescu (2018), Nouaceur & Murarescu (2020), Fhorest Yao & Soro (2021) also find similar results in West Africa.

Rainfall variability and human activity: a combination that raises major issues in catchment areas

Rainfall variability has an impact on the runoff in the Vranso catchment in Burkina Faso. This impact is reflected in the variability of streamflow. The same observations were made by Karambiri et al. (2019) in the Sourou catchment in Burkina Faso. Zouré et al. (2023) add that the Mouhoun River, whose Vranso basin is affected by climate variability. Other studies have been carried out in Côte d'Ivoire (Kouassi et al., 2012; Fossou et al., 2014; Kouadio et al., 2020; N'dri et al., 2021), Niger, Ghana (Akpoti et al., 2016), Senegal and Gambia (Bodian et al., 2018). Rameshwaran et al. (2021) and Sidibe et al. (2019) report that West African watersheds are affected by climate variability.

Livestock rearing, agriculture and gold mining have caused surface water in the catchment to dry up in places. This situation is reflected in the early drying up of watercourses in the Vranso catchment, particularly the Boulpon and Nazoanga reservoirs. Yira et al. (2016) also noted this situation in Burkina Faso. Several other players have noted the same trends. Indeed, Giertz et al. (2005), Togbévi et al. (2022) and Eba et al. (2021) note that land use has a significant impact on West African river basins. In the catchment area of the river Orla, in western Poland, Kupiec et al. (2021) noted that agricultural activities have a negative impact on the river's water quality.

Conclusion

The Vranso watershed is subject to highly variable rainfall, with dry periods in the period 1984-1999 and wet periods in the period 2000-2014. Agriculture, livestock and gold panning are the main socio-economic activities. The combination of rainfall variability and socio-economic activities has disrupted surface water runoff, leading to premature drying of dams on the watershed. The watershed is also affected by soil erosion and crusting of riparian soils due to repeated trampling by livestock. It is therefore important to keep a watchful eye on this area, from which several hundred thousand people derive the bulk of their water needs, or risk catastrophe if vigorous action is not taken.

Conflicts of Interest: The authors declare no conflict of interest.

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