

Analysis of the Physical State and Operation of Hydraulic Infrastructure in the Konni Irrigated Area before Rehabilitation

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Abstract

In Niger, irrigated agriculture constitutes the main alternative for meeting family needs. It is within this framework that the state and its partners have adopted strategies to promote irrigated production sites. This study was carried out on the Konni irrigated perimeter, the objective of which is to analyze the physical state of hydraulic infrastructures and their operation before the rehabilitation of the said perimeter. The methodology adopted consisted, first of all, of documentary research focused on data relating to this scope and our theme to properly guide the collection of data in the field. The field phase was then followed with an observation of hydraulic infrastructures one by one in order to assess their condition. Thus, the collected data was processed and analyzed. The results of this study show a notable deterioration of hydraulic infrastructure which affected the operating yield of the study area, with the development of barely 700 ha out of 1226 ha planned by the basic study for off-season production (57%). Bathymetric measurements showed that the volume of sediment that accumulated in the Zongo Dam is 1.2 million m³, which reduces its initial capacity from 12 million m³ to 10.8 million m³ after 43 years of service. The expansion joints of the feed canal are all in poor condition. 90% of the total length of the tertiary canals are degraded, 82.32% of the panels of the main canal C are degraded and 17.68% are cracked. All crossing structures are blocked between the RN1 and the Zongo dam. Based on this critical situation, it would be essential to consider rehabilitation work on all infrastructure in order to restore the hydraulic and even agronomic performance of the Konni irrigated area.

Keywords

Irrigated Area, Dams, Rehabilitation, Work Monitoring, Distribution Network, Konni

1. Introduction

Niger is a Sahelian country located in West Africa, which is characterized by the most unfavorable climatic conditions, with low rainfall and very often poorly distributed in time and space. In Niger, as in other Sahelian countries in the West African sub-region, the population is repeatedly confronted with food crises. Rainfed agriculture is based on sandy soils, which are characterized by a natural poverty of organic matter, a low content of nutrients (notably phosphorus and nitrogen), and low water retention which is added to the water deficit, which can all influence soil productivity [1]. To fight against the famines that populations frequently face, the authorities of Niger have highlighted the development of irrigated crops in regions where water and land potential exist.

This political will was manifested through the development of several types of irrigation systems, namely hydro-agricultural developments with total water control, off-season perimeters, private irrigation, collection of water from runoff, large and medium commercial irrigation [2]. In the area of total water control, this policy materialized through the development of approximately 13939.75 ha including 8408.05 ha of rice fields and 4696.75 ha of mixed farming [3].

These areas are distributed between 67 perimeters between the regions of Tillabéry, Dosso, Tahoua, Maradi, Zinder, Agadez, Diffa as well as the urban community of Niamey. Hydro-agricultural developments which were built before the 1980s are in most cases in a dilapidated state.

In Niger, as in most irrigated areas with total water control, the factors which influence the degradation of hydraulic infrastructures are among others: degradation of ridges, breakage and/or cracking of panels, existence of cracks, lack of defective seals at the panel level, grassing of irrigation or drainage canals, silting, lack of upkeep and maintenance means for these infrastructures and finally the floods [4]. These factors of degradation of hydraulic infrastructure coupled with climate change lead to the problem of insufficient irrigation water in irrigated areas. We need to think about rational and sustainable water management. Water management refers to sustainable use of water resources in the field, through better management of the soil-water-plant system through optimized use of water sources: rainwater, irrigation water as well as reducing water losses [5]. Sustainable management of agricultural water is one of the principles that the water manager or the director of the area must take into account, especially in our areas where the deterioration of hydraulic infrastructure is increasing from year to year. If this degradation reaches a critical threshold, where the infrastructure is obsolete, the solution is the rehabilitation of the perimeter.

This is the case of the Konni perimeter which is more than 40 years old and will be the subject of this study. The general objective is to make a diagnosis of the state of hydraulic infrastructures and their operation.

2. Material and Methods

2.1. Material

The materials that we used as part of this study are the study site, the data collection tools in the field and finally the tools for analyzing and processing this data.

Konni irrigated perimeter

The Konni perimeter is split into Konni 1 and Konni 2, each managed by a cooperative. The Konni 1 perimeter with an area of 1012 ha brings together 15 Mutualist Producer Groups (GMP). The perimeter of Konni 2 covers an area of 1440 ha and is made up of 19 Mutualist Producer Groups. The 34 GMP became 23 hydraulic sectors as part of the reform of cooperatives and ONAHA, which led to the creation of the Association of Irrigation Water Users (AUEI).

The area is used by 3150 families from 12 villages and there are more than 4000 heads of families who operate this hydro-agricultural development in Konni. It is fed by the Maggia, a river which flows only in the rainy season, two earthen dams Zongo and Mozagué having respectively a capacity of 12 and 30 million m³ at creation. These two dams supply a buffer reservoir in Tcherassa via a 15 km long supply canal. **Figure 1** illustrates the geographical location of the Konni perimeter with its related infrastructure.

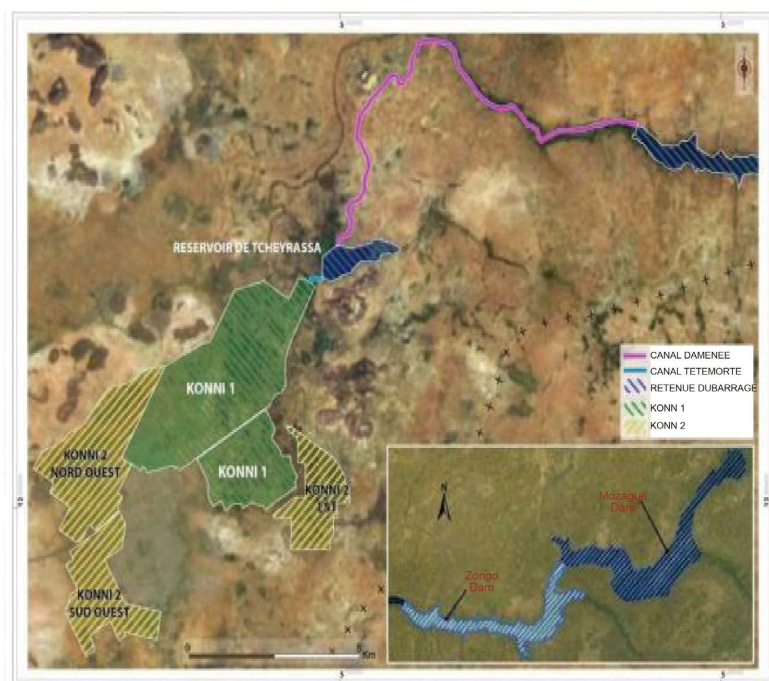


Figure 1. Overview of Konni 1 and 2 Irrigated areas, Zongo and Mozagué dams [6]. On the left and below, we have Konni 2 Irrigated area (yellow) and Konni 1 Irrigated area (green). On the right, bottom, Zongo dam (light blue) and Mozagué dam (dark).

2.2. Methods

The methodology that we adopted is summarized in two steps (2):

- This phase allowed the development of tools allowing us to meet the objectives of the study. This is a sheet developed to collect data relating to the physical state of hydraulic infrastructures over the entire study area and their operation;
- The second phase served to cover all of these infrastructures such as mobilization and transport works, irrigation canals, protection and drainage networks, in order on the one hand to assess the physical state of these works as well as than their operation. This will make it possible to identify as much data as possible relating to the state of these structures.

Good management of an irrigated area requires a diagnostic approach. With some differences, the same methodological approach is applied to all the sites selected for this diagnosis. It is based on the “Participatory Diagnosis and Planning of actions to improve the performance of irrigated areas (DPRP)” method developed by IWMI and ARID [7]. It is an approach which seeks, in collaboration with farmers, to analyze the performance of their irrigated system. It makes it possible to diagnose the main constraints and then produce an action plan with a view to improving the system. In this study, we used the DPRP method in half for all stakeholders, that is to say we only carried out a diagnosis of hydraulic infrastructure.

To achieve the objectives set for this study, it is essential to adopt an appropriate methodology. The methodology adopted is presented in three (3) essential stages which are: site visit, documentary research, field work.

Step 1: Visit the site

The visit is organized for reconnaissance of the site, contacting irrigators, technicians and informing them of our upcoming visits. This first phase aims to justify our visit and obtain general information on the area.

Step 2: Documentary research

As knowledge can never be based on a single source and the information is scattered and sometimes contradictory, it is imperative for us to consult the documents relating to the Konni irrigated area from the competent institution which is the ONAHA (National Office for Hydro-Agricultural Developments) documentaries.

Step 3: This is a set of semi-directives, qualitative interviews with the cooperative, the Director of the perimeter and the operators to collect information on the physical state of the Hydraulic infrastructures at the level of the study perimeter;

In terms of the data collection method, taking into account the different groups of stakeholders involved, the following tools were used:

- ✓ An interview sheet with the area director;
- ✓ A survey sheet at the producer level;
- ✓ and a sheet for collecting data relating to the physical state of hydraulic infrastructure in the Konni perimeter.

Step 4: Field work

- The summary field survey which consisted of making visual observations of the hydraulic infrastructures;
- Interview with the different management structures on the perimeter (cooperative and AUEI), the DP, the producers;
- The pumping system (pumping station and energy source and hydraulic operation).

Physical observation consisted of exploring the perimeter to note the physical state of the plots and hydraulic infrastructures. At the end of this observation, a comparison of ideas is made with the aim of correcting certain erroneous information that was given during the interviews.

An interview guide adapted to each type of actor has been developed. The idea is not to fill a questionnaire, but to let the interlocutor express themselves freely, starting with a historical overview, while subsequently asking for clarification on certain points.

3. Results and Discussion

3.1. Results

3.1.1. Water Mobilization Works

a) Dam of Mozagué

Bathymetric measurements showed that the volume of sediment that accumulated in the Mozagué dam reservoir is 9.77 million m³, which reduces its initial capacity from 30 million m³ to 20.2 million m³ after 35 years of service.

b) Dam of Zongo

Bathymetric measurements showed that the volume of sediment that accumulated in the Zongo Dam reservoir is 1.2 million m³, which reduces its initial capacity from 12 million m³ to 10.8 million m³ after 41 years of service.

c) Tcherassa reservoir

Initially, in its normal filled state, the Buffer reservoir has a useful volume of 1.2 million m³. Bathymetric and topographical surveys carried out by [7] show that the current useful volume is 1.05 million m³, *i.e.* a reduction in its capacity of around 150 thousand m³ compared to the initial state. The total volume of siltation corresponds to the volume of the dead section to which we add the current siltation, *i.e.* a volume of 0.42 million m³.

3.1.2. Transportation Network

a) Feed channel

Water is conducted from the Zongo dam spillway to the irrigated area by a 15 km long intake canal. The investigation carried out during the first phase of the study showed that the cracked panels of the intake channel have one or more cracks. These cracked panels represent significant water leak points even if the length and thickness of the crack is minimal. The expansion joints are all in poor condition. Their complete replacement is necessary. Panel cracks.

b) Dead Head Channel

The canal has horizontal and vertical cracks along its entire length apart from a few panels. All joints are in poor condition. The panels of average length of 2m are either cracked or grassed. 40 panels have a continuous horizontal crack demonstrating a general subsidence of this section. The berms are bare. This channel must be completely rebuilt in reinforced concrete.

3.1.3. Irrigation Networks

The greatest stress observed on all channels is the presence of longitudinal and transverse cracks in the covering panels. Also, it was noted that all the channels are unreinforced and cast in place.

Generally speaking, these structures present visible structural disorders and in particular:

- Deterioration of expansion joints, hence the permanent existence of water leaks through these seals;
- The presence of trees around the gutters;
- The absence of riders on either side to protect the canals;
- Cracking of canal edges and subsidence;
- Aging of unreinforced concrete.

✓ Primary channels

a) Primary Channel A

This canal extends over a length of 11,500 ml distributed over three sections:

The results of the diagnosis give: 2843 degraded panels (*i.e.* 96%), only 14 panels have repairable cracks and the rest (175 panels) are in good condition.

- The third section concerns the part located downstream of the RN1. This section is in poor condition state.

The diagnosis identified 39% of cracked panels, 3.6% of panels in good condition and 57.4% of degraded panels.

b) Primary Channel B

This channel extends over a length of 7,275 ml. In its part located between the PA and the RN1, this canal is in poor condition.

The summary status of the diagnosis of the entire PB channel gives:

- 70.8% of cracked panels and 27.6% of damaged panels;
- 1.6% of panels in good condition.

c) Primary Channel D

The diagnostic result gives:

- 67% of cracked plates and 32.8% of plates are damaged;
- 0.2% of plates in good condition.

d) Canal Principal C

The PC canal with a length of 2990 m presents the following failures over its entire length:

- 82.32% of the panels are damaged and 17.68% are cracked;
- Very degraded civil engineering (over 40 years old);
- Damaged berms and the embankment around the canal to be cleared;
- The crossing structures are blocked;

- All joints are damaged and the rider is damaged in places.

✓ **Secondary Channels**

Plates in good condition concern plates 1m long. As soon as the length of the plates exceeds 2 m, cracks are apparent in the majority of the plates and the degradation of the plates intensifies. Photo 1 shows the condition of the secondary canals before the rehabilitation activities (**Figure 2**).



Figure 2. Very degraded secondary channels [8].

✓ **Tertiary Channels**

The diagnosis of the tertiary canal network gave the following results:

- 2477 m representing 2% of the total length of the tertiary canals are cracked. These are the canals rehabilitated in 2014 with some visible cracks.
- 8597 m representing 8% of the total length are in good condition. These are the canals rehabilitated in 2014.
- 101,821 m, representing 90% of the total length of tertiary canals, are degraded.

Sprinklers

The diagnosis of the watering channels of the second phase shows that these channels, executed in compacted fill, have disappeared. They were replaced by channels maintained by farmers. These channels are grassy, with degraded banks, many termite mounds are found in the area of these channels and also trees and shrubs.

At the end of each sprinkler there is a discharge facility into the nearest colature. These masonry structures are all degraded and broken and are no longer functional.

The diagnosis of this equipment shows a large number of mask modules presenting a sealing problem with often significant water leaks.

3.1.4. Crossing Works

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All structures are blocked between the RN1 and the Zongo dam. This is due to the lack of maintenance and cleaning of these structures. Due to the difficulty of

access and the growth of thorny trees and shrubs around these structures, these hydraulic structures do not work well.

Inverted Siphon

The structure of the Civil Engineering parts of this work is in a stable state. No protection device is installed at the entrance to the siphon (grid), which encourages the accumulation of large waste at the entrance to the structure and thus blocks the flow. This sometimes encourages water to overflow upstream of the structure.

3.1.5. Drainage Network

The secondary and primary colatures have a total length of 56751m. There are 7 primary colatures (A, B, C, D, J, K and L). The general condition of the colatures is:

- The majority of secondary colatures are blocked and cultivated making their operation impossible;
- The connection and branching works on the drainage network for the first phase are either buried or deteriorated and their rehabilitation requires their total construction in masonry riprap;
- Primary colatures have a well-marked section. The beginning of these colatures is plugged and planted;
- All crops are planted and cultivated (whether primary, secondary or tertiary);
- The connections from the secondary to the primary are in poor condition and due to the absence of well-marked secondary ditches, the connections are in an advanced state of degradation with marked washouts on the banks of the colatures and neighboring tracks.

The lack of maintenance of these colatures has made their operation impossible in some places. Rainwater follows the tracks all around and favors the gulying of the tracks and the banks of the colatures.

3.1.6. Protective Network

The diagnosis carried out during the first phase of the study shows the following state of the dikes:

- ✓ They are very grassy with a problem of inaccessibility and subsidence in places;
- ✓ the discharge works in the Maggia are grassed and blocked;
- ✓ The embankments are degraded at the level of the access tracks;
- ✓ The absence in places of the laterite layer thus favoring the degradation of the surface layer of the dike.

3.2. Discussion

The results of this study show that before the rehabilitation activities, the water mobilization works of the Mozagué and Zongo dams, the Tcherassa buffer reserve are faced with the problems of silting, aging of the basic materials and the lack of maintenance which reduced the operation of the perimeter and the performance of the irrigation system. These results are consistent with those obtained by [9]

who affirms that the reduction in performance of the Konni irrigated area would probably be due on the one hand to the siltation of the two dams (Zongo and Mozagué) and the Tampon de Tcherassa reserve and on the other hand, the reduction in the number of irrigation could come from the significant infiltration at the Zongo dam which caused the significant infiltration at the basin level of the said dam and that the Mozagué dam was created. Concerning water transport and distribution structures, we note an advanced deterioration of hydraulic structures presenting enormous cracks on almost all of these structures. The same goes for the transport network and the irrigation canals which are in a poor structural state, visible and often widespread, with longitudinal and transverse cracks. This leads to leaks due to lack of maintenance and especially the aging of these structures. These results are consistent with the work of [10] on the irrigated area of Galmi, who stated that the degradation of the hydraulic infrastructure of this development is due to the lack of maintenance and their dilapidation. These results are also not far from those obtained by [11] on the Daibery perimeter where he showed that the main channels are cracked, invaded by plants, damaged jumpers and defective seals due to the aging of this arrangement. But the cracking observed and the defective seals are the most recurring problems on the main channels. Our results are consistent with those obtained here also by [12] who pointed out that the degradation of primary and secondary canals derives from the main problem of aging of hydraulic structures. Thus, as reported by [13] in his diagnostic study of hydraulic structures in an irrigated area of Djirataoua which revealed that the water transport and distribution structures are in a state of aging with a high level of degradation. This could be due to the age of the hydraulic infrastructure.

Indeed, when the perimeter is created, a significant volume of water supplies all of the plots. Based on the observation of the current seriously degraded state of the hydraulic works in the area of Djirataoua, there is undoubtedly a real problem of maintenance or even renewal of these works. However, the observation is the same as [14], who noted that all of the structures are in a state of aging with a high level of degradation. Indeed, although these areas do not have the same characteristics of the irrigation system, we encounter the same constraints there.

4. Conclusion

In view of all the above, we can say that the Konni perimeter faces many problems, namely the deterioration of infrastructure due to lack of maintenance and their aging. These problems include, among others, the silting/silting of the dams and the buffer reservoir, the deterioration of the irrigation network (several panels of the main canal are broken or shifted, and the secondary canals must be taken over a good length), the rupture protection and closure dikes and the exploitation of colatures and drains by operators. It is estimated that only 700 ha are irrigable out of the entire 3000 ha perimeter.

Conflicts of Interest

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

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