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Impacts of Surface Water Mobilization Structures on the Dynamics of Waterbodies and Vegetation in the Maggia Watershed in Niger

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ABSTRACT

Niger has experienced a series of droughts season that have severely impacted natural resources. To respond to this disaster, the country has turned towards the implementation of structural developments in the watershed. The objective of this study is to evaluate the impacts of developments on waterbodies and vegetation dynamics. In addition to population data, this study used climate data, and multi-dated landsat images. The methodology consisted of field surveys of 130 farmers in order to collect their perception on the problem. These surveys were complemented by an inventory of surface water mobilization structures, an analysis of climatic parameters and land use mapping of the valley. Dams and spreading thresholds are the main hydro-agricultural developments identified in the Maggia Valley. More than 90 % of the respondents say that these developments have had a positive impact on the dynamics of the basin's vegetation. For climatic parameters, they show an upward trend over almost the entire period of study. Land use has changed, first with the degradation of the entire vegetation cover from 1980 to 2000 and then its improvement from 2000 to 2020. This study shows that surface water mobilization structures contributed to the improvement of vegetation throughout the watershed and the reduction in the area of water bodies located downstream. It is therefore interesting to foresee the fate of the waters around the spreading thresholds.

Keywords: Maggia, Spreading Threshold, Dam, Vegetation

NTRODUCTION

Niger is characterized by an arid climate [1] with high variability of rainfall in space and time which exposes it to risks. These factors, combined with anthropogenic actions, lead to the degradation of natural resources, which reduce agricultural production performance by complicating living conditions for populations [2]. Thus, to meet their basic needs, populations engage in agro-pastoral activities that accentuate the ecological imbalance [3]. The most significant facts are the effects of droughts in the 1970 and 1980, which were accompanied by degradation of productive potential with loss of vegetation cover in catchment areas [4, 5] accentuating erosion. Thus, since the 1970, periods of exceptional drought have led to a severe degradation of natural resources and ecosystems with a significant negative impact on rural development [6]. Indeed, Niger recorded only eleven years of agricultural surpluses in the period 1960-2003 [7]. In response to this concern, the country has adopted strategies including the implementation of developments, including works for the mobilization of surface water for irrigation and the improvement of productive potential [8]. The period from 1970-1990 is the first phase of major development in the Niger River valley, the Komadougou, the Goulbi Maradi and the dry valleys of the Adder-Doutchi-Maggia [9]. After this, there are other series of relatively recent structural works. These were water retention techniques such as the threshold, retention basins, micro-dams, dams, etc., with the objective of restoring degraded lands with improved production [6]. All these measures are taken with the aim of reversing the degradation trends on natural resources. Generally, the impacts of development are observed after their evaluation. However, in the context of the Maggia, dams and spreading thresholds were not evaluated. It is therefore necessary to conduct the present study; whose objective is to assess the impacts of surface water mobilization structures on the dynamics of water bodies and vegetation.

METHODOLOGY

Presentation of the study area:

The Maggia Valley (Figure 1) is located between 5°30’ at 6°00’ E and 13°45’ at 14°30’ N. Drains the departments of Bouza, Malbaza and Konni before plunging into the Kalmano Pool in Nigeria [10, 11]. With an area of 1826 km^2, its orientation is North-East/South-West for the upstream part, while the downstream half is in the form of an arc of circle whose upstream branch is North-South and the downstream branch is East-West. The average altitude of the valley is 300 m [11]. The Maggia has a relatively steep slope and the impermeable nature of the soil limits degradation on its tributaries. It comprises three distinct zones [12]: (i) a slightly undulating plateau, dotted with lateritic blocks from the decomposition of ferruginous sandstone; (ii) a branched system of secondary valleys cut into the previous plateau and (iii) the alluvial Maggia valley, covered with a wide variety of soils. The climate is of the southern Sahelian or semi-arid tropical type, characterized by a fairly hot and humid rainy season, followed by a long dry season, first cool then very hot [13, 14]. The Maggia regime belongs to the Sahelian tropical type, which is characterized by intermittent flow from July to September and a strictly zero flow during the rest of the year [12]. The morphology of its basin is determined by the sedimentary sequence lithology, the stratigraphic series is covered with quaternary deposits constituted by alluvions, old and recent, by colluvions and usually stabilized wind deposits [14]. The geological profile of the Maggia basin is characterized by: upper Cretaceous, lower Eocene, continental terminal and quaternary.

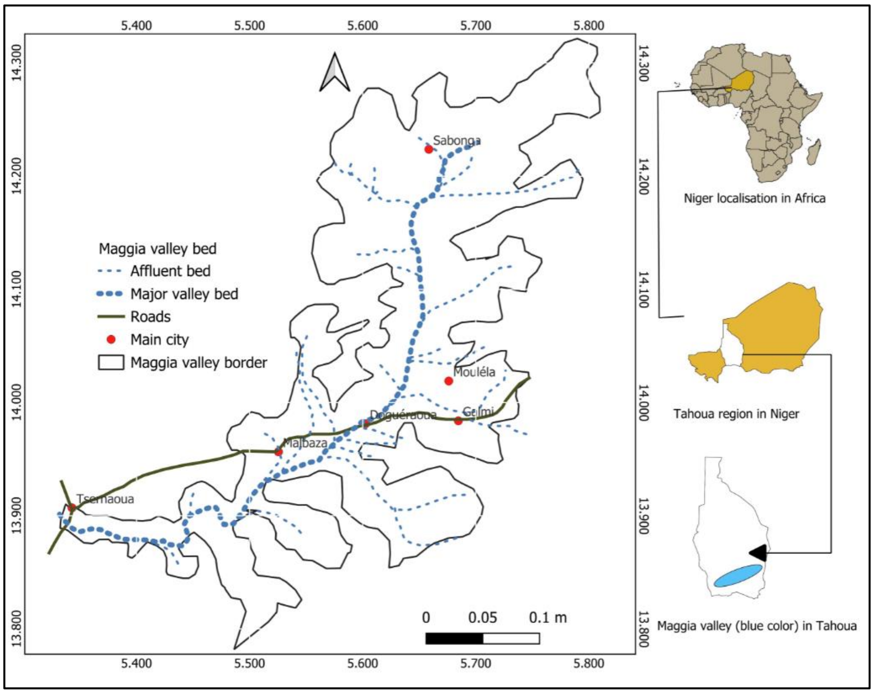

Figure 1. Map of Maggia location

Field survey and inventory of water mobilization structures:

First, various tools were used to facilitate the collection of field data. These are the interview sheets for operators, the observation sheets on developments and the watershed sheets. Surveys collected the perceptions of farmers on water issues. They focused on watershed degradation. A total of 130 farmers were surveyed corresponding to a sample of ten (10) surveyed per structure. The choice of farmers was made on the basis of their age and experience in watershed management. The inventory of developments was carried out in two phases. Information on developments was collected from the technical services, namely rural engineering and the National Office of Hydro-Agricultural Developments (ONAHA). Georeferencing using GPS of the works not in the technical services database. This georeferencing work required the involvement of local residents in order to indicate the structures that have not been identified but are located in the valley.

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Analysis of climate parameters:

This analysis covered the rainfall and temperature series of the Konni weather station. The station was chosen because of the availability of data and its proximity to the study area (Maggia valley). Data collected covers the period 1960-2023.

Development of land use maps in the watershed:

In order to track changes in the watershed, this land use maps have been elaborated each 20 years. For this reason, 1980 was considered as a reference year because it coincides with the great drought and also with the start of the development campaign in the valley. Landsat satellite images from the 1980, 2000 and 2020 were processed to produce the maps. The result of each year was interpreted and analyzed to assess change in the watershed.

RESULTS

Farmer's Collection and Distribution of Structures in the Valley:

All farmers surveyed stated that the watershed has changed over time. In addition, according to the same actors, sediment deposits are also found at the thresholds with a reduction in their height. Also, structures such as the thresholds that are completed 4 years ago have contributed to the reduction of the flow of the Maggia. The 85 % of farmers who testify that the level of the water table has risen against a decrease in floods compared to the period before the developments. For surface water mobilization structures, two (2) types (Figure 2) have been identified in the valley. Thus, a total of fourteen (14) structures including six (6) dams and eight (8) spreading thresholds were identified. They are mainly built on the minor bed and the tributaries of the Maggia (Figure 3). Dams are the oldest structures in the Maggia. However, the achievement of the application thresholds is concentrated on the period 2000-2020 (Table 1).

a. Guidan Magagi Dam (05/08/ 2024)

b. Threshold 2 Balgaya (08/10/2024)

Figure 2. surface water mobilization structures

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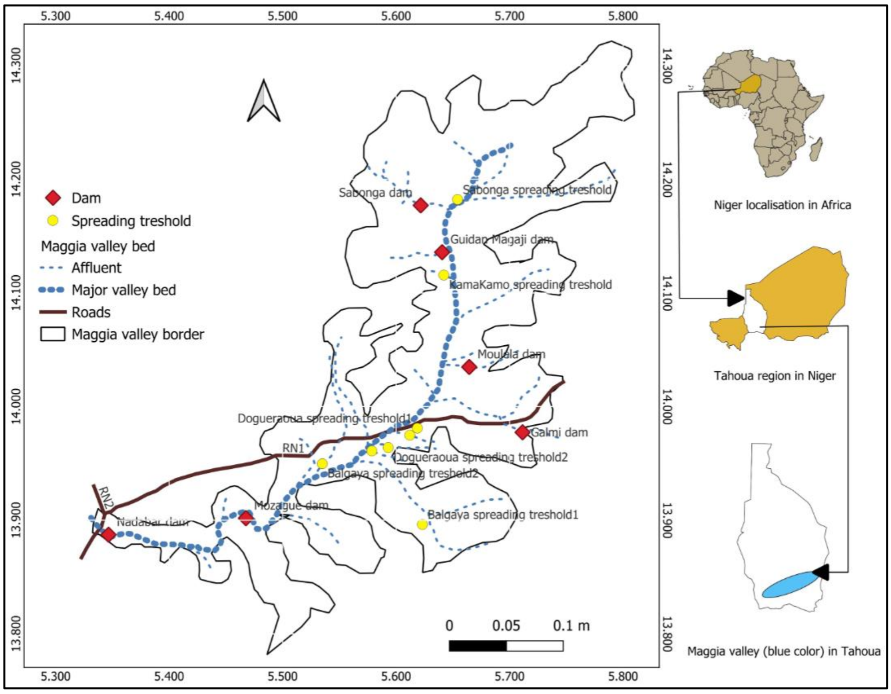

Figure 3. Distribution of water mobilization works in the Maggia

Table-1. Typology of structural works

N°	Type of structure	Year of construction	Realisation period
1	Sabonga Dam	1967	Before 1980
2	Mouléla Galmi Dam	1968	
3	Nadabar Dam	1977	
4	Galmi Dam	1982	From 1980 to 2000
5	Mozagué Dam	1981	
6	Guidan Magagi Dam	2013	From 2000 to 2020
7	Threshold Sabonga	2019	
8	Threshold 1 Doguéraoua	2020	
9	Threshold 2 Doguéraoua	2020	
10	Threshold 3 Doguéraoua	2020	
11	Threshold Kamakamo	2020	
12	Threshold Kouréga	2020	
13	Threshold 2 Balgaya	2021	After 2020
14	Threshold 1 Balgaya	2021	

Analysis of climate parameters :

- *Rainfall :*

Figure 4 shows the change in rainfall from 1960 to 2023. The analysis of this shows a main peak at the level of 2021 where rainfall exceeds 800 mm. Other peaks no less important are observed at the level of 1984 and 2006 with rainfall values ranging between 700 and 800 mm. Overall, the trend curve shows an increase in the amount of rain in the area with an average around 500 mm. The rainfall index at Konni is shown in Figure 5. Analysis of this shows three (3) distinct periods namely the normal, dry and wet period of 1960-1971, 1972-2020 and 2021-2023 respectively.

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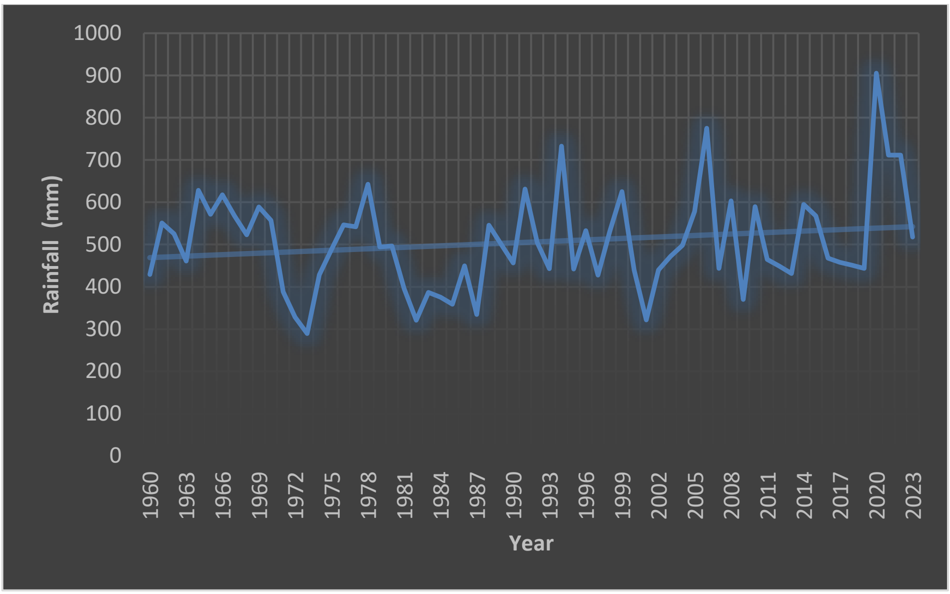


Figure 4. Maggia Rainfall Evolution [15]

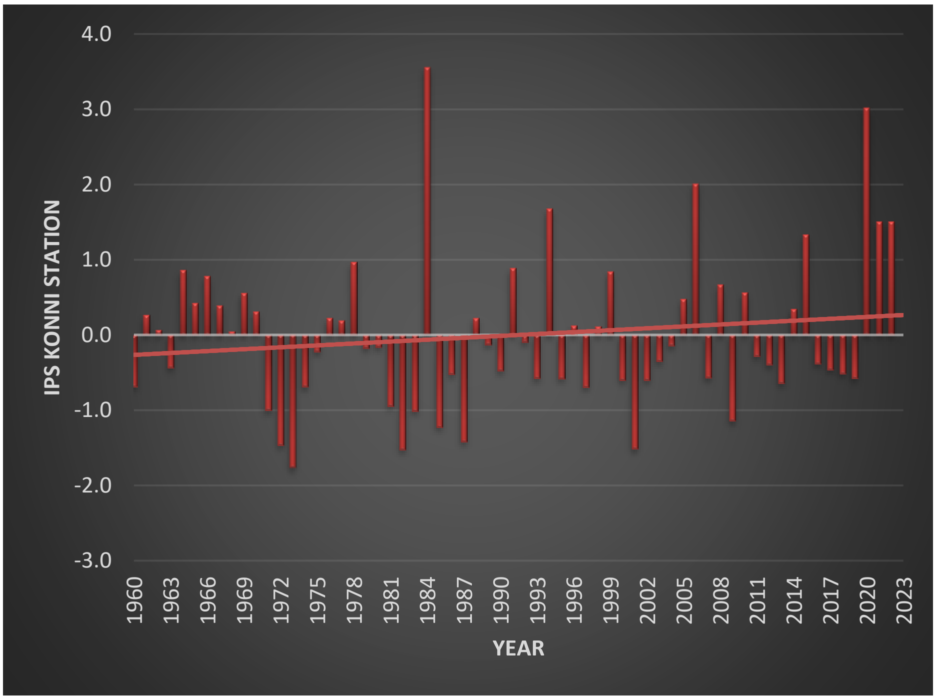


Figure 5. Rainfall index for the period 1960-2023 at Konni station [15]

- ***Temperature:***

The variation in maximum and minimum temperatures is shown in Figure 6. The two (2) curves are almost uniform over the period 1960-2017. For the period 2018-2023 there is a difference, the minimum temperature increases while the maximum temperature evolves like a sawtooth. Both the maximum and minimum average temperature have an increasing trend.

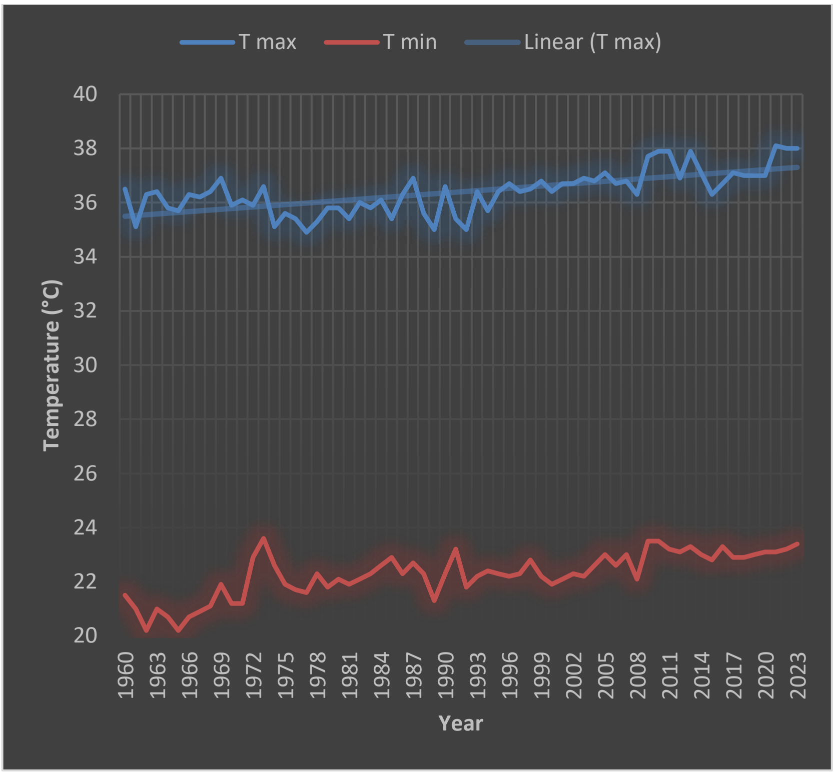


Figure 6. Variation in temperatures in the valley [15]

Land use evolution:

Figure 7 shows the area occupied by land use units for each year. The different units are shown in Figure 8. They concern bare soil, water bodies, vegetation composed of the riparian sheath, shrub savannah and the gardening area of the 1980, 2000 and 2020. Analysis of these shows an increase in the area of water bodies between 1980 and 2000, then its decrease in 2020. These bodies of water are mainly concentrated downstream of the catchment and concern the Mozagué and Nadabar dams. Soil has changed in each year of the study. Thus, an improvement in the area occupied by the riparian sheath over the entire study period is observed in the Maggia. On the other hand, a decreasing trend of shrub savannas was seen in the period 1980 to 2000, leaving bare soil. However, in 2020 the bare soils are decreasing to the benefit of densification of vegetation especially on the right portion. The growing area covers a larger area in 2020 followed by the 1980 and 2000.

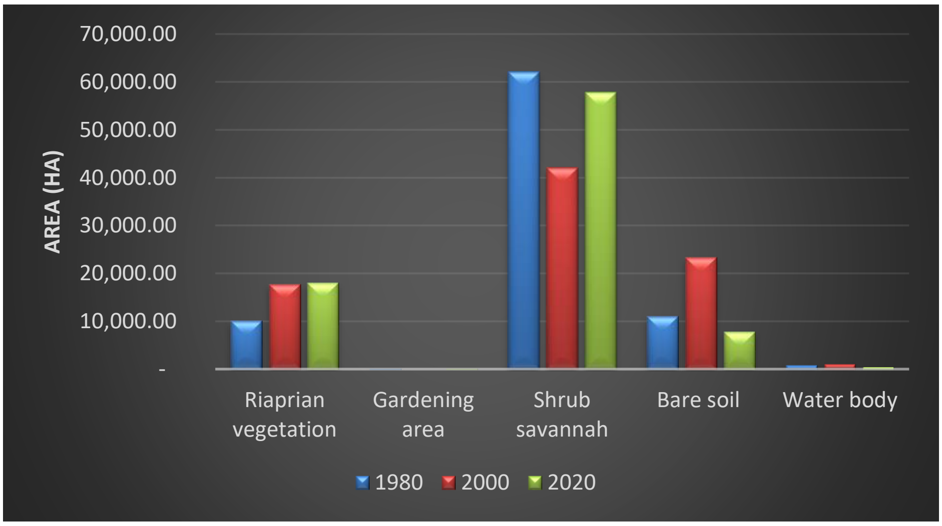
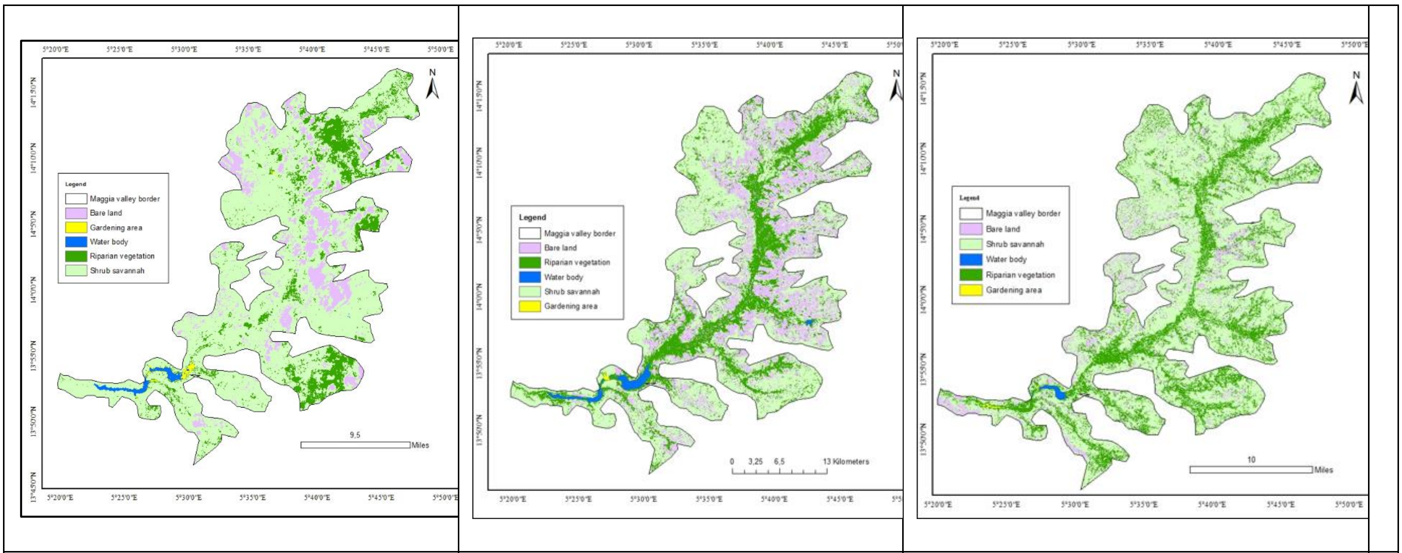


Figure 7. Evolution of land use units



1980	2000	2020

Figure 8. Land use in 1980, 2000 and 2020

DISCUSSION

At construction, the surface of the water bodies of the Mozagué and Nadabar dams is about 2000 ha [16] compared to 450 ha in 2020. Indeed, this decrease is observed with the achievement of the application thresholds. According to [17], a significant number of structures in a watershed influence the flow dynamics of watercourses. Thus, the spreading thresholds built on the bed of the Maggia reduce the flow of water streams while preventing them from reaching the structures downstream. By contrast, the small number of developments in the 1980 allowed the Maggia to benefit from major floods which fed the area [18]. These changes show that the thresholds play one of their roles, namely the accumulation of sediments that enrich irrigated land. This state, which is found again in the area of influence of the structures, allows a good development of the vegetation cover. Indeed, the thresholds with a vocation to and improve sediment deposition [19] facilitates spreading, access to water and development of vegetation cover. This result is reinforced with the realization of new land management technics implement around 2020 which reduces the flood and increased water storage in the Maggia. Those advantages have been confirmed by all farmers working in the area.

Climate parameters are trending upwards. This development is part of the dynamic of the country that is increasing [20, 21] and on the other hand the global one [22]. Also, the results found corroborate on one hand the work of [4] and [5] which testified to the drought of the 70-80 and another by the study carried out by [23] on the Mountséka kori (covered by the meteorological station of Konni) which shows a succession of normal, dry and wet periods from the year 1961 to 2011. Indeed, the intensity of rainfall allows formation of water bodies and development of vegetation cover [15, 23]. However, the variation in climate parameters (rainfall, temperature) affect water bodies and vegetation in the watershed. This is due to the increase in evapotranspiration on unprotected surface waters and soil [24, 17].

The observation in 2020 of the largest area occupied by the ripicole sheath is explained by the fact that this year coincides with the achievement of the thresholds of application thus testifying to the positive role they played. The ripicole sheath is characterized by the presence of dominant species such as *Acacia nilotica*, *Mitragyna inermis*, *Anogeissus lerocarpus* in the bed and *Pilostigma reticulatum*, C*ombretum glutinosum*, *Faidherbia albida*, *Acacia nilotica*, *Zizyphus mauritiana* in the bottom [10]. However, its low density for other periods is linked to anthropogenic actions such as deforestation and drought. These results corroborate [25] who showed the transformation of almost all land use units in watershed is due to the degree of anthropogenic or natural pressures. This or mutation is characterized by a decrease in water body and vegetation. Such dynamics combined with torrential rains and steep slopes erode the land that is drained to streams and water bodies, thereby reducing their area [26, 14, 27, 28].

Hence, a decline in the shrub savanna between 1980 and 2000 throughout the basin is observed, leading to an increase in bare soil over the same period. Bare soils facilitate erosion from the watershed to the seabed [18, 29]. This dynamic results in the reduction of water bodies due by the increase of sedimentation [30, 31]. The improvement of vegetation in 2020 is counted towards land development actions carried out with development. During this period, various investments were made by the state to increase rain-fed and irrigated agricultural production in order to guarantee food security [8].

CONCLUSION

Niger is facing the climate hazards that contribute to the degradation of natural resources. Several physical actions were taken to reverse the trend. The number of structural developments has increased in the Maggia Valley. Climate parameters are tending to increase. During the drought period, soil degradation has led to silting up of dams and a reduction in the surface area of water bodies. The new developments have resulted in improved vegetation with reduced bare spaces. Finally, this study shows that surface water mobilization structures contributed to the improvement of vegetation throughout the watershed and the reduction in the area of water bodies located downstream. It is therefore interesting to foresee the fate of the waters around the spreading thresholds.

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Conflict of Interest Statement: All authors have nothing else to disclose.