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Original Article

Hydro-Agricultural Development, Integrated Water Resources Management in Climate Variability and Agricultural Migration Context in the Plandi 2 Sub-Watershed of Upper Mouhoun, Burkina Faso

Fatimata Sanogo[1,2], Fatoumata Kabore[3], Adama Kekele[4]

[1]*Ziniaré University Centre / Joseph KI ZERBO University, 03 BP 7021 Ouagadougou, Burkina Faso.*
[2]*Permanent Secretariat for Integrated Water Resources Management 03 BP 7005 Ouagadougou 03, Burkina Faso.*
[3]*ArGenCo, GEO3, Hydrogeology and Environmental Geology, Liège University, Quartier polytech1, allée de la découverte, B52, 4000 liege/Belgique.*
[4]*Dynamics of Spaces, and Societies Laboratory, Joseph KI ZERBO University, 03 BP 7021 Ouagadougou, Burkina Faso.*

Corresponding Author : diefatibs@gmail.com

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Abstract *- Burkina Faso is characterised by unfavourable hydrological conditions and the population's need for water to increase. In response, the authorities developed a policy of water resource mobilisation to satisfy the requirement of agro-pastoral and domestic needs. The Hauts-Bassins region benefited from these developments with the transfer of agro-pastoral populations. Natural resources are subject to anthropic pressure, consequences of the transfer of populations and the spontaneous movements attracted by these developments. The objective of this paper is to analyse the field implementation of Integrated Water Resource Management (IWRM) in the context of pressure on natural resources and climate variability. The methodology combines participatory, spatial and systemic approaches. The sub-watershed shelters a perimeter developed for hydro-agricultural purposes and has received a significant migratory flow of agro-pastoralists looking for "new land" since the 1970s. In 2018, 78.61% of the area was occupied by fields. The area occupied by wetlands decreased from 5.56% in 1988 to 0.45% in 2018. The fields of 65.66% of households surveyed are in the lowlands, and 35.61% of those of migrants. This pressure on natural resources is challenging the implementation of IWRM in Burkina Faso.*

Keywords *- Climate variability, Agricultural migration, Water governance, Watershed, Burkina faso.*

1. Introduction

The victory against onchocerciasis in West Africa liberated so-called 'new lands'. In Burkina Faso, the liberation of the Volta valleys (black, white and red volta) from onchocerciasis and trypanosomiasis and the rural development policies of the 1970s undertaken by the authorities lead to the important movements of agricultural populations to these regions, unloading the pressure on the northern and central regions [1–6]. Following the major droughts of the 1970s and 1980s, the mobilization of surface water was at the center of the country's rural development policies to satisfy water use requirements and especially to ensure food self-sufficiency. These projects included hydro-agricultural development of the plains and lowlands in partial or total control with the transfer of populations. Hydro-agricultural areas were developed in the Volta valleys, particularly those of the upper Mouhoun (ex-Black Volta). The overpopulated northern and central parts of Burkina Faso, with about 80% of agro-pastoralists, have been experiencing climate variability. These populations have spontaneously moved to these 'new lands'. These organized and spontaneous movements strongly pressured natural resources, often resulting in conflicting uses [7–18]. Therefore, water resources, which are fundamental for production, are subject to anthropic pressure and climate variation. Soils are more and more degraded while the agro-pastoral population and basic needs increase. In 1998, Burkina Faso engaged in Integrated Water Resources Management (IWRM) as a new form of water governance launched in 1972 at the Stockholm Earth Summit and consolidated at the 1992 conference on water and the environment in Dublin. The river basin is thus defined as the appropriate framework for planning and managing water resources. This new form of water governance defines a new territory of intervention other than the classic territorial organization of the country, which goes from the region,

province, and commune to the village [19–23]. Pressure on natural resources, land saturation and the new intervention framework do not facilitate the acceptance of IWRM actions by the populations. Measures for protecting water resources are traditionally proposed with the materialization of an easement strip at the level of the banks of 100 m from the highest water level of the reservoir, within which any agricultural production activity would be excluded. Implementing this measure is struggling to be carried out due to the refusal of producers who have been massively installed on the banks of water bodies since the market gardening boom of the 1990s[24]. How can IWRM be implemented under these conditions? This paper makes the link between hydro-agricultural development and spatio-sociological dynamics and analyses the governance of water resources in the Plandi 2 sub-watershed.

2. Methodology

2.1. Study Area

The Plandi, the local name of the Mouhoun River in the region of Hauts-Bassin before its confluence with the Kou River, is subdivided into three (3) major sub-watersheds, including Plandi 2. The Plandi 2 sub-watershed is located in the upper part of the Mouhoun River. It straddles the provinces of Houet and Kénédougou. It is bordered to the northwest by the commune of Kourouma, southwest by Djigouéra in the province of Kénédougou, to the east by the commune of Bobo-Dioulasso, to the northeast by that of Padema and finally to the north by the commune of Dandé in the province of Houet. It covers an area of 2688.48 km^2 (Figure. 1). The climate of the sub-watershed is Sudanian, with a wet period of 5 to 6 months. Annual rainfall is between 900-1100 mm per year. The sub-basin is located in the Taoudéni sedimentary basin. The main geological formations are dolerites and fine pink and schistose sandstones. The landscape is generally hilly and marked by armour-plated sandstone mounds. The vegetation formations are tree and shrub savannahs with some riparian formations along the watercourses, orchards and a herbaceous carpet on the uplands as well as in the lowlands. The populations of the communes in the sub-watershed grew significantly between 1975 and 2006 (RGPH, 2006), with a density of 56.20 inhabitants/km2 in 1975 and 459.56 in 2006.

2.2. Methods and Tools

Participatory, spatial and systemic approaches were exploited. The spatial analysis was based on LANDSAT (1972) 60 m resolution and SPOT (2018) 10 m resolution image data. The image was processed automatically (LANDSAT) and manually (SPOT). LADSAT images from 1972 were exploited to obtain the reference situation and SPOT 2018 images for the current one. Supervised classification with « maximum likelihood » using a priori knowledge to create classes or land use units was used to process LANDSAT images. Visual analysis of the SPOT images with Arc-GIS was used to design an interpretation key based on pixel clustering and spectral similarity. A reconnaissance field trip of the land use units was carried out before finalizing the land use maps.

Data collection was carried out using the questionnaire administered to 300 heads of households; 46 interviews conducted with resource persons and local officials and 12 focus groups conducted with groups of migrants (adult men and women), indigenous people (adult men and women), youth, women (migrants and indigenous people). To compensate for the lack of recent village-level data, a three-stage sample design was applied to obtain the sample. In the first stage, the primary units, i.e. the communes, were selected in a reasoned manner from those covered by the study area. The choice is made considering factors such as high migration and the existence of conflicts related to the exploitation of natural resources. At the second level, ten villages were selected on the basis of the above factors. At the third level, the concessions were selected using the Epi method, taking into account all of the neighbourhoods in the village. Once in the concession, the choice is random. A list of households in the concession is drawn up. Each household is assigned a number (1,2,3...), and the household with the odd number is chosen. The questionnaire is administered to the head of the selected household.

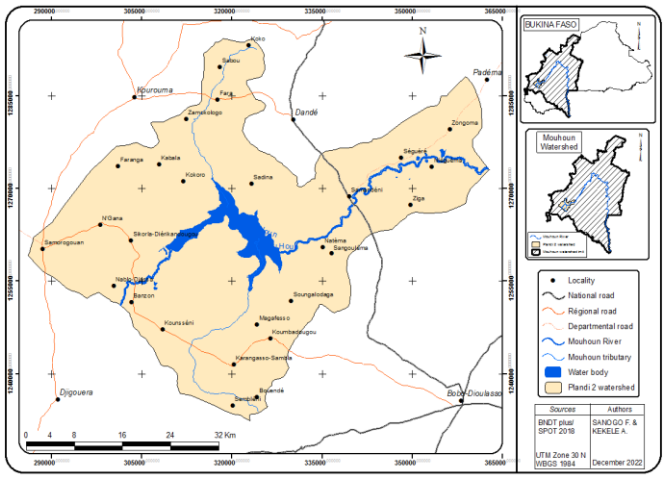

Fig. 1 Plandi 2 sub-watershed situation

3. Results

3.1. Hydro-agricultural Developments, Socio-Spatial Dynamics

The developments carried out in the upper Mouhoun basin (ex. Black Volta) were accompanied by the transfer of agro-pastoral populations to the sites. The migrations, whether supervised by the state or spontaneous, to the upper Mouhoun were favoured by natural factors, particularly pedoclimatic, which contrast with the realities of the localities of departure, located in the north, in the centre of Burkina Faso. To this must be added the favourable socio-cultural factors of the host communities.

3.1.1. Climate variability, Development and Agricultural Migration

Agro-pastoral populations in the northern and central parts of Burkina Faso are vulnerable to the effects of climate variability. Development policies (adaptation to droughts) triggered the movement of populations in these areas in search of conditions conducive to their activities. The pedoclimatic factors of the Plandi 2 sub-watershed are favourable to agro-pastoral activities, contrary to the areas of departure of the migrants. In addition, human factors such as the hospitality of the populations, the flexibility of land tenure and customary law favoured the reception and settlement of populations in the villages of the sub-watershed—the migration flow in the Plandi 2 sub-watershed dates to the early 1900s.

Initially low, it was intensified with the development of the plains and lowlands of the sub-watershed and neighbouring sub-watersheds (Kou, Banzon, Niéna Dionkélé). The flow, relatively low from 1900 to 1960, intensified with the hydro-agricultural developments and the droughts that severely affected the northern and central parts of the country. From an average of 0.1 arrivals per year between 1900 and 1960, an average of 3.5 arrivals per year was recorded between 1976 and 1985. Most migration is permanent or long-term. Many migrant households are recording their third or fourth generation. These families do not plan to leave the sub-watershed. Some of the children of migrants claim to be from the sub-watershed.

3.1.2. Demographic Growth

The dynamic and sustained migratory flow with a predominantly permanent type of migration led to strong demographic growth in the villages of the Plandi 2 sub-watershed. The density, which was 56.2 inhabitants per km2 in 1975, rose to 459 inhabitants per km^2 in 2006 [25]. The number of valid arms per family has increased. According to [26], in the beginning, 1 ha was exploited by 4 active members of a family or association of assets. In 2018, this family had 40 to 50 members. The main activity of these migrants is agriculture. These workers moved out of the developed areas and created their fields on the uplands. Meanwhile, the number of workers in the indigenous families is also increasing.

3.1.3 Soil and Vegetation Cover Degradation

Satellite image data indicate a strong degradation of the vegetation cover. In 1972, the Plandi 2 sub-catchment was almost covered by abundant vegetation of various species. The natural formations alone, therefore, occupy 97.99% of the surface area of the sub-watershed (figure 2). In 2018, vegetation formations occupied only 15.77% of the total area of the sub-watershed and the cultivated area occupied 78.61% (Figure 3). The degradation of the vegetation cover has been accentuated by extensive agro-pastoral techniques with high use of pesticides (insecticides and herbicides). The development of the plains and lowlands improved the conditions of access of the farming population to inputs and equipment, which partly led to the development of cash crops, which consume space and increase the extraction of soil nutrients, particularly cotton. The sub-watershed is an area of high cotton production, as evidenced by the existence of a cotton ginning factory created in 2004 in the sub-watershed and another in 1998 in the neighbour sub-watershed of Plandi 2. Using animal traction and tractors encouraged land clearing in the sense that the time saved is reinvested in extending farm areas.

The fields opened to consider the agricultural equipment. This equipment, combined with the advent of herbicides, has contributed greatly to the degradation of the vegetation cover. Land pressure no longer allows for following. Of 300 heads of household surveyed, only 18 practice following, only 13 leave their fields to rest for a period of 1 to 3 years, and 5 go beyond 4 years. When the soil is exploited without rest, with the addition of high use of chemical inputs, the result accelerates its degradation. According to farmers in the study area, “The quantity of inputs we use today is higher than when we arrived in the sub-basin. The cause is soil degradation. The soils are no longer productive. The average soil production in the 1970s was about 6 tonnes per hectare. However, obtaining 3 tonnes per hectare with the same crops is difficult today. There is inevitably degradation due to the fact that the migrants exploit the soil in a savage way, and as they are the most numerous and the techniques they develop are not very respectful of soil quality. So we have to use a lot of inputs to hope to have good harvests" (field surveys, July 2018).

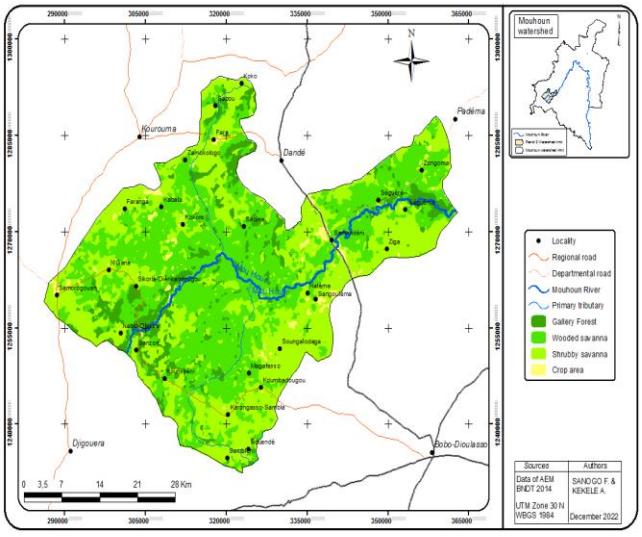

Fig. 2 Land use units in the Plandi 2 sub-watershed in 1972

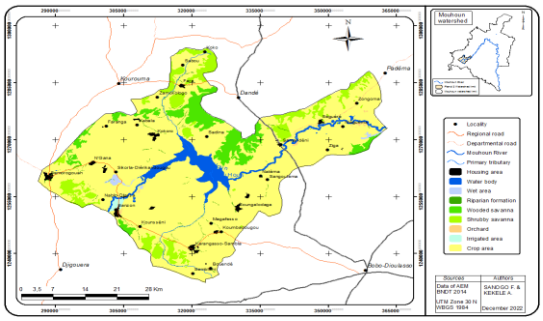

Fig. 3 Land use units in the Plandi 2 sub-watershed in 2018

3.1.4. Degradation of Water Resources

Water is a limited and vulnerable natural resource. It is an essential element for the life of all animals, plants and soil. There is a hydrological, sociological, economic and ecological interdependence in the catchment areas. This resource is now threatened by the disruption of the balance between its various related elements as a result of anthropic pressure on them. The ploughing carried out by 80% of the population is fine. They facilitate the transport of the soil that has been mobilized towards the watercourses and bodies of water. Land pressure has led to the exploitation of hillsides, hillocks and also armoured and sandstone plateaus. Their exploitation further weakens the soils, which are shallow. The parent rocks are dug up and loosened. Producers use pesticides that destroy the herbaceous cover by exposing the soil. The runoff in the sub-catchment is sometimes torrential and sometimes sheet flow. When heavy rainfall, loose materials and boulders are transported from these heights to the watercourses, water bodies, and pesticides. The watercourses are thus clogged. The loaded water degrades the banks, causing trees to landslides and uproot or dislodge along the watercourses.

These trees eventually fall into the water and cause it to clog. Farms are often located less than one metre from the riverbed. In the survey sample, 65.66% of households have their fields in the lowlands. Some farmers occupy the minor bed when the water recedes. "Some watercourses have disappeared in our commune today. People exploit the banks and even the riverbeds. Several watercourses disappeared. Their traces are no longer perceptible. When there is a year of heavy rainfall, the water flows back and causes damage to the farmers (Figure 4). In this village, all the watercourses were permanent. However, the populations occupied the beds of these streams. As a result, the springs that fed these streams were blocked or intermittent. The chemicals used on the farms are washed away and transported into the streams and water bodies" (focus group, July 2018). Off-season cultivation is practised by a large part of the population of the communes in the sub-catchment area on the riverbanks, leading to its rapid degradation. Initially practised by migrants, it is now conducted by the indigenous population. "The indigenous population did not use the banks for market gardening. It was practised on the developed perimeters of the water reservoirs or the plains and lowlands. Today, the riverbanks are invaded by natives and migrants" (field survey, July 2018). According to statistics from the provincial directorates (Houet and Kénédougou) in charge of agriculture (2019), dry season crops occupy between 20,000 and 35,000 ha in the communes of the Plandi sub-watershed. The inventory of riverbank occupants conducted by the Mouhoun Water Agency (AEM) in 2017 counted 27 riverbank farmers in the commune of Padema, 65 in the commune of Banzon and 189 in the commune of Bama. This census only covered farmers living on the banks of the main Plandi River. These results do not consider the tributaries of this river. In terms of surface area, the population of the sub-basin and mainly the riparian communes of the main Plandi 2 River, occupy 1241.25 ha, that is 1138.74 ha for the commune of Bama, 69.51 ha for Banzon and 33 ha for Padema. The majority (72%) is located less than 100 metres from the riverbed (Figure 5).

The reasons given by the populations for occupying the riverbanks are multiple. The main ones are easy to access to these lands, land pressure on the uplands, degradation of upland soils, and diversification of production; 33.33% of migrants and 37.50% of natives occupy the riverbanks because of the lack of land on the uplands; 44.44% of migrants and 59.38% of natives mention the problem of access to upland; 22.22% of migrants and 25% of natives mention insufficient rainfall (search for land that retains moisture for a long time) and for 5.5% of migrants, it is a question of diversifying production. T

he producers surveyed use pesticides and herbicides. At the beginning of the migration, the quantity of pesticides used per hectare was low. Moreover, few producers used them. 10/142 migrant households surveyed used them, compared to 139/141 today. For natives, it is 09 out of 148 before or at the start of migration and 148 out of 150 today. The location of the exploitation plots near the rivers beds and water bodies constitutes a threat to the quality of the resource. The consequences include contaminating surface water with nitrates and the eutrophication of stagnant aquatic environments. The reduction or elimination of these impacts appears difficult in the short term because the objectives of agricultural development are food self-sufficiency, and little attention is paid to environmental protection, particularly water resources [27–32].

Groundwater resources are also negatively impacted by high population growth due to their exploitation for drinking water and, often, agricultural needs. The high population density (average 459 inhabitants/km^2) leads to an increase in the number of abstraction points and the number of facilities. This results in pressure on groundwater [37] notes in her study of the Kou River basin that the flow rates of the Guinguette water sources and those exploited by the water and sanitation National Office, which were respectively 1.78

m^3/s and 0.5 m^3/s in 1995, dropped to 1.47 m^3/s and 0.4 m^3/s. These flows, therefore, decreased by 0.3 m^3/s and 0.1 m^3/s, respectively. Her investigations indicate that 40% of this decrease is due to pumping for drinking water supply.

Fig. 3 (Plate by Sanogo F, September 2020) Stream struggling to resume its normal course in a cotton field, Soungalodaga commune

Fig. 4 (Plate by Sanogo F, June 2019) Occupation of the major bed of the Plandi tributary, commune of Padema

3.2. Water Resources Governance

In this context of the degradation of natural resources (vegetation, soil and water), strong demographic growth and diversification of the population's water needs, how should these natural resources be governed? The answer is integrated management of natural resources, particularly water resources. In 1998, Burkina Faso engaged in Integrated Water Resources Management (IWRM) as a new form of water governance launched in 1972 at the Stockholm Earth Summit and consolidated at the 1992 conference on water and the environment in Dublin.

3.2.1. Integrated Water Resources Management

Burkina Faso's commitment was reflected in the adoption in 1998 of the document "Water Policy and Strategies". This policy document was transcribed into law n°002-2001/AN of 8 February 2001 on the orientation law on water management, the implementation of which is set out in several application texts, including the Financial Contribution for Water (CFE). Integrated Water Resource Management is based on a global vision that takes into account the dynamics of water resources within natural spaces such as river basins or aquifers. It involves all the stakeholders in the water sector in a new management framework that makes it possible to reconcile all the uses for the continued development of a region or a country while preserving the needs of future generations. Burkina Faso aims to achieve a balance between the use of water as the basis for the livelihood of a growing population and its conservation to ensure the sustainability of its functions and characteristics. The framework for intervention is the river basin, whose division does not follow administrative boundaries but the river system. The hydrographic network is organized around three international watersheds: the Volta, the Niger and the Comoé. These 3 basins are themselves subdivided on the national territory into 4 national watersheds: the Nakanbé (81,932 km^2), the Mouhoun (91,036 km^2), the Niger (83,442 km^2) and the Comoé (17,590 km^2). These 4 basins are, in turn, subdivided into 5 management areas of the water agencies that are the Cascades Water Agency (AEC), Gourma Water Agency (AEG), Liptako Water Agency (AEL), Mouhoun Water Agency (AEM), Nakanbé Water Agency (AEN) which are functional. To respect the texts of the water domain on the ground, Water police services have been set up within the regional directorates in charge of water. The areas of the agencies are subdivided into small sub-basins or portions of sub-basins representing the management areas of the Local Water Committees (CLE), the basic links in IWRM in Burkina Faso. The governance of water resources involves representatives of the State administration (all ministries whose interventions impact water or are related to water), local authorities, users, non-governmental organizations, civil society, and natural or legal persons with resources. This parity is respected in all IWRM bodies.

3.2.2. Water Agencies

The Water Agencies and local structures have the objective of enhancing the value of the river basin as an appropriate framework for knowledge, planning and management of water resources through the coordination of related actions and through consultation to prepare and implement under optimal conditions of rationality, the orientations and decisions taken by the government in the water field. The bodies and authorities of the water agencies are the basin committee, the board of directors and the local water committees. The Local Water Committees (CLE), local bodies for consultation, promotion, animation and exchange involving all local stakeholders in integrated water resources management, are the local bodies for implementing IWRM. They are the basic links of the Agencies at the sub-basin or portion of the sub-basin level. The members of the CLE are representatives of the colleges of the administration, the communities and the users. The main missions of the CLE are:

- seek the permanent support of stakeholders (administration, users, local authorities, customary

authorities, civil society organisations) for the concerted management of water resources by raising awareness, providing information and training in their management areas;

- undertake measures/activities for the protection and restoration of water resources and the environment within the reach of the CLE;

- preventing and/or managing local conflicts related to water use (organising the equitable sharing of water between all the different users) of its management area.

IWRM develops the participatory approach through consultation and involvement of all stakeholders in the governance of water resources. It offers the prospect of greater efficiency in water conservation and demand management equitably shared between water users and greater reuse and recycling of wastewater to complement the development of new resources. When water resources are scarce, and different interest groups have needs for them at the same time, competitive and conflicting responses emerge. In a context of climate variability where water resources are most vulnerable, the water agencies, through the local committees, carry out several actions on the ground regarding consultation, knowledge, protection, restoration and allocation of water resources.

3.2.3. Local Water Committees

At the level of the Plandi 2 sub-catchment, the CLE Plandi 2 has been set up and carries out several activities in the field in collaboration with the General Direction of the Water Agency and its development partners. The CLE coordinates the governance of water resources in its management area. Within the hydro-agricultural development framework and the Mouhoun River's recalibration, the CLE has been asked to conduct consultations with the riparian populations to solicit their support. It has developed a participatory action plan for protecting and restoring the Samendeni Dam water resources, the third large dam in Burkina Faso located in its management area. The CLE carries out actions to protect water resources, such as filtering dams, stone barriers, grass strips and reforestation. It sets up monitoring committees around watercourses and bodies of water. It arbitrates empirically on the allocation of water resources and prevents and manages conflicts related to water resources. It is supported in its tasks by the water police department. The Hauts-Bassin region water police department supports the CLE in protecting the banks of the rivers and water bodies in its management area.

3.2.4. IWRM Challenges in the CLE Plandi 2 Management Area

The CLE has several challenges to face, mainly the adhesion and commitment of the different actors to the concerted management of water resources. The notion of watershed or sub-watershed seems not to be understood by the stakeholders. Local authorities are struggling to integrate IWRM into their interventions. The commitment of actors from the State administration is timid. The mobilization of actors around IWRM actions and the question of financing remain a major difficulty. The specific case of riverbank protection divides the actors. The farmers are not ready to free the riverbanks; for a good reason, these are the richest lands suitable for almost all speculations. They retain water over a long period of the year and can be exploited in the dry and wet seasons. Releasing 500 meters of the riverbank is seen as a great loss for producers. The issue is very sensitive in the Plandi 2 sub-watershed because migrants (36.4% not in favour) who are settled in the lowlands or on the banks no longer have the possibility of obtaining other farms due to the saturation of the space. The landowners (35.45% not in favour) have almost no reserves left.

4. Discussion

Climate variability is a threat to natural resources, which are also subject to anthropic pressure. Water management as an integrated solution in rural development policies in Burkina Faso attracted the movement of people towards these structures and even beyond. These previously sparsely occupied areas are under demographic pressure. The irrational exploitation of natural resources led to their degradation and conflict uses. According to his study [34] obtained, conclusions indicate that the agricultural practices of farmers in tropical environments, particularly in cotton-growing areas, do not maintain the fertility of these soils in the long term. In this context, the participatory governance of these resources adopted by the Burkinabe government is struggling to be adopted by the stakeholders. However, the future of these natural resources does not look good. For [38], the pessimistic scenario indicates a trend towards soil aridification and a decrease in groundwater reserves. The optimistic scenario predicts that even with environmental changes, soil moisture will be maintained until 2040. [36] reached the same result in the Sourou watershed of Burkina Faso. Fatoumata Kabore's work [37] in the south-central part of the country showed a drop in the piezometric level with a non-return to the pre-1997 level due to anthropic pressure (abstraction and degradation of the vegetation cover). From the results of [38], there is a real risk of decreased runoff and aquifer recharge rates in the southwestern half of Burkina Faso. The suggestions summarise the operationalization of IWRM due to the interdependence of water, soil, and biodiversity.

IWRM has the advantage of empowering stakeholders, reconciling the interests of users and raising funds (the land contribution for water, already implemented in Burkina Faso) dedicated to protecting and restoring water resources. Soil restoration and recovery is a means of restoring vegetation cover, thereby increasing infiltration for possible groundwater recharge. The recovery of natural resources

contributes to the fight against poverty in Third World countries as they are the main factors of production. In addition, the arbitration of water uses, a fundamental mission of the Water Agencies, and structures for implementing IWRM reassure producers who can invest rationally and without fear. The challenge of mobilizing stakeholders around IWRM remains. It is then necessary to annex development projects to IWRM to facilitate its anchoring, especially its acceptance by the actors.

The liberation of riverbanks with large dimensions, advocated by IWRM actors, can be a factor of demobilization and non-commitment of actors to IWRM. Environmentally friendly riverbank management techniques need to be considered on a case-by-case basis and allow farmers to continue working on the riverbank without damaging the integrity of the water. With the pressure on land and the scarcity of arable land, the total removal of the banks from exploitation can be a factor in demobilizing the actors and tearing apart the social fabric. The results of a study carried out on the Mogtédo and Kierma watershed in the Nakanbé by [24] clearly show that solid transport from the upstream sub-catchments is the main source of sedimentary input into the reservoir basins. Management measures aimed at limiting the sedimentation of the reservoirs by evicting installed producers and reforesting the 100 m strip of the bank may not achieve their expected results. The objective of protecting the reservoirs from silting up must include the development of their catchment area. Nature-based solutions must be considered. According to this approach, the protected and/or restored resource must contribute to the population's well-being. This requires the development of technologies that will enable people to use these resources without moving and compromising their integrity.

The watershed approach needs to be further explained to stakeholders to enable them to take ownership of integrated management because the defined IWRM territory is unfamiliar to stakeholders and populations in Burkina Faso [19,20,23]. The interdependence of water resources does not seem well understood by these actors, especially the populations. People in other localities have traditionally integrated the management of water resources. They need to be identified and developed. These practices are often easier to implement and accept. Authors should discuss the results and how they can be interpreted from the perspective of previous studies and the working hypotheses. The findings and their implications should be discussed in the broadest context possible. Future research directions may also be highlighted.

5. Conclusion

The phenomenon of migration, coupled with the growing needs of the populations, undoubtedly has a considerable impact on natural resources. Indeed, the various studies of soil and water resource degradation showed the influence of the populations on these resources. The water resources of Plandi 2 are no less degraded, and the results show that the arrival of migrants led to an anarchic occupation of the riverbanks by both these migrants and the local population, trained strong pressure on this resource. To limit the degradation, the government adopted since the 1990s the Integrated Management of Water Resources, which breaks with the sectorial and anarchic management of the resource. Thus, water agencies have been created with local water committees as the basic link to ensure local water management. This management brings together the state, local authorities, civil society and users to operationalize the protection and management of water resources. This operationalization is not yet effective in the field, so much so that the populations, due to the lack of cultivable land, invade the banks to satisfy their basic needs. In view of all these difficulties, it is obvious to redirect the reflection on the criteria for freeing the banks. To do this, it is necessary to develop technologies allowing the population to exploit these resources without compromising their integrity.

Author Contributions

Conceptualization, SANOGO Fatimata; methodology, SANOGO Fatimata; software, Fatimata SANOGO, Fatoumata KABORE, Adama KEKELE; validation, Fatimata SANOGO, Fatoumata KABORE, Adama KEKELE; formal analysis, Fatimata SANOGO, Fatoumata KABORE, Adama KEKELE; investigation, Fatimata SANOGO; resources: Mouhoun Water Agency/ Permanent Secretariat for Integrated Water Resources Management. ; data retention, Fatimata SANOGO; writing-preparation of the original version, Fatimata SANOGO.; writing-proofreading and editing, Fatimata SANOGO, Fatoumata KABORE, Adama KEKELE; visualization, Fatimata SANOGO, Fatoumata KABORE, Adama KEKELE; supervision, Fatimata SANOGO, Fatoumata KABORE; project administration, Fatimata SANOGO; acquisition of Fatimata SANOGO funds. All authors have read and approved the published version of the manuscript.

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