

HYDRO-AGRICULTURAL DEVELOPMENT AND RICE FARMING RENEWAL IN THE DIOULOULOU WATERSHED, SENEGAL

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Abstract

Although sometimes produced on a small scale, rice is a major strategic commodity in the Senegalese government's public policy options. For several years, investments in hydro-agricultural infrastructure have been made by the State for the development of rice cultivation in Lower Casamance, which is facing the effects of climate change and rice labour shortages. The objective of this study is to analyze rice land reclamation strategies in the Diouloulou watershed. The study was mainly based on individual and group interviews with farmers (heads of households), structures (state or not) that evolve in the field of rice cultivation, farmers' organizations, rice farmers, village chiefs and mayors of the communes that polarize the Diouloulou watershed. The results show that for several years now, initiatives for the development of rice-growing land in the Diouloulou watershed have been underway. These include the installation of anti-salt dikes and micro dams, the introduction of mechanization, reforestation of mangroves, and the improvement of plots by organic fertilizer and access to inputs. Despite these efforts, there has been a gradual reduction in the area of rice that can be cultivated in the Diouloulou watershed and, in turn, a decline in production. This is linked to environmental constraints (salinization, acidification and silting), socio-economic constraints (inefficient management of hydro-agricultural structures, low manpower, supervision of producers, etc.) and agronomic constraints (low mechanization, limited access to inputs and motorized machinery, linked to lack of financial resources). Today, most of the valleys in the Diouloulou watershed are underexploited.

Keywords: revitalization, rice farming, watershed, Diouloulou, Casamance.

I. INTRODUCTION

Before the episodes of drought, Casamance experienced a favorable climate (it should be noted that the period 1950-1967 was itself especially wet) and has long been a focus of particular interest for rice cultivation issues. To realize its potential and develop a more productive rice farming, the management of rice fields became imperative. This led to the development of lands occupied by mangroves, where "salty rice" has been cultivated for over 500 years [1]. Indeed, mangrove areas could be cleared without causing particular problems concerning land use rights. The Diola farmers who occupied these hostile lands mastered water management perfectly, making fertile the mudflats that were difficult to cultivate [2]. Ingeniously arranged rice plots were located at varying distances from the village. The harvest was then sufficient to ensure the survival of these populations. Surplus was stored in preparation for occasional years or for rural festivals and trade needs (barter). Mangroves at that time provided additional resources.

However, starting from the 1970s and 1980s, drought disrupted the situation, making some rice fields unusable (salinization, acidification, lack of water, etc.). Thus, several rice-growing areas were abandoned; production and yields declined considerably. At the same time, a growing national demand for rice was observed. The State implemented a development policy for these lands after independence. Initially, the problem was the use of traditional methods on a larger scale and the addition of more effective technologies, especially regarding drainage, to better desalinate the soil. The experiment was conducted between 1963 and 1975, but unfortunately ended in failure due to a lack of understanding of these soil acidification processes [3].

To better control water resource management in the Casamance river tributary valley, it was planned to build dams whose operating principles were modeled on those used by farmers in rice watershed areas. The idea was to introduce salty water during tide and drought periods to prevent acidification and to drain desalinated water from the rice soil during the rainy season. The flap gate system ensured this operating principle, allowing water to pass in both directions. Several projects started in the 1970s and 1980s, such as the Guidel and Affiniam dams, which were commissioned in 1983 and 1987 respectively.

Monitoring results from the Guidel dam indicate that the initially proposed management system was modified. The upstream land, being acidified [4, 5], must now be exploited with a saltproof dam. The climatic situation deteriorated in the 1980s. The small valley extending to the continental shelf quickly worsened. To stop the ruthless advance of salty water, people began constructing small salt dikes with external financial support. These concrete or non-concrete structures, often equipped with an opening device, allow the storage of runoff water and the evacuation of water that washed the salty soil at the beginning of the rainy season [6].

The PIDAC was responsible for the construction and monitoring of 75 of these small structures, all located in Lower Casamance. They complement other works carried out by the Chinese delegation and the AFVP. These investments are already significant considering the results obtained in rice production. In 1985, the cost of the Guidel dam was estimated at about 2 billion FCFA for 800 ha of salty lands still to be developed. The Affiniam dam cost nearly 6 billion FCFA, three times more than Guidel, not including development for 5,000 ha of degraded lands [5].

Thus, these large developments could not meet the expectations of farmers, who primarily wanted to protect rice fields from salinization but also to recover abandoned rice fields. Following the failures of these large developments, the State initiated a program to build small structures (anti-salt dikes) with the Integrated Agricultural Development Project in Casamance (PIDAC) in 1984, in perfect collaboration with villagers. Farmers fully participate in maintenance and management activities of these structures. This appeared to be a great success [7].

Several structures have thus been built in various valleys of Lower Casamance, notably in the Diouloulou watershed. But since the onset of the Casamance armed conflict coinciding with the worsening climatic

conditions in Casamance, expected results are endangered. Lower Casamance has since experienced a disorganization of productive forces and rice production conditions, negatively impacting farmers' yields. With small dams requiring relatively low expenses, less than 10 million FCFA at that time (1980–1990), at least 100 hectares of land could be protected. Therefore, demand among farmers became strong, necessitating the construction of many such structures.

Indeed, for the search for lasting peace in the region, other programs and development projects, such as the Casamance Rural Development Support Project (PADERCA), emerged to support the revival of socio-economic activities through the National Agency for the Revival of Economic and Social Activities in Casamance (ANRAC).

It is also important to note the role played by non-governmental organizations (NGOs), notably the Research and Implementation Group for Rural Development (GRDR) and other partners working for rural development, in recent years, in the context of armed conflict, for maintaining rice-growing activities through various initiatives to protect and rehabilitate degraded production systems and support Farmers' Organizations.

Furthermore, in some cases, certain small dams worked relatively well, especially where soils were light. However, it must be recognized that the production gain was not as expected [7].

The whole issue of managing dams and dikes remains acute because no solution is ideal or unique. It is about choosing the one that presents the least disadvantages on an already degraded environment. It is certain that operation as an anti-salt dam is now required in the dry season to secure fresh rice fields and limit chemical soil degradation.

The development of upstream lands is more relevant than ever. This is a long-term task that requires significant human and material resources.

The current agricultural development strategy in Lower Casamance must abandon the initial objectives, which consisted of increasing cultivated lands and yields. It must first aim at securing rice production and rehabilitating degraded lands, when technically and economically feasible.

Presentation of the Study Area

The Diouloulou watershed is located in the Ziguinchor region (southern Senegal) and north of the Bignona department. It centers the communes of Diouloulou, Kataba 1, Djinaky, and Kafountine (see map 1). It covers an area of 502 km². The overall topography is low, with the highest altitude being 45 m and the majority of altitudes below or equal to 10 m. It is characterized by a dense drainage network that subjects the entire watershed to the influence of bolongs' waters and accentuates salinization.

II. Materials and Methods

The study was based on socio-economic surveys of rice farmers, interviews, focus group discussions with various stakeholders in rice farming, and direct field observations. The qualitative information obtained from interviews (interview guides and focus groups) served to confirm the trends observed in the household surveys.

Interview guides were administered to village chiefs (7 in total), to farmers (5 per village), and to the mayors of the various communes within the Diouloulou watershed: Diouloulou, Kataba 1, Kafountine, and Djinaky.

Interviews were also conducted with leaders of farmers' organizations, notably:

- **CADEF** – Action Committee for the Development of Fogny,
- **ED** – Diouloulou Cooperative,
- **APAD** – Association of Planters of the Diouloulou District,
- **ASAPID**,
- **CRCR** – Regional Framework for Rural Dialogue.

They were also conducted with officials from institutions (both state and non-state) involved in rice cultivation, particularly:

- **DRDR** – Regional Directorate of Rural Development,
- **GRDR** – Research and Implementation Group for Rural Development,
- The head of the **ISRA/Djibélou** research center (Senegalese Institute for Agricultural Research),
- **PPDC** – Casamance Development Hub Project,
- **SDDR** – Departmental Rural Development Service,
- **Forestry and Soil Conservation Service** of Bignona,
- **ANCAR**,
- **WFP** – World Food Programme.

Focus groups were organized in the 7 villages included in our sample: **Kabiline, Mahmoudou Cherif, Dar Salam, Darou Khairy, Birkamading, Colomba, and Badionkotong**. The goal was to bring together local knowledge holders to gather credible information through guided discussions. To achieve this, all social groups were represented — young farmers, adult farmers, elderly men and women farmers, and retired farmers (if any), in order to identify emerging trends. Each socio-cultural group was thus included.

The inclusion of these groups was motivated by the diversity of perceptions regarding the effects of climate variability, rice field degradation, land development efforts, constraints, and resilience strategies. Elderly farmers were included to benefit from their lived experiences and to gain insights into past conditions. Adult farmers were interviewed as they are the current main actors in rice production. Meanwhile, young farmers were involved because they are expected to sustain rice production in a context of rice field degradation and socio-economic, cultural, and environmental transformation.

These focus groups provided a general understanding of the dynamics of saline lands and their effects on socio-economic activities, land development strategies, household food security, and the environment.

In total, **seven focus groups** were conducted — one in each village: **Kabiline, Mahmoudou Cherif, Dar Salam, Darou Khairy, Sambouladiang, Colomba, and Badionkotong**.

The information gathered from discussions with farmers helped identify the overall trends in changes that have occurred since the pre- or early-drought periods up to the present.

II. Results

2.1 Initiatives to Address Constraints in the Development of Rice Plots

Salinization and acidification are the major constraints in the use of rice-growing lands in Lower Casamance. While methods to combat them exist, they require proper management of water resources — which is particularly difficult in such a flat region, even though the **Bainouks, Diolas, Pepels, Floups, and Manjaques** have mastered these techniques for at least 1,500 years. Numerous works have been carried out in the region to provide effective technical solutions.

2.1.1 Mechanical Measures: Anti-salt Dikes and Micro-dams

To combat the salinization that has significantly reduced the rice-growing areas in Lower Casamance, hydro-agricultural developments were introduced between **1980 and 1985**. Two types of infrastructure were created to fight the effects of salinity:

1. **Large-scale anti-salt dam projects**, such as those at **Affiniam** and **Guidel**;
2. **Small anti-salt structures**, built by local populations and development organizations, to prevent saltwater intrusion into small alluvial valleys.

Despite all these efforts, **salinization and acidification** of rice lands **continue to be observed** throughout Lower Casamance and are **spreading over time and space**, now even affecting terraced areas that had previously been spared.

Faced with this issue, rice farmers in Lower Casamance in general, and in the Diouloulou watershed in particular, have developed strategies to protect their crops. The **abundance of rainfall** does help maintain a balance suitable for rice on lands that are naturally salty due to marine water intrusion into groundwater. However, this balance was **disrupted by the droughts of the 1970s and 1980s** [8].

The **salt concentration in soils**, not sufficiently leached by rainfall, has increased to levels that negatively affect yields or even **jeopardize production**.

To combat the degradation of their lands, farmers had long implemented specific tools.

- On the **sea and mangrove side**, they built **dikes** to halt the advancement of saltwater intrusion.
- On the **land side**, they constructed **small dams and reservoirs** to **capture rainwater** (see **Diagram 1**).

This carefully collected water can then be fully used to **form a layer of freshwater** over the rice fields.

dans les rizières.



Planche 1 : des drains pour faciliter l'évacuation des eaux (Cliché Sané 2023)

Thanks to these efforts, carried out at the scale of individual plots or entire valleys, some farmers have managed to **recover previously abandoned rice fields** and **maintain their farming activities**.

However, these infrastructures are **difficult to keep in good condition**—they constantly need to be reinforced, repaired, or rebuilt. Another limitation of mechanical interventions lies in their **partial effectiveness**.

Beyond the traditional dikes built by the local populations themselves, **modern dikes** (constructed using heavy machinery) and **improved traditional dikes** (built by communities using rudimentary tools but with **technical assistance from NGOs**) have also been constructed.

These dikes generally serve **two functions**:

1. **Anti-salt function (anti-salt dike)**: The dike protects or isolates an area of land from the encroachment of saltwater.
2. **Retention function (retention dike)**: The dike slows down the flow of water and expands the flooded area over a larger cultivable surface.

They are often equipped with **micro-dams**.

Indeed, **micro-dams** simply block **surface runoff**, but they **do not act on subsurface flow** (see Diagram 2). As for **anti-salt dikes**, they often lack an **appropriate drainage system** to evacuate salt-laden water after leaching.

Therefore, **any mechanical strategy for developing the rice lands in the Diouloulou watershed** must first address the following questions:

- **How can rainwater be channeled** to leach salts and promote the **drainage of salty water**?
- **How can the surface layers be drained** while **maintaining the hydromorphic properties of the deeper layers**, in order to prevent...

l'oxydation de la pyrite et l'acidification des sols ?



Planche2: quelques méthodes de lutte mécanique dans le bassin versant de Diouloulou : endiguement et micro barrage (Cliché Sané, 2023)

The Main Drainage Problem

The main issue with drainage lies in **establishing an appropriate work schedule** for the necessary activities. A misjudgment in timing can reduce the effectiveness of the infrastructure. It is therefore essential to choose the **right moment** to open the valves and **discharge the salt-laden water**:

- **Opening the valves too late** leads to the **re-salinization** of the soil profile due to water evaporation.
- **Opening them too early** does not allow for sufficient **leaching of salts**.

Once the land is protected from the main degradation factors, **supporting measures or complementary strategies** must be implemented to ensure its productive function can be sustainably maintained.

2.1.2 Agronomic or Cultural Control

This strategy aims to **limit water loss** through **capillary rise** and **evaporation**. To do this, **surface tillage** and **mulching with a layer of straw** have proven effective.

2.1.3 Shallow Tillage

The study of **surface soil conditions** has helped improve understanding of how the **topsoil layer functions** in **acidic and saline soils** of the Diouloulou watershed. It particularly highlighted the major constraints on the site that act as **barriers to recovery strategies**.

One of these constraints is the **crystallization of salt on the surface** in **bare areas**, especially in the villages of **Dar-Salam, Darou Khairy, Colomba**, and others. This phenomenon generally results from the **capillary rise of salty water** from the water table, which is **exacerbated by intense evaporation** over a long part of the year (January to June).

It has been shown that **reclaiming these acid and saline soils** must first address the influence of **salty water from the estuary** (during high tides) or the **salty water table**. **Diking** can help partially solve the issue by reducing **marine water intrusion** (horizontal component). As for the **saline groundwater** (vertical component), a **partial solution lies in shallow tillage** of the soil.

This soil work generally **disrupts the upward movement** of salty water. The **discontinuity zone** created between the **tilled topsoil** and the **underlying horizon** acts as a **buffer** or barrier, **preventing salty water from reaching the surface**.

Soil Desalinization: A Complex Challenge

Desalination of land is a challenge faced by many countries [8]. While **ancestral techniques** may have shown promising results, **desalination in mangrove zones** remains a **delicate process**, as the **substrate is particularly fragile**. It is sometimes **unrealistic** to fully desalinate these soils, as they are **constantly influenced by marine waters**.

A **superficial desalination** may be sufficient to allow for **successful replanting of rice seedlings** during transplanting in the rice fields of **Lower Casamance**, and especially within the **Diouloulou watershed**.

The **ridge-furrow cultivation method** (see Diagram 3), traditionally practiced by **Diola farmers**, facilitates this process [9, 1].

It should also be noted that a **well-adapted drainage network** is generally an **essential complement** for **removing dissolved salts** from the soil...

parcelles rizicoles.



Planche 3 : labour au « kadiandou » et repiquage du riz dans la vallée de Kabiline (Cliché Sané, 2024)

2.1.4 Introduction of Mechanization in Rice Farming in the Watershed

The trend toward **professionalization** primarily concerns **seed production**, but the **State**, as part of its policy to develop rice farming, places emphasis on **mechanization of production** through the **distribution of threshers, power tillers, and tractors**, which are **subsidized at 60%**.

However, these distributions appear to be **progressing very slowly**. Similarly, **rice hullers** are also being distributed to improve both the **quality of milled grains** and the **volume of marketable rice for consumption**.

Indeed, the **provision of agricultural equipment** (tractors, power tillers, threshers, hullers, etc.) to the **Diouloulou Union** has contributed to **easing the workload** of both men and women farmers, and to **increasing the cultivated areas** in the **Kataba 1 district** (see Diagram 4).

In certain localities like **Kabiline**, **several parcels that were previously abandoned** due to **salinization** or **lack of labor** are now **being cultivated again**.

For example, for **seed multipliers**, some agricultural work can be **paid in kind after harvest**, and the **surplus production is purchased**. This partly addresses the issue of financing rice farming activities.

Table 1: Agricultural Equipment Service Activities and Payment Methods

Agricultural Equipment	Type of Activity	Price & Payment Method for EGAD Members	Price & Payment Method for Others
Tractors	Plowing	20,000 CFA Francs/ha/day, payable after seed commercialization	25,000 CFA Francs/ha, paid immediately after service
Power Tillers	Plowing	10,000 CFA Francs/ha, payable after sale of produced seeds	12,500 CFA Francs/ha, paid in cash after service
	Transport (Manure, sand, wood, etc.)	3,000 CFA Francs per load, paid in cash	3,000 CFA Francs per load, paid after service
Threshers	Rice threshing	500 CFA Francs per 50 kg bag, payable in cash or in kind after seed commercialization	500 CFA Francs per 50 kg bag, paid in cash
Hullers	Paddy rice hulling	1,000 CFA Francs per 40 kg bag of paddy, paid on the spot	1,000 CFA Francs per 40 kg bag, paid on the spot

Source: Dembo Diédhiou, Vice-President of EGAD.



Planche 4: opération de labour au tracteur à Kabiline (Cliché Sané 2024)

2.1.5 Mangrove Reforestation

Like the whole of Lower Casamance, the Diouloulou watershed experienced degradation of mangrove vegetation during the years of drought.

The degradation of the mangrove is considered a factor that can increase the risks of salinization of rice fields, as mangroves play a significant protective role against salinization.

Thus, several reforestation programs have been initiated in the Diouloulou watershed by various NGOs in close collaboration with the farmers. The water and forestry services also participated in this activity in partnership with the Millennium Challenge Account (MCA). Additionally, there is strong involvement from the Abéné Marine Protected Area (AMP) in these reforestation efforts.

The choice of propagules for reforestation focuses mainly on the **Rhizophora** genus. This is justified by the fact that this species is hardy and regenerates more easily and very quickly in clay soil.

Diagram 5 illustrates the mangrove reforestation efforts in Colomba.



Planche 5reboisement de la mangrove à Colomba (La Fédération Régionale des Groupements de Promotion Féminine de la région de Ziguinchor) (Cliché SANE, 2024)

2.1.5 Amendment of Rice Fields with Organic Fertilizer

The spreading of manure, dead leaves, compost, peanut shells, crop residues, wood sawdust, cow dung, chicken droppings, and ash during the dry season or at the approach of the rainy season is a technique practiced by some rice farmers in the Diouloulou watershed (see Plate 6).

The basic principle is simple: it aims to combat soil salinization by promoting the leaching of salts and the replacement of sodium ions (Na^+) with another cation (for example, Ca^{2+}) which moderates the soil environment.

This technique has proven to be very effective in the recovery of salty soils by farmers. Indeed, organic matter promotes the leaching of salts through organic acids that bind sodium ions and carry them away with the rainwater [11].

The spreading of manure on rice plots was widely practiced before and at the beginning of the drought years, a period when there was a young and abundant labor force. However, this practice is less common today except in a few rare localities where farmers are trying to maintain it.



Planche 6: collecte de fumier organique (feuilles de manguiers et bouses de vache) pour la fertilisation des rizières à Kolomba (Cliché Sané, 2024)

1.1.6 Access to Inputs (Fertilizers, Certified and Improved Seeds)

The use of certified and improved seeds aims to increase rice production. Most of these seeds are certified and adapted to current climate disturbances and environmental challenges.

In the Diouloulou watershed, the most active player in facilitating farmers' access to inputs is the Entente de Diouloulou, with its main partners being the PPDC and, more recently, SODAGRI.

In addition to PPDC, the Entente also has a wide network of partners including:

- **Local authorities:** the 4 communes of the Kataba 1 district (Kataba 1, Diouloulou, Djinaky, and Kafountine)
- **Decentralized State services:** DRDR, SDDR, CADL, Kataba 1 sub-prefecture

- **Agencies and institutions:** ISRA, ANCAR, Agricultural High School of Bignona, Water and Forests Service, SODAGRI, Baila Technical Training Center, CNFTAGR, CICR
- **Projects/programs:** Naatal Mbay, USAID KAWOLOR, PRGTE, NGOs: FONGS, SOS FAIM, COOSPE
- **Associations:** DIOULOLOU, CRCR, ASDCOD, AJAC, CLCOP, ASCE, APAD, FRGPF, ASAPID, CADP
- **Financial institutions:** CNCAS

All these partners participate directly or indirectly in revitalizing rice farming (free or subsidized access to inputs, seed production, mechanization, training, supervision, processing, combating salinization, promoting new technologies (see Plate 7), varietal choice according to soil toposequence, etc.).

Thus, it is through its various partners that it provides free or subsidized seeds, depending on the varieties requested by the population. Different distributed varieties are listed: BG 90/2, WAR, Tox728-1, BW248-1, WAP 56-50, DJ, IRAT 10, ROK 5, NERICA, and SAHEL. With these varieties, yields can reach up to 1.80 tons per hectare (Table 2). Seeds are sold to rice farmers at 100 FCFA per kilogram and are repurchased after harvest at 250 FCFA per kilogram by the Entente de Diouloulou. The Entente also provides subsidized inputs (Table 2).

Table 2: Seed Production in 2018

Variety	Production Level	Area (ha)	Yield (T/ha)	Production (T)
BG90/2	Base	43.6479	1.69	73.76
	R1	62.6305	1.69	105.84
WAR	Base	17.671	1.65	29.15
	R1	121.4174	1.65	200.33
Tox 728-1	Base	1.2	1.77	2.124
	R1	11.872	1.77	21.013
BW248-1	Base	3.15	1.86	5.85
	R1	5.106	1.86	9.42
WAP 56-50	R1	0.38	1.26	0.47
DJ	Base	0.1485	1.57	0.23
	R1	4.53	1.57	7.11
IRAT 10	R1	0.4	1.25	0.5
ROK 5	Base	5.106	1.52	7.76
	R1	14.159	1.52	21.52
NERICA	Base	1.36	1.37	1.86
	R1	3.6915	1.37	5.05
SAHEL	Base	1.15	1.54	1.77
	R1	56.2305	1.54	86.59
Total	—	—	—	580.347

Source: Report of Entente Diouloulou, 2018

Adding calcium or phosphate fertilizers helps raise the pH of acidic soils. Many studies from around the world support this [12], showing a very noticeable improvement in yields when phosphate fertilizers are applied. Soluble forms seem more effective than natural or insoluble ones. The natural phosphate from Senegal, **Taïba tricalcium phosphate**, still shows significant effects. The use of crushed oyster shells, rich in lime, may constitute another possible source [13].

In this watershed, fertilizer use varies from one locality to another. It is observed that chemical fertilizer is more used in the village of Kabiline. In that village, the majority of farmers amend their rice fields with chemical fertilizer. This can be explained by the relationship that exists between them and the Entente de Diouloulou. With the Entente de Diouloulou, a bag of chemical fertilizer may cost **10,000 FCFA**. During the 2021 campaign, many farmers received **“GREEN OK” bio-fertilizer** for free from SODAGRI. It should be noted that in this locality many farmers are involved in seed production; as a result, certain cultural practices are required of them (use of industrial fertilizer amendments, adherence to the cultural calendar, timely transplanting—i.e. transplanting rice seedlings when they have two leaves).

On the other hand, systematic recourse to amendments sometimes encounters economic constraints. The operational costs of a rice field are significantly increased for some rice farmers. So, they prefer natural fertilizers which also require transport or available, young labour, but which a household can do with existing means. Some believe chemical fertilizers gradually reduce soil fertility.

Table 3: Access to Inputs in 2018

Input Type	Quantity (kg)	Number of Beneficiaries	Number of Women Beneficiaries
Seeds	40,000	2,881	1,424
NPK Fertilizer	75,000	2,881	1,424
Urea	85,000	2,881	1,424
Total	—	2,881	1,424

Source: Report of Entente de Diouloulou, 2018

2.2 Technical and Socio-Economic Blockages to Development of Rice Valleys in the Diouloulou Watershed

Agricultural and rural development in Lower Casamance is heavily threatened and constrained by various factors of different natures. In the valleys of the Diouloulou watershed, the environment and production systems are gradually degrading despite the efforts made [14]. This degradation is perceptible in most valleys that have been rehabilitated and developed in recent years with hydro-agricultural works (anti-salt dams, retention dikes, etc.). This is what justifies, in part, in several localities of the study basin, a gradual reduction in cultivable rice areas and, by extension, a decline in yields.

2.2.1 Environmental Factors Blocking the Development of Rice Valleys in the Diouloulou Watershed

Salinization, soil acidification and, to a lesser degree, sand deposition are the main phenomena observed in the valleys of the Diouloulou watershed. This process of rice land degradation observed after the major droughts still leaves traces and makes rice farming vulnerable (Table 4). The salinity in those rice fields is often linked to the advance of the salt tongue or to the invasion of water from the bolon [15]. It should be noted that, in the waterways of the Diouloulou watershed, the electrical conductivity (EC) value is around **45 mS/cm** in the rainy season (August 2017) and **65–75 mS/cm** (March 2018 to June 2018) in the dry season.

Upstream in the valleys, there are areas where **sand deposits** exist at the transition zones between plateaus and lowlands. This causes in those areas a retreat of rice fields toward the plateau and a reduction in the effectiveness of some development structures such as retention and anti-salt dams. Table 4 shows the environmental factors blocking the development of rice valleys in the Diouloulou watershed.

9).



Planche 8 : digues détériorées par manque de renouvellement dans la vallée de Birkamading (Cliché Sané, 2024)



Planche 9 : barrage abandonné par manque de renouvellement de la Dig ue à Karongue (Cliché Sané, 2024)

Several of these developments are either not maintained or poorly managed (Board 9). Many of them are no longer functional and have been left to the mercy of nature (Photo 9).

Today, despite efforts made in the development of the valleys, most of these rice-growing valleys are underexploited (Board 10). This underutilization is due to:

- On one hand, the lack of labor and technical means for the renewal of dikes, rice farming work, organization for the management of hydro-agricultural infrastructure, and a low level of support for farmers;
- On the other hand, the wandering of animals, which poses a complex problem that is difficult to manage, especially in the localities of Mohamouda Chérif, Darou, Khairy, Badionkotong, and Birkamading. Farmers are sometimes forced to abandon certain plots due to a lack of labor for surveillance.



Planche10 : digue d'environ 1, 5 km dont la partie protégée des rizières est sous exploitée à Karantaba (Cliché Sane 2024)

Table 5: Socio-economic factors limiting the development of rice valleys in the Diouloulou watershed

Factors	Observation/Interview	Direct and Indirect Causes Findings and (Observation/Interview) Interviews
Management of structures and water	- Deterioration of water management systems - Malfunctioning structures - Poor management of infrastructures	- Lack of maintenance Observed in all - Lack of organization for developed valleys infrastructure management Reported by rice - Weak monitoring/support farmers and local system by public institutions authorities (interviews) (interviews)

Factors	Observation/Interview	Direct and Indirect Causes (Observation/Interview)	Findings and Interviews
Labor force	Progressive impoverishment	- Low generational renewal - Aging of farmers (interviews) - Insufficient number of extension workers - Low generational renewal	Reported by rice farmers and local authorities (interviews)
Extension and support	Low level of farmer support, mostly tied to national and international aid programs	- Lack of technical and logistical means, as well as economic incentives for extension workers - Lack of public institutional support - Lack of monitoring of extension activities (interviews)	Reported by rice farmer groups and local authorities (interviews)

Source: Sané, 2024

2.2.3. Agronomic factors limiting the development of rice valleys in the Diouloulou watershed

In the Diouloulou watershed, as in the broader geographical setting of Lower Casamance, the use of traditional tools such as the Kajendu for plowing remains a major limitation for agricultural development. Mechanization is very limited. Yet, “mechanization is undoubtedly a key technical tool for reducing working time, increasing yields, expanding cultivated areas, and coping with the progressive decline and efficiency of the labor force” [17].

Table 6: Summary of per-hectare investment for seed production

Designation	Unit	Quantity	Unit Price	Amount
Land preparation	Ha	1	20,000	20,000
Seeds	Kg	40	100	4,000
NPK	Kg	150	66	9,900
Urea	Kg	100	64	6,400
Herbicide	Liter	4	10,000	40,000
Bags	Number	40	300	12,000
Labor	Ha	1	61,400	61,400
Other costs	-	1	15,000	15,000

Designation	Unit	Quantity	Unit Price	Amount
Total Costs				168,700
Production (FCFA)	Kg	1,600	250	400,000
Gross margin per hectare (FCFA)				231,300

Source: Entente de Diouloulou Report, 2018

However, rice farmers consider the purchase prices of agricultural equipment, inputs, and services to be too high in the context of subsistence rice farming. Subsidized seeds usually arrive very late, forcing farmers to rely on their own harvest, whose preservation is not guaranteed. To respect the cropping calendar and avoid delays, some farmers set aside part of their harvest as seed for the next season.

In the watershed, most farmers who use certified seeds, chemical fertilizers, or service provision rely on the Entente de Diouloulou. Often, demand exceeds supply, especially for tractor plowing. If a request is not made early, farmers risk not receiving service for the entire season. These factors combined significantly limit rice exploitation in the Diouloulou watershed.

Table 7: Agronomic factors limiting the development of rice valleys in the Diouloulou watershed

Factors	Observation	Direct and Indirect Causes	Findings and Interviews
		- Social division of labor: men on uplands, women in valleys (Mandinka areas)	
		- Soil preparation by men, transplanting and harvesting by women (Diola areas)	Observed in all visited
Animal traction	Hardly used in the valleys; mainly owned by men	- Valley soils too hard, especially early in rainy season - Equipment poorly adapted to animal power and required work - Simultaneous demand for services - Parcels very small	Reported by rice farmers and local authorities (interviews)
Mechanization (motorization)	Insufficient mechanization equipment in valleys	- High purchase and operating costs - Lack of skilled labor for use and maintenance	Observed in all valleys visited Reported by rice farmers

Factors	Observation	Direct and Indirect Causes	Findings and Interviews
Farming operations		- Poor planning of technology and local authorities supply for local context (interviews)	
		- Small parcels	
		- Simultaneous demand for services	
	- Inadequate soil preparation	- Almost exclusively manual plowing	Observed in most valleys
Seeds	- Poor weeding	- Labor shortage	(except Kabiline)
	- Inefficient post-harvest processing	- Limited diffusion of line-sowing	Reported by rice farmers and local authorities
	- Ineffective storage and conservation	- Lack of tools for post-harvest operations	(interviews)
	Limited dissemination of quality seeds, especially for lowland rice	- Insufficient production of certified/improved seeds	Reported by rice farmer groups, local authorities, and the Entente de Diouloulou (interviews)
Inputs		- Lack of equipment	
	Limited access to fertilizers	- Limited availability	Reported by some rice farmer groups, local authorities, and the Entente de Diouloulou (interviews)
		- High cost	
		- Lack of training and technical assistance for rational use	

Source: Sané, 2023

III. Discussions

The Diola people have long been recognized as skilled technicians in rice field development, particularly in building dikes and bunds that serve both for water management and land demarcation [2, 18, 19, 20, 15, 1]. These dikes and bunds were regularly maintained. Although effective, this Diola system is very labor-intensive, requiring a large and youthful workforce, since the tools used (Kadiandou, mainly) are rudimentary and energy-demanding [2].

Since the 1970s drought, however, Lower Casamance, including the Diouloulou watershed, has faced a labor shortage. Many young workers migrated to towns in search of employment and better living conditions [2, 17, 20, 21]. This led to a decline in rice farming due to the strenuous labor required in lowlands (plowing, transplanting, harvesting), heavy earthworks (dike construction and maintenance), and fertilization with organic manure.

To revitalize the sector, successive governments and NGOs have launched multiple projects and programs in the region [15]. Lower Casamance has long benefited from state and partner interventions (SOMIVAC, MAC, PPDC, PRIMOCA, GRDR, WFP, ISRA, SODAGRI, Entente Diouloulou, etc.) aimed at overcoming development bottlenecks, reducing poverty, and boosting rice production and rural incomes.

Despite these efforts, rice farming continues to face the consequences of the 1970–1990 droughts, even under current rainfall recovery [23]. Results on the ground fall short of state and partner investments. Support structures remain unclear in scope and effectiveness, with many unresolved problems resulting in significant losses. A reorganization of agricultural policy in Casamance is thus urgently needed.

Currently, the land utilization rate in many developed valleys remains low. Some rice parcels gained through infrastructures (dikes and sluices) are not exploited. In some cases, structures are in poor condition, especially the mobile and metallic parts of sluices [24, 25]. This reflects a lack of knowledge or appropriation of hydraulic functions by users.

Conflicts often arise over water management calendars between rice farmers and managers. Some farmers prioritize keeping fields flooded to ensure crop survival, unaware of risks of salinization and acidification. According to Mr. Diatta, Head of SDDR Bignona: “Even if the infrastructure protects against saline intrusion, retaining freshwater in the plots requires above all improving soil structure through organic matter input.”

Meanwhile, some hydro-agricultural infrastructures are abandoned due to lack of maintenance (collapsed dikes, rusted or broken sluices). They no longer regulate freshwater retention or saltwater intrusion. In the Diouloulou watershed, labor shortages continue to hinder dike renewal and land development.

Another major problem is cattle intrusion (Plate 11), especially at night, which devastates crops and is difficult to control, as noted by the village chief of Mohamouda Chérif [27]. This contributes to under-utilization of rice valleys, except in Kabiline, where with Entente de Diouloulou’s support (inputs, equipment, seed production services), rice farming is well organized. Each year, new parcels are cultivated, water management and infrastructure are efficiently maintained, and animal intrusion is controlled.



Planche11 : bœufs en divagation dans la vallée de Mohamouda Chérif (Cliché, Sané, 2024)



Planche 12 : clôture pour protéger les rizières contre la divagation des bœufs à kataba1(Cliché, Sané, 2024)

So far, the other villages in the Diouloulou watershed have not managed to follow the example of Kabiline. Rice production has declined to the point where it risks not being able to cover households' daily rice needs. Despite these conditions, many farming communities have managed to adapt by changing their practices, diversifying their sources of income, and adopting new crops as well as new land-use practices that generate reasonable income [28].

Thus, young farmers (the active labor force) are increasingly less interested in rice cultivation, favoring instead non-rice activities that are more profitable. They are increasingly turning to other less strenuous and financially rewarding activities such as arboriculture and market gardening, exploitation of forest resources, and palm oil processing. Fruit arboriculture is well developed in the south of the country, which provides most of the citrus fruits (oranges, lemons, tangerines, grapefruits) and so-called tropical fruits (mango, banana, etc.) [27]. these activities enable them to meet their food needs.

Despite its decline, rice cultivation remains central to community life and continues to mobilize everyone. Other activities such as palm oil production, fishing, and salt extraction are secondary and involve smaller economic units.

Conclusion

For several years now, most villagers in the Diouloulou watershed have experienced an agricultural decline, particularly in rice farming. Cultivated areas have decreased, and consequently, rice production has dropped [27].

To address this decline, multiple and diverse responses have been proposed by different actors, including the state, development partners, NGOs, and local populations themselves. Their interventions in rice farming have taken the form of building hydro-agricultural structures, providing agricultural equipment, subsidized seeds and inputs, and farmer training—especially in seed production.

However, agricultural and hydro-agricultural development policies have not solved the problems faced by farmers. In this context, marked by a reorganization of rice-growing areas and farming practices that are poorly adapted, rice policies (hydro-agricultural developments, rural development projects and programs) do not appear, for now, to be producing the expected results. The infrastructures are either ineffective or poorly maintained.

In some areas, however, such as Kabiline, rice farming has been preserved, as shown by the expansion of cultivated rice fields [22]. The example of Kabiline could be replicated in other areas of the watershed, and even throughout Lower Casamance.

Despite the return of rainfall and the commitment of the state and its local and international partners to modernize rice cultivation in the valley, farming methods remain traditional. This makes rice farming increasingly unattractive to young people, who prefer more profitable extra-rice activities such as arboriculture and market gardening. Such a situation makes the strategies for developing rice farming in some parts of the Diouloulou watershed uncertain.

The key question is therefore: What is the future of rice cultivation in the village lands of the watershed, in a context where non-rice income-generating activities, which are more profitable, are increasingly developing?

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