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DIAGNOSTIC OF THE FACTORS REDUCING THE STORAGE CAPACITY OF THE TOUKOMTORE DAM IN BURKINA FASO

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ABSTRACT

The Toukomtore dam in Burkina Faso was built as a road embankment to meet the water needs of the populations of the commune of Koubri. The dam's watershed is not immune to the various climatic and anthropogenic pressures that have caused it to fill up. The objective of this study is to identify the sources of sediment supply to the dam. To do this, the study relies on documentary research, individual interviews with agents of the deconcentrated technical services of the State and users as well as field observations. The results of the study reveal that the sediments in the dam basin come from intense gullying areas, bare areas, bank erosion, market gardening plots and local drains, but also from aggregate extraction sites and brick factories. The results also show that the basin of the dam has lost its initial capacity of reception due to the phenomenon of filling. These results provide indicative elements on the potential origin of the sediments of the dam and are useful for the implementation of the recommendations that have been formulated.

Keywords: Burkina Faso, Dam, Dam filling, Sediment, Erosion

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1. INTRODUCTION

Burkina Faso is a landlocked Sahelian country dependent on rainwater that falls on its territory. The country receives virtually no water from neighboring countries and all rivers that originate in the country drain to the ocean via neighboring countries with a coastline. Since the 1970s, there has been a decrease in rainfall of approximately 15 to 20% in Burkina Faso (Mahé, 2010, p. 2), thus affecting water availability. It is in this context that the various governments of Burkina Faso have undertaken the construction of surface water storage facilities in order to increase its availability to users. The construction of these facilities began before independence but accelerated from 1980. The number of reservoirs in the country has reached 1453 according to the "ADB" database of the General Directorate of Hydraulic Resources Inventory (DGIRH) (Cecchi, 2006, p. 2). In 2011, the latest inventory of dams conducted by the Directorate of Studies and Information on Water (DEIE) identified more than 1,800 surface water bodies, including more than 1,000 dams. These dams contribute to achieving the objectives of Burkina Faso's food security policy, which is based on dry season agricultural activities. However, it has been noted that the majority of dams built over the past thirty years are subject to silting/siltation, which has caused these structures to lose a significant portion of their volume (AEC, 2018, p. 8; Maiga et al., 2006, p. 606), thus jeopardizing socio-economic activities around these water points. In Burkina Faso, a few authors have addressed the issue of dam sedimentation such as the work Bagré (2017) on the filling of rivers in the Sudano-Sahelian domain of West Africa, Saltani et al., (2015) on the origin of the silting phenomenon of the Tarfaya coastal basin, southwest Morocco; Boena, (2001) on the causes and consequences of silting of Lake Bam, Burkina Faso; Sanon, (1998) on the silting up of the Tamasgho dam in the Sanmatenga province in Burkina Faso, Karambiri, (1998) on the dams of Gouinré, Nagréongo, Salbisgo and dam n°2 of Ouagadougou; Dipama, (1992) on the sedimentation of dams n°1, n°2 of Ouagadougou. This phenomenon of filling is observed with acuteness on the water reservoir of the Toukoumtoré dam. In this context, questions arise: what are the agents of the micro-catchment area that promote the evacuation of sediments towards the water basin of the dam? What recommendations can be made to mitigate the phenomenon? The objective of this study is to contribute to answer these questions with the case of the Toukomnoré dam and to formulate recommendations to reduce the rapid filling of the water reservoir.

2. MATERIALS AND METHODS

2.1 Characteristics of the study environment

The water basin of the dam is located in the rural commune of Koubri, 42 km southeast of the city of Ouagadougou. It is an earthen dam built at the outlet of a tributary of the Nagleyiare River, itself a tributary of the Nakanbe River. The structure is a dam in the form of a road

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embankment fed by a basin of 1131.6 ha and the basin itself is 24 ha. The perimeter of the sub-watershed is approximately 14.44 km. Three major branches of the watershed feed this reservoir (Fig1). The length of the main stream is 4.6 km. The overall slope index of the sub-watershed reaches 10.5 m/km. The relief of the watershed is characterized by the absence of large elevations. The maximum elevation is 300.00 m and the minimum is about 251.6 m (Table 1).

Table 1: Some morphometric characteristics of the study area

Parameters	Value	Units
Area	1131.6	Hectares
Watershed perimeter	14.441	km
Altitude Max	300.00	m
Min Altitude	251.6	m
Length of the watercourse	4.6	km
Overall slope index	10.5	m/km

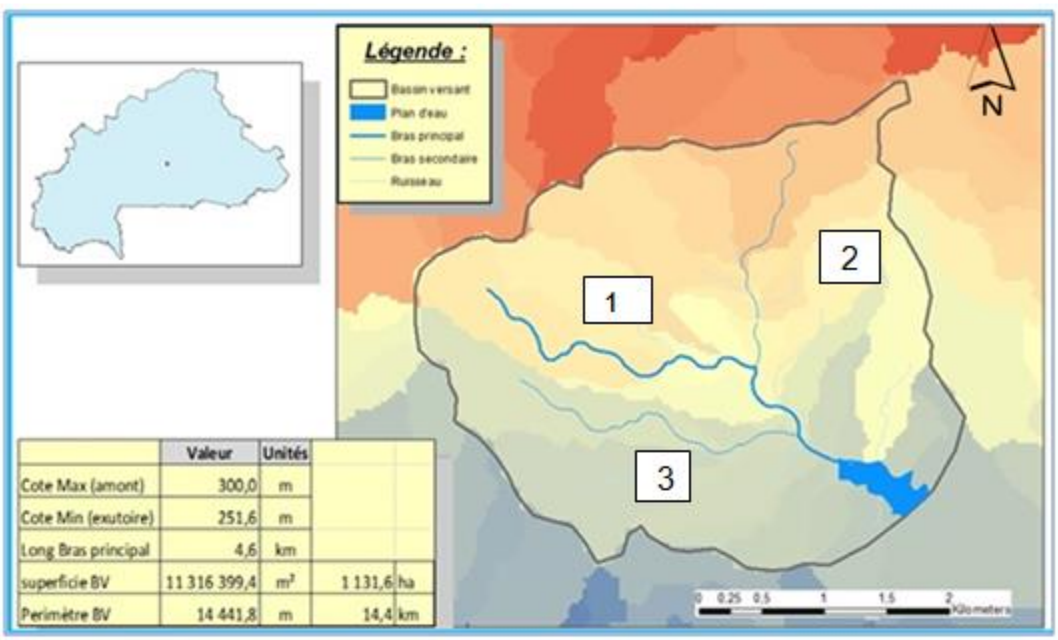

Figure 1: Toukomtore dam catchment area

The climate in the study area is Sudan-type, with a dry season from November to May and a wet season from June to October. The average annual rainfall is irregular and varies between increasing and decreasing over the period 1981-2015 (Fig2). Annual rainfall ranges from 600 to 900 mm/year (Ibrahim, 2012, p. 22). In the study area, annual rainfall in a dry decadal year is

595.5 mm; it reaches 793.1 mm in an average year and about 890.7 mm in a wet decadal year. The winds are relatively weak and blow on average between 1.67 m/s in November and 2.47 m/s in February. As for the temperature, its monthly value is around 28.6°C (Bagre et al., 2022a, p. 121).

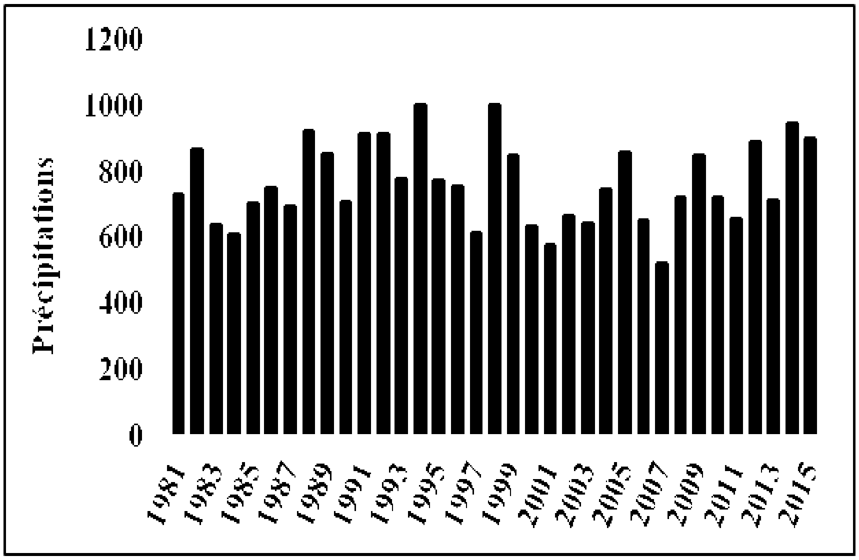

Figure 2: Inter-annual variability of precipitation at the Kombissiri station

Source: Agriculture Service de Kombissiri

Tropical ferruginous soils are the dominant soils (95%). The vegetation is a wooded savanna with a grassy cover (Bagre et al., 2022, p. 121). From a geological point of view, two granitic complexes with a northeast orientation cover the watershed. These are the biotite granite in the upper part of the watershed and the biotite porphyroid granite located in the lower part (Fig3).

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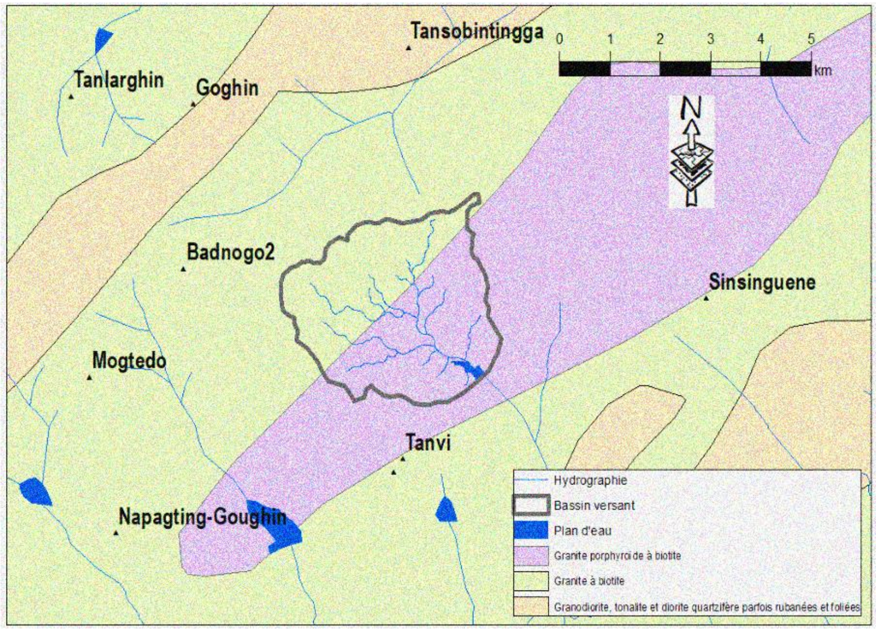

Figure 3: Geology of the Toukomtoré dam site

Source: BNDT, 2012

Hydrologically, the flows are essentially dependent on the rainfall conditions of the study area. At the outlet of the Toukomtore dam over the period 1981-2015, average water inflows are relatively high in average years with a value of more than 1600000 m^3 and can reach up to 2 217415 m^3 in wet decennial years. However, these inflows are modest in a dry decennial year with about 400,000 m^3 (Table 2). These volumes stored throughout the rainy season are subject to losses due to infiltration on the banks during floods but also to direct evaporation on the open water table.

Table 2: Water inflow volumes at the dam outlet

Période	Dry decennial year	Mean year	Ten-year wet year
Flow coefficient $K_{e\ (\%)}$	6	18	22
Volume of inputs (m^3)	404 320	1 615 449	2 217 415

According to the population projections of the communes of Burkina Faso from 2007 to 2020 carried out by the Institut National Statistique et de la Démographie (INSD), (2017, p. 345, 349), the population of the commune of Koubri increased from 43924 inhabitants in 2007 to 61771 inhabitants in 2020.Agro-pastoral activities and market gardening occupy the daily lives of the people of the commune, as they do elsewhere in Burkina Faso.

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2.2 Méthods

The main data used in this study are: data from the National Topographic Data Base (NTDB, 2012) and the Shuttle Radar Topography Mission (SRTM) image with a resolution of 90 m, used to produce the Digital Terrain Models (DTM); the *ArcGis 10. 4* software was used to produce the digital terrain model (DTM), which consisted of delimiting the study area and its hydrographic network, calculating the area and perimeter of the study basin and the length of the main branch of the river, etc. Rainfall data were obtained from the Kombissiri rainfall station located 15 km from the study area and covering the period 1990-2015. An interview guide was administered to the local stakeholders concerned by the problem: the users of the reservoir, the members of the local management committee of the reservoir, the technical services of the Ministries in charge of water, agriculture and livestock. In addition, field observations also made it possible to identify all of the socio-economic activities around the water body.

As the watershed of the reservoir was not subject to flow measurements, the average annual runoff, which represents the portion of rainfall that actually flowed towards the outlet of the reservoir, was estimated by the Dubreuil-Vuillaume method (1975). It is based on the physical and climatic characteristics of the watershed (soil-hydrological elements, quality of the water transfer network (marked bed, degraded or not), geology and precipitation. It is applicable between isohyets of 400 and 4200 mm (Office for Scientific and Technical Research Overseas, 1998, p. 96). Its formula is (1).

$$V_{inflow}\,(m^3) = Ke.\ S.\ P_{an} \quad (1)$$

With: V_{inflow} = total volume flowing to the outlet, Ke = basin runoff coefficient expressed as a percentage, S = catchment area, P_{an} = annual rainfall measured on the catchment.

3. RESULTS

The field investigations show that several factors contribute to facilitate the evacuation of sediments in the Toukomtore reservoir bed. In fact, the basin has six major sources of sediment that contribute to the filling of the structure, which reduces its storage capacity as mentioned by the various users.

Source 1: Bare areas or "Zipellé" above areas of intense gullying

On the right bank of the Toukomtore reservoir watershed, there is a degraded zone (Photo 1). This area is called "Zipellé" in the Moore language. The vegetation is almost absent and the soils are compacted, which favors intense runoff, giving rise to numerous gullies.

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Photo 1: Heavily degraded area with gullies

Source: Kambiré, 2019

Source 2: Areas of intense gullying

This area located above the water body is characterized by the presence of numerous gullies that expand from year to year (Photo 2). In the rainy season, the water currents are very strong, encroaching on fields, tracks and roads. At the beginning of erosion, the gully is simply traced, but gradually it deepens and the soil becomes a real relief. These gully areas are the major sources of sediment supply to the reservoir water basin.

Photo 2: Gully area above the reservoir

Source: Kambiré & Bagré, 2019

Source 3: Streambank erosion

The phenomenon of bank erosion along the main stream (Photo 3) has been observed. The disappearance of the vegetation covers due to the cutting of wood and clearing of land for agricultural purposes, and the trampling of animals would explain this phenomenon.

Photo 3: Eroded main stream branch

Source: Kambiré & Bagré, 2019

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<u>Source 4</u>: Market gardening plots installed on the riparian strips and the canalization system

Around the water basin of the reservoir, particularly on the left bank, market gardening has developed (Photo 4) at the expense of the gallery forest. The soils loosened during the dry season constitute an important source of sediment that will be deposited in the reservoir basin during the first rains. Also, as the water in the basin recedes, farmers dig hand-dug trenches from the reservoir bed to the market garden plots in order to bring the water closer to the plot (Photo 5). These trenches dug into the riparian land are sources of sediment for the reservoir.

Photo 4: Market garden crops on the banks of the reservoir *Photo 5: Water* intake channel on the banks

Source: Kambiré & Bagré, 2019

<u>Source 5</u>: Brick making sites on the reservoir bed

The removal of banco and the making of bricks are activities observed in the field. Indeed, the high demand for bricks for house construction has allowed this income-generating activity to develop in the village (Photo 6). This activity contributes to loosening the soil and promoting the transport and deposition of sediments in the reservoir basin.

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Photo 6: Brick-making site in the reservoir bed

Source: Kambiré & Bagré, 2019

Source 6: Sand collection sites on the river bed of the reservoir

With the expansion of the city of Ouagadougou located less than 50 km away, the demand for sand and gravel has become very important for the construction of buildings. As a result, the collection of sand from the main river and from the basin and its commercialization is an important source of income for the population. These aggregates are collected on the bed of the main river or on the banks. Dump trucks that are responsible for removing these aggregates create paths along the banks, loosening the soil and promoting water erosion and sediment deposition in the reservoir (Photo 7).

Photo 7: Sand collection in the main stream

Source: Kambiré & Bagré, 2019

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4. DISCUSSIONS

The phenomenon of the filling of the Toukomnoré reservoir basin is observed by producers who note the early drying up of the reservoir, the shortening of market garden production cycles and the reduction in the area farmed. Denuded areas and gullies above the reservoir, degradation of the banks through deforestation, cultivation of land along the banks of the reservoir and the main river, brick making and the collection of sand from the reservoir and the river are the main factors in the filling of the Toukomtore reservoir. These results are consistent with the work of Ibrahim (2006, p. 128); Collinet and Zante (2005, p. 72); Rosse et al. (2000, p. 317); Roose and Rodriguez (1990, p. 8). Roose et al. (2000, p. 122) showed the importance of gully erosion over three years of monitoring in Algeria. According to the results, solid transport reaches 90 to 300 t/ha/year.On two pairs of gullies near Tlemcen in Algeria, Chebbani and Belaidi, (1997, p. 157) observed that the average erosion per gully is respectively 272 t/ha/year, 206 t/ha/year, 186 t/ha/year and 289 t/ha/year for gully 1, 2, 3 and 4.On the long Sudano-Sahelian glacis with a slope of 1 to 3%, gully erosion reaches 20 to 100 t/ha/yr (Roose and De Noni, 2004, p. 124). In the watershed of the small Mrichet El Anse reservoir in central Tunisia, Roose et al (2008) showed that 65% of the sediment arriving at the reservoir in a rainy year comes from the slopes and the rest is produced by the overcrowding of gullies and bank collapses, i.e. a rate of 35%. Kambou and Zougmoré, (1996, p. 20) explained that clearings, also called "zipelle," are characterized by the existence of an erosion crust on the surface that prevents any water infiltration into the soil. Roose, (1985, p. 514) added that on bare soil, runoff is multiplied by 20 to 50 on the other hand erosion, it is multiplied by 100 to 1000. Kanfando (2013, p. 29) mentioned that the factors and processes of stream deterioration are of several orders. The analysis of the results also showed that market gardening plots, bricklayers, and aggregate extraction promote sediment transport to the reservoir water basin. These results are similar to the work of Boena, (2001, p. 59) on Lake Bam, who showed that the development of irrigated perimeters on the banks without any protective measures is one of the most important factors in the silting of the lake. On the Niger River, Ferry et al. (2012, p. 20) showed that sand mining has resulted in low solid flows causing bed incision and undermining of banks, resulting in the loss of agricultural land and endangering engineering structures. Kafando (2013, p. 56) found in the Bomboré stream in Burkina Faso that catch basins installed on the minor bed or on the floodplain are practically full of sediment after the rainy season reflecting the importance of deposits. He also observed the decrease in the volume of water from the Mogtédo reservoir, which is subject to heavy agricultural exploitation. In the same vein, Le Breton (2005, p. 26), on a larger scale, mentioned that the modifications of the Niger River and its tributaries result in an increase in solid flows and therefore in a significant increase in sedimentary inputs and silting of the Niger River.

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The reduction of land erosion, and therefore of the transport of solids, requires the restoration of intense gully spaces and the recovery of denuded areas (Palé et al., 2020, p. 71; Roose, 2000, p. 132; Vlaar, 1992, p. 21). For these authors, SWH techniques have clearly demonstrated their effectiveness in reducing the volume of water runoff and sediment. These developments, while fixing a large part of the rainwater on the developed slopes, reduce the filling of the reservoirs. Kambou and Zougmoré (1996a, p. 19) have shown that in the Nakambe River watershed, the application of surface mulching and/or zaï techniques has resulted in the recovery of the initially heavily encrusted zipellé for subsistence cultivation. For Roose (1985a, p. 515), the restoration of land degraded by the implementation of erosion control measures first requires a study of the forms of erosion and their causes. The delimitation of protection zones and the revegetation of banks are measures to reduce the volume of scoured material carried by runoff towards the reservoir (Delage, (2002, p. 4). Drabo (2007, p. 46)on the Gourouol river in Burkina Faso mentioned that the restoration of the riverbanks involves raising the awareness of the populations on silting, the treatment of gullies, the protection of the riverbanks and the fixing of the dunes and the setting up of a development and ecological monitoring plan.

5. CONCLUSION

The various studies that have been carried out on the issue of filling of water reservoirs have all shown the importance of the phenomenon. This is the case of the Toukomtore reservoir. The phenomenon is worrying when we see the efforts that the public administration and its technical and financial partners are making to provide users with sufficient water to meet the various needs of the population. In the light of our investigations, a certain number of actions are recommended to reduce the phenomenon of filling of the reservoir even if the cleaning is carried out:

Action 1: Conduct information and awareness campaigns for the local population on the impact of their activities on the reservoir, particularly filling.

Action 2: Treat the bare or "zipped" areas above the reservoir by creating half-moons for sorghum cultivation. To do this, it is necessary to train producers on how to make half-moons.

Action 3: Treat the gullies located above the reservoir

When small or medium-sized gullies with restricted drainage areas are present, it is often possible to stabilize them by planting woody species across the water flow line, at a distance of 10 to 15 cm and in shallow trenches, and by protecting them with rows of stakes that are placed downstream at about 30 cm above the shrubs so that they can benefit from the retained soil. These shrub barriers, by slowing down erosion, allow the soil to pile up, which gives the spontaneous vegetation a chance to settle and take root in the soil. In order to be effective, these

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shrub barriers must be placed fairly close together. They should only be used in ravines that have a fairly gentle slope.

Catchment reservoirs can be constructed in a large ravine or dry stream bed to control erosion and flooding and to provide a water supply for livestock and wildlife. Filtering dikes can be made from free stones (not masoned and therefore without binders). The objective is to slow down the flood waves and stop the erosion by gullying in the immediate surroundings of the dike. These are anti-erosive structures positioned perpendicularly to the gully axes, more or less anchored in the ground, and equipped or not with a weir.

Action 4: Revegetate banks without vegetation

Two options have been retained:

- ✓ Protection of the stream banks by respecting a 50 m easement strip along the stream
- ✓ Revegetation of the stream bank.

Action 5: Establish a 50m protection strip around the water body and watercourses above the reservoir

Delineate a 50-meter-wide band around the reservoir. However, we must also be aware of the disadvantages that it may present, especially for the riparian population:

- ✓ High consumption of space for a rather low economic value (unless it is limited to a simple cordon);
- ✓ Feeding of the river with wood torn off by the floods, likely to create logjams, to obstruct bridges and to aggravate the floods locally;
- ✓ Contribution of organic matter due to the decomposition of leaves;
- ✓ Difficult access for fishermen.

Action 6: Develop a market gardening area for the population

To do this, it is necessary to build more suitable pipes (concrete) for market gardening activities.

Action 7: Identify favorable sites for brick production

Action 8: Identify sites suitable for sand collection

Action 9: Develop watering troughs and access roads to these troughs for animals

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