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Dynamics and Vulnerability of Hydrogeomorphological Units to the Degradation of Climatic Conditions in the Watershed of the Birnin Lokoyo Pond (Iullemmeden Basin, Southwestern Niger)

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Abstract

The present study concerns the lowlands of the Birnin Lokoyo watershed located in the Matankari Rural Commune (Southwestern borders of the large Iullemmeden basin in the Niger). Dominated by the Birnin Lokoyo pond, this watershed faced with the continuous silting up of the minor bed, dissipates further upstream in the east, so that it moves downstream to the west for the benefit of the populations of Matankari city. The main objective of this work is to analyze the representative elements of the new climatic and environmental situation as well as the various factors determining the surface conditions in the watershed. The methodological approach is based on documentary research, field observations, individual surveys and interviews with targeted groups. The results show that the silting up of the lowlands is the result of the concomitant degradation of the plant cover and the soils, which, as a result, triggered the development of crusting surfaces and area erosion on the slopes. The study underlined the importance of endogenous knowledge in the choice of remedies against the silting up of lowlands. In addition, rational land management practices on plateaus and structures (within the watershed) do not seem to be in phase with topographical factors and the tectonic framework. This work is part of the vision of better management of glacis on the banks, but also of sills subject to regressive erosion upstream and in order to guide the policies of resilience of the populations.

Keywords

Niger, Birnin Lokoyo, Wetlands, Hydroclimatic Variability, Soil Degradation, Silting Up

1. Introduction

In the Sahelian environment and particularly in a context of strong anthropization, uncertainties now relate to the extension of the phenomenon of runoff on the slopes [1]. These flows make it a dynamic hydro-sedimentary system, where changes in surface conditions play a major role in the gullying, widening or even deepening and silting up of watercourses [2] [3]. Numerous studies in these regions have linked this dynamic to changes in land use and to developments previously carried out by humans [4]-[9].

In Niger, [10] and [11] confirm the links established between the increase in runoff and the cultivation of land by showing that this leads to the crushing of soils. Due to the already difficult climatic conditions and/or changes, the problem of soils erosion arises acutely to become a major environment issue which consequently affects agricultural practices [12]. Thus, throughout the century, food security should be affected in its four aspects, namely: access, stability, availability and quality [13].

Therefore, responding to adapt to the reality of climate change is one of the strategic priorities of all communities and Nations. This is why farmers have taken a great interest in lowland lands since the drought of 1984-1985 [4]. What characterizes these wetlands is the vital role they play in preserving biodiversity, and the fight against poverty and food insecurity [14]. However, these ecosystems are in the process of silting up significantly, in other words undergoing extensive degradation, resulting in a drop in their production potential and a persistence of various conflicts [15] [16]. This is the case of Birnin Lokoyo pond where the hydrogeomorphological units of the watershed undergo quantitative transformations of surface states, as well as the influence of qualitative and consubstantial processes of climatic and environmental deterioration [17] [18].

The propose of the present work is to investigate and evaluate the main representative elements and determining factors of surface conditions. More specifically, it is about: 1) identifying the weight of the demands of use and development in a physical context subjected to severe tests, 2) present the different opportunities and challenges for the community, and 3) propose perspectives allowing to lay the foundations of a reflection framework on sustainable management of the Birnin Lokoyo watershed.

2. Material and Methods

2.1. Area of Study

The Birnin Lokoyo pond watershed is as sub-basin of the Dallol Maouri [14], which flows from the Ader heights in the north-east and descends to the east in the southwestern edge of the Niger sector of the larger Iullemmeden Basin (**Figure 1**). Located about 20 km north of Dogondoutchi (**Figure 1(b)**), it is confined within the latitudes 13.76707˚N - 13.83590˚N and longitudes 4.02905˚E - 4.08867˚E (decimal degrees).

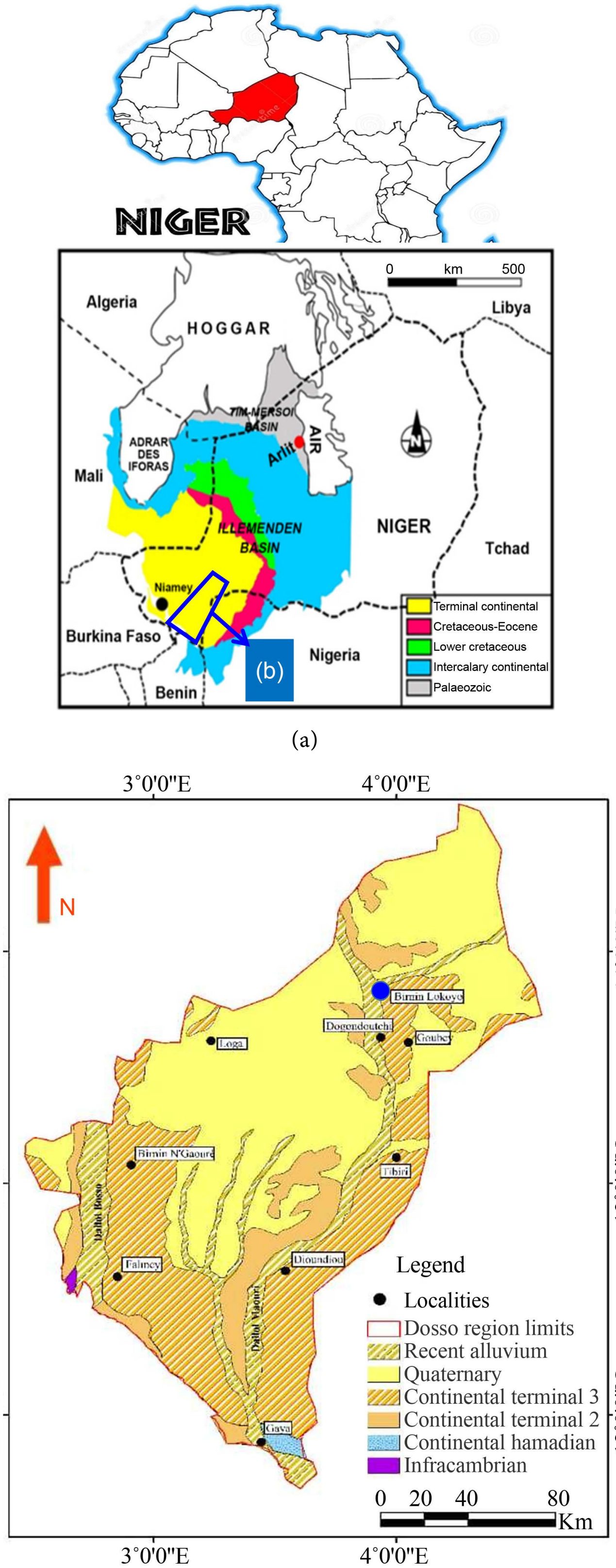
Extending over an area of circa 43.7 km^2, the watershed has an elongated shape of an isosceles triangle whose base is materialized by the lateritic Matankari-Bagadji (**Figure 2**). The area belongs to the central southern phytogeographic sector of the Sahelian zone (600 - 300 mm per year) and experiences a rainfall regime that varies in time and space [21]. The rainy season lasts between five and six months between from May to October. The dry season occupies all the rest of the months of the year with its cold and hot variants. The temperatures are high and the prevailing winds are the harmattan (in the dry season) and the monsoon (in the rainy season) [18].

The Iullemmeden basin is characterized by a detritical infilling, mainly Paleozoic in age in its northern part, while Mesozoic and Cenozoic sediments occupy its southernmost part [19]. The study area consists of two main overlying formations represented by an upper unit (Oligocene to Miocene in age) of the Continental terminal 3 (Ct^3) and Quaternary deposits. The Quaternary formations are composed mainly of sands of ancient erg, various colluvium and recent alluviums [20].

The geomorphological landscape is organized from the residual reliefs (witness mounds and tops of the Ct^3 platforms) to the flat-bottomed basins and lowlands which constitute preferential areas for the accumulation of runoff water coming down the slopes of surrounding hills. The lowlands are also areas of high groundwater recharge [22], and it is along such landforms that water reservoirs (e.g. the Birnin Lokoyo pond) and other hydro-agricultural development works are constructed [14]. A moderate slope and a specific drop of 59.5 m characterize the framework of the study area relief [17].

The noch of the valley and the well-defined major forms which dominate it testify to a character inherited from a paleogenesis attributable to the humid beginning of the Quaternary [23]. The end of the intense runoff, and therefore the intense digging of the valleys, resulted in the establishment of dunes [24]. These dunes are attribuable to the dry period of the Ogolian (20,000 to 12,000 years BP) during which Aeolian veneers formed on the plateaus, against the sides of the hills, between the hills and the gorges [25]. In the study area, the most visible protusions of these veneers or even Aeolian reworking are those on the north (on the borders of Mazankwoila) and south (western of Natchira) slopes (**Figure 2(b)** and **Figure 3**).

The typical formation of the plateau tops of the Continental Terminal 3 (Ct^3) is the tiger bush characterized by the alternation of covered areas and bare bands [26]. For this author, the bare bands play the role of an impluvium for the downstream wooded areas. In clayey sandstone slopes, vegetation cover is found along the koris that incise them [17]. It mainly consists of species such as



(a)

(b)

Figure 1. Iullemmeden basin geological schematic map (a) after [19], modified and localization of study area (b) within Iullemmeden basin [20].

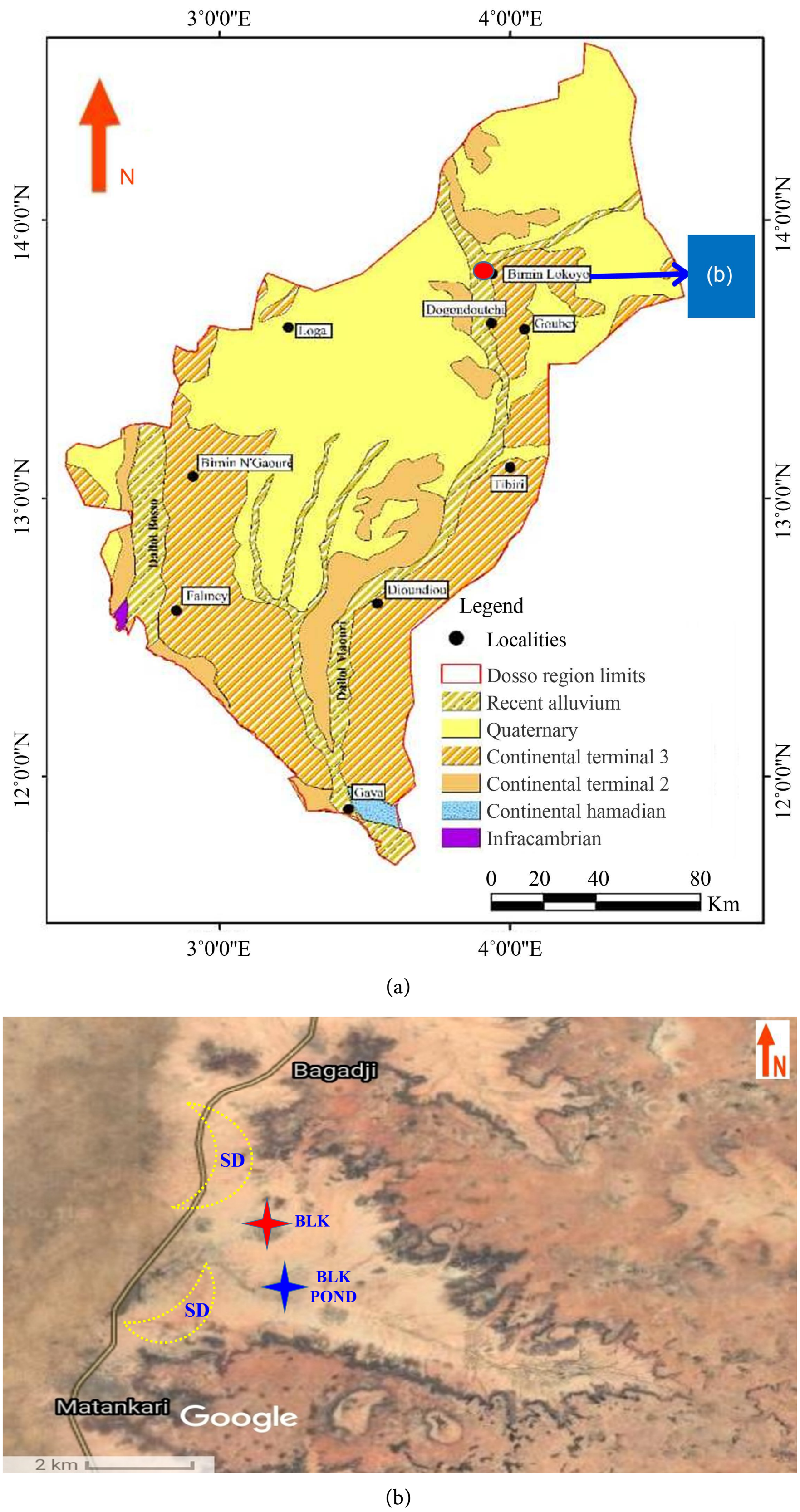


Figure 2. Location (a) [20], boundaries and physiography of the Birnin Lokoyo (BLK) pond watershed (b) and dune Sands Areas (SD) (Google Earth 2021).

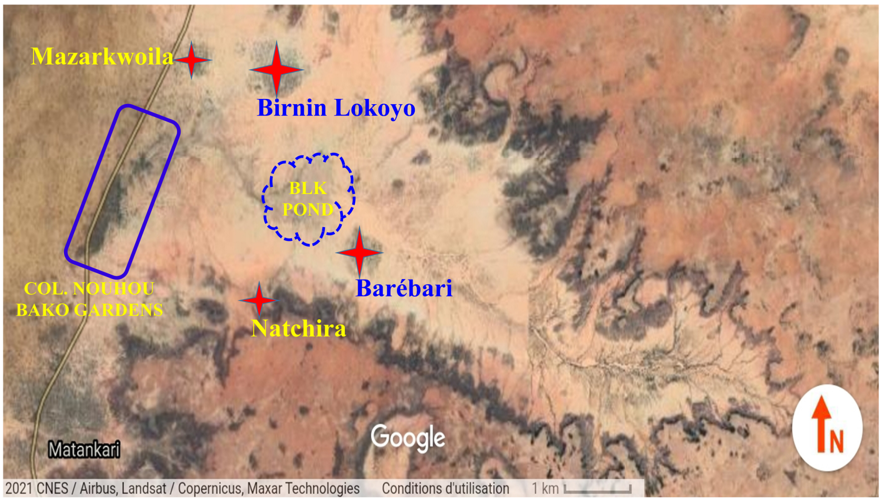


Figure 3. Boundaries and Toponymy in the Birnin Lokoyo (BLK) pond watershed (Google Earth 2021).

Combretum micrantum, *Guiera senegalensis* and grasses, as well as the tops of the plateaus. In glacis, generally short and steeply sloping [27], there is very sparse vegetation which is limited to a few species (*Guiera senegalensis* and combretaceae) along the flow axes. The vegetation of lowland areas is mainly characterized by *Annona arenaria*, *Faidherbia albida*, *Guiera senegalensis* and the herbaceous layer mainly grasses [17]. Feet of *Hyphaene thebaica*, in a sparse "green fascine" position in the minor bed of the main kori (*i.e.* wadi), still materialize the ancient expanse of Birnin Lokoyo pond. Understanding the dynamics that affect the lowland unit allows us to have an idea of stability or instability for better management of the watershed.

Three types of soils are commonly encountered in the municipality of Matankari, namely: 1) sandy soils, 2) clay soils and 3) loamy soils. According to [18], these soils are generally leached and hardly offer good agricultural yields. The population of the Birnin Lokoyo pond basin (Hausa, Peulh, Touareg and Zarma), always in search of fertile land, actively intervenes in the enhancement of wetlands, such as the shallows of the pond which constitute a palliative for climatic variability.

2.2. Methodological Approaches

2.2.1. Documentary Compilation

It marked the first phase of this study. It consisted of consulting as many scientific works as possible (articles, theses, dissertations) and previous work relating to this topic. As a result, administrative reports, consulted at the level of the town hall of the Matankari Rural Commune (MRC) enabled data to be gathered on rainfall, temperatures and wind speed. This exercise found that the MRC does not have a complete set of rainfall data for at least 30 years. To conduct the climatic study of the MRC from 1961 to the present day, data from neighboring meteorological stations, in particular those of Dogondoutchi and Dosso, were used. So, it is by interpolation of the few measurements obtained on precipitation, temperatures and winds that the climatic situation of the MRC is deduced. *Ultima forsan*, land use maps taken from [18], in addition to giving a fairly representative overview of the diachronic evolution (1986-2016) of the mineral landscapes of the municipality, made it possible to compile the climatic risks incurred in the study area. In short, this phase, in addition to taking stock of existing results, has the advantage of making it possible to assess the relationship between climatic variables and pressure from use. Basically, this involved an immediate site visit during the rainy season (July-August 2020), then another data collection in the dry season (December 2020).

2.2.2. Field Investigation

It was about collecting data directly in the field. Two approaches were used to identify the contours of the surface conditions and to know how the populations perceive and integrate the climatic deteriorations in the study area. The first was to make direct and systemic observations. Thus, visits were made throughout the watershed of the pond to observe the state of the latter, in its initial places of yesteryear and new of today. A notepad was used to note what was observed. A Sony camera and Android phones were used for relevant shots instead of the stakes in the dynamics of the pelvis. A GPS MAPS 64 was used to take the geographical coordinates of the places. The elements of geodynamics (e.g. erosion characteristics, hydrographic interfluve and confluence heads, or even NRM structures) outside the watershed were assessed by Google Earth framing on the computer and/or on an Android phone, before and during the field camp.

The second approach is based on questionnaires (in a focus group). This method makes it possible to visit the collective memory as well as the adaptations that these populations perpetuate. Several sites and towns were therefore visited in order to compare the reality on the ground (observations from step 1) with the perceptions of local stakeholders (approach 2). The agglomerations concern a sample of three villages (Birnin Lokoyo, Barébari and Natchira) and the town of Matankari (**Figure 3**). The choice of agglomerations is made based on their proximity, but above all on the dominance of their nationals in the exploitation of the pond. The choice of the villages of Barébari, Birnin Lokoyo and Natchira (not Mazarkwoila) was also imposed because they constitute the mass of the former operators of the pond. We therefore call this component: the eastern component mass (East) of the watershed. The city of Matankari constitutes the new western component of the population exploiting the pond. The respondents are chosen at random, according to their knowledge of the pond before and after its displacement, in addition to knowledge of old and/or new activities [28]. In the old component area, ten (10) people were chosen from each village (n = 30 people). At the level of the new component, forty (40) people were surveyed. A total of seventy (70) people were investigated in the Birnin Lokoyo pond watershed.

3. Results

3.1. Hydroclimatic and Morphodynamic Trend of the Landscape

A graphical representation of precipitation, annual mean temperature and maximum annual standardized wind, derived from the compilation of data for the years 1960-2010, is presented in **Figure 4**. Since the 1960s, the 1980s were the least rainy in the Matankari Rural Commune (**Figure 4(a)**). After the 1990s, there was a sudden increase in rainfall. In addition, we observe that from 1960 to 2009, the last decade was the rainiest. The break observed in the 1990s is also characterized by an increase of +1.3˚C (**Figure 4(b)**) and the maximum annual linear trend of the wind (**Figure 4(c)**).

Satellite images from 1986 (**Figure 5(a)**) and 2016 (**Figure 5(b)**) show the evolution of soil, vegetation and surface water resources in the area under study. This allows to see roughly the dynamics of the watershed of the Birnin Lokoyo pond. By comparing the two images, one can see the existence of koris (*i.e.* wadis) in 2016 in the watershed, whereas in 1986 there were no koris but many gullies, and therefore vegetation that lives on the edge of running waters. These landscapes presented here are a good illustration of the drying up of the pond, hence the lack of gullies.

Google images and field observations in the Matankari and Bagadji watersheds show that most of the lineaments are aligned with the drainage network along the NW-SE, NE-SW and N-S directions (**Figures 6-9**). The sub-basins of the dallol Maouri are superimposed on NW-SE direction lineaments (**Figure 2**). The lineaments of NE-SW and N-S directions, still very active, are used by new secondary koris. On the southern borders, at Matankari and along the Angoal Kara basin, the lateritic plateaus present sinkholes and show a process of widening of the secondary basins according to the N-S and NE-SW fractures (**Figure 7**). To the East, towards the Goubey basin, a phenomenon of regressive erosion is in coupling with lineaments in NE-SW and N-S direction (**Figure 8**). In the north, the hydrosedimentary entities (sinkholes and slopes) sometimes form closed systems and the regressive erosion of the slopes leads to exchanges of sand with the lowlands downstream (**Figure 9**).

3.2. Main Sources of Vulnerability in the Watershed

3.2.1. Human Activities on the Banks and in the Major Bed of the Watershed

The populations of the surrounding villages dig on the banks to find mud and gravel (**Figure 10**). This extraction of local materials on the banks partly clears the beds of torrents and accelerates the phenomenon of water erosion, in addition to promoting wind deflation in the dry season. Each year, field work as well as human traffic promotes the destruction and weakening of soils, as well as the disruption of the hydrological regime in the southern part of the watershed (**Figure 11**).

Water erosion has also created encrusted surfaces at the foot of the banks of Natchira and Barébari (**Figure 12**). We can therefore observe the existence of

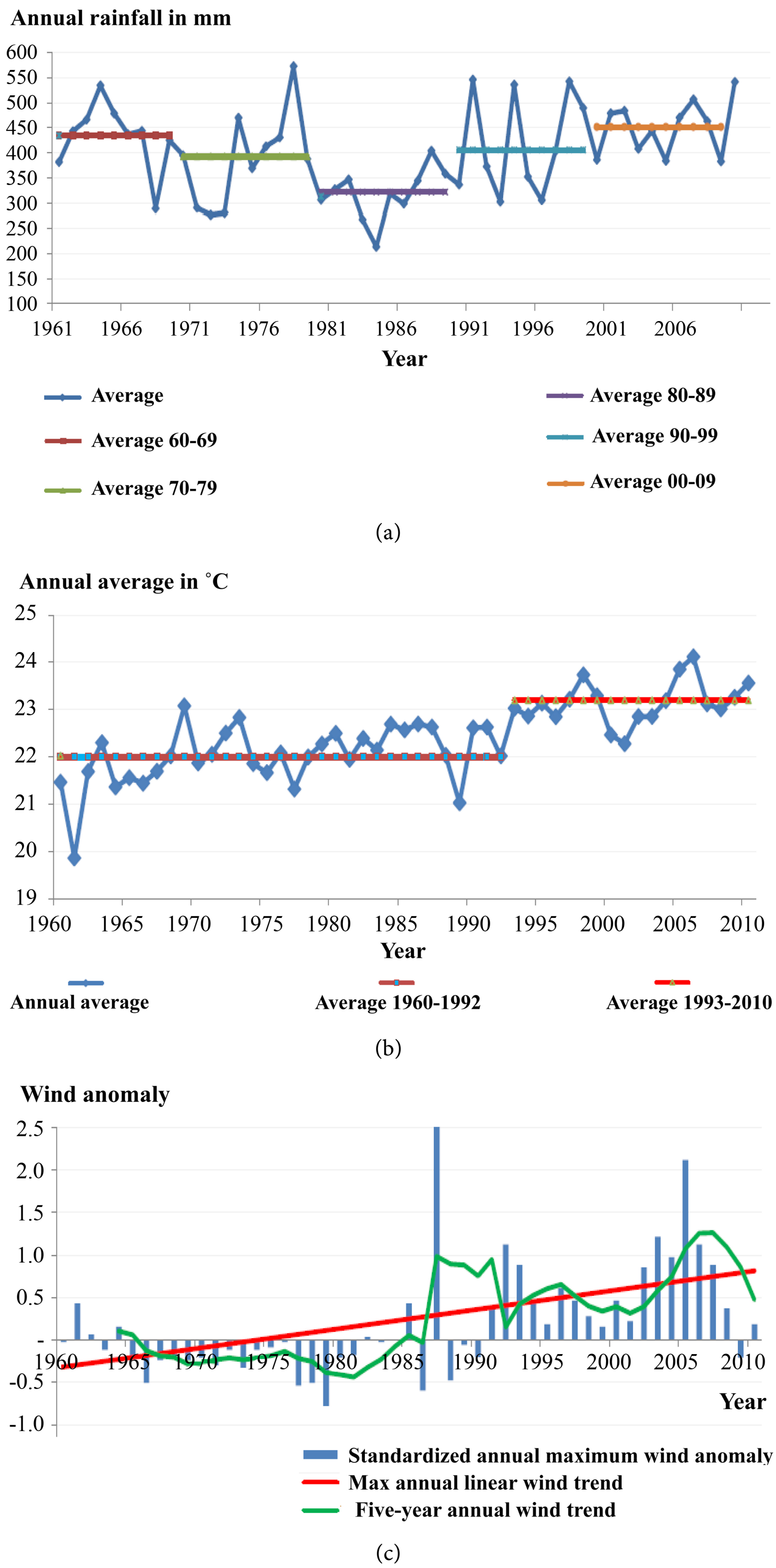


Figure 4. Ten-years rainfall trends (a), temperature change (b) and (c) maximum annual standardized wind anomaly in Matankari [18].

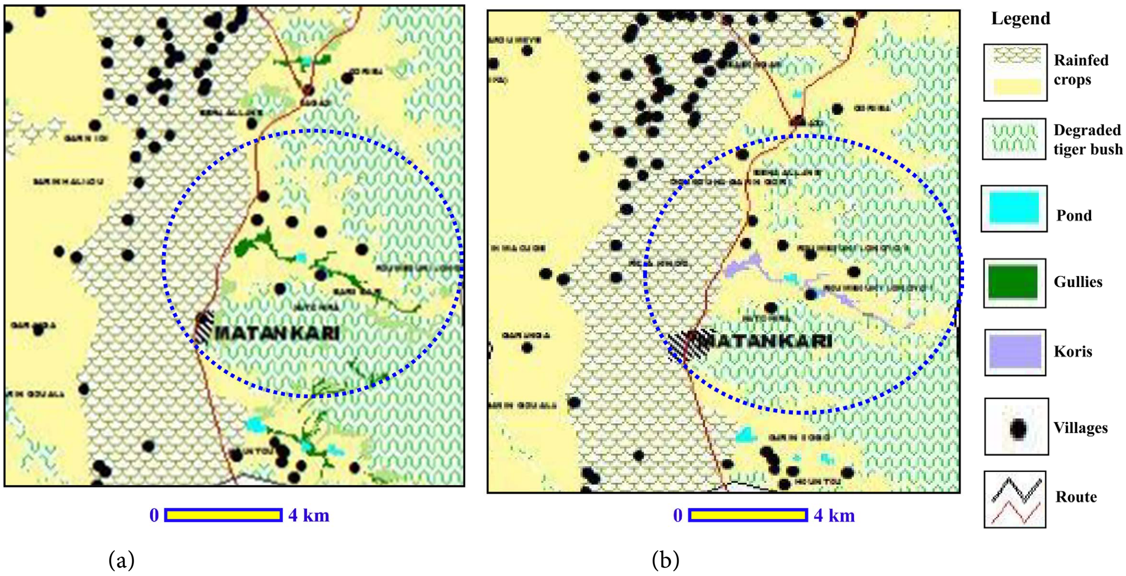


Figure 5. Land use, situations 1986 (a) and 2016 (b). The circle in blue marks the area under study [18].

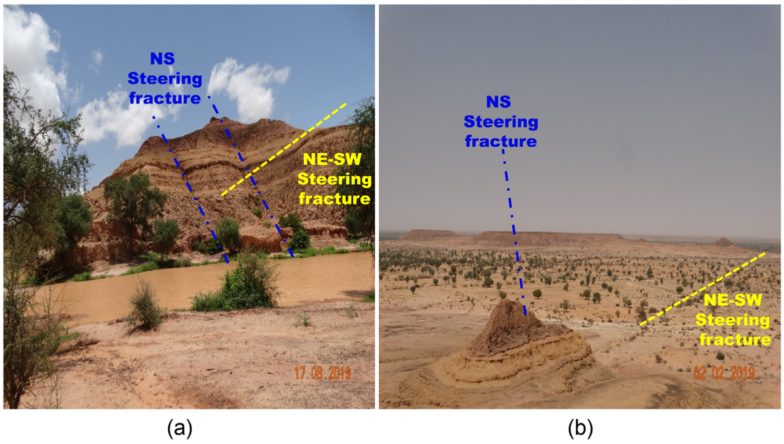


Figure 6. Main structural directions at the entrance of Matankari (a) and East of Bagadji (b).

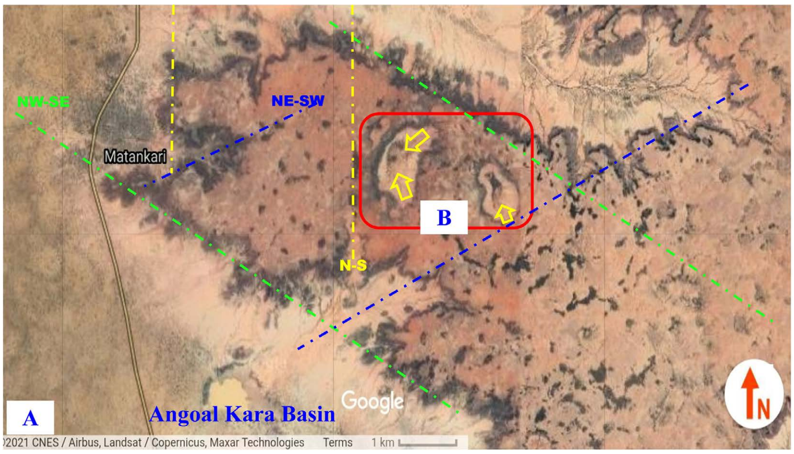


Figure 7. Major fractures and degradation marks in Matankari area and in northern Angoal Kara basin. (B) Sinkhole systems in southern plateau (Google Earth 2021).

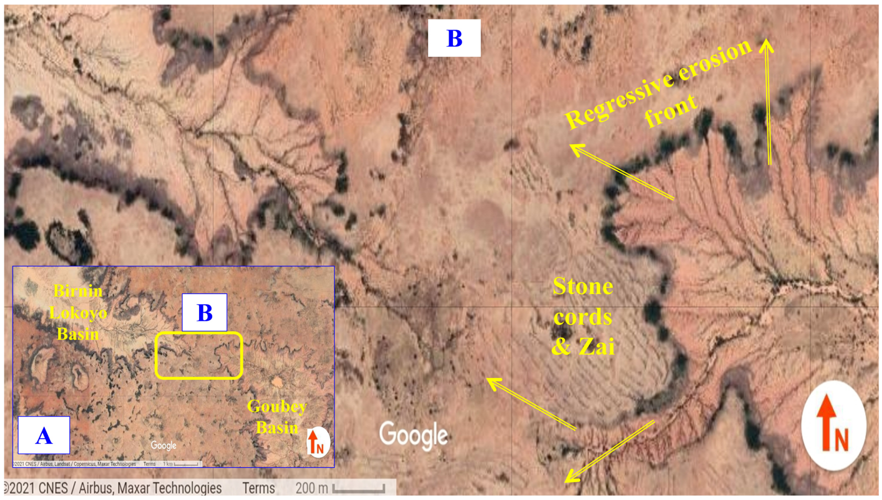


Figure 8. Inset presenting the stone cords and zaï in the interfluve zone of the Goubey and Birnin Lokoyo basins. High regressive erosion rate and water flow bypassing the stone cords at the risk of a water capture for the benefit of Goubey (Google Earth 2021).

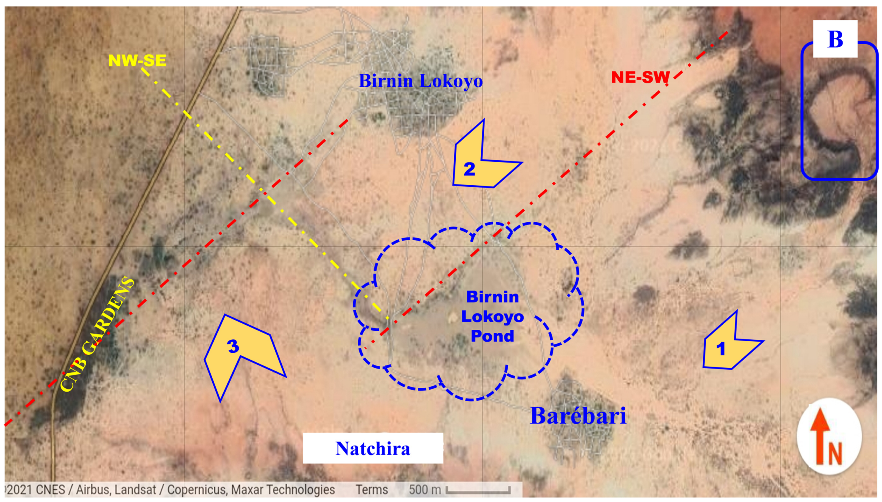


Figure 9. A. Major fractures in the pond and directions of dynamics accelerated by the regressive erosion of talus. (1-2) Red sands from the northern sinkholes (B) and Birnin Lokoyo NE banks. (3) Availability of materials related to soil borrowing and Natchira-Barébari bare surfaces (Google Earth 2021).

ferruginous rocks which are left by runoff water on large bare surfaces (**Figure 12(a)**). In addition, the formation of encrusted surfaces in the banks left imprints which, in terms of water competence, could thus contribute to gullying (**Figure 12(b)**). This would increase the risk of the secondary beds being silted up. Thus, on the southern banks, near Barébari and Natchira, there are branches which bring sand to the minor bed of the pond (**Figure 13**).

The silting up (**Figure 14**), despite the population's attempts to prioritize water retention, caused the pond to recede, in addition to the displacement of its water towards the town of Matankari. According to the population of Barébari, the dike (**Figure 15**) that they built to prevent the flow of water is the second.

(a) (b)

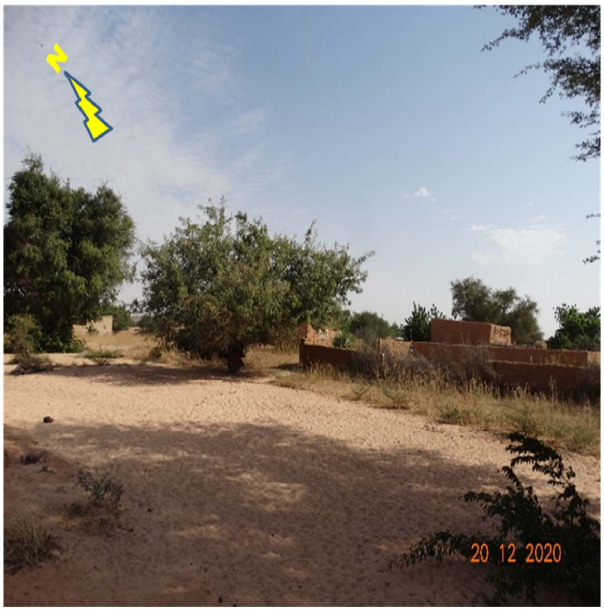
Figure 10. Human activities on the southern shores of the watershed. (a) Upstream, southwest of Barébari. (b) Downstream between Natchira and Matankari.

(a) (b)

Figure 11. Illustrations of the cases of impacts of human activity on the southern banks of the major bed of the basin (between Natchira and Barébari). (a) A bare field. (b) A path transformed into a ravine.

(a) (b)

Figure 12. Crusted (a) and stripped (b) surfaces at the edges of ravines in the south-west of Barébari.



(a)

(b)

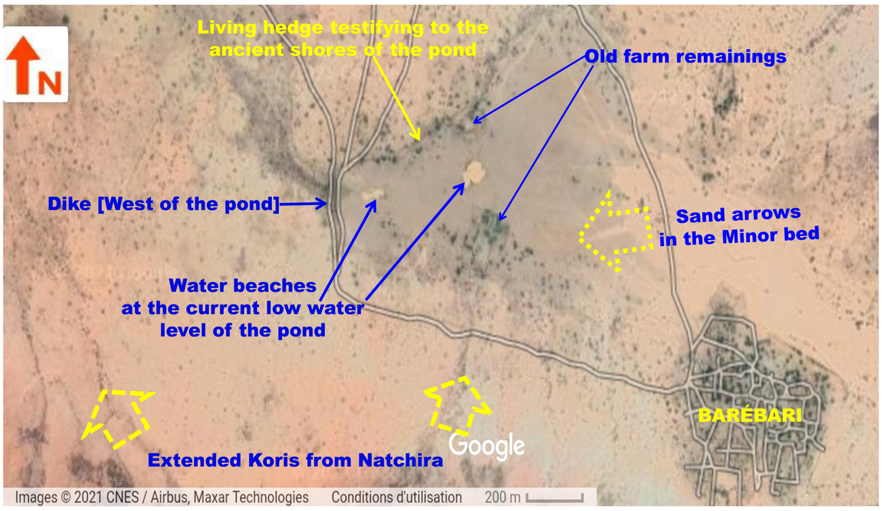
Figure 13. Surface states in Barébari. (a) Sand line at the western limit of Barébari. (b) Gully at the southwest of Barébari and source area of the sandy deposits from the west of the village.

(a)

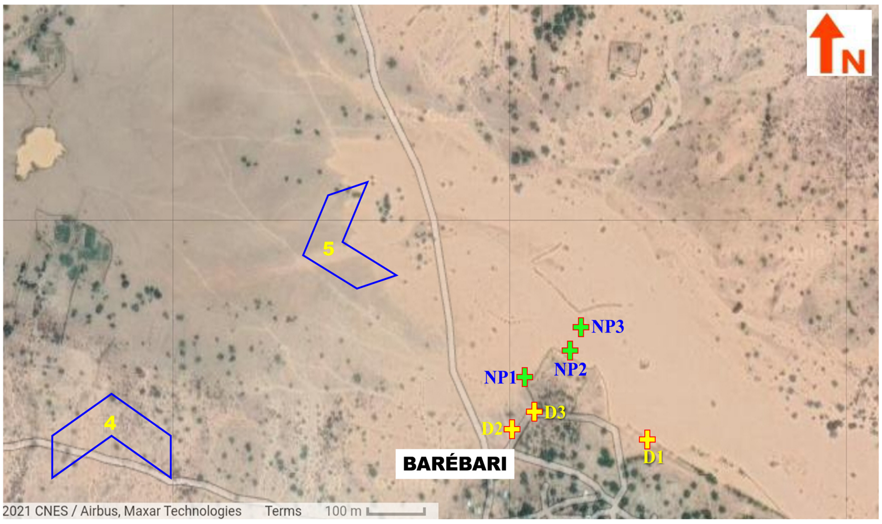
(b)

Figure 14. Surface states in the minor bed of the basin at Barébari. (a) and tree almost "smothered" upstream in the minor bed, north of Barébari. (b) Shooting (in rainy season) of the limit of the pond from the entrance to Barébari, showing the eastern head of the silting up of the minor bed.

The first was built 25 years ago and could not prevent the water coming from the pond to the west. The water even flooded the protective dike. Today there are only about ten farmers due to insufficient water and they can only grow cassava, squash and watermelon (**Figure 15(a)**).



(a)



(b)

Figure 15. Satellites view of the pond showing the state of play and various issues. (a) Dike marking the western limit of the pond and the protection parade against the advance of the pond towards Matankari. (b) Some general features of the hydro-morphological units and dissection impacts by runoff water on the parades. (4) Sand from the Western Barébari Bare surfaces. (5) Sand arrows in the minor bed. D1-D3: Damaged Dike of Barébari and NP1-NP3: Natural parades in the minor bed of the basin (Google Earth 2021).

3.2.2. Environmental Management Methods and Impacts on the Degradation Process

The survey shows that several projects have supported the well-to-do villages in the eastern component of the watershed. It was about donations of motor pumps and the construction of wells. These, unfortunately too deep, led motor pumps are stored in a store in Birnin Lokoyo. In addition to aforementioned dike, it is fitting that the protection of production sites in the first areas to be exploited is limited to wire fences. The western component (downstream of the basin), which has experienced flooding, undergoes an extension of gardens (**Figure 16**)

(a)

(b)

(c)

(d)

Figure 16. Type of fencing found in the western component of the watershed (gardens in Matankari). (a) Wire mesh fence. The market gardener indicates the level reached by water in 2018-2019. (b) Fence in branches of thorns around a garden (case of new extensions to the Colonel Nouhou Bako site). (c) Organic manure and (d) compost.

to the north (towards Mazarkwoila) and improvisations of fences drawn from thorny species (**Figure 16(b)**).

In order to achieve good agricultural performance, gardeners use fertilizers and amendments. The different types listed in the field include urea and NPK (15-15-15), but specially compost and organic manure (**Figure 16(c)** and **Figure 16(d)**). As shown in **Figure 17**), Matankari growers (at Colonel Nouhou Bako's site) use self-prepared insecticides from ripe Neem seeds (*Azadirechta indica*). However, the survey shows that phytosanitary products, distributed by the SWISSAID and Lux Dev projects, are also used.

Under these conditions of water runoff from the pond and its advance towards Matankari, silting is gaining ground upstream and becomes a daily and permanent concern for the populations of the eastern component upstream of the basin. Among the other consequences of the reduction in the duration of the flow of the pond, one can point out that the dike protecting against the advance of water and certain works to fight against water erosion, such as lifting, does not prevent the appearance of gullies (**Figure 18**).

The reality on the ground shows that the gullies are widening, damaging more and more the displays and threatening the houses and the mosque, the road and paths, schools and fields (**Figure 19**).

According to the population, some houses in Birnin Lokoyo fell by the runoff of water from tributaries of the pond so that landowners could be moved. To stop the sand advancing from the banks towards the pond, upstream in the minor bed of the main kori and the northern banks (towards Birnin Lokoyo), the species *Sida rhombifolia* was planted by making a curtain of living hedge (**Figure 20**). Wherever there is this species (*i.e. Sida rhombifolia*), alone or in association with *Hyphaene thebaica* (**Figure 20(c)**-NP2 and **Figure 19(b)**-NP1), it is more difficult for the sand to pass through it.

3.2.3. Concentration, Effects and Adaptations of Herbaceous and Woody Formations

The main species found at the study site that, over the years, have declined the most on both sides of the pond are *Faidherbia albida*, *Eucalyptus pauciflora*, *Piliostigma reticulatum*, *Mitragyna inermis*, *Accacia macrostachya* and *Cassia mimosoides*. At the height of Natchira and Barébari (**Figure 3**), it is the species naturally present on the banks that block the sand and slow the wind speed. These include species such as *Guiera senegalensis*, *Combretum micranthum* et *Andropogon gayanus* (**Figure 21**).

In the minor bed of the pond, the species *Vetiveria nigritana*, naturally present, also retains the sand (**Figure 22**). By its roots, it fixes the water, which allows the clay to remain. This species is very important to humans and animals. Thus, the local populations use it to make the clay bricks compact, while it constitutes a place of pasture for animals. Moreover, there are Fulani Peulh herders who have settled there in the confines of the pond to feed their cattle (**Figure 22(c)** and **Figure 22(d)**).

(a)

(b)

(c)

(d)

Figure 17. Photographs of some insecticides used by producers at the Colonel Nouhou Bako site in Matankari. (a) Rambo; (b) Momtaz; (c) Sumitex 40 EC and (d) Super Karto.

Figure 18. Paving in the western Barébari.

4. Discussion

The Birnin Lokoyo lowlands are undergoing more and more environmental changes. The most spectacular fact is the enormous quantity of sand which settles there at the bottom of the minor bed of the catchment basin in particular at its lowest point: the pond. The silting up caused a gradual decrease from year to year in irrigated cultivation part of the watershed to the benefit of the western

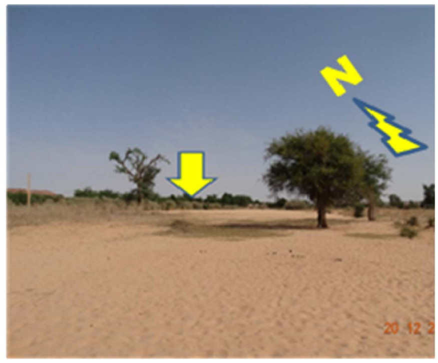
(a)

(b)

(c)

(d)

Figure 19. Northern borders of Barébari (cf. **Figure 15**). (a)-D1: Ancient dike on the south bank of the minor bed. (b)-NP1: Living hedge of protection in Barébari. (c)-D2: Forced water-forced breach of the protective dike at the northern entrance to Barébari. (d)-D3: Flood protection dike at the northern entrance to Barébari.



(a)

(b)

(c)

Figure 20. Planting of *Sida rhombifolia* against the ensalisation of the pond and the ravine (a) in Birnin Lokoyo (southern exit, leaving towards Barébari); (b) upstream in the middle of the minor bed and (c) upstream on the southern slope of the pond at the entrance to Barébari. There are in (c) plants of *Hyphaene thebaica* in the foreground and left. Note that photos (c)-NP2 and (b)-NP3 correspond to sites NP3 and NP2 in Figure 15, respectively.

(a)

(b)

(c)

Figure 21. Species: (a) *Combretum micranthum*; ((b) and (c)) *Guiera senegalensis* and *Androppogon gayanus* against silting up.

(a)

(b)

(c)

(d)

Figure 22. The species *Vetiveria nigritana* against silting up and its potentialities. (a) On the western shores of the pond above the discharge dike towards Matankari. (b) Brick-making activities on the western shores of the pond (in the south, towards Natchira). (c) Cattle in the minor bed, upstream at the eastern limit of the pond. (d) Ubiquitous installations of some breeders on the northern banks, towards Birnin Lokoyo.

area, towards the town of Matankari downstream. Gaining an increasing agricultural yield every year, the farmers of the Matankari site claim that the irrigated crop allows them to meet all their needs or even prevent them from leaving for an exodus [28].

4.1. Triggers of Pond Silting up Problems

Interpolating data on climatic elements shows that the decade 2000-2010 is the wettest. This is why [17] estimates that the hydrodynamics in the municipality of Matankari are parallel of this increase in rainfall. These results confirm those of [3] who, after observing an increase in rainfall in the watershed of the kori of Mountséka (south central Niger), made the obvious but interesting observation that the flows increased, accentuating the influence of the phenomena of gullies, the stripping of loose soil, and therefore the availability of sand borrowings. In the same vein, [29] [30] and [31] went into more detail and found after a comparative analysis in the basins on basement and sediment cover a strong correlation between the improvement of rainfall and the intensification of climatic aggressiveness to admit that the increase in flows is respectively related to climate and man.

Thus, the large quantities of sand in the watershed of Birnin Lokoyo are the result of an evolution of the koris on the banks and specially of the great competence of the runoff water which transport them from their deflation or erosion towards the minor bed. In addition, the available enlisted surfaces and ferruginous rocks have increased with the decrease in vegetation cover on the southern edges of the basin. Decrease in land cover leads to increase closure of infiltration pores and therefore accelerated runoff [6] [27]. Furthermore, the increase in runoff remains dependent on the draining of materials on the banks by the population, which in addition to accentuating the creation of some gullies has also led to the extension of the drainage network in depth and space. In this sense, and from season to season, the stripping work in the banks makes koris the main geodynamic force which deteriorates the little that remains of "natural display parades" but also aging gabions. As a result, over time, many plants become bare upstream (**Figure 10**) and downstream buried and smothered (**Figure 14**). This observation is very close to those of [29] [32], as detailed in the methodological approach for building a database for monitoring hydrogeomorphological systems in the kori Dantiandou basin (Niamey square degree).

4.2. Amplifying Factors of the Silting up Problems of the Watershed

Analysis of the Google images (**Figure 9** and **Figure 15**) revealed that the northeast of the pond experienced a significant increase in the rill erosion more concentrated around the slopes which lose soil after the stone ridges on the plateaus. This tendency to increase the availability of red sands must have led to the loss of market gardens to the east and today supports a bypass of the former expanse of the pond to the north. With the borrowing of pebbles on the bare slopes of Natchira, these red sands constitute the new constraints imposed on the western component of the pond at the foot of Matankari (**Figure 9**).

Under the confession of an operator of the Matankari perimeter, it is already remarkable that the last two years are the least flooded (**Figure 16(a)**). In this context, it is therefore to be fear that the lost of water from the pond will have a higher vertical component than the intense overflow of water at the level of the threshold of the protection dike to the west. The infiltration of water through the dike and in the downstream areas is justified by the intensity of the connection of the NE-SW and NW-SE fractures, and therefore their fortuitous and respective topographic position (**Figure 9** and **Figure 15(a)**). These observations join those of [20], who showed that most these linear structures evolve to become permanent or temporary watercourses from which groundwater recharge takes place in the southwestern part of the Niger and the Iullemmeden basin.

Beyond the convergences of geodynamic factors of transformations that connect these different terrains, the other elements of kinship are linked to the evidence of the major role of powerful local decision-makers in the development of these processes. It is not a question here of denying the existence of a material reality of physical works and protection projects, but of questioning the theoretical foundations and representations that justify their context of execution. However, a number of criticisms can be leveled at their sources of unequivocal vulnerabilities. To paraphrase [7], the issue was not only ecological (e.g., stone cords on the plateaus to the north and east of the watershed; **Figure 8**). On the basis of fieldwork, with a very simplistic observation model, it is shown that the location of the protective structures, like that of the fenced perimeters on the southern banks, is not based on the dynamics of the basin and material realities of local knowledge (**Figure 19** and **Figure 20**). The actions of the management of natural resources (MNR) visible on the ferruginous plateaus were more effective than the desirable correction of slopes of glacis and koris on the banks. This poor consideration of the species "parades" in the major bed explains that they are not only the causes and severity of land degradation that are observed, but also their extension and the ultimate solution.

4.3. Impact of the Changing Surface Conditions of the Plateaus on the Productive Potential of the Birnin Lokoyo Lowlands

Over the years, the degradation of the vegetation covers on the plateaus (for the sake of motorized machines!) has given way to crusting on the bare slopes and thus an increase in the speed of flows in the glacis and low terraces. The dominance effect of recovery work plays its full role (**Figure 7** and **Figure 8**). To say that their presence certainly comes from the fact that wind deflation would be less [33] [34]. However, the jurisdiction of the land is already affected so that the stabilization of slopes and slopes will resist for sometime in the face of running water and local collapses (e.g. sinkholes; **Figure 7** and **Figure 9**). These sinkholes, which are really mini basins, would be responsible for a certain loss of water to the benefit of the Angoal Kara basin to the south (**Figure 7**). In addition, an increase in runoff combined with an extreme superimposition of secondary koris, according to the lineaments of NE-SW and N-S directions, will aggravate the water lost to the south (Angoal Kara) and West (Matankari).

A significant regressive erosion trend, combined with NE-SW and N-S fractures, is also observed in the interfluve zones of the Goubey and Birnin Lokoyo basins (**Figure 8**). This highlights the decisive role of the southwestern arm of the Goubey basin in driving a flow of water bypassing the stone ridges in favor the eastern basin. In the outliers and escarps of Ct^3 (**Figure 6**), the combination of the N-S and NE-SW fractures is accompagnied by stalls in favor of an increasingly pronounced plunge of the slope towards the Sud-East. This finding can thus be used as a structural argument and to invoke probable catches of water inflow ("exoreism") to the east by contiguous watersheds. In short, the decrease in water volumes in the east and an increase in losses to the southern sinkholes could lead to the drying up of the Birnin Lokoyo watershed even more quickly and fairly early. These results confirmed the research carried out by [35] who found that, in the Iullemmeden basin, 85% of the ponds that have disappeared or tend to disappear are located in the river beds where the intensity of the erosive dynamics generates their siltation or fragmentation.

Finally, the difficulty of defining "good" indicators is all the more important since the defects in the protections of the surfaces concerned and the degradation processes and the ensalting at work also result from the shortcomings of the spatial positioning of the structures (e.g. paving) used as parades. To say that if the experimental effort has been insufficient or even destroyed upstream of the watershed, it is time to support downstream the nobles and valiant young people who value the land in the confines of the garden of the late Colonel Nouhou Bako (peace to his soul) in Matankari! In this, it is time to frame the problem of the cessation of flood margins in the watershed by planning and relying on deep drilling at high flows.

5. Conclusion

This study has made it possible to identify the vulnerabilities and environmental management factors that influence socio-economic trends in the face of surface state degradation processes in a context of climate change in the Birnin Lokoyo watershed (Matankari, Dogondoutchi). The physical elements of the new climatic and environmental situation remain mainly the anarchic appearance of koris, gullies and bare or encrusted surfaces in the watershed, but also silting up of the Birnin Lokoyo pond. The most striking adaptation and parade strategies are paving in the shallows, stone cords and zaï on the plateaus. Using Google Earth panoramas, a correlation is established between the regressive erosion of koris, the main morphological variants (*i.e.* embankments, gullies, dolines), an "exoreism" of the waters towards the East or South and the tectonic dislocations of N-S and NE-SW directions. As NE-SW flows seem to be more active and the most competent, the primary silting up of the pond is a consequence of sand movements corresponding to the unsecured landscapes of the NE banks of the watershed. The results of the study show that the former farmers of the pond (villages of Barébari, Birnin Lokoyo and Natchira) find themselves without activity because it is the pond that allowed them to satisfy many needs. Nevertheless, the advance of the pond towards the West is an asset for the inhabitants of the town of Matankari.

Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

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