RESADE

Improving Agricultural Resilience to Salinity Through the Development and Promotion of Pro-Poor Technologies

ASSESSMENT OF EXISTING IRRIGATION AND DRAINAGE INFRASTRUCTURE






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Improving Agricultural Resilience to Salinity Through the Development and Promotion of Pro-Poor Technologies

Final Report

Project Activity 4.2

ASSESSMENT OF EXISTING IRRIGATION AND DRAINAGE INFRASTRUCTURE

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From Authors

The RESADE project is led by the International Center for Biosaline Agriculture (ICBA) and is being implemented with the collaboration of the national partners in the target countries: the National Agricultural Research Institute of The Gambia (NARI), Mozambique's Institute of Agricultural Research (IIAM), Togolese Institute of Agronomic Research (ITRA), Sierra Leone Agricultural Research Institute (SLARI), and Central Agricultural Research Institute of Liberia (CARI). These national partners have provided unwavering support and technical expertise in achieving the project objectives. Their contributions to this report in particular and to the RESADE project in general are highly appreciated.

This report titled "Assessment of Existing Irrigation and Drainage Infrastructure" is based on an analysis of the primary and secondary data collected during the course of the project. The collected data include a bibliographic review, project documents and reports, and information obtained from site visits. The collected data were analyzed to create a history of accomplishments related to water collection and storage, crop yields, and other uses. Surveys were conducted to record stakeholders' views regarding the effectiveness, relevance, and usefulness of the irrigation and drainage infrastructure.

The authors are extremely grateful to Dr. Tarifa Al Zaabi, ICBA Director General, for her overall guidance and leadership for the successful implementation of this project. We express our gratitude for the invaluable support extended to the project by our esteemed partners and we remain steadfastly committed to the successful execution of this pivotal initiative. We also extend our appreciation to the field teams and scientists in all target countries for actively contributing to the data collection and analysis.

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This report is a part of the project "Improving Agricultural Resilience to Salinity Through the Development and Promotion of Pro-Poor Technologies (RESADE)," jointly funded by the International Fund for Agricultural Development (IFAD) and the Arab Bank for Economic Development in Africa (BADEA). The RESADE project aims to provide effective solutions to the growing problems of soil salinization in seven sub-Saharan African (SSA) countries: Botswana, Namibia, Mozambique, Liberia, Sierra Leone, The Gambia, and Togo. This project assesses and identifies deficiencies in water management and irrigation infrastructure to improve agricultural resilience in SSA countries. Improving irrigation and drainage infrastructure should be a top priority for sustainable production and livelihoods in the agricultural sector.

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Executive Summary

Irrigated agriculture is considered the most remunerative farming to ensure sustainable agricultural production and livelihood of poor rural farmers. In most African countries, rainfed agriculture is practiced because of the scarcity of irrigation water, resulting in lower and unpredictable crop yields. Consequently, more than 400 million people are malnourished in Africa, with 218 million living in sub-Saharan Africa (SSA). Despite intensive attempts over three decades, the rate of poverty reduction in Africa is far lower than in other regions of the world. The number of poor people in SSA (<USD 1.25/day) dropped by 23% from 1993 to 2011 compared with the world average of 59% during the same period. Therefore, development of the agricultural sector is central to combating hunger, reducing poverty, and achieving economic growth in this region.

In addition to improving the efficiency of on-farm water management practices, adequate collection and disposal/reuse of drainage effluent is crucial to ensuring the sustainability of crop production systems. Considering the fragmented information on irrigation and drainage infrastructure in SSA, there is a need to assess the status of the infrastructure to determine the fundamental limitations that influence irrigation delivery, irrigation management, and disposal of drainage effluent.

Performance assessment of irrigation and drainage infrastructure involves the systematic observation, documentation, and interpretation of the management of an irrigation and drainage system. This assessment is needed to ensure that the infrastructure fulfills the basic irrigation needs to meet crop water requirements and overcome leaching of salts to maintain an appropriate salt balance in the root zone. This evaluation is needed to monitor the overall system's performance and efficiency in terms of sustainability of the cropping system.

This report aims to examine and document the current state of irrigation and drainage infrastructure in the five target countries (The Gambia, Liberia, Sierra Lione, Togo, and Mozambique) of the RESADE (Improving Agricultural REsilience to SAlinity through DEvelopment and Promotion of Pro-Poor Technologies) project. This study assesses the factors that influence irrigation delivery, management, and disposal of drainage effluent. This report also highlights the system's critical deficiencies that contribute to soil salinization and low productivity of land and water.

Two types of data and information were collected, including primary and secondary data. Secondary data collection consisted of a bibliographic review of public administrations and private services related to water management. Existing project documents and reports have been received, read, and analyzed. This made it possible to make a history of achievements regarding water collection, crops, and other uses. Several projects were visited to obtain information from the managers and technicians on different aspects of the irrigation schemes. For each project, a rapid description of the basin, general characteristics of irrigation and drainage infrastructure, cropping pattern, and information on the irrigation facilities were collected. A maintenance guide was used to inform the types of work, the materials used, the technical specifications, and performance in terms of yield and durability. Opinion surveys with beneficiaries were also conducted to obtain their perceptions of effectiveness, relevance, and usefulness.

This study is undertaken with the collaboration of the target countries' irrigation, water management, and agricultural extension departments. The data used in this study consist of irrigation network and farm-level information (irrigation channels/outlets and current irrigation systems such as surface, furrow, drip, and sprinklers and their extent). The collected data also include irrigation water quality, irrigation practices, depth and quality of groundwater, and characterization of drainage systems (structures, depth of drainage network, efficiency, drainage type, expected life, and drainage maintenance system). Despite abundant water resources, their current use for agricultural production is still limited. Water resource management in these countries faces several challenges. The lack of information about distribution, scale, and use of water resources severely impacts water resource planning, allocation, and monitoring. Challenges also include low and unreliable water resource protection, conservation, and management financing; poor land management affecting the rehabilitation and protection of catchment areas; and increasing water demand due to population growth and urbanization. Additional challenges are changing

weather patterns and increasing likelihood of extreme weather events because of climate change, along with poor stakeholder involvement and awareness. Developing necessary competence through training is of paramount importance for enhancing agricultural productivity.

In general, these countries lack a systematic approach to irrigation and drainage development. The existing irrigation and drainage infrastructure is destroyed or non-functional for different reasons. The lack of engineering skills results in poor designs and quick decay of irrigation infrastructure. Irrigation efficiencies are low, resulting in a higher operational cost. The farmers do not have the technical skills needed to operate pumps and irrigation schemes. Extension services in most countries are inadequate and improvement measures are not included in irrigation projects. The governments need to incentivize farmers to adopt new technologies and move toward intensifying agricultural production. The governments should introduce a decentralized and participatory approach to developing irrigation schemes. Many donor-financed projects evaluated as successful on completion in recent years have adopted this approach.

Improving irrigation and drainage infrastructure should be the top priority of the governments' development agenda in the agricultural sector. Irrigation development can contribute to food security and economic growth only if investments are profitable at the farm level, economically viable, and environmentally sustainable. Therefore, the kind of investments that give the best return needs to be identified. The governments should encourage private investment in irrigation by developing the legal and institutional framework and investing in infrastructure, research, and development. The relative roles of public and private investment must be clarified to foster private investment.

Acronyms

ADP	Agricultural Development Project
AEZs	agro-ecological zones
AfDB	African Development Bank
BADEA	Arab Bank for Economic Development in Africa
CDC	Colonial Development Cooperation
CRRn	Central River Region north
CRRs	Central River Region south
CU	Concern Universal
FAO	Food and Agriculture Organization of the United Nations
FASDEP	Food and Agriculture Sector Development Project
GAFSP	Global Agricultural and Food Security Programme
GALDEP	Gambia Lowland Development Project
GBOS	Gambia Bureau of Statistics
GCAV	Gambia Commercial Agriculture and Value Chain Development Project
GDP	gross domestic product
HP	horsepower
ICBA	International Center for Biosaline Agriculture
IFAD	International Fund for Agricultural Development
ILWAC	Integrated Land and Water Management for Adaptation to Climate Variability and Change
IRDEP	Rice Development Project
IsDB	Islamic Development Bank
JPSP	Jahally & Pacharr Smallholders Project
LADEP	Lowland Agricultural Development Project

LEAP	Livelihood Enhancement Agricultural Programme
LHDP	Livestock and Horticultural Development Project
LIFDC	Low-Income Food-Deficit Country
LRR	Lower River Region
MOA	Ministry of Agriculture
MT	metric tons
NaNA	National Nutrition Agency
NARI	National Agricultural Research Institution
NASS	National Agricultural Survey System
Nema	Agricultural Value Chain Development Project (AVCDP), the National Agricultural Land and Water Development Project
NERICA	New Rice for Africa
RAD	Regional Agricultural Directorate
RESADE	Resilience to Salinity through Development and Promotion of Pro-Poor Technologies and Management Practices
ROC	Republic of China
SSWCP	Small-Scale Water Control Project
UNDP	United Nations Development Programme
UP	United Purpose
URR	Upper River Region
USD	United States dollar
WASDA	Wuli and Sandu Development Agency
WCR	West Coast Region

1

Country Profile
The Gambia

1.1. General Context

The Gambia is a small West-African country with a total area of 10,689 km^2 and a population of 1,882,450 (about twice the population of Montana), of which 40% live in rural areas (GBoS, 2013). Population density is 176 people per km^2, one of the highest in Africa. Poverty is a significant development challenge for the country. According to the 2017 UNDP Human Development Index, the country ranked 174 out of 189 (BRL ingénierie, 2019). Most of the population lives below the poverty line.

The total cultivable arable land covering all six regions is 558,000 ha, representing 54% of the land area. Agricultural production meets only 40.2% of the national food requirement. This means that the country relies heavily on food imports, with high food insecurity. The agricultural sector accounts for 29% of GDP. It employs 75% of the country's population. Agricultural production is primarily rainfed and, throughout the past 30 years, rainfall distribution has been erratic and inadequate. However, the country has vast water resources that could be used to increase food production. The Gambia River is the primary surface-water source in the country, suitable for tidal and pump irrigation. Abundant underground water resources are also available for drinking and irrigation purposes.

The history of the development of irrigation schemes in the country dates back to the 1970s through support from China. This started with developing irrigation schemes mainly in the country's rice hub, that is, Central River Region north and Central River Region south (CRRn and CRRs) and Upper River Region (URR). Most of the schemes, however, collapsed after the Chinese left. Donor partners such as the World Bank, IFAD, IsDB, and AfDB have also invested heavily in developing irrigation schemes for rice production and vegetable gardens within the lowlands. Most of the donor contributions to the ANR sector in 2016- 17 were grants (Yaya et al., 2017). The major challenge that hinders irrigation development in the country is the beneficiary communities' lack of preliminary engineering and managerial skills. As a result, most of the schemes quickly became dilapidated.

1.1.1 Economic context

The Gambian economy is characterized by its small size, narrow base, and large re-export trade comprising about 80% of its merchandise exports. Re-export trade contributes from 53% to 60% of domestic tax. From 2004 to 2009, the country had a stable macroeconomic performance and steady economic growth, averaging 5-6% per annum. Economic growth was based on services (58%), agriculture (30%), and industry (12%). Real GDP growth at factor cost was 7.2% in 2009 and domestic debt was 32.2% of GDP in 2008. Per capita GDP was estimated at USD 556 in 2009.

1.1.2 Agricultural sector

The natural vegetation type of The Gambia is Guinea Savanna Woodland in the coastal area, which gradually changes into Open Sudan Savanna in the east. The climate is Sudano-Sahelian, characterized by a short rainy season from June to October and a long dry spell from November to May with scattered vegetation and forest cover. The country has a total arable land area of 558,000 ha and 320,000 ha (57%) are cropped annually. The estuary basin of The Gambia River is a tidal inlet with saltwater intrusion ranging from 180 km in the rainy season to 250 km in the dry season. Agriculture is primarily rainfed, and only about 6% of the irrigation potential has been used.

1.1.3 Agro-ecological zones (AEZs)

The land area in The Gambia is approximately 400 km long and 30 km wide on both sides of The Gambia River. The country's climate is semi-arid, with only one rainy season and the remaining period seven to nine months of dry period.

The Gambia is divided into three AEZs (Figure 1):

1. AEZ 1: Sahelian (extreme north of Central River Region)
2. AEZ 2: Sudano-Sahelian (north bank, Lower River, Central River, and Upper River regions)
3. AEZ 3: Sudano Guinean (western, extreme south of Upper River Region)

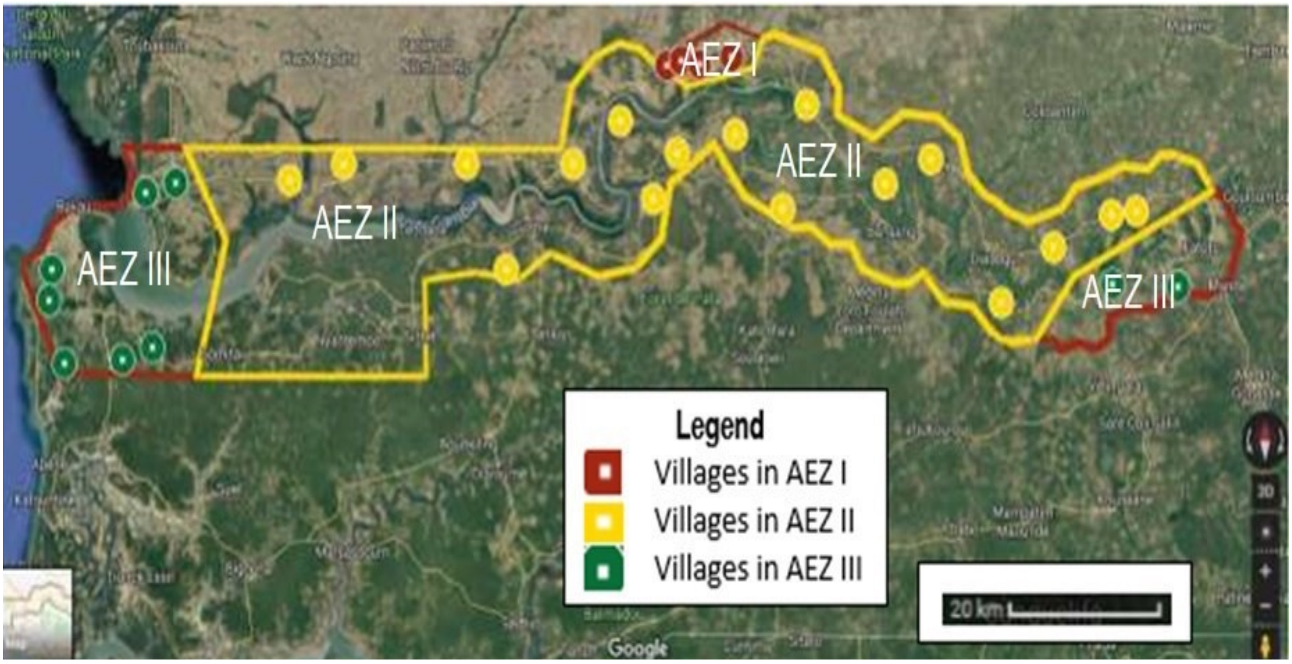


FIGURE 1. AGRO-ECOLOGICAL ZONES OF THE GAMBIA.

1.1.4 Contribution of agriculture to the economy

The agricultural sector accounted for 29% of GDP in 2009. It employs 75% of the country's population and meets about 50% of the national food requirements. Its share of the country's total exports is 70%, thus constituting a substantial part of The Gambia's foreign exchange earnings. Agriculture is also the sole means of income for most poor rural households. A total of 91% of the population is abysmal in The Gambia and 72% of the poor work in agriculture. The agricultural sector is regarded as the prime sector for investments to raise income, improve food security, and reduce poverty. Notwithstanding the unimpressive performance of the agricultural sector over the recent past, The Gambia does enjoy comparative advantages for lowland rice, groundnuts, coarse grains, cotton, and vegetable production. The livestock sector contributes 33% to agricultural GDP, groundnuts 23%, other crops 43%, fisheries 3%, and forestry 2% (GBoS, 2009).

1.1.5 Structure of the sector

The agricultural sector is characterized by small-scale, subsistence rainfed crop production (mainly groundnuts, coarse grains, rice, and cassava), traditional livestock rearing, semi-commercial groundnut, horticultural, and small cotton production. Agricultural output is generated by about 69,000 farm households (with 500,000 people engaged in farming). Of the cultivated area, about 30% is devoted to groundnut production, 144,000 ha for grains, and 72,000 ha for rice cultivation under rainfed conditions. Cotton is grown on about 3,000 ha annually, while cassava, potato, and horticultural crops occupy from 1,500 to 2,000 ha per year. An estimated 2,500 ha are annually dedicated to irrigated rice, mainly in the CRR, with 800 ha under horticulture (NASS/MOA, 2009).

The Gambia is classified as a Low-Income Food-Deficit Country (LIFDC) and it produces about 50% of the total food consumption needs. Its national requirements for rice (major staple food) are from 180,000 to 200,000 metric tons (MT), against the national production of polished rice of only 12,000 MT (only 6% of the total requirement). Despite increasing cereal production, the gap between supply and demand widened from 1991 to 2007 because of the increasing population (2.77%). The cereal consumption deficit increased from 65,600 MT in 1991 to 150,000 MT in 2007 (GAFSP, 2010). The food deficit is bridged by commercial rice and wheat flour imports coupled with food aid. Soaring food and fuel prices (through increased transportation fares) affected the living standards of Gambians as a large proportion depend on rainfed agriculture for their subsistence and thus cannot meet their subsistence requirements.

1.1.6 Paddy rice production in The Gambia

The Republic of China (ROC) technical mission has been promoting paddy rice production and the expansion of paddy fields since 1995. Increasing unit output and reducing production costs resulted in improved rice varieties and more advanced technology. Old paddy areas were gradually replanted after the intensive application of irrigation technology and agricultural machinery.

Nonetheless, rice imports are continuing to increase. The Gambia's current agricultural policy is still to achieve self-sufficiency in grain production. However, to reach an annual production of 80,000–90,000 tons, it is essential to develop the irrigation sector. This can be achieved through the close collaboration of local farmers, the government, and international organizations.

Paddy rice is grown primarily along the middle and lower reaches of The Gambia River (Figure 2), whose water is used for tidal irrigation in certain parts of the country. Although rice is a staple food in The Gambia, most farmers are too poor to buy the required fertilizer and agricultural machinery. The small cultivation area and primitive farming technology keep output low, at about 1.5 tons/ha. The government allows the free import of rice, thus discouraging farmers from growing the crop. Most grow only enough rice to meet their own needs, with the result that the 20,000 tons produced annually account for less than one-quarter of domestic demand. Over the years, the government has made increasing rice output a major policy objective, and it has used foreign aid money to develop 6,000 hectares of new rice paddies. However, most of those paddies have been abandoned because of poor management and a lack of resources. National projects have been promoting paddy rice production. Improved rice varieties are introduced, and more advanced technology increases unit output and diminishes production costs.

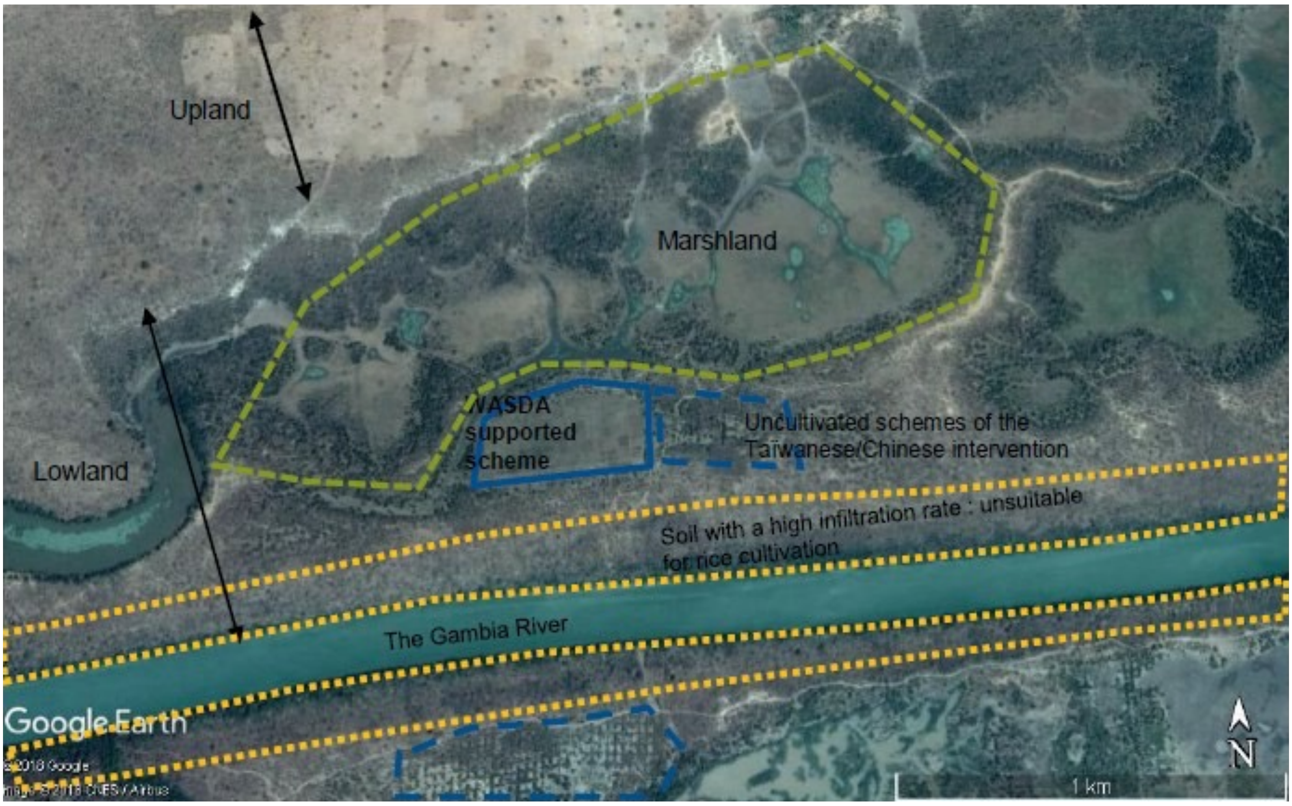


FIGURE 2. THE LANDSCAPE ALONG THE GAMBIA RIVER (SOURCE: BRL INGÉNIERIE, 2019).

1.1.7 Rainfall

Mean annual rainfall varies from 900 mm in the southwest to about 500 mm in the northeast. Mean temperatures vary from 14 to 40 oC and are generally higher in the eastern part of the country. With this short-duration and unreliable rainfall, crop and livestock production become tricky. The absence of adequate water control and irrigation structures that ensure continuous production of food and cash crops has seriously hampered progress in agriculture over the past years.

1.1.8 Rice cultivation zones

Based on the BRLi Sambalagou dam feasibility study, the rice-growing areas can be identified (Figures 3 and 4):

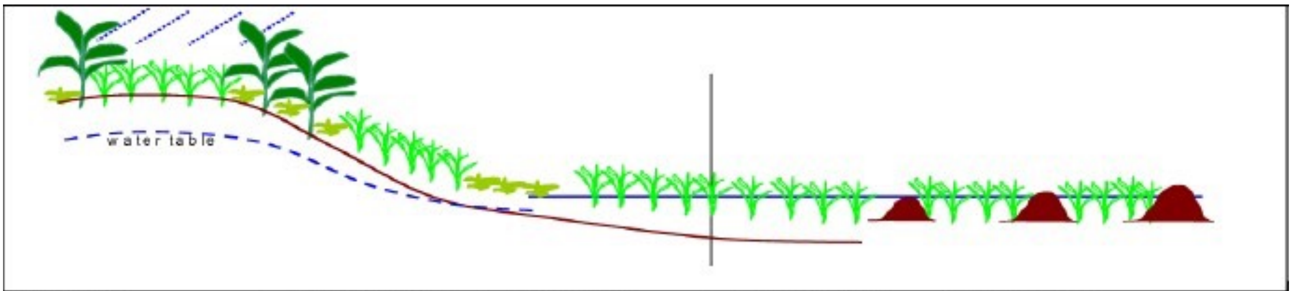
Rainfed rice in the uplands. This form of rice growing was quite common due to the high yield and short growth cycle of rainfed NERICA varieties. However, erratic rainfall has resulted in a loss of trust in this culture during the past two years. Moreover, considering the increasing land pressure and decreasing soil fertility in the uplands, NERICA varieties are not adapted to the local conditions. Only a few farmers grow NERICA varieties as the farmers do not have many options.

Rice grown in the flood recession depressions and swamps in the vicinity of the river. There is no water control for this type of farming, hence consequential losses in terms of harvest due to flooding in rainy years. Often referred to as "swamp rice," local varieties with long growth cycles (140 days) are generally used. This type of rice-growing is gradually losing cultivated surface since the introduction of rainfed rice.

Rice irrigated by tidal action, referred to as "tidal rice," is the most widespread. It is being intensified, and improved varieties are being introduced.

Rice irrigated by pumping became popular in the 1970s but then collapsed and was replaced by the tidal rice system, which is less expensive to operate. Recent years show a revitalization of irrigated rice in the Upper River Region.

Rice farming in the estuary called Bantafaro, where dikes protect the paddy fields against saltwater in the river and irrigation water is derived from runoff or small watercourses. Yields are low and there is no water control.



Upland	Hydromorphic slopes	Lowland	Intensified lowland	Irrigated lowland
Main water supply: Rainfall	Rainfall + water table	Rainfall + water table + flood water	Regulated flood water	Irrigation

FIGURE 3. RICE PRODUCTION CONTINUUM (SOURCE: ABIBOU, 2019).

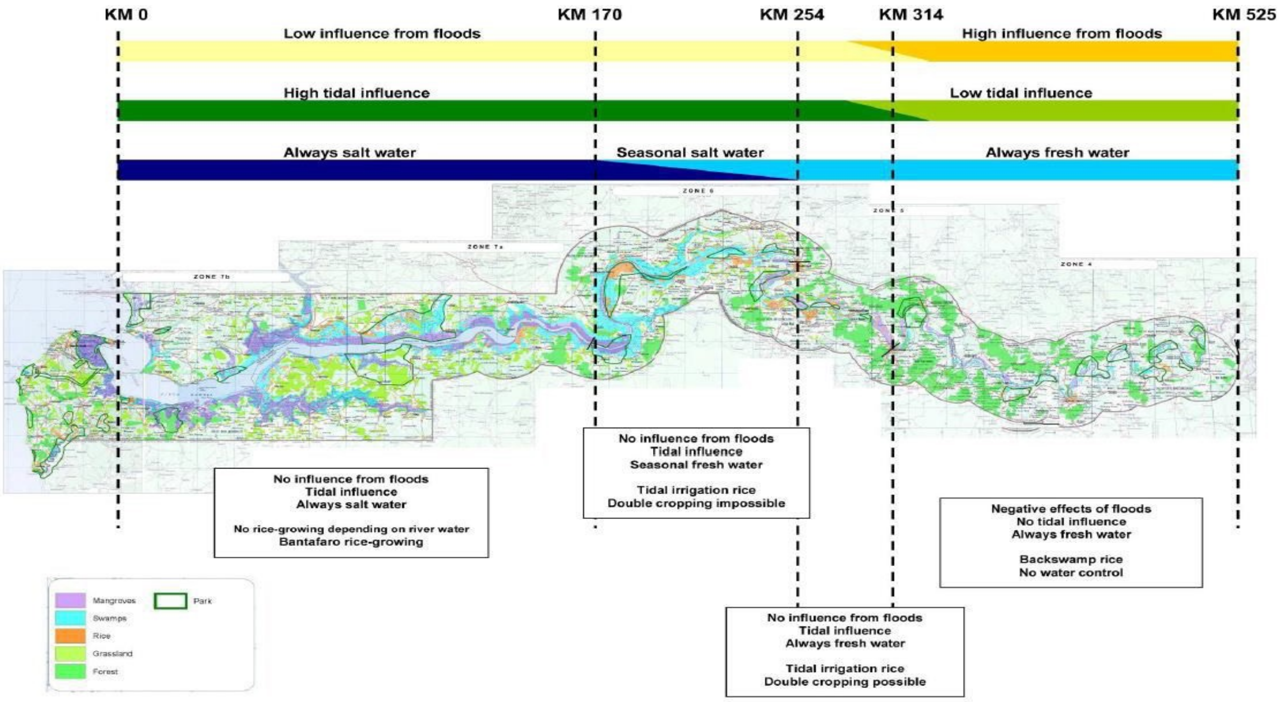


FIGURE 4. Rice system zoning in The Gambia (BRL ingénierie feasibility study, 2019).

1.2 Water Resources of The Gambia

The Gambia's water resources consist of surface waters (mainly The Gambia River and its tributaries and coastal streams) and sub-surface waters found in multiple aquifers throughout the country (Figure 5). The Gambia River is a highly seasonal transboundary river, with flows ranging from 5 m^3/s in April and May to 1,000 m^3/s by the rainy season. As a result, the saline/freshwater interface fluctuates from 250 km upriver during the dry season to less than 100 km in the rainy season. The country also has phreatic and deep sandstone aquifers, estimated to store 0.1 km^3 and 80 km^3, respectively. The main surface-water body, The Gambia River, is affected by tides of 0.1 m to 2.2 m in amplitude in Banjul and more than 0.1 m at Gouloumbo (526 km from Banjul). These marine influences occur for two months or longer in the year and in more than half the length of the river's run in the country. Flow, which can be as low as 5 m^3/s in April and May, increases significantly starting from June and reaches a peak of about 1,000 m^3/s toward the end of the rainy season in September/October. However, the river water resources are divided into fresh, brackish, and salty water, respectively, from land to the Atlantic Ocean. The river is a thoroughly mixed estuary with no evidence of stratification (layering of water of different densities). Furthermore, the river is fresh year-round in its eastern reaches and saline year-round in its western part. As a result of the seasonality of flow levels, the saline/freshwater interface can shift from a maximum of 250 km upriver in the dry season to less than 100 km upriver in the rainy season.

FIGURE 5. THE HYDROGRAPHIC SYSTEM.

The geographical distribution of water area, lines, and rivers in The Gambia. DIVA-GIS software (version 7.5) obtained from the DIVA-GIS website (http://www.diva-gis.org) was used to create the maps.
The Gambia also has deep aquifers connected to regional flow systems and/or leakage from overlying aquifers. Renewable surface-water and groundwater resources are estimated at 6.5 km^3 and 1.5 km^3, respectively. At least 85% of the annual flow representing renewable surface water comes from the upper Gambia River Basin.

Hydrological processes and water resources engineering combine in multiple ways to impact land degradation at both the watershed and farm levels. Where hydrological processes occur, land degradation at the landscape level is tied to changes in the flow components of the hydrological cycle, resulting in soil salinization, acidification, and erosion. Changes in flow components of hydrological processes at local and catchment scales also pressure vegetation and soils. This is amply demonstrated by the impacts of a decline in rainfall across the Sahel that occurred in the late 1960s (abetted by obstruction of flows by riparian landowners in cross-border sub-catchments) on soil and vegetation along the lower reaches of the Bintang Bolon (Bojang and Sillah, 2000). Fertile land on the edge of the floodplains around Carrols Wharf (at 199 km from the mouth of The Gambia River) has also been transformed into barren mudflats because of saline encroachment, evaporation, and drying of potential acid sulfate soils.

1.2.1 Water quality degradation

The quantity and quality of both surface- and groundwater resources are decreasing because of pollution of shallow wells by floods, intrusion of saline water in freshwater rice-growing environments, and the salinization of The Gambia River because of the increasing frequency of droughts, climate change, and climate variability.

1.2.2 Irrigation technologies

The country has an untapped potential for water resources that could be used to enhance food production. The Gambia River is the primary surface-water source for tidal and pump irrigation. Abundant groundwater resources are also available for drinking and irrigation.

Water resources are available and should increase with the Sambangalou dam. According to the hydrological studies carried out for this dam's environmental and social impact assessment, the water flow in the Upper River Region during the dry season should be artificially increased. However, it is difficult to anticipate this because the water availability in the dam is unknown.

The country has four main categories of irrigation technologies:

Pump irrigation: Small low-lift pump-irrigated perimeters (diked lowland fields) located in swamp areas adjacent to the main river or its tributaries.
Tidal irrigation: In low-lying marshy areas, tidal flows are employed for irrigation purposes. This is feasible in the river's middle reaches, beyond the 240-km mark, where river water is not salty. Tidal irrigation differs from ordinary gravity or pump irrigation as it takes advantage of the ocean tides to force river water onto the fields. Tide heights vary from 3.5 m at the mouth of The Gambia River to 0.9 m at Basang, 310 km upstream. Tidal irrigation can be used to water marshy fields with an elevation of fewer than 1.7 m above the average sea level. A water control valve is usually installed where water enters the system, and the system should have separate inlets and outlets. River water is allowed to flow into the system at flood tide and the outlet valve is shut as the tide ebbs to keep the water on the fields.

There is a tendency to avoid pumping and develop tidal irrigation or convert pump irrigation into tidal irrigation. This is because of its lower investment costs and cheaper and simpler operation and maintenance. However, the challenges with tidal irrigation are the uneven water distribution to all fields. Some fields are flooded while others don't have water, leading to unending conflicts among farmers. Drainage is another challenge, especially in the rainy season, thus permitting ostly? single-season cultivation.

Sprinkler irrigation: Practiced in a few private and community garden projects primarily using groundwater.

Drip: Drip irrigation for gardens is promoted in The Gambia. However, farmers have not yet adopted and practiced it except in a few private gardens. On-farm demonstrations and intensive capacity building would be paramount in convincing farmers to adopt this technology.

Inland valley bottoms: Mangrove swamps and freshwater swamps, where rice is grown from August to January, by constructing simple protection dikes. The irrigation technologies implemented in the country are tidal schemes and groundwater systems by rehabilitating boreholes, wells, and pumping systems. Irrigated lowland rice has also proven successful.

1.2.3 History of transformation of the agricultural sector through irrigation

Over the years, the government has made increasing rice output a significant policy objective, using foreign aid to develop new rice fields. However, most of these fields have been abandoned because of poor management and a lack of resources.

In 1953, the Colonial Development Cooperation (CDC) Rice project started the first pump irrigation scheme at Jahally and Pacharr swamps. The Taiwanese mission project later converted this into a tidal irrigation scheme in the 1960s, which developed 1,200 ha covering 193 villages in the CRR and URR.

In 1973, the World Bank-financed Agricultural Development Project (ADP) developed 500 ha with a minimum plot size of 0.4 ha. In 1976, the Agro Technical Team of China developed 2,600 ha of smallholder rice irrigation schemes and improved those developed earlier in the CRR and URR. Most schemes became dysfunctional after the phasing out of the projects and the collapse of the Cooperative Union due to poor management and a lack of resources to maintain the infrastructure.

Rice production increased because of the Taiwanese and Chinese missions in the 1970s, which brought new infrastructure and agricultural technologies to farmers (new varieties, fertilizers, etc.).

In 1987, the government decided to withdraw fertilizer subsidies, which caused an abrupt end to the increasing trend. Fertilizer sales dropped significantly, alongside yields, and fertilizer use is now less widespread among Gambian farmers.

From 1991 to 1996, the Small-Scale Water Control Project (SSWCP), financed by the International Fund for Agricultural Development (IFAD), developed 482 ha of tidal irrigated land. The area was small and some of the lands produced only one rice crop per year. Other irrigation projects, which ended in the same year, were the Jahally & Pacharr Smallholders Project (JPSP), funded by the African Development Bank and the World Bank, and the Rice Development Project (IRDEP), financed by the African Development Bank. The Rice Irrigation Development Project (RIDEP), which commenced in 1988, has addressed the rehabilitation of many pumped irrigation schemes in the CRR. The objective was to rehabilitate the numerous deteriorating rice irrigation schemes to provide double cropping and encourage self-sufficiency in operation and maintenance. It was planned to develop 1,250 ha to benefit 25,000 people by 1996, but only 243 ha were in operation by 1999. The JPSP developed 849 ha of tidal irrigated land and 560 ha of pump-irrigated land. The IRDEP developed 243 ha of pump-irrigated land.

Also, a 20-year Lowland Agricultural Development Project (LADEP), funded by IFAD and the AfDB, began in 1997 with its goal to develop 3,735 ha of land during the first eight years. The technical team of this project made careful surveys to that effect and made topographical maps of potential rice-growing areas that can be used to determine the feasibility of tidal irrigation in specific areas. The technical mission results indicate that the feasible areas for tidal irrigation include Wassu, Kuntaur, Tubakuta, Sukuta, and Barajali on the north bank, and Sapu Willingara and Yidda, among others, on the south bank. Where tidal irrigation is feasible, these potential rice-growing areas differ considerably in ecological conditions and requirements for production.

In relatively upland areas, pumps can be used for irrigation. In low-lying marshy areas, tidal flows can be employed for irrigation purposes. In dryland areas, where pumping is expensive, the farmers depend on natural rainfall. Unfortunately, inadequate rainfall can lead to drought and a poor harvest.

Many NGOs have risen to tackle this issue. Concern Universal (CU), now renamed United Purpose (UP), through its local partner, Wuli and Sandu Development Agency (WASDA), has implemented ten irrigation projects in the Upper River Region under a 3-year Livelihood Enhancement Agricultural

Program (LEAP) since 2013. With support from the Regional Agricultural Directorate, they tried to revitalize small rice schemes irrigated by a pumping system. However, they were faced with engineering challenges leading to abandoning some fields.

The government of The Gambia has been renewing its anti-hunger campaign. In 2013, the government announced that The Gambia would not import rice after 2016. Farmers across the country, especially those in the provinces, were spurred to increase production to meet the presidential declaration. The government also pledged a staggering USD 100 million package for Gambian farmers to boost production and attain the country's most yearned objective of food self-sufficiency, whereby the entrenched dependency on imports would become a thing of the past. However, success has been limited among these irrigation projects over the past three decades.

The Gambia Commercial Agriculture and Value Chain Development Project (GCAV), from 2014 to 2019, aimed at improving productivity and market access of targeted agricultural commodities for smallholders in the project area. The project supported targeted investments to improve productivity and efficiency and build organizational and institutional capacities for private and public stakeholders along the value chains of the targeted commodities. The project also worked on rehabilitating irrigation infrastructure to enhance the resilience of agricultural production systems to climate change-induced shocks in selected areas (GCAV Implementation Support Mission, 2015). Current projects are undertaking land development and establishing tidal and pump irrigation schemes in CRRs and CRRn and URR, respectively. These projects are the Agricultural Value Chain Development Project (AVCDP), the National Agricultural Land and Water Development Project (Nema), etc.

1.3 Assessment of existing irrigation and drainage infrastructure

The existing irrigation and drainage infrastructure assessment for rehabilitation and upgrading was conducted in June 2020. All six agricultural regions were visited (Table 1): the North Bank Region (NBR), Central River Region north (CRRn), Upper River Region (URR), Central River Region south (CRRs), Lower River Region (LRR), and West Coast Region (WCR). In each region, the Regional Agricultural Directorate (RAD) identified the existing and dilapidated irrigation structures with great potential for crop production. An extension officer with good knowledge of the area accompanied the team to the various sites where the farmers received them.

The schemes visited in the rice-cultivated areas once benefited from the Republic of China's pump irrigation projects in the 1970s. When the Chinese left the country in the 1980s, the government could not provide resources to farmers to buy inputs. Farmers were not organized to manage the schemes and support the cost of the inputs (especially the fuel cost for the pumping system). The schemes quickly collapsed because of low maintenance and insufficient technical skills to operate the infrastructure.

The vegetable gardens were started mainly by the communities and later gained support from the projects or were sometimes initiated by the projects. The beneficiaries of the gardens were mainly women farmers who cultivated vegetables for the family and economic grains in the dry season. They cultivated rice in the lowland and other upland crops in the rainy season. Some were also engaged in backyard animal husbandry.

1.3.1 Central River Region north

i. Wassu tidal irrigation scheme

This scheme has been operational for a long time and is managed by farmers with the help of extension services (Figure 6).

ii. Wassu pump irrigation scheme

The World Bank installed the pump during the First Republic. At present, the scheme has been abandoned because of dilapidated structures (Figure 7). Farmers are experiencing high fuel consumption because of excessive leakages in the broken canal. The bunds have eroded, including the peripheral dikes. Neither the pumping machine nor the machine house is in good condition.

Bushy canal

Eroded canal

fence to Prevent animal intrusion

Inlet gate

FIGURE 6. PICTURES OF THE WASSU TIDAL IRRIGATION SCHEME.

Dilapidated canals

Sunk filled with debris

Eroded main canal from the river

Machine house

Irrigation pump

FIGURE 7. PICTURES OF THE WASSU PUMP IRRIGATION SCHEME.

iii. Kuntaur tidal irrigation scheme

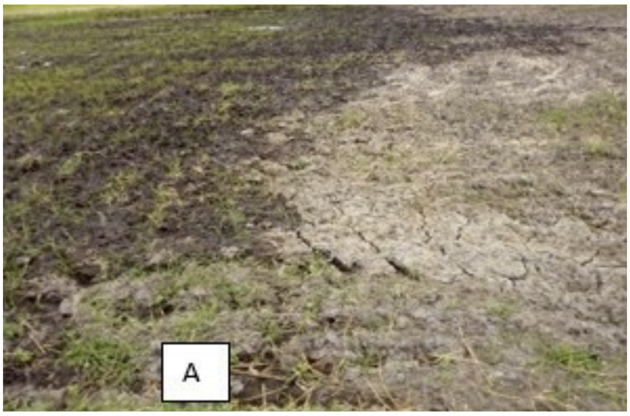
This scheme has cluster sites in four villages: Kuntaur, Fulakunda, Tubakuta, and Jakaba (Figure 8).

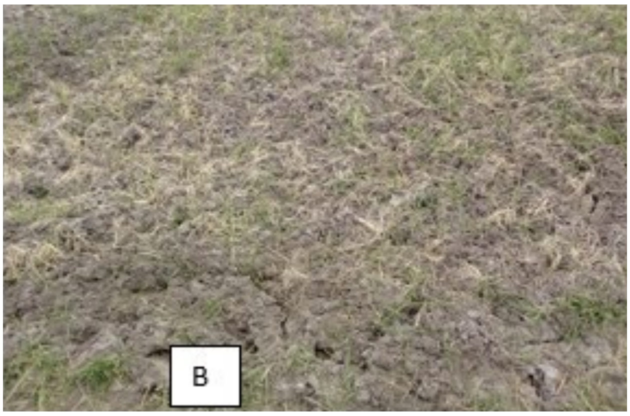
Inlet gates

Outlet gates

Collapsed culvert

Weedy canal





Partially wet plot (A) and completely dry plot (B) due to engineering problems

FIGURE 8. PICTURES OF THE KUNTAUR TIDAL IRRIGATION SCHEME.

iv. Sukuta irrigation scheme

This scheme has problems similar to those of the other schemes (Figure 9).

Main canal from river

Erosion on the main canal

Potholes on the culvert

Broken canal

Weedy and sand filled canal

FIGURE 9. SUKUTA IRRIGATION SCHEME.

iv. Barajali tidal irrigation scheme.

The National Agricultural Land and Water Development Project (Nema) rehabilitated this scheme (it is two years old). The farmers are in their second season of production. However, they face some challenges, mainly water management and animal intrusion (Figure 10)

Grazed fields by animal

Farmers attempt to control water

Farmers attempt to block leakages

Farmer's bed to scare hippos

Leaking gate

Flooded field due to uncontrolled water

FIGURE 10. PICTURES OF BARAJALI TIDAL IRRIGATION SCHEME.

TABLE 1. SCHEMES IN THE CENTRAL RIVER REGION NORTH (CRRN).

Name of scheme	Type of irrigation	Irrigated area (ha)	Status of scheme	Possibility of rehabilitation/upgrading
Wassu	Tidal	36 Rice fields	Functional	Leveling, the raising of peripheral dikes, maintenance of inlet and outlet gates, canal cleaning, fencing
	Diesel pump	- Rice fields	Not functional	Rehabilitation of canals, bund raising, construction of peripheral dikes, leveling, and fencing
Kuntaur	Tidal	173 Rice fields	Functional	Access roads, canal cleaning and desilting, inlet and outlet gate maintenance, leveling
Sukuta	Tidal	105 Rice fields		Leveling, fencing, desilting, raising of peripheral dikes, access roads, maintenance of inlet and outlet gates, canal cleaning, and desilting
Barajali	Tidal	Rice fields	Functional	Leveling, maintenance of canals and gates, fencing, raising of the peripheral dike
	Diesel pump	Rice fields	Not functional	Construction of new canals, bund raising, construction of peripheral dikes, leveling, fencing, provision of a complete set of irrigation pumps

1.3.2 Upper River Region (URR)

i. Chamoi pump irrigation scheme

This was started in 2013-14 by the Wuli and Sandu Development Agency (WASDA), with financial support from former Concern Universal, now United Purpose (Table 2). It was implemented in the URR to revitalize agriculture in the lowland. The community was tasked with developing the land, including the manual felling of trees, bond erection, leveling, plot boundary setting, and canal construction (Figure 11). WASDA provided the community with cement to construct the canals, a 22-HP diesel engine, and a pump. The developed land was divided among the registered farmers.

Remains of irrigation pipes

Manually developed land

Canal structure

Discussion with farmers

Source of water for irrigation (Gambia river)

FIGURE 11. PICTURES OF CHAMOI PUMP IRRIGATION SCHEME.

ii. Bani vegetable irrigation scheme

The vegetable garden has a solar pumping system, but the women encounter a lot of water shortages on non-sunny days (Figure 12). Another part of the garden needs an extension of reservoirs for water access. The women use buckets to scoop water from the reservoirs to flood the plots.

Meeting with farmers

Solar system

Leaking reservoir

FIGURE 12. PICTURES OF BANI VEGETABLE IRRIGATION SCHEME.

iii. Sare Alpha pump irrigation

Rehabilitation work is ongoing, but only a small portion of the area is rehabilitated (Figure 13). There is a need to expand to give a more significant part of the population access to cultivable land. The rehabilitation work has stopped; no one knows why and when it will start again.

Incomplete rehabilitation work at the site

Water source for irrigation

Vegetation at the site

FIGURE 13. PICTURES OF SARE ALPHA PUMP IRRIGATION SCHEME.

iv. Pirai pump irrigation scheme

This scheme failed when the Chinese left and new management took over but could not supply the required water to the fields. The land has been abandoned for almost 30 years. All the bunds and peripheral dikes have eroded. There is a re-growth of shrubs. The land is divided into two parts by a stream, thus requiring a small bridge for crossing (Figure 14).

Discussion with farmers

Main water source from the River Gambia

FIGURE 14. PICTURES OF PIRAI PUMP IRRIGATION SCHEME.

Regional Youth Development vegetable irrigation scheme

Refugees from Sierra Leone once occupied the land where the scheme is operating. After the war, the refugees returned and the land was requested for use by the regional youth. They started cultivating the area in 2013 when they obtained support from the Livestock and Horticultural Development Project (LHDP), put in fencing, dug a borehole, and installed an irrigation system (Figure 15).

Solar system and tank

Leaking pipe

Broken pipes

Discussion with farm manager

FIGURE 15. PICTURES OF THE REGIONAL YOUTH DEVELOPMENT IRRIGATION SCHEME.

TABLE 2. SCHEMES IN THE UPPER RIVER REGION (URR)

Name of scheme	Type of irrigation	Area put to irrigation	Status of scheme	Possibility of rehabilitation/upgrading
Chamoi Bunda	Diesel pump	Rice fields	Not functional	The access road, leveling, raising of peripheral dikes, canal construction, fencing, complete set of irrigation pumps
Bani	Solar pump	2.5 ha Vegetable garden	Functional	Additional reservoirs and installation of energy storage devices to keep irrigation system functional on non-sunny days
Sare Alpha	Solar pump	2.5 ha Vegetable garden	Functional	Maintenance of reservoirs
	Diesel pump	25 ha Rice fields	Not functional	Complete rehabilitation
Pirai Mandinka	Diesel pump	Vast area	Not functional	Complete construction and construction of 10-m bridge
Kulari	Solar pump	5 ha Vegetable garden	Functional	Maintenance of leaking pipes and reservoirs
Regional Youth Development "Kafoo"-Kundam	Solar pump	5 ha Vegetable garden	Functional	Replace solar pump with higher capacity, installation of inverter with batteries for an energy source. Replacement of the current chain-link fence because of its low quality leading to animal intrusion; replacement of pipe networking due to high leakages

1.3.3 Central River Region south (CRRs)

i. Bansang Bantanto pump irrigation scheme

This scheme has been in operation for the past 26 years. The RIDEP developed the area in 1994-95. After the area's development, it was handed over to the community, who managed it to date. A vast amount of land is not used for production because of dilapidated irrigation structures. The farmers have been trying on their own to construct a canal using cement block, have been blocking leakages with rags and polythene, and have replaced the old Lister engine with a power-tiller engine to continue pumping water (Figure 16).

The main pipe due to leakage

Pump station with old engine and pump

Still basin (outlet)

Sump (inlet)

Management of leakages in main pipe

Attempt to block leakages in the canal

Broken canal structures

Dilapidated distribution box

Canal constructed by farmers

Canal patched by farmers with cement

Sand-filled drainage canal

Field not reached by water

Uncultivated land due to lack of water

FIGURE 16. PICTURES OF BANSANG BANTANTO IRRIGATION SCHEME.

ii. Sankoli Kunda and Jangjangbureh Farabaa Lee pump 1 irrigation scheme Sankoli Kunda

These schemes have been in operation for a long time. However, the farmers were forced to abandon them because of the dilapidated structures and high fuel cost related to design problems and leakages (Figure 17). They were developed by the RIDEP in 1994-95, like in Bansang Bantanto.

Pumping station

Sump (inlet)

River Gambia (source of water irrigation)

Still basin and machine house

Main canal

Water tunnel

Distribution box

Abandoned field

FIGURE 17. PICTURES OF SANKOLI KUNDA IRRIGATION SCHEME.

Jangjangbureh Farabaa Lee

This scheme is still functional even though the community encounters challenge similar to those of Sankoli Kunda (Figure 18). Children were also found swimming in the canal.

Pumping station

Main canal from the river

Eroded machine house

Main canal

Distribution box

Secondary canal

Cracks on the main canal

FIGURE 18. PICTURES OF JANGJANGBUREH FARABAA LEE IRRIGATION SCHEME.

iii. Pacharr pump scheme

This was one of the first pump irrigation schemes in The Gambia. Jahally & Pacharr Smallholders Project (JPSP), funded by the African Development Bank and the World Bank, developed 849 ha of tidally irrigated land and 560 hectares of pump-irrigated land (Figure 19). The IRDEP, financed by the AfDB, developed 242.6 ha, all pump-irrigated. Other recent projects such as FASDEP and Nema also intervened in land development. However, flooding, the water distribution network, leveling, canals, and pumping machines remain challenging. A canal was constructed to drain floodwater from the fields but, unfortunately, floodwater enters through it into the fields.

Dilapidated canal

Distribution box filled with sand

Old structure of the main distribution box

Main canal from the pump

Leaking gates


Collapsing culvert

Entry point of floodwater from upland

Canal through which water floods the fields


Canals requiring cleaning

FIGURE 19. PICTURES OF THE PACHARR IRRIGATION SCHEME.

TABLE 3. SCHEMES VISITED IN CENTRAL RIVER REGION SOUTH (CRRS).

Name of scheme	Type of irrigation	Area irrigated (ha)	Status of scheme	Possibility of rehabilitation/ upgrading
Bansang Bantanto	Diesel pump	26 Rice fields	Functional	Leveling, raising of peripheral dikes, canal maintenance and construction, fencing, pre- and postharvest equipment, maintenance of the still basin and sink, desilting around the water source
Sankoli Kunda pump 1	Diesel pump	2.5 Rice fields	Functional	Redesigning of some canals and maintenance, reconstruction of distribution boxes, raising of peripheral dikes and fencing
Jangjangbureh Farabaa Lee	Diesel pump		Not functional	Raising of peripheral dikes, an extension of the inlet pipe into the river to avoid no pumping during low tide, canal mainenance
Pacharr	Tidal pump		Functional	Peripheral dike maintenance and creating a waterway for runoff in the rainy season to avoid flooding. Land leveling and maintenance of ditches, canals, inlet/outlet gates.
Regional Youth Development "Kafoo"- Kundam	Solar pump	5 ha Vegetable garden	Functional	Replace solar pump with higher capacity, installation of inverter with batteries for an energy source. Replacement of the current chain-link fence because of its low quality leading to animal intrusion; replacement of pipe networking due to high leakages

1.3.4 Lower River Region (LRR)

This region depends on rainfall for agricultural activities in the lowland. This part of The Gambia River has saline water. In the upland, irrigated areas belong to women's vegetable gardens.

i. Jasson pump-irrigated vegetable garden

The community initiated the garden and later obtained assistance from the National Nutrition Agency (NaNA), which provided the community with sunken-lined wells, watering cans, fencing wires, and seeds (Figure 20). The FAO also gave them seeds and watering cans. The community dug three wells and did the fencing. Some wells have dried out and others are collapsing. They are still not enough for the women. They had extra land for expansion but could not expand because of their limited resources.

Inspection of lined well

Diaplapidated well

Dried well

Fence structure

Garden land

FIGURE 20. PICTURES OF JASSON IRRIGATED VEGETABLE GARDE

TABLE 4. SCHEMES VISITED IN THE LOWER RIVER REGION (LRR).

Name of scheme	Type of irrigation	Area irrigated (ha)	Status of scheme	Possibility of rehabilitation/ upgrading
Jasson	Solar pump	1.5 Vegetable garden	Not functional	Fencing, installation of borehole water distribution network, and expansion of the garden

1.3.5 West Coast Region (WCR)

i. Kamamudou pump-irrigated vegetable garden

This scheme consists o five villages: Chewel, Kamamudou, Kansambou, Jiwunke, and Kampassa. The garden was supported by GALDEP 20 years ago (Figure 21). The project fenced it, drilled a borehole, installed a solar pump, erected a tank and reservoirs, and provided processing equipment. The pump became burned with the inverter, and some panels were stolen soon after the watchman left. Before they could obtain a replacement, the reservoirs leaked.

Discussion with farmers

Inspection of reservoir

Cracks on the reservoir

Burnt inverter

Solar system with missiong panels

Tank

FIGURE 21. PICTURES OF KAMAMUDOU IRRIGATED VEGETABLE GARDEN.

ii. Pirang pump-irrigated vegetable garden

This garden started as a community garden mainly used by women. They received support from projects (such as the former Concern Universal), dug wells and erected reservoirs, integrated land and water management for adaptation to climate variability and change (ILWAC), drilled a borehole, and installed solar panels, tanks, and pipe networking (Figure 22). The Gambia Commercial Agriculture and Value Chain Management Project (GCAV) expanded the garden, drilled another borehole, and installed a drip system in the expanded area. The women, unfamiliar with the drip system, disconnected the drip lines and connected the main supply pipes to the reservoirs. The system is no longer working.

The last solar panels were stolen, making the first borehole redundant. There is a need for more reservoirs as many are small, others are leaking, and the second borehole inverter is faulty.

System not in use because of stolen panels

Lined well

Small reservoir with drip pipe

Drip lines removed drip pipe

Removed and stored drip lines

Solar system and borehole

Filter tank

GCAV tank

FIGURE 22. PICTURES OF PIRANG IRRIGATED VEGETABLE GARDEN.

TABLE 5. SCHEMES VISITED IN WEST COAST REGION (WCR).

Name of scheme	Type of irrigation	Area irrigated (ha)	Status of scheme	Possibility of rehabilitation/ upgrading
Kamamudou	Solar pump	5 ha Vegetable garden	Functional	Renovation of reservoirs, replacement of solar pump and inverter, additional solar panels
Pirang	Solar pump	2.5	Functional	Installation of solar panels, replacement of inverter, renovation of reservoirs, additional reservoirs, and sensitization and capacity building on drip irrigation

1.4 Conclusions

The government of Gambia has highlighted the need to develop affordable irrigation technologies and practices to improve productivity and increase their resilience to climate change to ensure sustainable food and nutrition security, poverty alleviation, and environmental protection. However, with the current annual rainfall from 500 to 1,100 mm distributed over four months, reliance on irrigation for crop production is paramount.

The Gambia has potential water resources that could be used to enhance food production. The Gambia River is the primary surface-water source in the country and is suitable for tidal and pump irrigation. Abundant underground water resources are also suitable for upland crop irrigation.

Development of Irrigation schemes in the country started in the 1970s through support from mainland China. Irrigation schemes were developed in the country's rice hub, that is, CRRn, CRRs, and URR. Most of the schemes collapsed, however, after the Chinese left.

Other donors such as the World Bank, IFAD, IsDB, and AfDB have also helped to develop irrigation schemes within the lowlands for rice production and vegetable gardens. The major challenge that continues to hinder irrigation development in the country is insufficient engineering skills in most schemes, leading to flooding, poor water distribution, high leakages in the concrete lining, poor drainage, and low-quality construction work. The absence of a public-private sector partnership and the lack of managerial skills of beneficiary communities have also contributed to the unsustainability and quick destruction of the schemes.

1.4.1 Lessons learned

- Insufficient engineering skills and poor design in most of the schemes led to flooding, poor water distribution, high leakages in the concrete lining, poor drainage, etc.
- The beneficiaries had little involvement in the design and implementation of projects.
- Insufficient capacity building of farmers on the maintenance and operation of water and irrigation structures.
- The lack of a public-private sector partnership contributes to the unsustainability of the schemes.
- The lack of an irrigation policy.
- Inaccessibility (roads).
- The intrusion of wild and domestic animals (hippopotamus and bushpig).

1.4.2 Recommendations

For the sustainable development and operation of irrigation schemes in The Gambia, the following measures are recommended:

- There is a need to develop suitable policies, legislation, and water management practices related to water use in agriculture.
- The scale and sophistication of irrigation and mechanical technologies employed and their relevance to the national economy and the socioeconomic conditions of the farmers are critical for effective beneficiary involvement and sustainability of outputs, including issues of spare parts and local maintenance and repair service skills.
- The Gambia's current agricultural policy is to achieve self-sufficiency in grain production. However, reaching an annual production of 80,000–90,000 tons will require developing and using efficient tidal and pump irrigation. This requires close collaboration of local farmers, the private sector, the government, NGOs, and international organizations.
- The capacity for drainage during the highest water level in The Gambia River is not ensured. To ensure double cropping, it will be necessary to undertake a hydrologic study to take effective drainage measures. Farmers must be able to take advantage of floods to increase rice production.
- A robust participatory approach involving all potential beneficiaries is needed to ensure the relevancy of the activities and good ownership of the infrastructure.
- Adjacent uplands should also be developed to avoid soil erosion upstream when developing lowlands.
- Rainwater catchment facilities should be installed to extend and increase agricultural production during the dry season through irrigation.
- The flooding process caused by lateral runoff from uplands to lowlands at potential sites should be assessed.
- The capacity of all stakeholders should be enhanced to avoid post-project failures. Because of the
- lack of farmers' capacity, most of the infrastructure has been abandoned after closing the projects.
- Farmer associations and other similar organizations must be established or strengthened, and cooperation must be improved. Such associations could handle agricultural loans, savings, etc.
- Irrigation water use associations should be established to manage water resources and irrigation operations and extend irrigation facilities within their districts. These duties are currently being performed by the implementing units of the various projects, but without much success.
- Farmers must be trained in effective rice cultivation techniques.

1.4.3 General challenges

- No policy document on irrigation is available in the country.
- The lack of engineering skills results in poor designs and quick decay of irrigation infrastructure.
- The distribution system shows low irrigation efficiency, resulting in a higher cost of pump operation.
- Many rice irrigation schemes in the country do not have internal drainage systems or flood protection works. This will be crucial to increasing irrigation systems' resilience to climate change.
- Poor leveling of irrigation fields is a significant challenge.

- The farmers do not have the technical skills to operate pumps and irrigation schemes.
- There is a lack of a systematic approach to irrigation development. The scale of analysis and understanding of the irrigation projects is often inadequate and results in misunderstanding a project's potential impacts.
- Extension services in most parts are inadequate and improvement measures are not included in the irrigation projects.
- Access is difficult, especially during the rainy season. The distance between the irrigation schemes and the communities is approximately 5 km.

1.5 Country Summary and Recommendations

The Gambia is a small West-African country with a total area of 10,689 km^2 and a population of 1,882,450, of which 40% live in rural areas. Population density is 176 people per km^2, one of the highest in Africa.

Poverty is a significant development challenge for the country. The total cultivable arable land covering all six regions is 558,000 ha, representing 54% of the land area. The country relies heavily on food imports. The agricultural sector accounts for 29% of the GDP. It employs 75% of the country's population and meets about 40% of national food requirements.

Agricultural production is primarily rainfed, with highly erratic and inadequate rainfall patterns. The country has vast water resources that could be used to increase food production. The Gambia River is the primary surface-water source, suitable for tidal and pump irrigation. Abundant underground water resources are also available for drinking and irrigation purposes.

The history of the development of irrigation schemes in the country dates back to the 1970s through support from China. It started with developing irrigation schemes mainly in the country's rice hub, that is, CRRn, CRRs, and URR. Most of the schemes collapsed, however, after the Chinese left. Donor partners such as the World Bank, IFAD, IsDB, and AfDB have also invested heavily in developing irrigation schemes for rice production and vegetable gardens within the lowlands. Most of the donor contributions to the ANR sector in 2016-17 were grants. The major challenge that hinders irrigation development in the country is beneficiary communities' lack of preliminary engineering and managerial skills. As a result, most of the schemes quickly became dilapidated.

The Gambian economy is characterized by its small size, narrow base, and large re-export trade comprising about 80% of its merchandise exports. Re-export trade contributes from 53% to 60% of domestic tax. From 2004 to 2009, the country had a stable macroeconomic performance and steady economic growth averaging 5-6% per annum. Economic growth was based on services (58%), agriculture (30%), and industry (12%). Real GDP growth at factor cost was 7.2% in 2009 and domestic debt was 32.2% of GDP in 2008. The per capita GDP was estimated at USD 556 in 2009.

The natural vegetation type of The Gambia is Guinea Savanna Woodland in the coastal area, which gradually changes into Open Sudan Savanna in the east. The climate is Sudano-Sahelian, characterized by a short rainy season from June to October and a long dry spell from November to May, with scattered vegetation and forest cover. The country has a total arable land area of 558,000 ha, and 320,000 ha (57%) are cropped annually. The estuary basin of The Gambia River is a tidal inlet with saltwater intrusion ranging from 180 km in the rainy season to 250 km in the dry season. Agriculture is primarily rainfed, and only about 6% of the irrigation potential has been used.

The Gambia's agricultural policy is to achieve self-sufficiency in grain production. However, reaching an annual production of 80,000–90,000 tons will require developing and using efficient tidal and pump irrigation. This requires close collaboration of local farmers, the private sector, the government, NGOs, and international organizations.

The Gambia needs to develop suitable policies, legislation, and water management related to water use in agriculture. There is a lack of a systematic approach to irrigation development. The scale of analysis and understanding of the irrigation projects is often inadequate and results in misunderstanding a project's potential impacts.

The drainage capacity during the rainy season in The Gambia River needs to be enhanced to avoid flooding. Farmers must be able to take advantage of floods to increase rice production. A robust

participatory approach involving all potential beneficiaries is needed to ensure the relevancy of the activities and good ownership of the infrastructure. The lack of engineering skills results in poor designs and quick decay of irrigation infrastructure. Irrigation efficiencies are low, resulting in a higher operational cost. The farmers do not have the technical skills to operate pumps and irrigation schemes. Extension services in most parts are inadequate, and improvement measures are not included in the irrigation projects. The extension services must be strengthened to enhance farmers' capacity to manage and operate irrigation systems.

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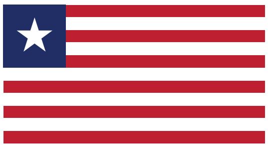


2 Country Profile LIBERIA

The irrigation potential in Liberia is estimated at 600,000 ha, consisting mainly of freshwater swamps. There is no updated information on the total irrigated area in Liberia. Rainfed agriculture is the predominant system practiced by more than 70% of the Liberian population. The use of water control technology is scarce and consists mainly of unregulated manual irrigation and using watering cans or water pumps during the dry season. Using surface water from the lowlands for localized irrigation is a mitigating factor against climate change. Liberia is one of the most water-rich countries in West Africa, but the water- and irrigation-related policies and institutions are poorly developed. The per capita water availability in Liberia is highest in the coastal counties of the country. However, the withdrawal level of renewable water resources for human use is still relatively modest.

The availability of arable land is also generally not a constraint to farmers in Liberia. However, the lack of adequate irrigation infrastructure is an obstacle to harnessing these water resources; this is evident by the high costs of irrigation development, which largely depends on the degree of water control, the topography of the site, and the type of irrigation system.

Irrigation in Liberia is confined to surface-water exploitation from river diversions and reservoirs via gravity-fed pumps. Groundwater use is limited, although several counties possess substantial reserves of groundwater. The cost of lifting water appears to be the primary constraint for most smallholder farmers in the country; however, rice is the principal irrigated crop during the wet and/or dry season. During the dry season, most rice fields are irrigated using water from head dikes, which serve as a reservoir for irrigation through gravity or by lifting water using pumps. From rice to various horticultural crops, a diversified range of crops is grown in the dry season. Still, water availability largely determines the choice of crop and the area to be cultivated.

Rice and cassava are the major staples. Although rice is highly consumed, it is imported on a large scale. Enhancing agricultural activities is possible given the fertile soil, good climatic conditions, adequate arable land, and abundant water resources. However, less than 5% of the land is under permanent cultivation and less than 1% is irrigated.

Freshwater resources are under increasing pressure globally due to overuse and pollution from human activities. The situation in Liberia is no exception. Although the current situation is generally good, projections of future water requirements show that there will be increased competition between different water users in the country. Therefore, proper assessment and management of these water resources are essential to overcome current and future problems of supplying water of adequate quantity and quality to all users in the country. Basins and drainage network delineation are prerequisites for further systematic studies of Liberian hydrology, climate, hydropower potential, and adequate water resource management.

2.1 Water Resources of Liberia

Water is one of the significant natural resources of Liberia, and it is hugely underused (Figure 23). Liberia has 71,000 m^3/year/person of water availability, one of the highest in African countries. Nevertheless, its use is not well managed. The agricultural sector is estimated to use 57% of the water resources, the domestic sector 28%, and the rest 15%, for other indoor sector activities (Figure 24) (FAO, 2000).

Liberia has six principal river basins, although smaller rivers and streams can be distinguished. These rivers empty into the South Atlantic Ocean, leading to frequent sea intrusion and salinization of freshwater resources in coastal regions (LINC, 2013).

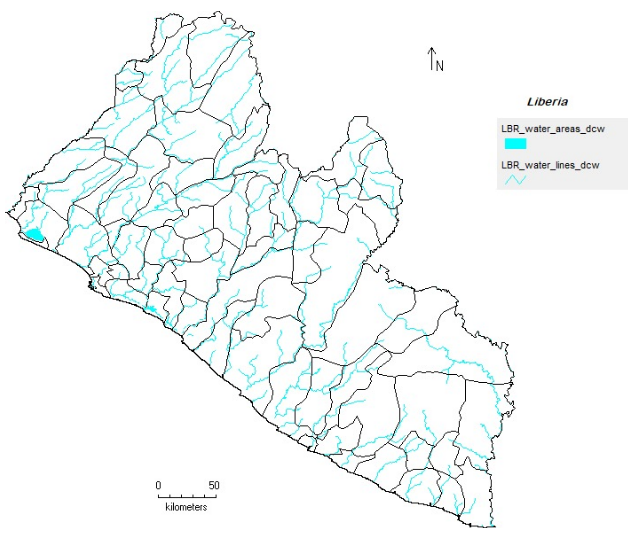


FIGURE 23. LIBERIA'S HYDROGRAPHIC SYSTEM.

Furthermore, out of an estimated 600,000 ha of available irrigation potential, only 1% of the land is under irrigation (LNRDS, 2012).

The geographic distribution of Liberia's water area, lines, and rivers. DIVA-GIS software (version 7.5) obtained from the DIVA-GIS website (http://www.diva-gis.org) was used to create the maps.

The water resources of Liberia can be divided into two kinds of river systems:

1. The significant basins drain 97% of the country in the northeast and southwest. Six major rivers originate in Sierra Leone, Guinea, or Côte d'Ivoire, including the Mano, Lofa, Saint Paul, Saint John, Cestos, and Cavalla rivers, and they drain 65.5% of the country.
2. The short coastal watercourses drain 3% of the country. Internal renewable surface-water resources are estimated to be 200 km^3/year, and internal groundwater is estimated to be 60 km^3/year; all of the latter is believed to be drained by watercourses. Thus, the total internally produced renewable water resources are about 200 km^3/year, while an additional 32 km^3/year come from Guinea and Côte d'Ivoire, bringing the total renewable water resources to 232 km^3/year (Table 6). Liberia is one of the African countries with the highest amount of renewable water resources per inhabitant: more than 71,000 m^3/year (see Table 6).

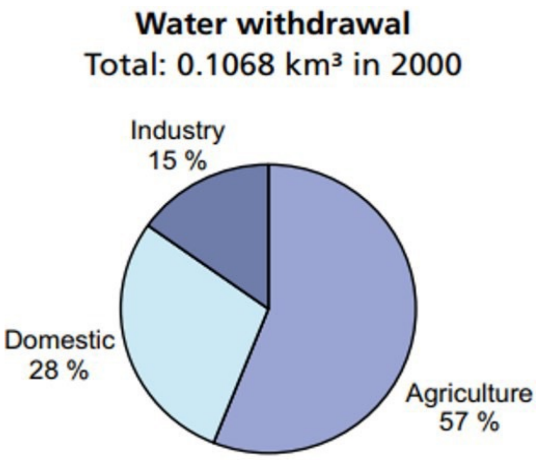


FIGURE 24. TOTAL WATER WITHDRAWAL IN LIBERIA (2000).

Liberia shares all of its major rivers with neighboring countries (Sierra Leone, Guinea, and Côte d'Ivoire). Liberia receives abundant surface water during the rainy season, but there is a drastic decrease during the dry season when most rivers are dry. The drying of the rivers creates unfavorable conditions for irrigation. It makes irrigation costly and labor-intensive (most farmers are compelled to use watering cans or water pumps to irrigate their fields). To mitigate the problem of irrigation and water shortage during the dry season, proper water management should be considered a priority to sustain irrigation activities in Liberia.

TABLE 6. WATER RESOURCES OF LIBERIA.

Renewable water resources	**Year**	**m^3/yr**	
Average precipitation	2,391		
		266.3	109 m^3
Internal renewable water resources		200	109 m^3
Total actual renewable water resources		232	109 m^3
Dependency ratio		13.80%	
Total actual renewable water resources per inhabitant	2004		66,533 m^3
Total dam capacity		-	106 m^3
Water withdrawal			
Total water withdrawal	2000	106.8	106 m^3
Irrigation + livestock	2000	60	10 m^3
Domestic	2000	30.4	10 m^3
Industry	2000	16.4	10 m^3
Per inhabitant	2000	36.3	m^3
As % of total actual renewable water resources	2000	0.05	

2.2 Irrigation and Drainage Infrastructure Improvement

2.2.1 RESADE project

The RESADE-CARI project is a significant intervention in the Liberian agricultural sector that will help address several thematic challenges faced by smallholder farmers, especially those located in the salt- affected areas of the country. The project will introduce innovative climate-smart technologies to improve agricultural productivity on smallholder farms. These may include soil and water management practices aimed at improving soil fertility and mitigating salinity, low-cost water, and energy-efficient small-scale irrigation technologies, thus improving the productivity of existing cropping systems and assisting farmers in adopting climate-smart crops with high tolerance against abiotic stresses and possessing high nutritional and economic value. The project was implemented at three Best Practices Hubs established to address the concerns of climate change and food security in Liberia.

2.2.2 Description of the project area

The site selected for the project is located in the plunker community in compound #1 of Grand Bassa County. Grand Bassa County is one of the counties in Liberia believed to have salt-affected soil. According to a salinity model map developed by ICBA, several salt-affected areas were identified for ground-truthing of modeling results. The site selected for the project is located close to a river (Mechline River) that connects to the Atlantic Ocean. The area's river water salinity (EC) during the dry season is above 6.7 dS/m. However, it drops below 2 dS/m during the rainy season because of the dilution effects of the rain.

2.2.3 Cropping pattern in the project area

The smallholder farmers in the project area do not have access to irrigation water, agricultural inputs, and credit facilities. Government support for the growth and development of the agricultural sector is insufficient and dwindles every year. This has influenced the cropping patterns in most farming communities in Liberia, compelling farmers to grow only rainfed crops.

In Grand Bassa County, agriculture combines (upland) rice and cassava intercropping. The county is situated in the coastal zone where agricultural activities are described as cassava with rice and (river) fishing (FEWS NET, 2011). There is a slight emphasis on cassava over rice as cassava farmers are more abundant than rice farmers in the county. Maize is also a significant crop, followed by vegetables (hot pepper). At the same time, coconut trees are grown on the beaches, and the fruit is harvested in large quantities from wild-growing trees throughout the year (Table 7).

Several private-sector interventions have helped rice and vegetable farmers to increase crop productivity and income, mainly through supplying irrigation equipment and food processing. The private sector has played a significant role in the extension and availability of technological packages, awareness campaigns, and building skills at the farm level, particularly in water-saving and irrigation-monitoring technologies and suitable cropping patterns applied in each agro-ecological zone.

2.2.4 Data collection

There is no existing irrigation scheme/system in the RESADE-CARI project area. The greatest hope of the project is that the farmers will have the first irrigation facility ever built/constructed in that local community. Farmer access to the irrigation systems in the RESADE-CARI project area is presented in Table 8.

TABLE 7. CROPS PRODUCED BY FARMERS IN RESADE-CARI PROJECT AREA.

Major cultivated crops in the project area (2020)	Frequency of farmers involved with crop cultivation	Percentage of total respondents
Cassava	41	64.1
Maize	13	20.3
Rice	9	14.1
Pepper (vegetable)	1	1.6
Total respondents	64	100

Source: RESADE-CARI field survey 2020.

TABLE 8. ACCESS TO IRRIGATION FACILITIES IN THE RESADE PROJECT AREA.

Access to irrigation	Number of farmers with access to	Percentage of total respondents
No access	64	100
Access	0	0
Total respondents	64	100

2.3 Liberia's Agricultural Sector Rehabilitation Project

In 2010, the government of Liberia (GoL) secured a grant from the African Development Bank for an Agricultural Sector Rehabilitation Project (ASRP). Part of the grant was assigned to Liberia's irrigation systems (RIS) rehabilitation. A total area of 1,620 ha of 30 lowland rice schemes in the four southeastern counties of Liberia (Grand Kru, Maryland, River Gee, and Grand Gedeh) were selected for rehabilitation to improve rice productivity and increase household income. The project was completed in 2016; however, it did not meet all of the objectives because of unsubstantiated reasons.

2.3.1 Description of the project area

(a) Philadelphia swamp in Maryland County

The Philadelphia swamp has an ASRP-constructed dam with a reservoir and a large spillway (Figures 25 and 26). A concrete-lined channel conveys the water from the reservoir to the swamp intake structure over more than 300 m. This swamp was constructed by Chinese engineers for rice cultivation in the lowland area of the country. Before the ASRP implementation, the swamp was in bad shape. The dam structure has been compromised and so has the spillway structure (some residents were using the spillway area as a car wash; these activities led to an uncontrolled outflow beyond the spillway). The required head dike for the irrigation system operation could not supply water through the canals. In addition, the spiral gate that opened into the intake canal was stuck and could not be operated. Therefore, the ASRP focused on repairing these damaged structures before initiating other activities.

2.3.2 Current status of irrigation facility of Philadelphia swamp

To date, the dam intake gate is damaged. Water in the catchment area is overflowing in many directions. According to the farmers, the field has been flooded with water and other foreign material from the river. Floodwater has washed away some of the swamp plots. The total area of the irrigation scheme is approximately 35 ha.

2.3.3 Cropping pattern in the area

Lowland rice cultivation requires adequate water availability during the cropping season for optimum

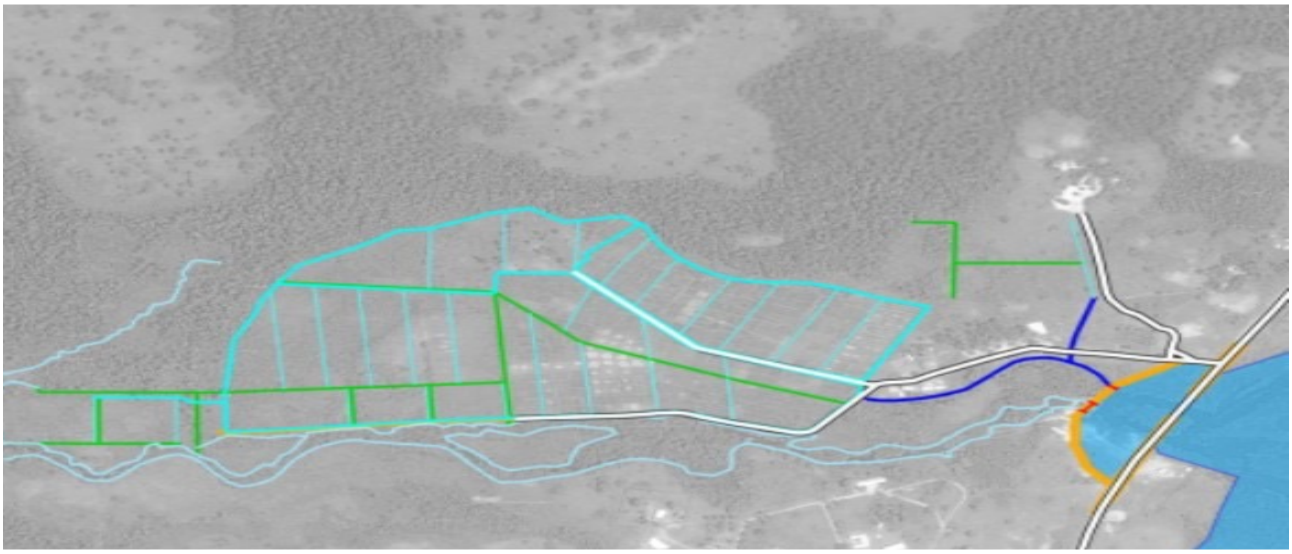


FIGURE 25. THE GENERAL LAYOUT OF THE PHILADELPHIA IRRIGATION AND DRAINAGE SYSTEM.

FIGURE 26. A PICTORIAL OF THE PHILADELPHIA SWAMP AREA BEFORE THE ASRP INTERVENTION.

crop productivity. There is a high risk of yield loss and crop failure due to a lack of irrigation water, especially at the critical crop development stages. Rice is the major crop being cultivated in the Philadelphia irrigated lowland area. The cropping pattern is influenced by water availability from the seasonal river flow and the fluctuating water volume in the reservoir.

According to the geography of Liberia, the wet season runs from April to November and the dry season from December to March. Therefore, an effective rainfall with a 70% probability is applied. The average rainfall (50% probability) during the wet season is 1,800 mm and is 281 mm during the dry season. The sizable seasonal rainfall fluctuations affect water availability for crop production. Therefore, irrigation is considered necessary for year-round cropping.

2.3.4 Data collection

Information about the irrigation systems was gathered through irrigation development agencies in Liberia, reviewing past literature, online publications, reports, and files on donor projects with components on irrigation in Liberia. It was challenging to gather information on four counties (Grand Gedeh, Grand Kru, River Gee, and Grand Gedeh) due to the unavailability of data and past literature.

2.4 Rehabilitation of Irrigation Systems Project

Through a partnership arrangement between the Liberian and Swiss governments, a project was launched in 2012 to address the increased food security development issues in Lofa and Nimba counties (Figure 27). The project was called the Rehabilitation of Irrigation Systems in Liberia (RIS). Building on the tremendous benefit and potential of domestic rice production in lowland ecosystems in Liberia, the RIS project primarily focused on rehabilitating existing lowland irrigation infrastructure and constructing new irrigation schemes with improved drainage and water storage facilities on smallholder rice farms in the target counties. During 2012-13, the RIS project rehabilitated 34 swamps totaling 132 ha in Lofa and Nimba counties.

The irrigation schemes were constructed using low-cost, user-friendly, and environmentally sustainable layouts of swamps and hydraulic engineering along with traditional and modern expertise and technology that could quickly be disseminated among farmers and institutions of the public and private sectors.

The RIS intervention was aligned with the National Rice Development Strategy (LNRDS) and the institutional development and land and water management program of the Agriculture Investment

Program (LASIP) under the framework of the Comprehensive African Agriculture Development Program (CAADP). It partnered with the Ministry of Agriculture (MOA), World Food Program (WFP), and African Development Corps (ADC), formerly known as Visions in Action (VIA), and supported local private-sector participation in the construction of irrigation schemes (Figure 28).

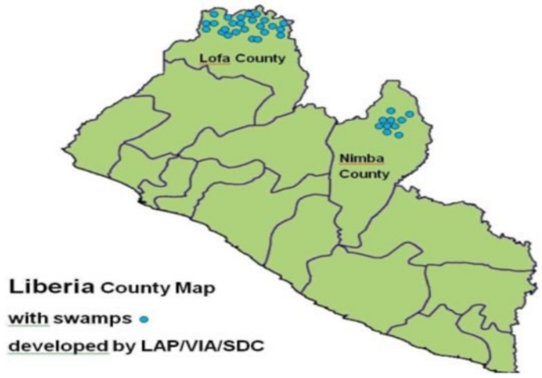


FIGURE 27. REHABILITATED SWAMP/LOWLAND IN RIS PROJECT AREA.

FIGURE 28. STONE-PAVED CHUTE FOR FLOODWATER DRAINAGE IN THE PROJECT AREA.

2.5 Description of Mission Town 2 and Gasoti Irrigation Schemes (Proposed)

As part of the ASRP, the Mission Town and Gasoti Lowland rice schemes were prioritized to enhance rice production, increase food security, and improve farmers' livelihoods. Mission Town is located in Garraway District, Grand Kru County. Figure 29 presents the scheme location overview. A new lowland area was identified for further development as a lowland rice field for cultivation. The Decoris River is the closest river to the proposed scheme.

2.5.1 Locations of the schemes

The Gasoti scheme is located in Felojekwi District, Grand Kru County. The scheme location overview is presented in Figure 30. The scheme lies about 7 km northeast of the coastline and about 4 km west of Gasoti Town. A new lowland was also identified for further development as a lowland rice field in Grand Jru County. The river closest to the scheme is the Betu River.

2.5.2 Proposed areas for development

Seventy-one hectares were earmarked for developing the Mission Town 2 scheme, comprising an irrigation canal, drains, and irrigation blocks. Because the water is drawn directly from the Decoris River

FIGURE 29. LOCATION OVERVIEW OF MISSION TOWN 2 IRRIGATION SCHEME.

FIGURE 30. LOCATION OF GASOTI IRRIGATION SCHEME.

through the river intake, no reservoir was proposed for the scheme development. Similarly, 123 ha of lowland areas were identified for developing the Gasoti irrigation scheme, comprising irrigation canals, drains, and irrigation blocks. Because the water is drawn directly from the Betu River through the river intake, no reservoir was proposed for the scheme (Table 9).

2.5.3 Cropping pattern of the areas

The cropping pattern in the areas (mid-April until January) depends on the rainfall pattern, traditional planting practices, and buffer capacity of the reservoir. The wet season runs from April to November and the dry season from December to March. According to the Ministry of Agriculture, the county has two cropping seasons for rice cultivation. The total amount of water required for the 116 ha and 68 ha is 1,800,000 m^3/yr and 1,000,000 m^3/yr for the Gasoti and Philadelphia rice irrigation schemes.

2.6 Project for Inland Swamp Rehabilitation and Development (ISRD)

Despite the lack of existing irrigation systems for cultivating crops other than rice, the country has good experience in developing inland swamps/ inland valleys for rice cultivation. Through donor-funded projects or bilateral arrangements between the government of Liberia and friendly governments, most of the activities related to swamp development have been accomplished in the country directly or indirectly by the government or its partners. The inland swamp rehabilitation and development project was a NEPAD-CAADP Bankable Investment Project to increase food production and rural income by developing inland swamps in three central rice-producing counties in Liberia.

The selected project counties had a potential area for cost-effective development of inland swamps of about 31,000 ha. The selection of the counties was based on their potential for swamp development, past project experience, and the high rural development needs of the targeted rural communities. River Gee County has a vast range of inland swamps drained by the same rivers as Grand Gedeh because they share a common border. River Gee was one of the areas in Liberia where intensive farming activities took place before the civil conflict, but now farming in River Gee County is no longer intensive. Most farm families have shifted from crop production to mining, which is now the fastest means of earning a livelihood. Despite government and NGO interventions, the county has made little progress in agricultural rehabilitation since the post-conflict era.

TABLE 9. PROPOSED AREAS FOR DEVELOPMENT.

Scheme	Reservoir area (ha)	Proposed scheme area (ha)	Actual rice field area (ha)
Gasoti		123	116
Mission Town 2		71	68

TABLE 10. ESTIMATED ANNUAL PADDY RICE PRODUCTION UNDER REHABILITATION AND DEVELOPMENT OF INLAND SWAMPS (NEPAD-CAADP INVESTMENT PROJECT).

County	Rehabilitation of IVS		Development of IVS		Total	
	Area rehabilitated (ha)	Production (tons)	Area developed (ha)	Production (tons)	Area rehabilitated & developed (ha)	Production (tons)
Lofa	493.6	3,948.80	740.4	5,923.20	1,234	9,872.00
Grand Gedeh	580.8	4,646.40	871.2	6,969.60	1,452	11,616.00
River Gee	466.8	3,734.40	700.2	7,002.00	1,167	10,736.40
Total	1,541.20	12,329.60	2,311.80	19,894.80	3,853	32,224.40

Note: Swamps developed in the country's southeast region were long abandoned before the civil crisis, and most of the farmers in the southeast have become miners.

Lofa County has one of the most extensive inland valley swamps in the country's north. The Liberia civil conflict had a devastating effect on the crop production activities of Lofa County. Therefore, the government deemed it necessary to strengthen the county's rice production in the inland valleys, especially as Lofa was one of the counties that received the worst destruction during the war compared with the other counties (Grand Gedeh and River Gee).

Grand Gedeh County is located in the southeastern region of Liberia, including the country's second-largest rainforest area. It has a vast range of inland swamps, part of the country's Cavalla River, and other watersheds. This county was less affected by the Liberian civil war in terms of infrastructure. However, it has limited roads, a dense forest, and scattered villages where several farmers, mainly rice farmers, reside and cultivate crops (Table 10).

2.7 Conclusions

The inland valley swamps of Liberia can be classified in terms of their manageability in developing water control. The main types of swamps are as follows:

1. Swamps with surface water throughout the year: These swamps are found in the eastern part of the country, where moisture availability is higher. Swamps in this category require little water storage for a second crop season but may require some mechanism to control floodwater entering the swamp from the side and built head catchments.
2. Swamps with surface water until January/February: These swamps usually have lower moisture content because of the lower rainfall. Such swamps are found in the country's northwestern part, where the growing period is shorter (about 260 days). This type of inland valley swamp requires water storage to expand the growing period through January and February.
3. Inland swamps with sand-laden runoff from the catchments are subject to excessive flooding. These swamps are common in the country's Coastal Plains and have coarse-textured soils easily erodable by runoff. These swamps need improved drainage and prevention of natural sand-laden runoff from the side catchments into the cultivated areas.

2.8 Country Summary and Recommendations

Irrigation in Liberia is confined to surface-water exploitation from river diversions and reservoirs via gravity-fed pumps. Liberia is one of the most water-rich countries in West Africa, but the water- and irrigation-related policies and institutions are poorly developed. Liberia has about 71,000 m^3/year/person of water availability, one of the highest in African countries. However, the withdrawal of renewable water resources for human use is still relatively modest, and their use is not well managed. The agricultural sector uses 57% of the water resources, the domestic sector about 28%, and the remaining 15% are for other indoor sector activities. Groundwater use is limited, although several counties possess substantial reserves of groundwater. The cost of lifting water appears to be the primary constraint for most smallholder farmers in the country; however, rice is the principal irrigated crop during the wet and/or dry season.

The irrigation potential in Liberia is estimated at 600,000 ha, consisting mainly of freshwater swamps. However, only 1% of the land is under irrigation. There is no updated information on the total irrigated area in Liberia. Rainfed agriculture is the predominant system practiced by more than 70% of the Liberian population. The use of water control technology is scarce and consists mainly of unregulated manual irrigation and using watering cans or water pumps during the dry season. Using surface water from the lowlands for localized irrigation is a mitigating factor against climate change.

The availability of arable land is also generally not a constraint to farmers in Liberia. However, the lack of adequate irrigation infrastructure is an obstacle to harnessing water resources for agriculture. Irrigation development costs are high, mainly depending on the degree of water control, the topography of the site, and the type of irrigation system.

Rice and cassava are the major staples. Although rice is highly consumed, it is imported on a large scale. Enhancing agricultural activities is possible given the fertile soil, good climatic conditions, adequate arable land, and abundant water resources. However, less than 5% of the land is under permanent cultivation, and less than 1% is irrigated. During the dry season, most rice fields are irrigated using water from head dikes, which serve as a reservoir for irrigation through gravity or by lifting water using pumps. From rice to various horticultural crops, a diversified range of crops is grown in the dry season. Still, water availability largely determines the choice of crop and the area to be cultivated.

Freshwater resources are under increasing pressure globally because of overuse and pollution from human activities. The situation in Liberia is no exception. Although the current situation is generally good, projections of future water requirements show that there will be increased competition between different water users. Therefore, proper assessment and management of these water resources are essential to overcome current and future problems of supplying water of adequate quantity and quality to all users in the country. Basin and drainage network delineation is a prerequisite for further systematic studies of Liberian hydrology, climate, hydropower potential, and adequate water resource management.

2.9 Literature/ Documents Consulted

- Modernized Irrigation Technologies in West Africa (2017)
- SAPEC project report
- ASRP report
- FAOSTAT 2017
- RIS project
- SRD project
- FAO. 2000b. Special Program for food scurity, water control, and intensification components.

3

Country Profile

SIERRA LEONE

Acronyms and Abbreviations

ADfB	African Development Bank
FAO	Food and Agriculture Organization of the United Nations
ITCZ	Inter-Tropical Convergence Zone
ITD	Inter-Tropical Discontinuity
IVS	inland valley swamp
MoWR	Ministry of Water Resources
NWRMA	National Water Resources Management Agency
WASH	Water Sanitation and Hygiene
WHO	World Health Organization

Sierra Leone is located along the Atlantic coast of West Africa between longitudes 10o and 13o West and latitudes 7o and 10o North. Sierra Leone enjoys a tropical climate with two distinct seasons: a rainy season (May to October) and a dry season (November to April). Each season is characterized by the dominance of a unique air mass blowing over the country, brought by relative shifts of the Inter- Tropical Discontinuity (ITD) or Inter-Tropical Convergence Zone (ITCZ). While warm-moist monsoon winds dominate the rainy season, the dry season is dominated by cool-dry northeast trade winds.

Despite vast water resource potential, domestic and industrial water access is inadequate, mainly due to poor planning and investment in the water sector. Sierra Leone has a strong comparative advantage in agriculture because of its abundant rainfall (3,500 to 4,000 mm annual rainfall in a six-month rainy season) and a varied ecosystem comprising five different landscapes (forests, savanna woodlands, freshwater, wetlands, and marine resources). Sierra Leone can grow crops under rainfed conditions, including rice, maize, sorghum, millet, cassava, sweet potatoes, yams, groundnuts, bananas, and plantains, and cash crops such as cocoa, coffee, ginger, and cashew. Despite these endowments of vast surface-water and groundwater resources, they are unevenly distributed in space and time. In particular, during the dry season, they are inadequate to meet the country's water needs for domestic and agricultural purposes. The resources are also threatened by rapid population growth, increased industrial activities, and environmental degradation, causing soil erosion, wetland drainage, and river pollution.

3.1 Water Resources in Sierra Leone

3.1.2 Rainfall

The average annual rainfall varies from less than 2,000 mm in the drier areas of the northeast to about 2,500 mm in the southeast and more than 4,000 mm in the Freetown Peninsula alone (MoWR, 2015). However, a substantial amount of rainfall is lost by evapotranspiration, and most river flows discharge into the Atlantic Ocean unused. No exact estimates of renewable water resources are available for Sierra Leone. There has been a lack of published monitoring data and limited information on the quantity of surface water and groundwater currently extracted. The water resources remain untapped because of the lack of infrastructure for storage and further sustainable use. A significant amount goes out to sea during the rainy season, while some infiltrates the soil.

3.1.3 Surface water

Sierra Leone has vast water resources, including rivers, streams, springs, lakes, and inland riverine and mangrove swamps (Figure 31). The Great Scarcies, Little Scarcies, and Moa rivers originate in Guinea, while the Mano River Basin originates in Liberia (Figure 32). The Great Scarcies Sierra Leone forms an international boundary in some areas with the Republic of Guinea, while the Mano River forms an international boundary with the Republic of Liberia. These two main rivers are influenced by salinity from the Atlantic Ocean. To ensure sustainable water availability to meet future water demand, there is a need to understand river flow dynamics in the wet and dry seasons (MoWR, 2015). Good surface-water management will involve the re-establishment of river gauging stations on all major national rivers. Sierra Leone is also committed internationally to supporting the principles of transboundary water management through the work of The Mano River Basin Union. As part of our initial contribution, we will publish hydrological data and information and provide training and support to build on the success of our initial work on the Sierra Leone Water Security Project.

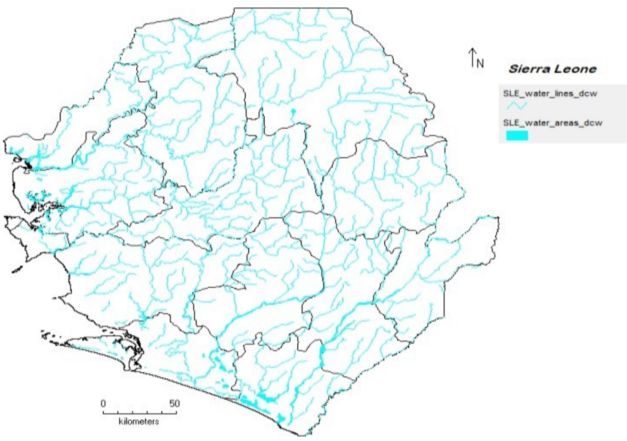


FIGURE 31. SIERRA LEONE HYDROGRAPHIC SYSTEM.

The geographical distribution of water area, lines, and rivers in Sierra Leone. DIVA-GIS software (version 7.5) obtained from the website (http://www.diva-gis.org) was used to create the map.

FIGURE 32. SIERRA LEONE RIVER MAP.

3.1.4 Groundwater

Groundwater is a vital element of the natural water cycle, helping sustain river levels and inland valley swamps (IVS) in the dry season. Groundwater is the primary source of drinking water for rural communities. Rural communities use this water in the IVS where the water table is high compared to the uplands. This water is exploited through hand-dug wells about 0-3 m deep to irrigate crops, mainly vegetables, using watering cans or a bucket and bowl. In Sierra Leone, groundwater abstraction is done from low-yielding hand-dug wells equipped with hand pumps. This requires establishing a network for groundwater monitoring in water, sanitation, and hygiene (WASH) programs. This also requires a small number of monitoring wells in each district, thus enabling Sierra Leone to establish and regulate a sustainable groundwater abstraction regime (MoWR, 2015).

3.2 Irrigation and drainage network design

Seven main rivers run across the country. These rivers cascade the country and give the country huge potential for irrigation. Sierra Leone's irrigation potential was estimated at 807,000 ha in 1981 (FAO, 1990). The total river catchment area ranges from 720 km^2 to 14,140 km^2. However, despite the total water potential, only an estimated 0.3 km^3/year is used, mainly for agricultural activities (MAFFS- MFMR, 2004), given the absence of a national strategy to use surplus annual rainfall to extend the growing season.

There are four agro-ecological zones in the lowlands and the uplands in Sierra Leone. These four agro- ecologies include IVS, bolilands, drainage depressions, mangroves in the coastal tidal zone, and annually flooded riverine grasslands. However, it should be noted that these 1,165,000 ha correspond to the total area of lowlands. Lowland suitable for development is about 807,000 ha (69.3%), corresponding to the above irrigation potential, leaving aside environmental aspects. Irrigated agriculture is poorly developed in Sierra Leone and no recent data are available. Generally, areas with reasonable water control and having the possibility of more than one crop a year are minimal. In 1992, 1,000 ha were reported to be irrigated for sugarcane and 28,360 ha of wetland were equipped for rice cultivation, although most of it is not operational (Figure 33) (FAO, 2005).

Sprinkler systems in Makeni Northern Sierra Leone for sugarcane farms

Furrow irrigation and drainage designs in the lowland of Sierra Leone

FIGURE 33. TYPES OF IRRIGATION SYSTEMS IN SIERRA LEONE.

3.3 Operations and maintenance of irrigation and drainage networks

In 1990, the country's target was to reach self-sufficiency in rice production, and the primary focus was the development of the inland valley swamps (Figure 34). These developments have failed mainly because of farmers' lack of appropriate water control technologies and economic incentives. Developing wetlands to allow double cropping has proved costly. Future efforts should therefore concentrate on increasing yields in swamp rice cultivation by focusing on the most productive land and intensifying available production technology (FAO, 2005). The returns from mechanization have proved to be higher in the riverine grasslands than in the other rice cultivation environments. Given their poor soil conditions, bolilands are not expected to play a significant role in rice production. Uncertainty and transition characterize the current situation, and no agriculture and food security policy and strategy are available at the central government level. For this purpose, support from the

AfDB and FAO would be needed to strengthen the capacity of the Ministry of Agriculture, Forestry and Food Security (MAFFS) (FAO, 2005).

Standing water in most swamps during the rainy season due to high water table

Typical mangrove swamps floodwater after reaching a certain height and recedes to the creeks

FIGURE 34. FLOODED SWAMPS. (INSIDE, CHANGE TO: TYPICAL MANGROVE SWAMP FLOODWATER AFTER REACHING A CERTAIN HEIGHT AND RECEDING TO THE CREEKS)

Developing inland valley swamps for irrigated rice production has encountered many problems, including serious technical ones in Sierra Leone. The technological requirements for the appropriate development of swamps differ because of variations in hydrological conditions even within the same AEZ. These have not always been understood and have, on many occasions, been ignored. The result has sometimes been that attempts to develop water control systems in some swamps have resulted in environmental damage and loss of productivity in the swamps. Lessons have been learned from such failures (NRDS, 2009).

3.4 Water Allocation for Farmers and Land

Water allocation for farmers in Sierra Leone has not been a practice as most farmers depend on rain. Rice is the country's staple food. The annual per capita rice consumption (104 kg) in Sierra Leone is among the highest in sub-Saharan Africa. About 70% of Sierra Leone's 4.9 million people are below the poverty line, with 52% living on less than USD 1 per day, while 26% cannot afford the minimum daily calorie requirements (NRDS, 2009). The most common water source for irrigation is groundwater, especially during the dry season in valley bottoms. Most farmers migrate from the upland after the rains to areas where soil moisture is within reach, especially valley bottoms. Because of water scarcity during the dry season, not many crops are grown. Crops are irrigated once or twice a day, depending on water availability and crop condition. Some areas experience waterlogging conditions throughout the year and are prone to flooding, resulting in the loss of entire crops and then famine.

Water resource management in Sierra Leone faces several challenges (Figure 35). The lack of information about water distribution, scale, and use of water resources severely affects water resource planning, allocation, and monitoring (NWRMA act, 2017). Challenges also include inadequate and unreliable financing for water resource protection, conservation, and management; poor land management affecting the rehabilitation and protection of catchment areas; and increasing water demand due to population growth and urbanization. In addition, with changing weather patterns and increasing likelihood of extreme weather events due to climate change and poor stakeholder involvement and awareness, and because water is viewed as "a gift from God," users typically do not pay.

FIGURE 35. A HAND-DUG WATER WELL IN AN INLAND VALLEY SWAMP USED AS A WATER SOURCE FOR IRRIGATION.

3.5 Cropping pattern

Almost all crops adaptable to the Sierra Leonean environment are grown in a mixed cropping pattern during the rainy season in the upland environment (Figure 36). Mixed cropping is also practiced during the dry spell but on a small scale because of low-quality water for irrigation. In drought conditions, only the tolerant crops with low yields are grown as susceptible crops die off, leading to total crop failure. For this reason, farmers migrate to the IVS, which has the potential to store water in the soil at a higher table to permit cropping.

FIGURE 36. MIXED CROPPING ON RAISED BEDS AND FLAT BEDS DURING THE DRY SEASON IN THE IVS.

3.6 Irrigation and Drainage Water Quality

Good water quality in streams, rivers, and estuaries is crucial for plant growth. Much remains to be done to establish routine water quality monitoring programs. Sources of pollution include widespread open defecation in rivers and streams, as most rural communities lack sanitation facilities. Dumping municipal waste is also common, especially in big towns and cities, along with erosion from hilltops to the sea.

For this reason, outbreaks of waterborne diseases are often a bitter experience resulting in high mortality rates, mostly in children. Two major rivers, the Great Scarcies River and the Mano River, are saline through the influence of the Atlantic Ocean. Soil erosion in catchments, over-abstraction of surface water, poor land-use changes, and riparian land decline lead to turbidity, flash floods, and siltation of water courses and reservoir facilities. These factors contribute to the acute degradation of the quality and quantity of water resources in some parts of the country (NWRMA). Water resources are also at risk from pollution due to mining activities and pesticides in commercial agriculture. Physical changes to land and water courses due to farming or artisanal mining also have an adverse effect.

3.7 Country Summary and Recommendations

Sierra Leone has vast water resource potential. However, water availability for the agricultural, domestic, and industrial sectors is inadequate due to poor planning and investment in the water sector. The country has a strong comparative advantage in agriculture because of its abundant rainfall. Sierra Leone can grow crops under rainfed conditions, including rice, maize, sorghum, millet, cassava, sweet potatoes, yams, groundnuts, bananas, and plantains, and cash crops such as cocoa, coffee, ginger, and cashew. Despite these endowments of vast surface-water and groundwater resources, they are unevenly distributed in space and time. In particular, during the dry season, they are inadequate to meet the country's water needs for domestic and agricultural purposes. The resources are also threatened by rapid population growth, increased industrial activities, and environmental degradation that cause soil erosion, wetland drainage, and river pollution.

Salinity buildup is observed only in the mangrove swamp, and no data have been reported of any prevailing soil salinity condition in other swamps. During the dry spell, salinity buildup can be detected, especially in those areas close to the saline seawater during flooding. This water is unsuitable for cropping and often results in complete crop failure during this period. This condition can be reversed during the rainy season, when the frequent and higher rainfall causes the soil to have less salt for growing only rice because of waterlogging.

In Sierra Leone, the most practiced cropping pattern is mixed cropping, often practiced during the rainy season in the upland environment. The lowlands do not allow growing more than one crop altogether except rice, which has adaptive features when flooded. During the dry periods, the farmers also mix cropping on mounds in the IVS when the water table is down. The bush fallow system is still practiced in the uplands as the soil depletes nutrients and fertilizers must be applied.

A significant challenge is accessing safe water for irrigation and drinking in rural and urban areas during the dry season. Streams and water wells are the primary sources of the rural water supply. Farmers use a watering can, bucket, and bowl to irrigate their crops. Because of the high rainfall during the rainy season, all the crops grown are subject to rainfed conditions. Saltwater intrusion into underground aquifers in coastal areas and pollution in water bodies often result in severe crop failures. Industrial mining activities exacerbate water shortages in rural areas, thus limiting safe drinking water and water required for irrigation during the dry season.

Water resource management in Sierra Leone faces several challenges. The lack of information about water distribution, scale, and use of water resources severely affects water resource planning, allocation, and monitoring. Challenges also include low and unreliable water resource protection, conservation, and management; poor land management that affects the rehabilitation and protection of catchment areas; and increasing water demand due to population growth and urbanization. In addition are changing weather patterns and the increasing likelihood of extreme weather events due to climate change, along with poor stakeholder involvement and awareness.

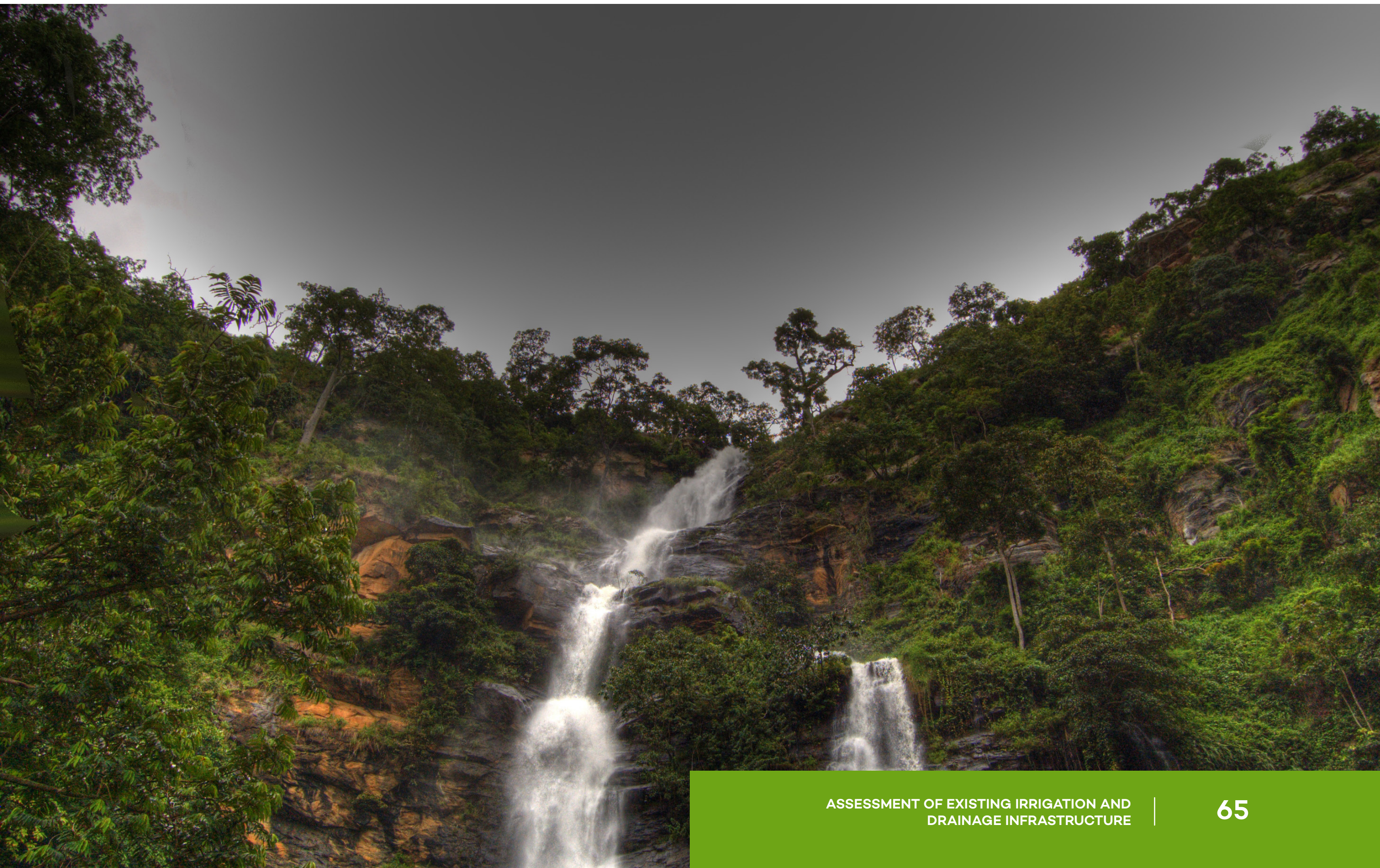
3.8 References

1. FAO - Irrigation in Africa in figures – AQUASTAT Survey. 2005. Ministry of Water Resources Sierra Leone (MoWR) - Data and hydrological understanding generated in the Water Security Project. Volume 3 of a three-volume set, March 2015.

2. National Rice Development Strategy (NRDS). 2009. Prepared for the Coalition for African Rice Development (CARD).

3. National Water Resources Management Agency (NWRMA). Five-year Strategic Development Plan (2019 -2023).

4 Country Profile TOGO



Togo has an extensive hydrographic system that covers the country (Figure 37). This hydrographic system has three main river basins: Volta, Mono, and Lac Togo. Agriculture is the most critical sector in Togo and contributes 40% of GDP (ITRA). It employs two-thirds of the active population working on small land (0.5 ha). Food crops represent two-thirds of production and are mainly used domestically for consumption. Cash crops and food crops are grown. Indeed, 44% of the cultivated land is used for food crops, mainly maize, rice, millet, sorghum, yam, cassava, peanut, bean, and vegetables, which are cultivated during the rainy season. Meanwhile, 15% of the cultivated land is used for cash crops, mainly cotton, coffee, cocoa, and cashew.

In recent years, significant efforts have been made to ensure water control in the production areas, particularly in irrigation infrastructure. This infrastructure has been put in place through specific strategic projects. Depending on the production area and targeted speculations, these different projects supported different types of irrigation. Information and documentation relating to this infrastructure are dispersed in each project's reports, making it impossible to have an accurate irrigation map in Togo. Taking stock of this infrastructure is necessary to determine the primary factors that influence irrigation, irrigation management, and drainage effluent elimination.

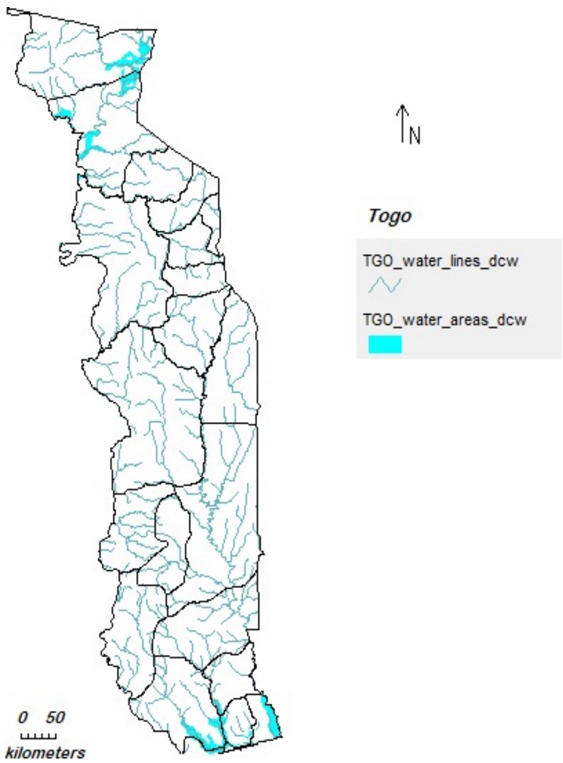


FIGURE 37. TOGO HYDROGRAPHIC SYSTEM.

Togo's geographical distribution of water area, lines, and rivers. DIVA-GIS software (version 7.5) obtained from the DIVA-GIS website (http://www.diva-gis.org) was used to create the maps.

The evaluation of the performance of irrigation and drainage infrastructure involves systematic observation, documentation, and interpretation of the management of an irrigation and drainage system to ensure that the infrastructure responds to basic irrigation needs (to meet crop demand and salt leaching to maintain an appropriate salt balance in the root zone) and drainage (to remove leaching effluent from the system through a drainage network). This evaluation is necessary on a larger scale (district scale) and local scale (farm scale) to assess the system's effectiveness in ensuring sustainability.

This report aims to examine and document the current state of irrigation and drainage infrastructure and assess the factors that influence irrigation, water management, and disposal of drainage effluents. The report also highlights the main system shortcomings that contribute to soil salinization and the

low productivity of land and water. The data collected covered the irrigation and drainage network, water quality, irrigation practices, groundwater depth and quality, and cropping systems.

4.1 Methodology Used to Assess the Existing Systems and Infrastructure

There were four stages in the methodological approach:

- Documentary review with the ministries of water and planning (water resource directorate) and FAO report
- Visits to hydro-agricultural perimeter sites
- Surveys/interviews/resource persons
- Data processing and analysis

Two types of data and information were collected: primary and secondary data.

Secondary data collection consisted of a bibliographic review of public administrations and private services related to water management. Existing project documents and reports have been received, read, and analyzed. As far as possible, this made it possible to make a history of achievements in terms of water collection, crops, and other uses. Among the institutions visited in this context were the Ministry of Water, Rural Equipment, and Village Water.

Several project sites were visited for exchanges with the managers and technicians of the various existing works in this field to collect primary data. A maintenance guide was used to inform the types of work, the materials used, the technical specifications, and the performance in terms of yield and durability. The site visits were also made to conduct opinion surveys with beneficiaries to obtain their perceptions of effectiveness, relevance, and usefulness.

4.2. Current State of Irrigation and Drainage in Togo

Crop irrigation is poorly practiced in Togo, representing only 1% of the total cultivated land, estimated at 3.4 million ha (Frenken, 2005). The three major irrigation types (surface, overhead, and drip systems) are used (Table 11). A surface irrigation system, which is the most important (70%), is found throughout the country. However, it is generally more present in the big hydro-agricultural development projects such as PARTAM, PBVM, and PDRD in the Maritime region.

The overhead irrigation system, which represents about 25% of the irrigated areas, is mainly practiced by vegetable farmers and gardeners who are settled

TABLE 11. LOCATION, AREAS, AND PARTNERS OF THE MAJOR IRRIGATION SYSTEMS ENCOUNTERED IN TOGO.

Types of irrigation	Locality	Area (ha)	PTF*
Immersion (gravity)	Agome-glozou (PBVM)	550	BADEA, BOAD
	Mission tové (PARTAM + aménagement local)	1,00	BOAD, BADEA
	Djagblé (PDRD)	340	BADEA, BID
	Anié (SINTO)	1,200	China
	Kpélé (Beme, Toutou)		Privé
	Kumbeloti	Inf. 50	Privé
	Koutoukpa	100	UEMOA
	Sada	14	BOAD
Aspersion	Littoral (Baguida, Avepozo, Gounoukopé…)	150	SCOOPS
	ITRA irrigation infrastructure	40	Togo
	UTCC Irrigation Infrastructure (CPMV)	2.5	Togo
	Along the rivers (Kara River, Kpondjo, Oti, Sada)	100	SCOOPS
	Dapaong (a partir de retenue d'eau)	15	Togo
Localized (drip)	Vogan	0.5	ETD, ADAPT
	Davié CRAL	0.3	Togo
	Agou (Glékopé)	5	Privé
	Sokodé	10	Privé

**PTF = technical and financial partners.*

along the beach (Baguida, Avépozo, Goumou Kopé, etc.) and the major rivers (Mono, Oti, Kara, Sada, Kpondjo, etc.). The drip irrigation system (5%) is found on some private agricultural farms in Vogan, Glékope, and Sokodé.

4.2.1 Irrigated crops in Togo

Irrigation and drainage practices are booming in Togo, especially in the valleys of Mono, Oti, Haho, and Zio rivers (within the framework of projects such as PARTAM, and PBVM), on agricultural farms, and in vegetable production areas. The irrigation systems used vary from one crop to another. Figure 38 shows the irrigation proportions by crop type. Two major crop groups benefit from irrigation and drainage systems: rice (lowland rice) and sugarcane (industrial production in the plains and valleys). Immersion irrigation is most practiced and vegetable crops are more cultivated by smallholding farmers with sprinkler and drip irrigation techniques. In addition, demand is strong for irrigation in arboriculture (papaya, plantain, citrus), with a strong propensity toward drip irrigation. A new recorded practice in irrigated rice perimeters is the association of fish farming.

4.2.2 IRRIGATION INFRASTRUCTURE AND IRRIGATION SYSTEMS IN TOGO

4.2.2.1 Irrigation infrastructure

Irrigation infrastructure can be grouped into three main categories for a given network:

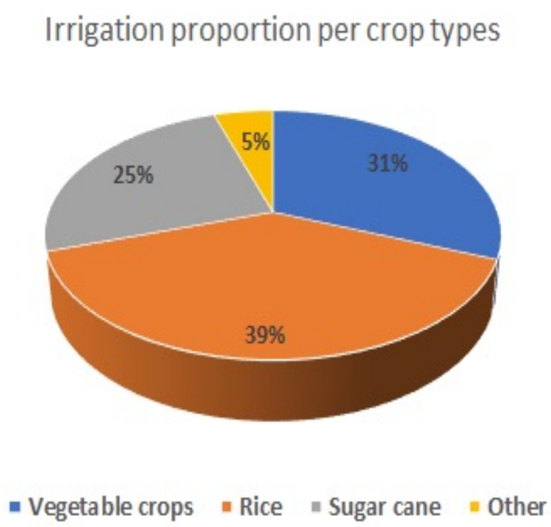


FIGURE 38. IRRIGATION PROPORTION PER CROP GROUP.

- Water source: This can be a stream, a river, a lake, a reservoir, a well, or a borehole. It is an essential condition for the existence of an irrigation system.
- The head station includes all the equipment and materials for water intake, filtration, etc.
- Facilities: This is the culmination of an irrigation network that supplies water to crops via pipes and conduits or drains, depending on the irrigation system chosen.

4.2.2.2 Irrigation systems in Togo

Togo has three main irrigation systems/methods/techniques:

- Immersion or gravity consists of bringing water to a plot and leaving it there for a given period before removing it. This method is generally used for growing rice.
- Sprinkling brings pressurized water in the form of rain to irrigate the entire plot.
- Localized irrigation or drip: at this level, the water leaves the source and is directly supplied to the plant under its roots, thus limiting a lot of water loss by evaporation and by infiltration.

Note that we have subsystems or options for the last two systems depending on the use: drip for rice and sugarcane; sprinkling and drip for vegetable and food crops.

a. Gravity or immersion system

This system floods the entire plot. This system has advantages and many disadvantages.
Advantages of immersion

- Relatively low cost
- Ease of implementation
- It does not require energy for pumping in most cases

Disadvantages of immersion

- Excessive and non-rational use of irrigation water
- An increase in operating costs due to a high number of weeding tasks on the plot
- Only practiced on land with a particular topography favoring the flow of water

Note that this irrigation system is practiced on the rice perimeters of Kovié, Mission Tové, by the PARTAM project, and the sugarcane production site by SHINTO, the Chinese group in Anié.

b. Sprinkling system

This is a pressurized irrigation system that sends water to crops in the rain, depending on the emitter (accessories/materials by which water reaches the plant) and its range of action. We will discuss micro spraying (range less than 5 m) and macro spraying (5-50 m).

This type of irrigation is practiced in market gardening for vegetables along the coast and around water reservoirs. The advantage of this system is its adaptability to different field conditions and its ease of installation. However, this system has a few drawbacks, such as the following:

- Significant use of water for irrigation
- Watering both weeds and the planted crop
- Creation of favorable conditions for the development of fungi
- Increase in operating costs due to the high cost of pumping

c. Localized drip irrigation

Unlike the two systems developed above, the drip system is a precision irrigation system that saves water and increases crop growth. The main constraints for this system remain its high investment cost vis-à-vis other irrigation systems. We can say that this system mainly has the following advantages:

- The system, by its operation, is quite economical in water and limits water losses. Indeed, the water leaving the source is conveyed to the root of the plant.
- The irrigation water is not in contact with the leaves of the plants. This does not allow the development of fungal diseases.
- For this system, we water only plants and not weeds, as in the case of sprinkling, with which we water both plants and weeds. This limits the number of weedings on the plot and thereby decreases operating costs.
- This irrigation system is insensitive to wind, so it is possible to water the field even during ventilation. But this is not possible with other systems.
- The system also saves energy (electricity, petrol, gas oil) during pumping because it is operating at low pressure.
- This system is suitable for the practice of fertigation (a technique that consists of giving water and fertilizer to the plant at the same time), so we do two operations at the same time.
- In addition to these advantages, we increase the crop's yield (two to three times) since this system gives the plant only the exact quantity it needs for its growth throughout its cycle.

In Togo, this system is used for market gardening and, to a lesser extent, for fruit production. It should be noted that the drainage system is almost non-existent in our irrigated perimeters.

4.3. Factors That Influence Irrigation Systems in Togo

Irrigation systems are influenced by economic, technical, climatic, energy, and political factors.

Economic factors

The installation of an irrigation system is often an expensive investment. In Togo, poor farmers often limit irrigation investment even if suitable climatic and topographic conditions exist. Smallholder farmers are mainly unable to invest in irrigation on their farms. The lack of suitable agricultural credit worsens the situation of financing small-scale irrigation schemes.

Climatic factors

At the climatic level, irrigation is influenced by the stocks of annual water resources. Dams and rivers feed most hydro-agricultural infrastructure. The quantity of water stored in dams depends on the dam capacity and rainfall during the rainy season. With the influence of climate change, some years are less rainy and cause insufficient water stocks in dams, thus limiting irrigation in the dry season.

Technical factors

Hydro-agricultural infrastructure contracts are often attributed to rural engineering companies with no irrigation specialist staff. Many big irrigation projects have been ill-planned, making them inefficient. This has made it difficult for farmers to use the sites. Also, it is essential to mention the capacity of the users to maintain the irrigation infrastructure after installation. The lack of qualified technicians at the local level to monitor the structures' functioning and maintenance is an important limiting factor. This diminishes the efficiency and performance of the irrigation systems.

Energy factors

The energy needed to pump water for irrigation is costly, especially in Togo. Electricity is often unavailable in some areas where irrigation equipment is installed, pushing farmers to adopt diesel motor pumping and solar energy. However, there are maintenance problems related to the last two options. These decrease the efficiency and performance of the installed structures.

Political factors

Water infrastructure is often built-in targeted areas depending on their potential. Farmers in the project areas are beneficiaries of these installed irrigation systems. The government does not have an irrigation policy to support smallholder irrigation.

4.4 Constraints That Influence the Practice of Irrigation Several constraints influence the practice of irrigation in Togo:

- Insufficient human resources in the field
- Drying up of certain rivers in the open countryside
- High cost of irrigation equipment

Apart from these constraints, certain shortcomings contribute to the salinization of the soil and the low productivity of irrigation water:

- Irrational use of inputs (pesticides, chemical fertilizers)
- Insufficient knowledge of precision farming (lack of knowledge regarding crop water needs)
- Lack of water management equipment when installing irrigation systems
- Lack of drainage and sanitation infrastructure for some projects. Indeed, apart from the drains intended to evacuate the water overflow on certain irrigated perimeters (rice and sugarcane), there is no drainage system for the other crops.

4.5 Irrigation Projects in Togo

Several irrigation projects have been implemented in Togo with domestic and foreign funding. These projects can be grouped into two categories depending on the implementation period. Thus, we have

(i) the projects carried during the period 1960-80 and (ii) the projects of the 2000s. Most of these projects were for rice production and sugarcane, for which gravity systems were used.

4.5.1 Hydro-agricultural projects in the Lower Mono River Valley

The Lowe Valley Mono hydro-agricultural development project (PBVM) is executed in Agomeglozou in Bas-Mono District. The Koreans made the first improvements since 1974 on 70 ha for rice production (Figure 39). Thus, varietal trials on rice were carried out at the site from 1982 to 1983. These projects would later be left to the producers in 1989. However, the beneficiaries abandoned these projects in 1989 because of the high operating costs. However, funding from the Arab Bank for Economic Development in Africa (BADEA) and the West African Development Bank (BOAD) made it possible to restart the project in 2007 with an effective resumption of development in 2010 (Figure 39). With a potential of 1,300 ha, the PBVM covers only 550 ha, including the 70-ha developed by the Koreans in 1974.

Conditions of access to developed plots

To be able to use the area, rice farmers should fulfill several conditions:

- Belong to a group or a simplified cooperative society (SCOOPS) in the locality.
- Pay land charges amounting to CFA 20,000/ha (note that this royalty was paid in kind at start- up in 2015 at the rate of 100 kg/ha of milled rice).
- Pay its energy and water charges set at CFA 30,000/ha.
- Pay a royalty of CFA 15,000/ha to the Perimeter Management Committee.

Irrigation system practiced on the perimeter

The irrigation technique practiced on the Agomeglozou perimeter is the pumped gravity or semi- Californian system. It combines the pressure pumping system at the head station and the gravity in the distribution channels. The water is taken from the Mono River through the chain that was built. The

Installation of new electropumps for the extension

Old electric pumps in operation

BOOSTER STATION BUILT

MONO RIVER AND THE LOCATION OF THE

Developments underway on the extension perimeter

FIGURE 39. LOWER VALLEY MONO HYDRO-AGRICULTURAL DEVELOPMENT PROJECT.

pumping of water at the chain level is ensured by three electric pumps with a power of 20 HP (Figure 39). The discharge of this sucked water occurs in primary, secondary, and tertiary canals before serving the rice paddies located downstream. This system enabled it to irrigate the 70 ha of trial plots rehabilitated in the project's first phase. The ongoing second implementation phase allows the river's east extension to reach the objective of 550 ha. The project was expected to end in 2019. The perimeter visit allowed us to see (i) the ongoing installation of the three new electro pumps for the extension and (ii) the completion of the construction of the booster station to relay the chain, which cannot contain water year-round.

4.5.2 Agricultural land development project in the Mission-Tové area (PARTAM)

This irrigated project of the Zio River valley resulted from an agreement between the Togolese State and Taiwan signed in 1965. It developed 137 ha, including 65.5 ha for Kovié and 71.50 ha for Mission- Tové. Irrigation was ensured with motor pumps installed on the banks of the Zio River.

Rice cultivation has been developed on these perimeters following the initiatives of the Togolese State to ensure food self-sufficiency and decrease the outflow of foreign currency. This project ended in 1978 with the Chinese investment in building a dam on the Zio and installing canals in the irrigated area. These achievements made it possible to release an exploitable potential of 660 ha, of which 360 ha are exploited. The PARTAM project aims at rehabilitating 360 ha of the old perimeter and 300 ha of the new perimeter.

Irrigation system practiced on the perimeter

The gravity irrigation system is practiced on the perimeter. The existing irrigation system consists of (i) Zio Kpota sill dam with a water intake structure located laterally on the left slope and a discharge structure equipped with a control valve; (ii) a supply channel (dead-end channel) with a length of 10,810 m of concrete (including a buried part of 1,600 m and the other part in the open air): (iii) two main reinforced concrete channels, one to the west, 6,770 m long, of semi-elliptical section passing through a flow of 1.66 m^3/s, and the other to the east, 3,271 m long, equipped with intake and crossing structures, and a drawing and a safety weir; (iv) a distribution network including secondary canals with an average length of 600 m and passing a flow of 0.11 m^3/s irrigating an area of 27.5 ha, tertiary canals, and sprinkler canals. The project started its initial phase (2006-12) with co-financing from BADEA and the Saudi Development Fund (FSD). The latter made way for BOAD in 2012. The project will end this year, and the CGP will manage the perimeter. However, studies and proposals are underway for a possible extension of the project financing because of the advanced state of degradation of the Ziowounou bridge supporting the perimeter supply channel. In other words, if this bridge gives way, the perimeter irrigation water supply will also stop.

4.5.3 Djagblé Plain Rural Development Project (PDRD)

The Rural Development Project of the Djagblé Plain (Zio prefecture) wants to ensure water control through the development of hydraulic infrastructure and an irrigated perimeter of 340 ha and related works, thereby improving the living conditions and incomes of the populations of the Djagblé area. More specifically, it will involve constructing the irrigation water mobilization structure (duckbill), the perimeter protection dike, setting up the irrigation networks (primary, secondary, and tertiary canals), and establishing drainage networks with the construction of related works (crossing, distribution, etc.). The project was effectively launched in February 2015 with the installation of the Project Implementation Unit (PIU). Three years later (February 2018), the Head of State officially launched the development of the plain. Today, the results of the various studies are known, along with work on constructing the primary canals, and the structure is underway.

4.5.4 Development project of 1,000 ha of the irrigated perimeter with UEMOA funding

The West African Economic and Monetary Union (UEMOA) has adopted the agricultural policy of the union (PAU) and the standard policy for improving the environment (PCAE). The three-year program for implementing environmental policy prioritized realizing a regional climate change program in

TABLE 12. REGIONAL DISTRIBUTION OF THE DIFFERENT SITES FOR UEMOA DEVELOPMENTS.

Region	Site	Planned area (ha)
Savanes	Sadori	100
Kara	Possao	100
Centrale	Agbandi	100
Plateaux	Koutoukpa	100
Maritime	Gape Kpodji	100
Total	500	

the water and agricultural sector. The WAEMU commission plans to support member states in executing the National Action Program for Adaptation (PANA) through this program. Thus, within the framework of the 2011 work plan, the realization and development of the irrigated perimeters in the commission's member countries were considered. In this context, provision has been made to develop 1,000 ha of agricultural land in Togo, spread over ten sites of 100 ha, with two sites per region (Table 12). During the execution stage, the target area was reduced to 500 ha for budgetary reasons, with one site of 100 ha per region.

Data collected during site visits.

The irrigation agency ensures the facilities for executing Urban Work with High Labor Intensity (AGETUR) and the Directorate of Development, Equipment, and Agricultural Mechanization (DAEMA). The expected duration for the implementation of the project is 48 months. The project ends this year, but negotiations are underway for a possible amendment to ensure the functioning of the works. Despite the high average execution rate (95%), the sites are still non-functional.

Our field mission allowed us to visit two out of the five sites developed by the region: Sadori (Oti prefecture) in the Savannah region and Possao (Guerin kouka prefecture) in the Kara region (Figure 40). The installations consisted of a water intake on the dead branch of the Oti River followed by its distribution on the perimeters by pumping. Once the water is pumped back into the pipes, it is distributed by gravity over the entire perimeter through the primary, secondary, and tertiary canals.

FIGURE 40. SADORI PUMPING STATION.

4.5.5 Small-scale irrigation projects and micro-irrigation

Project of agricultural production adaptation to climate change (ADAP)

This project is the fourth component of Togo's agricultural development support (PADAT). It aims to promote agricultural technologies and practices that will enable producers to cope with the harmful effects of climate change. With this in mind, drip irrigation was selected and promoted through the pilot micro-irrigation operation. This initiative allowed 300 drip irrigation kits of 500 m² to go to 100 market-gardening cooperatives selected and previously trained to use the new watering system (Figure 41).

FIGURE 41. INSTALLATION OF THE DRIP KIT.

Experimentation with the drip system for its extension in Togo

The West African Agricultural Productivity Program (PPAAO Togo) initiated a program to promote the drip irrigation system by establishing a demonstration unit in Sokodé (a locality in the central region). The approach aimed to set up a unit that would serve as a field school for market gardeners in the region (Figures 42 and 43).

Solar irrigation solutions by the NGO RAFIA

RAFIA, through Belgian funding, supported market gardeners from four localities in the Savannah region in 2017. Each site has benefited from a large-diameter market garden equipped with a submerged solar pump. The well water is stored in a 1,000-liter tank supported by a 3-m-high gantry, which allows drip irrigation of a 500-m² plot.

FIGURE 42. SITE VISIT FOR PRACTICE AFTER A THEORETICAL SESSION IN THE CLASSROOM.

FIGURE 43. OVERVIEW OF A DEMONSTRATION PLOT.

4.6 Strengths and Constraints of Large and Small Irrigation Projects

Strengths

- Improvement of crop yields at developed sites
- Presence of water year-round on-site
- Possibility of having two growing seasons (rainfed and irrigated)
- Improvement of the living conditions of beneficiaries
- Opening up of certain areas by service roads, thus increasing trade volumes

Several constraints at different levels are often mentioned, in particular the following:

At the land level

- Land pressure, lack of regulatory framework or weak application of laws, the duality between modern law and customary rules, and precarious access to land.
- The lack of regulations and their non-implementation worsen the situation of land tenure.
- Cultural constraints and land allocation criteria that exclude deprived social groups such as women.

At the technical level

- The low technicality of the companies recruited to make arrangements.
- The apparent lack of human resources in the field of irrigation and water control.
- Lack of drainage and sanitation infrastructure for some projects.
- Support services for production and marketing are not sufficiently developed.
- The isolation of certain areas with high agricultural potential and the lack of access roads.
- Salinity and lower soil fertility.
- Insufficient support and monitoring.
- Deficit monitoring during the execution of hydro-agricultural development works.
- The technical insufficiency of the feasibility studies and detailed execution or pre-project.
- Lack of professional companies for the development and installation of irrigation systems.

At the financial level:

High cost of adaptable land due to periods of inactivity (from evaluation to the search for financing and the procurement process).
Exorbitant financial proposals from companies to execute development work create financial gaps, causing work fragmentation.
Difficult access to financial services.
Lack of funds for access to irrigation equipment.
Insufficient professional irrigation materials and equipment in the market.

At the organizational level and for maintenance of the structures:

- Weak structuring of the rural world and the insufficient capacity of agricultural partners.
- Lack of appropriation of the management by the perimeter management committee.
- Poor management and low maintenance of existing facilities.
- Problems with recovering maintenance and operating costs and renewing equipment.
- Lack of equipment maintenance and poor plant performance.
- Degradation of hydro-agricultural developments.
- Non-effective appropriation of sites by operators.

4.7. Recommendations

Togolese agriculture must come together to control water use and establish a good irrigation policy. These challenges can be addressed at the following levels:

At the strategic and decision-making level:

- Include the notions of irrigation in the training and extension curricula.
- Create conditions allowing the installation of irrigation companies.
- Make irrigation equipment available by creating favorable conditions for importers.
- Subsidize the importation of irrigation equipment.
- Encourage and promote solar irrigation.
- Reduce taxes on the importation of irrigation kits.
- Organize field visits to import technologies (ICBA, Israel, and Burkina Faso, for example).

At the technical level:

- Overcome the lack of government support, extension, and monitoring structures on water management and irrigation systems.
- Couple the construction of reservoirs and boreholes to any road construction project.
- Provide training to irrigation projects/program staff on new irrigation technologies.
- Create demonstration irrigation plots (install all types of irrigation) at the level of technical services for training farmers.
- Entrust the operationalization of irrigation projects to companies that have the expertise.

- Encourage the capture of rainwater and rivers.
- Carry out studies to develop different types of land or agro-ecosystems.
- Foster the emergence of companies specializing in irrigation.

At the financial level:

- Facilitate access to financial services for agricultural entrepreneurs for land development.
- Facilitate low-interest loans to producers.

At the socio-demographic, organizational, and land level:

- Take socio-demographic aspects into account when defining irrigation policy.
- Involve local populations in any water control development project.
- Ensure land security to avoid any land problem related to water control.
- Organize producers into cooperative societies around the water points developed.
- Educate producers about the benefits of irrigation in the current climate change context.
- Strengthen state-private collaboration in irrigation (the private sector must support the state technically and financially in its actions).

4.7. Conclusions

Irrigation in Togo is still emerging when we consider the percentage of irrigated land vis-à-vis irrigable land. However, efforts are being made by the country's decision-makers jointly with the TFPs regarding hydro-agricultural development. Nonetheless, it is still challenging to have an impact on the beneficiary populations because of the (i) low level of appropriation of farms by the beneficiaries, (ii) low level of technicality of certain companies in carrying out the development, and (iii) severe lack of qualified human resources to ensure the follow-up of beneficiaries in the operation of the developed sites. As far as micro-irrigation is concerned, the various installations are mainly made by NGOs within the resilience and adaptation to climate change initiatives.

4.8 Country Summary and Recommendations

Togo has an extensive hydrographic system that covers the country. This hydrographic system has three main river basins: Volta, Mono, and Lac Togo. Agriculture is the most critical sector in Togo and it contributes 40% of GDP (ITRA). It employs two-thirds of the active population working on small land (0.5 ha). Food crops represent two-thirds of production and are mainly used domestically for consumption. Cash crops and food crops are grown. Indeed, 44% of the cultivated land is used for food crops, mainly maize, rice, millet, sorghum, yam, cassava, peanut, bean, and vegetable, cultivated

during the rainy season. Meanwhile, 15% of the cultivated land is used for cash crops, mainly cotton, coffee, cocoa, and cashew.

In recent years, significant efforts have been made to ensure water control in the production areas, particularly in irrigation infrastructure. This infrastructure has been put in place through specific strategic projects. Irrigation and drainage practices are booming in Togo, especially in the valleys of the Mono, Oti, Haho, and Zio rivers. The irrigation systems used vary from one crop to another. These are mainly rice (lowland rice) and sugarcane (industrial production in the plains and valleys). Immersion irrigation is most practiced, and vegetable crops are more cultivated by smallholding farmers using sprinkler and drip irrigation techniques. Demand is strong for irrigation in arboriculture (papaya, plantain, citrus), with a strong propensity toward drip irrigation. A new recorded practice in irrigated rice perimeters is the association of fish farming.

Irrigation development in Togo faces the following different challenges at different scales:

- Land pressure, lack of regulatory framework or weak application of laws, the duality between modern law and customary rules, and precarious access to land.
- Cultural constraints and land allocation criteria can exclude needy social groups such as women.
- The technical insufficiency of the feasibility studies and detailed execution or pre-project.

- Insufficiency of companies in the field of hydro-agricultural development and installation of irrigation systems on the ground.
- Difficult access to financial services.
- Lack of funds for access to irrigation equipment.
- Insufficient professional irrigation materials and equipment in the market.
- Poor management and low maintenance of existing facilities.
- Problems with recovering maintenance and operating costs and renewing equipment.
- Lack of equipment maintenance and poor plant performance.

These challenges can be addressed by taking appropriate measures at all levels.

At the strategic and decision-making level:

- Create conditions allowing the installation of irrigation companies.
- Make irrigation equipment available by creating favorable conditions for importers.
- Subsidize the importation of irrigation equipment.
- Encourage and promote solar irrigation.
- Reduce taxes on the importation of irrigation kits.
- Organize field visits to import technologies (ICBA, Israel, and Burkina Faso, for example).

At the technical level:

- Train specialists in irrigation projects/programs while importing new technologies in this area.
- Create demonstration irrigation plots (install all types of irrigation) at the level of technical services for training farmers.
- Entrust the operationalization of irrigation projects to companies that have the expertise.
- Encourage the capture of rainwater and river water.
- Facilitate access to financial services for agricultural entrepreneurs for land development.
- Facilitate low-interest loans to producers.

At the socio-demographic, organizational, and land level:

- Take socio-demographic aspects into account when defining irrigation policy.
- Involve local populations in any water control development project.
- Ensure land security to avoid any land problem related to water control.
- Organize producers into cooperative societies around the water points developed.
- Educate producers about the benefits of irrigation in the current climate change context.
- Strengthen state-private collaboration in irrigation (the private sector must support the state technically and financially in its actions).

5 Country Profile
Mozambique

5.1 Background

Agriculture plays a vital role in Mozambique's economy, contributing 23% to the GDP and employment of the population living in rural areas. Smallholder farmers cultivate 95% of the agricultural land and 70% of the population depends on subsistence farming (World Bank, 2007). The country has approximately 0.565 million hectares of arable land with ample renewable freshwater resources. Mozambique has abundant water resources for irrigation development. However, only 50,000 ha are currently used because of limited water management infrastructure; most water flows into the Indian Ocean without any beneficial use.

The majority of farmers are carrying out rainfed agriculture. Because of climate change and variability, most farmers are vulnerable to catastrophic events such as drought and floods that significantly affect their livelihood. The government of Mozambique created the National Institute of Irrigation in 2012 as part of the strategy to expand irrigation facilities. Several development programs have been executed to improve irrigation and drainage infrastructure. A total of 27,032 ha of land are being irrigated (MINAG, 2010) (Figure 44).

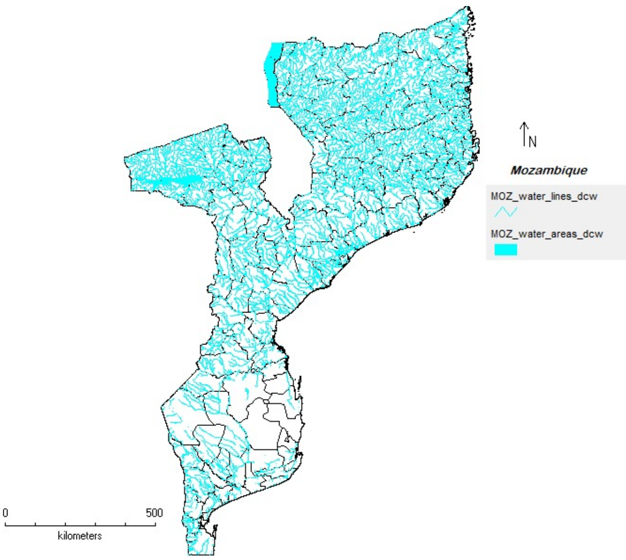


FIGURE 44. MOZAMBIQUE HYDROGRAPHIC SYSTEM.

The geographical distribution of water area, lines, and rivers. DIVA-GIS software (version 7.5) obtained from the DIVA-GIS website (http://www.diva-gis.org) was used to create the maps.

This report summarizes the status of irrigation and drainage infrastructure in Mozambique, focusing on two provinces where the RESADE project is being implemented. This report contributes to activity 4.2 of the RESADE project in Mozambique. General information about other provinces' irrigation and drainage infrastructure was also provided.

Information was collected from several past studies by government entities and development organizations to document the status of irrigation infrastructure for supporting intervention in this area to improve water access for irrigation.

Primary emphasis was given to Moamba District (Maputo Province) in southern Mozambique and Nicoadala District (Zambézia Province) in central Mozambique. In each irrigation scheme, the following information was collected: a rapid description of the basin, general characteristics of irrigation and drainage infrastructure, dominant cultivated crops in the irrigation systems, spatial information on the irrigation facilities, and other relevant irrigation system-related information. Information for improving irrigation schemes was included when available for different irrigation systems.

5.1.1 Classes and distribution of irrigation systems

Mozambique has great potential for irrigation development (3.3 million ha), of which only 50,000 ha are currently being used. Moreover, 60% of the irrigated land is used for commercial sugarcane production. The major food crops in Mozambique are maize, sorghum, millet, rice, cassava, vegetables, and fruits, and the major cash crops are sesame, cotton, tobacco, pigeon pea tea, sugar, and cashew. Only 8.8% of the farmers in the smallholder sector use any irrigation system (MASA, 2000; technical reports). Irrigation systems are grouped into three classes: class A: (less than 50 ha), class B: (from 50 to 500 ha), and class C: (more than 500 ha) (Table 13). Class A smallholder farmers generally operate within an irrigation scheme (individually or in groups) and/or associations of farmers or cooperatives. The water supply for irrigation is through small water pumps such as treadle pumps and other manual methods. These irrigation systems generally have low irrigation efficiency.

TABLE 13. TOTAL IRRIGATED LAND REHABILITATED OR CONSTRUCTED IN 2004 TO 2009.

Province	Irrigated land (ha) 2004-09						Total
	2004	2005	2006	2007	2008	2009	
Maputo	876	324	980	60	517	82	3,747
Gaza	930	1,520	598	2,300	500	1,432	15,175
Inhambane	80	120	252	321	143	201	1,164
Tete				20	13	13	416
Sofala		40	75	110	39	39	573
Manica		192	283				1,671
Zambezia		18	54	45	200	200	3,070
Nampula	20	-	119	70	57	57	619
Niassa	-	-	15	94	15	15	490
Cabo Delgado	-	-	-	-	23	23	107

Class B and C smallholder farmers generally operate through commercial companies such as sugarcane and rice production companies. Some companies use high-efficiency sprinkler irrigation or a central pivot irrigation system. Most irrigation systems are in southern Mozambique, accounting for approximately 80% of the equipped area. Table 14 shows the total area covered by each type of irrigation scheme.

TABLE 14. TYPES OF IRRIGATION SCHEMES IN MOZAMBIQUE (2002 DATA).

Class of irrigation scheme (ha)	Area (ha)		Rehabilitated
	Equipped	Operational	
Class A: (< 50)	6,389	3,276	3,113
Class B: (50-500)	19,547	4,680	14,967
Class C: (>500)	92,084	32,107	59,977
Total	118,020	40,063	78,057

The government has improved many irrigation schemes for smallholder farmers in recent years. The water sources for irrigation have been mainly rivers, while groundwater is through boreholes. Most state-operated irrigation systems perform poorly, and many are not used to their potential.

5.1.2 Historical perspective of irrigation in the country

The years 1968 to 1973

The First Irrigated Land Inventory (1968) revealed that irrigated land covered 65,000 ha, of which 72% is in the southern region. In 1973, the irrigated land increased by 35,000 ha with private sugarcane companies in the Incomati River basin and other enterprises in the Limpopo basin managed by Portuguese citizens (Sá e Mello Marques, 1973) before independence (June 25, 1975).
The year 1975

Another 20,000 ha were added to the irrigated land, most of it located within Maputo and Gaza provinces, except for the N'guri (1,000 ha) and Chipembe (160 ha) irrigation schemes located in the northern province of Cabo Delgado. During this period, some hydraulic structures for water storage were constructed on the Umbeluzi River (Pequenos Libombos dam), Sábiè River (Corumana dam) in Maputo Province, Elephants River (Massingir dam) in Gaza Province, and Chipembe dam in Cabo Delgado Province.

The years 1986 and 1987

The inventory carried out by Mihaljovich and Gomes (1986) and Sogreha (1987) revealed the existence of 20,000 ha of infrastructure, but only 42,000 ha were operational. The total infrastructure area was distributed as follows: 61% in the southern region (Maputo, Gaza, and Inhambane provinces), 33% in the central region (Sofala, Manica, Tete, and Zambézia provinces), and only 6% in the northern region (Nampula, Cabo Delgado, and Niassa provinces).

The year 1990

It was reported that 107,349 ha were equipped with infrastructure. Only 68,685 ha were occupied, but it did not specify whether they were operational. Some were under rainfed conditions and the other 38,664 ha were not under cultivation.

The year 1998

The Country Situation Report on Water Resources prepared by consultants for the National Directorate of Water Affairs (Direcção Nacional de Águas) estimated an irrigated area at 35,000 ha, out of 120,000 ha equipped with irrigation infrastructure, and 68% of it concentrated in the southern region. Unfortunately,

this report was not supported by the fieldwork inventory but was based only on the available reports and consultation with the staff of the irrigation department.

TABLE 15: DISTRIBUTION OF IRRIGATED LAND (HA) IN THE NORTHERN REGION (NIASSA, CABO DELGADO, AND NAMPULA PROVINCES).

Area (ha)		
Province	Equipped	Operational
Niassa	607.5	6.5
Cabo Delgado	1,764.0	45.0
Nampula	980.0	610.0
Total	3,351.5	661.5

5.1.3 Irrigated land inventory 2001-03

5.1.3.1 Irrigation and drainage infrastructure in the northern region

The intensive inventory of irrigated land was done during 2001-03. The first phase (Sept-Nov 2001) covered the northern region and 3,351.5 ha (3% of the total area nationally) were found equipped with irrigation infrastructure (Table 15). Only 661.5 ha were operational (20% of the total area with irrigation facilities). These figures represented a decrease in irrigated land compared with the statistics of the 1990s when 6,000 ha had the infrastructure and 3,395 ha were operational. Additionally, another 1,420 ha were projected for construction.

- Cabo Delgado Province had 1,764 ha of irrigation infrastructure and 2.6% (45 ha) was operational. Niassa Province had the smallest equipped area with irrigation infrastructure (607.5 ha) and only 6.5 ha were irrigated. Nampula Province has equipped area of 980 ha. It irrigates 610 ha in the region (62% of its total).
- For each province in the northern region, the Class A irrigation schemes show the largest operational percentage of the total equipped area (10% in Cabo Delgado, 80% in Nampula, and 80% in Niassa). All production units were managed by private or farmer associations except the seedling multiplication center of Nacaca.
- In terms of land equipped with irrigation infrastructure in the northern region, the emphasis is made on the N'guri irrigation scheme (1,000 ha), Chipembe (160 ha, Photo 1) in Cabo Delgado Province, and Matama (500 ha) in Niassa Province. These are owned by the state and were built soon after independence in 1975 to intensify irrigated crop production. At the inventory, all were non-operational, and scattered rainfed crop production fields of the family sector were observed within the areas equipped with irrigation infrastructure (Figure 45).
- Another irrigation scheme (200 ha) is in Monapo District, Nampula Province. It was built in the 1990s by a state seed production enterprise (SEMOC) and operated up to 1995. All other small and medium irrigation schemes were managed by private or farmer associations, except the three centers of seed multiplication (Nampula-Sede, Ribáuè, and Namuno), under the Provincial Directorate of Agriculture and Rural Development (DPADR).
- The main irrigated crops were vegetables (301.5 ha) associated with fruit trees (citrus, mangoes, and banana). Paddy rice covered an area of 360 ha and consisted of a simple rainwater retention infrastructure. Vegetables were produced during the cool and dry seasons and rice in the warm and rainy seasons. Because of better agro-ecological conditions and the availability of arable land in the northern region, major food crops (beans, maize, sorghum, cassava, millet, and groundnuts) are grown under rainfed conditions during the summer season. The scattered plot sizes vary from 0.25 to 1.5 ha and are managed mainly by farmers.
- The gravity irrigation method (furrows or basin) is the most dominant. The water is pumped from rivers, boreholes, or traditional water retention

Photo 1: Chipembe dam as water source for irrigation scheme, Cabo Delgado Province

Photo 2: Furrow irrigation method, applied in maize and vegetables production systems.

FIGURE 45. TYPES OF IRRIGATION SYSTEMS IN MOZAMBIQUE.

TABLE 16. DISTRIBUTION OF IRRIGATED LAND IN THE SOUTHERN REGION (INHAMBANE, GAZA, AND MAPUTO PROVINCES).

Province	Area equipped (ha)	Area operational (ha)
Inhambane	1,285	177
Gaza	50,323	8,825
Maputo	24,084	14,143
Total	75,692	23,145

basins. Manual irrigation (by the watering can) was frequently reported in tiny (house) gardens.

- Water use efficiency was high in the traditional rainwater retention basins (Cabaceira Grande and Ilepue) and small irrigated areas in Malema District (Nampula Province), especially in paddy production through only one harvest per year.
- From the various consulted documents on areas equipped with irrigation infrastructure in the northern region, we found that the region is at lower risk of crop failure due to the climate and rainfed crop production during the rainy season. However, the excess water causes crop failure, especially in the highlands of Niassa and Nampula provinces. This is why the farmers are less involved in intensive irrigated agriculture. Nevertheless, the second harvest of rice and vegetable production in the dry and cool season remains a challenge.

5.2 Irrigation and drainage infrastructure in the southern region

The irrigated land inventory in the southern region was completed in 2002. It was estimated that 75,692 ha (representing 64% of the total irrigated land in the country) were equipped with irrigation infrastructure, but only 23,145 ha were operational. The spatial distribution of equipped and operational irrigation units is given in Table 16.

The major irrigation schemes in this region are located in Gaza Province (Chówè: 30,000 ha; Macia: 8,000 ha; Matuba: 2,834 ha; and Xai-Xai: 2,970 ha) and Maputo Province (Açucareiras de Xinavane: 5,254 ha, and Maragra: 6,089 ha) (Figures 46, 47, and 48). In each province of the southern region, the irrigation schemes of Class A represent the highest figures (percentage) of currently irrigated land compared to those equipped with irrigation infrastructure (14.8% in Inhambane, 27.2% in Gaza, and 57.8% in Maputo provinces).

- This region's dominant irrigation method is gravity (furrows and flooded basin) and manual (watering cans). There were a reported 8,330 ha irrigated by sprinklers, 2,800 ha of peatlands

FIGURE 46. FURROW (GRAVITY) IRRIGATION SYSTEM

FIGURE 47. ELECTRIC PUMPING STATION OF DRIP IRRIGATION IN THE VEGETABLE PRODUCTION SYSTEM, INCOMATI RIVER, MOAMBA DISTRICT, MAPUTO PROVINCE.

FIGURE 48. WATER PUMPING STATION OF MOAMBA BLOCK I

(water table management), and 115 ha with drip irrigation. The water sources for irrigation are rivers, lagoons, water retention basins, and reservoirs. The water is pumped by diesel or electric pumps.

- A lack of farmers (mainly in the private and farmer associations) is the most constraining and challenging issue to be improved for higher yields in an intensive production system supported by the supplementary irrigation systems in the region.
- The high potential of peatlands (locally known as machongos) in this region is of paramount importance since they do not require energy (diesel, solar panels, and electricity) to support the current production system in the region. Still, investment needs to be improved on the drainage network already present in the region.

5.3 Irrigation and Drainage Infrastructure in Central Mozambique

The central region comprises Manica, Sofala, Tete, and Zambézia provinces (Table 17). It was surveyed in 2003 and a total area equipped with irrigation infrastructure was reported as 39,029 ha, and 16,257 ha were operational. Sofala Province accounted for 24,220 ha equipped with irrigation infrastructure, and 57.2% (13,850 ha) was operational. A total of 20,899 ha (96%) belong to state sugarcane production in Marromeu, Búzi, and Dondo districts.

- Tete Province recorded the smallest irrigated area. It covers a total equipped and operational irrigated land of 1,894.8 ha and 451.8 ha, respectively. In Manica Province, the total infrastructure area is 2,067 ha and 48% (989.8 ha) was operational. Zambézia Province has less operationally equipped irrigated land (10,847.7 ha). Of this, 7,000 ha belong to Luabo Sena Sugar Estates and only 964.7 ha (9%) were operational.

TABLE 17. SPATIAL DISTRIBUTION OF IRRIGATED LAND IN THE CENTRAL REGION (MANICA, SOFALA, TETE, AND ZAMBÉZIA PROVINCES).

Province	Area equipped (ha)	Area operational (ha)
Manica	2,067.00	989.8
Sofala	24,220.30	13,850.30
Tete	1,894.80	451.8
Zambézia	10,847.70	964.7

- In this region, the Class A irrigated land units are dominant and account for 28% of Zambézia Province, 45% of Sofala and Manica provinces, and 50% of Tete Province, even though these do not represent the major land areas equipped with irrigation infrastructure.
- The Class B irrigation-equipped schemes in Zambézia Province cover 2,852 ha, although only 23% (645) is operational. Manica Province has an operational irrigated land area of 730 ha (50%) out of 1,485 ha, and Sofala has less than 1% of the least irrigated land. Zambézia and Tete cover 23% and 15% of the operational irrigated land areas in this typology class.
- Class C irrigation infrastructure is highest in Sofala Province (23,199 ha), followed by Zambézia Province with 7,750 ha. There were no reported irrigation schemes of this typology in Tete and Manica provinces. The dominant crop in Class C is sugarcane (Mafambisse and Marromeu) in Sofala Province and Luabo, although not operational, in Zambézia Province.
- Regarding being equipped with irrigation infrastructure, the Sena Sugar Estates Açucareira de Sena (Marromeu District) covers an area of 5,706 ha, Mafambisse covers 8,093 ha (Dondo District), and the other 300 ha and 100 ha belong to private enterprises in Sofala Province. In addition, a non-operational area of 7,000 ha in Zambézia Province belongs to Açucareira de Sena (SSE Luabo).
- Related to irrigated land for sugarcane production in Sofala Province, Nhamatanda District has an additional 3,500 ha, an expansion area of Mafambisse Sugar Estate.

Summary

The last inventory showed 257 irrigated units with a total infrastructure area of 118,000 ha. The country's irrigation schemes with more than 500 ha were 21 units, representing 70% of the total available irrigated land. Those of medium dimension (50-500 ha) are 77 units with a total area of 20,000 ha (representing 17% of the total irrigated area). The irrigation schemes with less than 50 ha are 159 units and they cover 6,400 ha (13% of the total irrigated land). About 64% of the available irrigated land is in the southern region, 33% in the central region, and only 3% in the northern region.

General remarks

- Low degree of use of existing infrastructure: on average, the used irrigated land represents only 34% of the existing capacity (40,000 ha operational out of 118,000 ha with irrigation infrastructure). The small irrigation schemes are far better managed (51%) than the medium ones, with an average use of 24%, and 35% for those with equal to and more than 500 ha.
- Crop diversification is very low. More than 50% of irrigated crop production is sugarcane in irrigation schemes of medium to high dimensions.
- The water use efficiency is generally low. The sprinkler irrigation method is used in four high-dimension irrigation schemes. In the remaining 20,000 ha, the furrow or basin gravity irrigation method is used with an efficiency rate of 30%.

Main problems identified

The main problems related to the irrigation sector follow:

- Abandonment of the irrigated production units, which were the property of the former Portuguese citizens, soon after independence, and the lack of skills and financial resources for maintenance of the irrigation infrastructure.
- Migration of the rural population from the vicinity of production units to cities because of civil war.
- Lack of access to inputs, technical assistance, extension services, and maintenance of the irrigation infrastructure, and lack of markets.
- A gradual reduction in the public investment in irrigation infrastructure development; in addition, the increase in production taxes (fuel, energy, inputs, seeds, and agrochemicals).

Field investigations under the RESADE project

Mozambique is located between 10o33' and 26o 50' South latitude and 30o10'and 42o00' East longitude. The country comprises regions of highly varied topography, covered mainly by tropical and subtropical forests, with a total surface area of 799,380 km^2. Two districts were selected for implementation of the current project: (i) Moamba District, located in the southern region (Maputo Province), and (ii) Nicoadala District, located in the central region (Zambézia Province).

5.4 Moamba District, Maputo Province

Moamba District is in Maputo Province. The Republic of South Africa limits its entire western extension. Out of the four administrative posts, most of the irrigated areas are located in Moamba-Sede, Ressano Garcia, and Sábié. Moomba Village is about 80 km from Maputo City and is currently served by a highway (N4), which links Maputo to Witbank in neighboring South Africa. The district was severely affected by floods in 2000 and agricultural activity, the road network, bridges, and other accesses, as well as much other socioeconomic infrastructure, were fully or partially destroyed, still being reflected today in the agricultural activity of the district.

The average annual precipitation is 577 mm considering the district's annual averages of different meteorological stations, namely, 589 mm in Moamba-Sede, 565 mm in Sábié, and 571 mm in Ressano Garcia. Therefore, the variation in annual precipitation is considerable, reaching 200 mm minimum and 1,000 mm maximum. Precipitation occurs mainly from October to March (70-80%), with the highest rainfall from December to February. The average annual reference evapotranspiration is 1,377 mm in Sábié, 1,392.4 mm in Ressano Garcia, and 1,528.3 mm in Moamba-Sede.

Geomorphologically, Moamba District can be characterized by four land units: the Libombos mountains, the dissected highlands, the terraces of the Incomati and Sábié rivers, and the alluvial floodplains of the same rivers. The dissected highlands can also be differentiated according to the dominant deposits. In the Tertiary marine deposits is the Mananga platform, taking the shape of a plateau with a gently undulating relief. On the transition slopes between the highlands and the river terraces, the Post-Mananga

formations occur. According to the typology of the irrigated land inventory on the existing irrigation systems in the country, three classes were established:

- Irrigation schemes of Class A (<50 ha)
- Irrigation schemes of Class B (50-500 ha)
- Irrigation schemes of Class C (>500 ha)

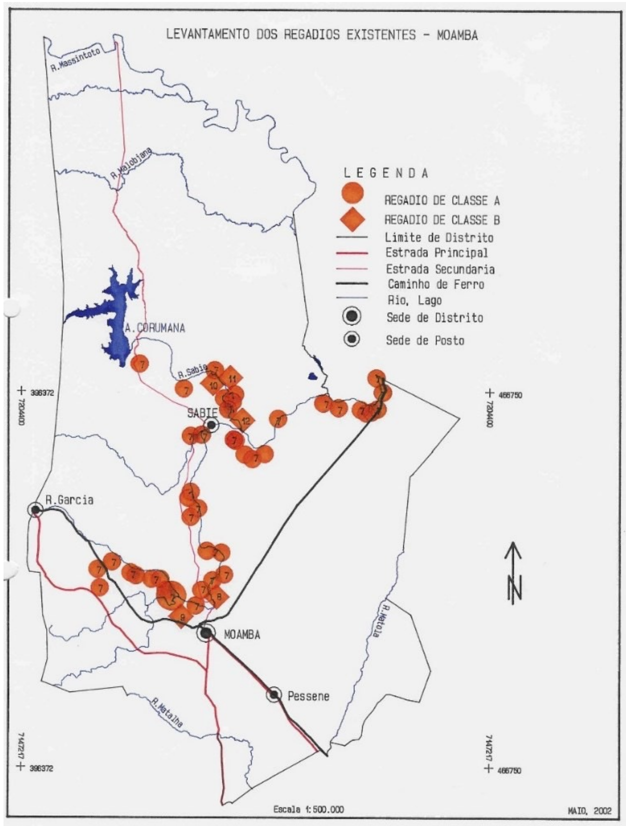


FIGURE 49. SPATIAL DISTRIBUTION OF IRRIGATION SCHEMES OF CLASS A (<50 HA) AND CLASS B: (50-500 HA), MOAMBA DISTRICT, MAPUTO PROVINCE.

In Moomba District, only irrigation schemes of classes A and B were found (Figure 48). The cumulative irrigated land in Class A covered an infrastructure area of 1,248.5 ha, and only 454.5 ha were reported to be operational. The irrigation schemes of Class B had a cumulative equipped area of 1,580 ha and, at the inventory, only 217 ha were operational. Moomba District has the most significant number of private farmer groups or farmers' associations owning Class A irrigation schemes. About 65 irrigation schemes were found, corresponding to an infrastructure area of 1,248.5 ha. It consists of approximately 30% of the total area of Class A irrigation schemes, although only 434.5 ha (35%) are operational.

5.4.1 Irrigation schemes of Class A, Moamba District

River basin: Incomati and Sábiè rivers.

The irrigated land equipped with irrigation infrastructure is 1,248 ha. Currently, irrigated area is 434 ha, scattered in small production units (1-50 ha), dominated mainly by farm sizes equal to or less than

20 ha, and managed by a private group of farmers or association of farmers.

Brief description of the region

The small (Class A) irrigated land units (managed by a private group of farmers or association of farmers) are located along the left and right banks of the Incomati and Sábié rivers. They cover different localities and communities: Chanculo, Condene, Chinhangoanine, Malengane, Goane I (Bigoane), Goane II (Magawane), Mbocodo, Wamogolombe, Luziveve, Aviação, Missão, and Bairro Comercial e Bondoia, along the Incomati and Sábiè rivers.

- Most of the scattered irrigated land units occur in the recent Quaternary deposits composed of alluvial and colluvial sediments, from which three sub-geomorphological units are distinguished: (i) dissected highlands, (ii) medium to high river terraces, (iii) and floodplain river terraces.
- There is a clear distinction between two climatic seasons within Moamba District: the warm and rainy season (October to March) and the cool and dry season (April to September). The average annual precipitation in the region (district) is 571 mm, but it varies: Moamba-Sede (587.3 mm), Sábiè (554.4 mm), and Ressano Garcia (571.4 mm). Heavy rains (70-80%) occur from November to March, but the cumulative rainfall in this period can vary from 200 to 1,000 mm. The average cumulative evapotranspiration is 1,377 mm (Sábiè), 1,392 mm (Ressano Garcia), and 1,528 mm (Moamba-Sede). The primary water sources for irrigation are the Incomati and Sábiè rivers, and the water quality was rated excellent. Although a single farmer referred to low water quality (water salinity) in the cool and dry season, it does affect the metal piping conduct on the farm.

General description of Class A irrigated schemes

In the 1980s, Moamba District was severely affected by drought during the cropping season, and the government mobilized financial resources to develop intensified irrigated agriculture in the region. The civil war also affected a large part of the southern region of Maputo Province and conditioned agricultural product availability, particularly at the city level. Approximately 1,200 ha were distributed to farmers, farmer groups, or farmer associations, primarily those affected by drought and the civil war. In parallel, the government provided water pumping engines (manufacturers such as Lister Storck, Briggs, Statton Storck, Lombardini, Deutz, Ruston, Maritz, and Huang Shan), trucks, tractors, technical assistance (extension services), repairing and maintenance of field equipment, and agricultural inputs.

Agricultural production was concentrated at the level of farmers in the cultivation of maize for self-consumption and vegetables for supply and sale in Maputo markets. Although this was the objective at the beginning of the project, the farmers, depending on the results and market offer, began to specialize and prioritize the intensive production of vegetables, particularly tomatoes (first crop), cabbage (second crop), pepper (third crop), green beans, garlic, onions, and other vegetables of less importance.

Concerning the Class A irrigation schemes, 900 ha were initially equipped with irrigation infrastructure, and 51 water pumping engines were allocated in Moamba, Sábiè, and Malengane communities. The water for irrigation was captured from the Incomati and Sábiè rivers, and the furrow irrigation method was the most dominant. The irrigation systems consist of a diesel pumping station with galvanized Bauer-type piping for transporting water to the fields or the network of ditches and irrigation channels on land. In some cases, it is still possible to use the old water infrastructure coated or blocky channels but they are poorly handled.

Description of other infrastructure associated with irrigation

There exists infrastructure of old properties (before independence) and Empresa Agricola da Moamba (post-independence) facilities, and the Sábié Project is in an advanced state of degradation. The services offered by the two maintenance and machinery repairing parks are limited, particularly at the level of Moamba, requiring renovation and rehabilitation and rethinking their mission. Therefore, their reorganization is essential as they are strategic services for agricultural development.

Although the secondary road network is passable, circulation in the tertiary network and access to farmers' properties are complex; in addition, vegetation has completely invaded some sectors. The most demanded market is in Maputo, with the

Malanga, Fajardo, and Central markets chosen by farmers for selling their products.

Status of irrigation systems

Most Class A irrigation systems are fully or partially operational. The pumping stations using diesel pumps are primarily operational. Still, there are many damaged pumps. The irrigated areas, with some exceptions, have less than the desired management and efficiency. It is possible to resize irrigated areas according to the infrastructure to make agricultural production profitable (35% of the infrastructure is operational). There is also a need to train farmers in organizing and managing the production process.

Main crops

The intensive and commercial agricultural production of vegetables is the irrigated area's primary agricultural production system. The main crops are tomatoes (first crop), cabbage (second crop), peppers (third crop), green beans, garlic, onions, and other vegetables of less importance. As alternative crops, potatoes and common beans are preferred by farmers in the region.

Existence of maps, executive projects, and other relevant studies

- Bonifica, SpA. 1989. Pedological and Agro-Hydrological Assessment Study of 800 ha - Moamba II Project. DINA, Maputo.
- Bonifica, SpA. 1990. Support for Agrarian Development in Moamba District - Moamba III. DINA, Maputo.
- DINA. 1985. Moamba Agricultural Rehabilitation Project - Moamba Project I. CEE-NA/83-30. DINA, Maputo.
- INIA. 1987. Summary of the Agricultural Potential of the Provinces of Maputo and Gaza. Technical Note No. 26. Land and Water Series. INIA, Maputo.
- Landell Mills Ltd. 1991. Evaluation of Moamba II. Final report. DINA, Maputo.
- Sinadinov, I. 1982. The Soils of the Moamba Area - Moamba District. Semi-Detailed Soil Survey. INIA-DTA, Maputo.

FIGURE 50. THE PUMPING STATION OF MOAMBA BLOCK I.

5.4.2 Irrigation scheme of Block I River basin: Incomati River.

This irrigation scheme is in Pessene, Moamba District, Maputo Province (see Figure 49). The central water pumping station is at 25o33'22.6" S latitude and 32o15'05.3" E longitude. The project area is 485 ha, the equipped area is 350 ha, the operational area is 0 ha, and 251 ha were distributed to farmers' associations and 32 ha were abandoned due to salinity problems. According to the last evaluation report of the Moamba II project (December 1991), the total area with irrigation infrastructure was 350 ha: 210.5 ha belonged to farmer associations, 88.5 ha to the family sector, 21 ha to the cooperative sector, and 30 ha were still to be allocated to other users.

Brief description of the region

The climate in the region is classified as a Dry savanna climate with a dry winter (according to the Köppen Classification System), with erratic and irregular rainfall distributed throughout the year. The annual average precipitation is 587.3 mm. The wettest period occurs from October to April and the average evapotranspiration is about 1,500 mm. The average monthly precipitation is all-year-round less than evapotranspiration. This irrigation scheme is within alluvial terraces with flat to almost flat terrain of the Incomati river plain with slopes of 0-1%.

Two soil units were developed from the recent fluvial deposited sediments on the right side of the river. The two soil units are black, gray-brown, deep to very deep, and medium-textured (loam, sandy-loam, sandy-clay loam, and clay), with some coarse sand in the topsoil or subsoil, moderately well-drained.

Brief description of the irrigation scheme

The Block I irrigation scheme was established in the 1970s to provide cereal and fresh vegetables to the markets of Maputo City. The scheme uses the furrow irrigation method. The civil war exacerbated the degradation of the entire irrigation infrastructure. The irrigation channels, drainage ditches, and water reservoirs were the most damaged because of a lack of maintenance and poor management. This was rehabilitated after the 1984 floods by the Moamba II project. This consisted of the central water pumping station, grass removal and deepening of the central canal, three electric pumping units plus one diesel motor pumping unit, a concrete coating canal (10,150 m), cleaning and deepening of drainage ditches (1,990 m), and building of 3,200 m of new drainage ditches, repairing of the water reservoirs, and land leveling.

The Agricultural Rehabilitation Project of Moamba (Projecto de Reabilitação Agrícola de Moamba) proceeded in 1986 (Figure 50). The Moamba II project began in 1992 to provide technical assistance, extension services, agricultural inputs (seed, fertilizer, agrochemicals), credit facilities, and transportation of farm products to the markets. The pumping stations were equipped with three electric pumps and a diesel pump as an alternative. The electric pumps operated 24 hours a day with an alternating schedule of 8 hours. The pumped water was stored in a main earth-compacted reservoir with a storage capacity of 15,000 m^3.

The water reservoir is equipped with concrete outlet valves that guarantee water distribution to the central canal that conducts the water directly to the second reservoir in addition to distribution to the other four canals (C1, C2, C3, and C4) that supply water to four other reservoirs. The main channel length is 3,213 m. The current drainage system is deficient and contributes to the salinization of irrigated soils. The main drainage ditch transports water to a depression in the terrain, but, because of the topography and low slope, the surface drainage is deficient, not allowing regular water flow. Although 32 ha were declared as salinized soils, the salinized area may be more extensive.

FIGURE 51. RECENTLY REHABILITATED BASIN AND WATER ACCESS CHANNEL.

Description of other infrastructure associated with the irrigation scheme

The electrical installation was rehabilitated. The electrical panel and the transformation station were vital components of the pumping station. The pumping house has been rehabilitated and renovated. Three dams must be repaired due to serious infiltration problems that limit their water storage capacity. The assets associated with irrigation, such as homes, offices, warehouses, and buildings, are under FDHA. The water use efficiency of these irrigation schemes is very low; therefore, redesigning of irrigated fields is needed to match them better with the water availability and distribution patterns.

Owner/beneficiary

This irrigation scheme belongs to the state, managed by the State Agricultural Company of Moamba during its construction in the late 1970s under cooperation between Mozambique and China, and later by DDADR with support from Moamba II until 1992. Currently, irrigation is under the tutelage of the FDHA/DDADR, but its management was partially handed over to a farmer association. The farmer association consists of 112 families that received 251 ha. The 251 ha are divided into plots of 1 to 15 ha distributed by association members. The association is paying all current expenses inherent to irrigation operations. It was impossible to know whether the members must pay an annual fee for irrigated land.

Main crops

Vegetables (cabbage, onions, tomatoes, peppers, carrots, and potatoes) are grown in the new season mainly and maize in the first season. The farmers use inputs. Irrigation (when operational) is done by gravity through secondary channels. Irrigation water is distributed to plots through tertiary channels. Under normal conditions, the production system is characterized by intensive vegetable production for commercial purposes, with Maputo markets being the preferred ones for selling agricultural products. According to old reports, only 20% to 25% of the vegetable production is consumed in Moamba District, with more of the production (>35%) going to Maputo, especially tomatoes.

Existence of maps, executive projects, and other relevant studies

Maps and drawings of irrigation structures are present in FDHA offices. However, they are not easily accessible. The following reports/maps are available in FDHA offices:

- Bonifica, SpA. 1989. Estudo Pedológico e de Avaliação Agro-Hidrológica de 800 ha.
- Projecto Moamba II. DINA, Maputo.
- Bonifica, SpA. 1990. Apoio ao Desenvolvimento Agrário do Distrito de Moamba – Moamba III. DINA, Maputo.
- DINA. 1985. Projecto de Reabilitação Agrícola da Região da Moamba – Projecto Moamba I. CEE-NA/83-30. DINA, Maputo.
- INIA. 1987. Sumário do Potencial Agrícola das Províncias de Maputo e Gaza. Nota Técnica Nº
- 26. Série Terra e Água. INIA, Maputo.
- Landell Mills Ltd. 1991. Avaliação de Moamba II. Relatório Final. DINA, Maputo.
- Sinadinov, I. 1982. Os Solos da Área de Moamba – Distrito de Moamba. Levantamento Semi-Detalhado de Solos. INIA-DTA, Maputo.

5.4.3 Irrigation scheme of Block II

River basin: Incomati River.

Area: According to the Final Evaluation Report of the Moamba II Project, Block II comprised an area of 350 ha distributed as follows: 41.1 ha private sector; 51.0 ha family sector; 6.1 ha others; 30.0 ha still to be split; 80.0 ha to be developed; 141.8 ha yet to be studied. The description of the region where the irrigation in Block II is located is similar to that developed for the irrigation in Block I, so it will not be necessary to repeat it, and it is recommended to consult the text referring to that irrigation scheme.

Description of the irrigation scheme

This irrigation scheme was established in the late 1970s to enhance agricultural production at a time when the area was considered the granary of Maputo Province to reduce the vulnerability of sequential agricultural production from irrigated agriculture. The scheme was dimensioned and created through technical assistance under the cooperation agreement between the governments of Mozambique and China. The scheme was designed to operate using the gravity irrigation method. Water is pumped from two groups of reactive electric pumps, with capacity to pump 24 hours a day in three 8-hour shifts. Each pump has a capacity of 200 L/s. The irrigation water is transported through a tubular, old, and causal conduit to a reservoir with storage capacity of 60,000 m^3.

The reservoir is built with stone walls, although, according to the final evaluation report of the Moamba II Project, the reservoir has been waterproofed. Flood discharge system is operational but needs maintenance due to its advanced oxidation. The water from the mother dam is distributed through a valve system that supplies the channels for 10 hours a day. It transports water through two main concrete-coated channels, 1,400 m and 1,600 m long, to eight secondary-coated channels. Distribution to both secondary and tertiary channels is done through the floodgate system. The water distribution for irrigation follows a scale managed by the farmers' association, guaranteed by the network of uncoated tertiary channels, whose management is the responsibility of the users.

The conservation of the secondary channels is critical, especially channels 8 and 10, which present some sections in poor condition and with damaged structures, requiring some engineering work. The drainage system consists of the main ditch and a network of secondary ditches on land that drains into two falls located at both ends of the main drainage ditch. According to the consulted technical documentation, the tertiary channels eventually, and in the case of excess water on the higher ground, may serve as tertiary drainage ditches, as represented in Figure 51. This is possible due to their better alignment through the slope, obeying the natural contours.

FIGURE 52. COMBINED TERTIARY IRRIGATION CHANNEL, DRAINAGE DITCH, AND CONSERVATION BANK (DINA, 1991).

Description of other infrastructure associated with irrigation

The installation at the electrical panel level needs repair or replacement. In particular, the posts need replacing in the energy transport network, as they are too inclined and may fail at any time.

Owner/beneficiary

This irrigation scheme belonged to the state and was managed by the Moamba State Agricultural Company at the time of its construction, in the late 1970s and under cooperation between the governments of Mozambique and China, and later by DDADR with support from the Moamba II Project (1984-85) and support for agrarian development of Moamba District, from 1986 to 1992. The state is the irrigation system owner, although the irrigation system is currently under the supervision of the FDHA/SDAE. Its management was partially handed over to the farmers' association of Block II, which already has its statutes. The association consists of 250 members. The association pays all operational expenses, particularly energy, water fee, land use, and benefits. According to information from SDAE, the association already has the title of use and improvement of land. Its members are asked to pay their contributions and, in case of non-use of their installations, they are penalized according to the provisions of the statutes. In addition to the association, Block II irrigation is also used by several private farmers.

Current situation of the irrigation system

The irrigation system is partially operational, presenting problems regarding its operation and potential risks of degradation if the respective corrective measures for soil and water management are not taken. Several limitations were identified, from the source of water intake to the distribution of water by the plots. The water source (Incomati River) does not offer guarantees of water supply for irrigation during a

part of the year, mainly in the dry season, which can extend from July to November. The sucker's place has been covered with mud since 1999, and the sucker itself lets out more coarse sediments.

The irrigation channels generally need cleaning and maintenance. However, the situation is more difficult at the level of the secondary channels (8 and 10) that need reconstruction and the tertiary network on land that needs cleaning. Perhaps the drainage system has the most significant limitations on the full use of irrigation. From what could be seen on the ground, the main drainage ditch is entirely covered by vegetation. Because of sedimentation, its depth has decreased, thus preventing water flow in the slope direction where the system drains the waters.

Main crops

Vegetables (cabbage, onions, tomatoes, peppers, carrots, and potatoes) are grown in the new season mainly and maize in the first season. Irrigation is done by gravity through tertiary channels. The production system is characterized by intensive vegetable production for commercial purposes, with Maputo markets being the preferred ones for selling agricultural products.

Unfortunately, no local agro-industry can absorb a part of the production or surpluses that have not been placed on the market. The vegetable production system has been sufficiently discussed in the description of Class A irrigation units existing in the district of Moamba, so its consultation is recommended given the similarities existing in both of those irrigated and Class B irrigation schemes.

Technical opinion

The irrigation system needs to be optimized because the projects are well-dimensioned and implemented. The irrigation system immediately needs to resize the deficient drainage system to avoid the risk of salinizing new production areas. The ditches' deepening and

the water runoff gradient correction are fundamental to the irrigation scheme's operationality and potential use. Greater attention should be paid to the potential risk of soil salinization when studying and analyzing the drainage system, considering the presence or absence of sodium and limestone subsoil associated with Mananga deposits, which are generally problematic from the point of view of management. The irrigated soils, those developed in the Post-Mananga deposits, occur in Block I or Block II, possibly being one of the potential causes of salinization of out-of-production plots since soils generally do not have salty irrigation water of good quality.
The efficiency of irrigation water for agricultural production can be improved if irrigation is not applied or practiced in more significant quantities than necessary for the development of crops and if the irrigation intervals are respected according to the different stages of plant development. Therefore, there is a need to introduce compatible cropping patterns so that the quantities and irrigation intervals, if not the same, can be close to achieving maximum irrigation efficiency.

Existence of maps, executive projects, and other relevant studies

Maps and drawings of some structures and works of art from this project were located at the FDHA offices in the district. However, finding any report or description of the project was impossible. There is a reference to some of the project documents being preserved or kept at the former headquarters of the Cooperative of Cattle Breeders in Maputo.

- Bonifica, SpA. 1989. Estudo Pedológico e de Avaliação Agro-Hidrológica de 800 ha – Projecto Moamba II. DINA, Maputo.
- Bonifica, SpA. 1990. Apoio ao Desenvolvimento Agrário do Distrito de Moamba – Moamba III. DINA, Maputo.
- DINA. 1985. Projecto de Reabilitação Agrícola da Região da Moamba – Projecto Moamba I. CEE- NA/83-30. DINA, Maputo.
- INIA. 1987. Sumário do Potencial Agrícola das Províncias de Maputo e Gaza. Nota Técnica Nº 26. Série Terra e Água. INIA, Maputo.
- Landell Mills Ltd. 1991. Avaliação de Moamba II. Relatório Final. DINA, Maputo.
- Sinadinov, I. 1982. Os Solos da Área de Moamba – Distrito de Moamba. Levantamento Semi-Detalhado de Solos. INIA-DTA, Maputo.

5.4.4 Irrigation scheme of Block 48 (Bloco 48)

River basin: Sábiè.
Area: total equipped area: 426 ha; equipped for **gravity irrigation:** 106 ha; equipped for sprinkler **irrigation:** 320 ha; operating by gravity area: 106 ha; **expansion:** not foreseen.

Description of the region

The irrigation scheme of Block 48 is located on the alluvial terraces and floodplain of the Sábié River, which consists of recent deposits (Quaternary) of fluvial origin, stratified and deposited by the Sábié River. The landscape is dominated on the left bank of the Sábié by the creation of Incomanine sandstone, separated from the floodplain by a marshy low (former) riverbed marginal to the sandy plain of the Mananga platform. The relief of Block 48 is flat and the topography is gently undulating in areas with depressions, as is the case of the central depression and other parts. Still, low valleys occur in the floodplain where slopes are more significant than 2%. The alluvial plain can also be differentiated into two land units:

i. the natural dike of the Sábié River (two levels of terraces where sediments are generally stratified, coarse, with a high % of sand, although the % of silt increases with the distance between river beds), and
ii. its settling basin (south of the central depression), with sediments of delicate nature (clay texture), which is not always distinct.

The textures are slightly less clayey due to the nature of the sediments of the Sábié River, which carries little clay, and due to the influence of the Incomanine sandstone formation, determining the varied nature of the sediments, that is, the river alluvium and the sandstone colluvium. The soils of the settling basin generally present high levels of salinity and sodicity due to the origin of the sediments (marine) and the position on the ground.

The region's climate is of the dry semi-arid type and, according to the Köppen classification, is a "BS-Steppe" climate, with maximum precipitation values in the hot season (November to April). The analysis of precipitation and evaporation in terms of monthly averages confirms the water deficit available in an average year and for all months. In Sábié Village, the average annual precipitation is 554 mm, with 1,378

mm/year for the reference evapotranspiration. Still, from a climatic point of view, because of the uneven distribution of rainfall and the risk of prolonged dry periods throughout the growing season, rainfed agricultural production is at high risk, with the necessity of resorting to either an irrigated agriculture supplement in the rainy months or full irrigation during the dry season.

The region's hydrology where Block 48 is located is complex due to a central depression that divides the block into two zones and drains into the current riverbed. Still, when floods occur, it is otherwise blocked by recent deposits that act as a natural dike of the river, thus limiting the normal drainage of rainwater and flooding after the waters recede. This fact contributes to forming a series of swamps with swampy characteristics. Also associated with the central depression are two small natural lakes, whose stagnant waters are salty, which might result from the accumulation of water from the runoff of the Incomanine sandstone hills.

Description of the irrigation scheme

The irrigation system was built in two phases. The first phase was completed in 1991, covering 106 ha, and the second phase was completed in 1992, corresponding to 320 ha. The Block 48 irrigation scheme was established for the Integrated Development Project of the Sábié-Médio-Incomáti-Massintonto Region, integrating the Second Organic Unit within the scope of investments in the agricultural sector and under the cooperation between the governments of Mozambique and Italy (Figure 52). Basic technical studies and specialized studies for dimensioning and developing irrigated agriculture in the region were carried out by the company Bonifica. In contrast, the engineering works, land movement, and irrigation construction were carried out by the company Ceta, Obras de Engenharia. Irrigation was designed for two irrigation methods: 106 ha for gravity irrigation and 320 ha for sprinkler irrigation. Although

FIGURE 53. THE PUMPING STATION OF BLOCK 48, WITH THE MAIN WATER CHANNEL DERIVED FROM THE SÁBIÉ RIVER.

the two areas can be considered equipped with infrastructure, only the 106-ha area of irrigation by gravity can currently be considered operational and there is now no plan for the expansion of irrigation. The subsequent irrigation can be considered partially operational since the sprinkler irrigation area has never worked since it was established.

An area irrigated by gravity (first phase) receives water from the Sábié River pumped from the pumping station approximately 900 m from the bridge of the Daimane downstream to Sábié Village. Block 48 (first stage, gravity record) is supplied with water for recording through a bypass along the primary channel that serves Block 50 (channel C1-CI). A derivation work consists of two automatic gates that regulate the flow of water toward Block 50 within the main channel (1,040 L/s) and a second one that regulates the flow of the water distributor (2,62 L/s) for the block supply 48. Whenever the floodgates are closed in the distributor, the water flow in the main channel stops automatically, depending on the increase in the water level in the distributor. The gates are calibrated to allow a flow of 250 L/s, considering that the height above the discharge level is 11.5 cm.

The distributor operates with ten metallic gates that supply ten tertiary channels of the first phase (approximately 5,600 m). Six tertiary channels are located to the left of the distributor and four to the right, and the water height of 11.5 cm allows the watering of the six channels on the left simultaneously. If the water height is lower, the gate may have to be readjusted to ensure the continuous flow of water to the tertiary channels (25 L/s per channel). Water distribution to the tertiary channels is made through duckbill-type structures, whereas, on the side, the spillway is rectangular. The system works effectively when the flow is maximum in the secondary channels. Otherwise, it decreases the tertiary water flow, thus damaging other downstream plots. The six tertiary channels on the left are supplied by a secondary channel 875 m long, while the remaining four tertiary channels are supplied by a secondary channel 675 m long.

It is necessary to manually readjust the water distribution in the tertiary channels in low flows. The first phase was dimensioned, taking into account the occupation of large plots of land by farmers, which partly determined the dimensioning and construction of the network of tertiary irrigation channels, which, despite working, is not suitable for irrigating small plots of land. The system was designed to irrigate ten lots simultaneously, with each lot served by its respective derivation network.

Each lot consists of seven plots or fields, each with an area of 1.6 ha. Each plot is irrigated for 10 hours, considering the flow rate of 25 L/s. For more details on irrigation operations, see the Water Management Manual prepared for the Project's Technical Unit (Smith, 1993). The drainage system consists of ditches that collect water at each plot's end and the tertiary channels' end.

The ditches drain into the main drainage ditch located along the block's northern limit, thus draining the waters in the central depression. The first phase of Block 48 developed 320 ha of land for sprinkler irrigation. A mobile sprinkler irrigation system irrigates 276 ha, and two plots of 23 ha were developed for gravity irrigation. The second phase was built after the first phase and, since the water supply and transport channel are different from those of the first phase, it was considered a separate block.

The second phase irrigation system is supplied with water through a cargo reservoir located in Daimane, on the left bank of the Sábié River, using the main canal, also known as C1-CI, designed to carry 700 L/s of water. From this channel, a branch is in development for Block 26, with a capacity to transport 347 L/s of

water. Block 48 second phase consists of a total of 14 lots irrigated by sprinkler. The size of these lots varyies from 11.39 ha (one lot) to 14.80 ha (one lot), 18.20 ha (five lots), and 22.76 ha (seven lots).

The distribution and arrangement of the hydrants and the remaining mobile components obey the size of the plots, with the larger plots being expected to be served by five side units. The smaller plots are served by only three sub-sides operating simultaneously. See the reference document for more details on the irrigation system and infrastructure layout, design, and dimensioning (Smith, 1993).

Description of other infrastructure associated with the irrigation scheme

During the implementation of the first phase, 3,500 m of type-E4 roads were built. In Block 48, second phase, seven water reservoirs are each equipped with two electric pumps with sufficient pressure to guarantee the operation of the sprinkler irrigation system. Other infrastructure such as homes, workshops, and warehouses is common to the project, not specifically Block 48. The state owns the Block 48 irrigation scheme and associated infrastructure. The beneficiaries are individuals, farmer groups, and farmer associations.

Current situation of the irrigation scheme

In Block 48, gravity irrigation is operational on 106 ha. The area irrigated by the sprinkler system never worked due to technical and operational problems. The pumping station that was supposed to serve the second phase is currently damaged and is not operational.

Main crops

Vegetables (peppers, cabbage, onions, beans, tomatoes) are grown in the dry season using full irrigation and in the rainy season with supplementary irrigation, using the preparation of their nurseries or importing plants for their transplanting. The system of intensive vegetable production for commercial purposes has Maputo City as the leading market. Part of the irrigated land (about 50%) is occupied by the family sector, whose main characteristic is the production of food crops for self-consumption, occupying areas ranging from 0.1 to 0.2 ha only. The crops include, in addition to maize, tomatoes, beans, and pumpkin.

Technical opinion

The potential is moderate to high for irrigation development in the area. However, it is necessary to pay more attention to the organizational and management component of irrigation users in Block 48. As in the previous cases, the lack of basic management principles regarding production systems, lack of access to markets, compatibility of crop calendars, product diversification, and minor specialization of farmers and their associations contribute to the poor or low performance of irrigation systems.

The viability of Block 48 is highly dependent on the completion of the work on the Corumana Dam, the construction of protection dikes, the construction of the bridge, and the repair of access roads. It is also pertinent to carry out minor repair work and maintenance of the irrigation infrastructure, such as

repairing the cracks in the channels, resizing the channels on land, repairing the power dissipation box from the station to the main channel, earth moving, and leveling of some installations.

5.4.5 Irrigation scheme of Block 5 (Bloco 5)

River basin: Incomati River Basin (Sábiè River Sub-basin in Incomati River Basin).
Area: project area: 596 ha; built area: 596 ha; equipped for gravity irrigation: 466 ha; equipped for sprinkler irrigation: 130 ha; operational area: 0 ha.

Brief description of the region

A dry semi-arid climate dominates the area of the Block 5 irrigation scheme. The average annual precipitation is 554 mm. December receives the maximum rainfall. The average annual evapotranspiration is 1,377 mm, with average monthly ETP values consistently higher than the average monthly precipitation. The lack of moisture availability for plant growth is compensated by supplementary irrigation in the rainy season. Block 5 is dominated by the floodplain of the Sábié River, which is characterized by recent deposits with very sharp stratification and variable granulometric composition and predominating medium-coarse sediments. The areas closest to the riverbed, lower terraces, and natural dike have mostly sandy deposits. The upper terraces have almost flat relief, the sediments are intermediate, and the soils have loam to clay-loam textures.

Description of the irrigation scheme

The Block 5 irrigation scheme was designed as a part of the First Organic Unit of the Integrated Development Project of the Sábié-Médio, Incomati-Massintonto Region, in the late 1980s. Block 5 was established to irrigate 466 ha of land using gravity irrigation and about 130 ha of land using sprinkler irrigation. The source of irrigation water is the Daimane sub-main reservoir. A total of 596 ha were equipped with irrigation and 466 ha were served by gravity irrigation until the 1990s. The irrigation system has been inoperative for two years since the floods of 2000.

The gravity irrigation system consists of coated water distribution channels through furrows. The conventional sprinkler irrigation system consists of buried piping and installed water outlets. The executive project document gives the layout of the channels and respective schemes. Block 5 is served by approximately 3,220 m of the main channel, 10,990 m of secondary channels, and 40,000 m of tertiary channels. The sprinkler irrigated area is divided into two parts. The total land area of 91.3 ha is separated by the main channel (34 ha, 30 plots) and the right side by 58 ha (about 50 plots). The plots occupy an average of 1.2 ha, although some differences might occur due to the topography.

Water is distributed through three electric pumps. An electric pump carries water from the water reservoir to the plots on the left bank of the channel, while two electric pumps serve the plots on the right bank. Water distribution for the second sprinkler system serving approximately 38 ha of land allows water through the main channel to fill the reservoir with a flow rate of 35 L/s for 24 hours a day, considering that the helpful volume (conservation) reservoir contains 1,183 m^3. The maximum flow is 47 L/s for 16

hours. The water is pumped from the reservoir by an electric pump (2.5 atmospheric pressure) directly to the sprinkler system. The area served by gravity irrigation was dimensioned to irrigate close to 38 lots continuously (out of a total of 46), with each one (areas from 10 to 14 ha) served by its tertiary channel system (water derivation consists of the structure's duckbill in the main section of the box and 25 L/s discharge modules).

Depending on the size and topography of the lot's land, the water flow can serve three to four channels. The system was designed to accommodate the rotation of the water supply between different land lots. Each plot is irrigated for 10 hours, corresponding to 2 ha, and the gravity irrigation system is expected to work 10 to 12 hours a day. The system was designed to irrigate each plot every 7 days (7 days are required to irrigate the 14-ha area of each plot). However, the interval can be reprogrammed according to the water needs and considering each ground's characteristics. The drainage system consists of secondary ditches arranged at the end of each irrigation unit, which drain into the main ditch, whose water drains toward the central part of Block 5.

Description of other infrastructure associated with the irrigation scheme

There are approximately 8 km of E3-type roads (6 m wide) and about 50 km of E4-type roads (4 m wide), which allow access to production units and the circulation of irrigation infrastructure maintenance teams. Roads during the rainy season are challenging to drive and require permanent maintenance. One of the main problems at the moment is the access to the production area or irrigated areas located in the Sábié region, which has to do with the removal of the mobile bridge that allowed the traffic between the villages of Moamba and Sábié.

The Corumana Dam is still to be concluded, particularly regarding the installation of the gates, thus limiting the operation and development of irrigation due to uncontrollable discharges in critical periods, which increase the risk of flooding and flooding of irrigated lands. There are no protection dikes. Marketing is done by the farmers, who prefer to market their products in the most critical markets in Maputo City. Rural markets along the road and villages are where some quantities of agricultural products are sold. The irrigated area currently benefits from electricity.

The state owns this irrigation scheme (FDHA), having two farmer associations as beneficiaries, namely, the family and the private sector. The irrigation system is managed collectively with responsibilities attributed to all parties, and the FDHA is responsible for pumping and cleaning the primary and secondary channels. The farmers are responsible for cleaning and maintaining the tertiary channel network. Irrigation users pay for some of the expenses related to the fees charged.

Current situation of irrigation

The irrigation system in Block 5, constituted by the gravity and sprinkler subsystems, is currently paralyzed. The irrigation channels, drainage ditches, and irrigable arable areas are currently invaded by vegetation and partially abandoned. It was possible to observe that the main irrigation channel has cracks in some sections and is silted. Several of the siphons at their junctions with the main channel are damaged. The main drainage ditch has a gap at the intersection with the secondary channel (D1). The suction piping shows severe corrosion at the pumping station, while the catchment basin and reservoir are silted and need cleaning. It is assumed that the entire network of secondary and tertiary irrigation channels and the network of drainage ditches require maintenance and cleaning.

Main crops

The primary agricultural production system is the intensive and commercial production of vegetables, associated with the semi-intensive production of vegetables by the family sector. The main vegetables are tomatoes, peppers, cabbage, beans, onions, and potatoes, while maize is the dominant cereal. There are differences between the two production systems concerning inputs and water management. More details regarding the production of vegetables can be consulted in the descriptive profiles of the previous records for Moamba and Sábié Administrative Posts.

Technical opinion

The infrastructure and equipment can recover since the effort can be concentrated on maintenance. There is a need for greater accountability of farmer associations regarding farmers' organizations since their level of knowledge needs to be updated to manage micro-agricultural companies and markets. It is essential to provide and train farmers with principles and standards for the functioning of associations to enhance their performance in individual and collective terms, looking for alternatives in diversification and specialization. The region, in agro-ecological terms, is favorable to intensive agricultural production using both supplementary and full irrigation.

Government institutions must find mechanisms to increase agricultural production through market protection schemes and more favorable and less penalizing rates for access to inputs, fuels, and lubricants. The possibilities and advantages of entering into contracts for production placement are the issues that associations will have to resolve or contribute to their solution. The difficulties in transporting and selling agricultural production and even competition from imported products immediately justify the installation of agro-industries for the processing of vegetables and their conservation through cold stores.

Existence of studies, maps, and executive projects

- Bonifica. 1991. Relatório Técnico – Projecto Executivo, Bloco 48. Projecto de Desenvolvimento Integrado da Área do Sábié-Médio Incomáti-Massintonto, Primeira Unidade Orgânica. FDHA.
- INIA. 1987. Sumário do Potencial Agrícola das Províncias de Maputo e Gaza. Nota Técnica Nº 26. Série Terra e Água. INIA, Maputo.
- INIA. 1990. Estudo Pedo-Hidrológico do Bloco 48 – Fazenda Piloto. INIA, Maputo.
- Smith, D. 1993. Water Management Guidelines – PUO Water Management Authority. FDHA.

Irrigation Scheme - Jacinto Manuel Chibure

River basin: Sábié.
Area: equipped with irrigation: 60-70 ha; operating area: 10-15 ha.

Brief description of the region

This area is classified as dry semi-arid, with an average annual rainfall of about 550 mm and annual reference evapotranspiration of about 1,400 mm. From December to March, usually the rainy season, the reference evapotranspiration is higher than the precipitation values for the same months. One of the main characteristics of the area regarding the pattern of the growth period is the possibility that, in 70% of the years, there will be two to three growth periods from November to April, which demonstrates the significant vulnerability of the region to the failure of

FIGURE 54. THE PUMPING STATION OF A PRIVATE FARMER ON THE SÁBIÉ RIVER, THE PRIMARY SOURCE OF WATER.

crops and their significant dependence on irrigation to guarantee good agricultural production. The irrigation or irrigated area is located on the alluvial terraces and floodplain of the Sábié River (Figure 53).

Description of the irrigation scheme

Farmers established this irrigation scheme in 1968. Under this scheme, fields are irrigated by gravity sprinkler irrigation, depending on crop type. The farmers own about 200 ha, although they irrigate 15 ha per crop season. Irrigation water is pumped from the Sábié River using a diesel motor pump. The number of motor pumps is large despite some being damaged, with five ranging from two cylinders (Ruston brand) to three cylinders (Lister brand) and four cylinders (two IFA and Perkins brands), all with high pressure. The water is transported by piping to the fields, and distribution and irrigation are done through hydrants. The area is irrigated by gravity using the furrow irrigation method. Phytosanitary treatments are carried out using large tanks (200, 300, and 400 L) prepared by mechanical traction.

Description of other infrastructure associated with irrigation

Some of the buildings, mainly the warehouses, are partially destroyed due to the floods of 2000. The agricultural products are commercialized in Maputo City. Maize is produced to manufacture animal feed and is sold in factories such as Bonsuíno. Cotton has been produced since 1973, and the production is sold to IAM, while vegetables are sold in different markets in Maputo City. The irrigation scheme is operational and carefully managed. Still, the farmers face financial difficulties in supporting operating costs and maintenance. Maize, cotton, vegetables (tomato, cabbage, pepper, cucumber, garlic, onion, carrots, lettuce, eggplant, etc.) are grown.

Technical opinion

The farmers can make better use of the irrigation scheme area. The current limitations to the better performance of production systems are related to market opportunities and input costs, often beyond farmers' means. The profit margins are insignificant, not allowing farmers to fulfill their financial obligations. The farmers, in particular, should be linked to the feed industry and institutions to promote cotton cultivation. This could establish more favorable financial conditions based on production contracts.

Existence of maps and executive projects

- Bonifica, SpA. 1991. Estudo Pedológico. Primeira Unidade Orgânica. Projecto de Desenvolvimento Integrado da Área do Sábié-Médio Incomáti-Massintonto. FDHA, Maputo.
- INIA. 1987. Sumário do Potencial Agrícola das Províncias de Maputo e Gaza. Nota Técnica Nº 26. Série Terra e Água. INIA, Maputo.

TABLE 18. SUMMARY OF PROJECTED, EQUIPPED, AND OPERATIONAL IRRIGATED LAND IN MOAMBA DISTRICT.

Moamba District	Projected	Equipped infrastructure	Operational
Class A (<50 ha)	1,800.00	1,248.50	434.5
Block I (Bloco I)	434.5	350	0
Block II (Bloco II)	350	208	96
Block 48 (Bloco 48)	426	426	106
Block 5 (Block 5)	596	596	0
Jacinto M. Chibure	70	60	15
Total for Moamba	3,676.50	2,888.50	651.5

IRRIGATED LAND (HA)
MOAMBA DISCTRICT, MAPUTO PROVINCE

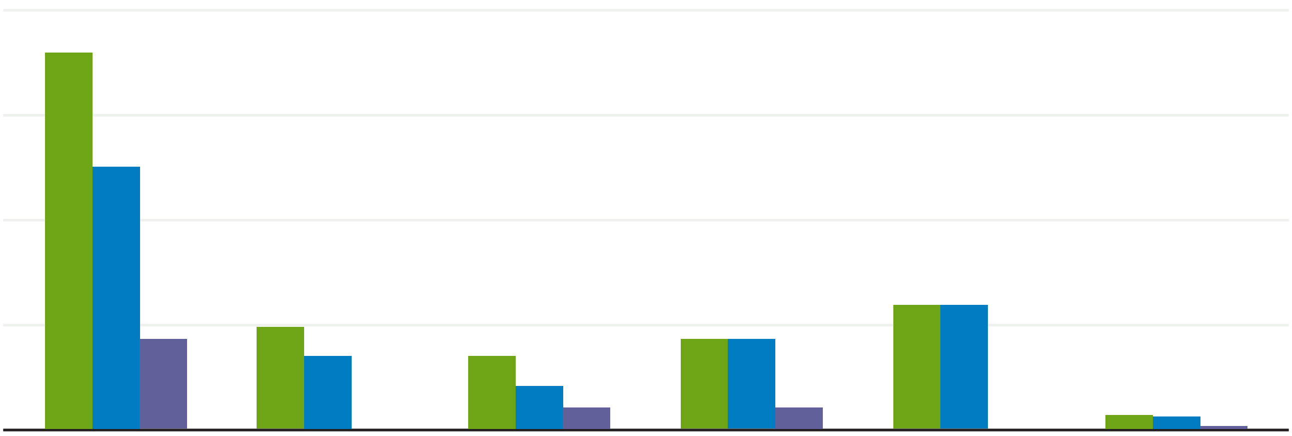


FIGURE 55. SUMMARY OF PROJECTED, EQUIPPED, AND OPERATIONAL IRRIGATED LAND IN MOAMBA DISTRICT

PROJECTED INFRASTRUCTURED OPERATIONAL

5.5 Nicoadala District, Zambézia Province

Nicoadala District is in the southeast of Zambezia Province. The climate is Tropical Rainy Savannah - AW (Köppen classification), with two distinct seasons: the rainy and dry seasons. The average annual rainfall is 1,428 mm in the coastal strip compared with the average annual evapotranspiration of 1,477 mm. The most rainfall falls from November to April, varying in quantity and distribution, both during the year and from year to year. The district is divided into two distinct units: (i) sedimentary basin comprising the recent Quaternary sediments constituted by coastal dunes associated with hydromorphic sands, fluvial-marine sediments, and river alluvium deposits that constitute tertiary sediments; and (ii) further north (inland), the district has sloping relief derived from the Pre-Cambrian Metamorphic and Eruptive Rocks, also known as "Mozambique Belt Gneiss-granitic Complex." In the latter, soils of varying texture and depth predominate.

5.5.1 Irrigation systems of Class A

River basin: Zambezi/Licuari rivers.
Area: equipped: 13.5 ha, and currently operational (scattered private production units of 0.25-5.0 ha, see Annex II); 8.5 ha with vegetable production only in the new season, paddy rice and maize in the hot and rainy season, most of them with an irrigable area of less than 5 ha.

Brief description of the region

The various agricultural production units under private exploitation are located along the Licuari River and its abandoned riverbeds, namely, Peti, Itione, Bati, and Teque-Teque lagoon in the district of Nicoadala, covering mainly the communities of Nicodala-Sede and Munhonha. Most of the agricultural units are located in an area characterized by relatively recent Quaternary deposits, partly covered by alluvium deposited by the Licuari River, which are not salty, non-sodium, and non-acid/alkaline soils.

Geomorphologically, the land unit comprising alluvial deposits can be distinguished into two sub-units, corresponding to (i) high terrace and/or natural river levees, with undulating relief, light-textured and stratified soils, with risk of periodic flooding; and (ii) almost flat terraces or settling basins or dry and abandoned riverbeds, with almost flat to flat relief, and medium- to fine-textured soils, with a risk of periodic flooding. Further inland and as it moves away from the alluvial plain of the Licuari River, the landscape is dominated by the sandy plain developed on the recent wind farms, from gently undulating to undulating and sometimes heavily undulating, quite regular to irregular, where the altitude varies from 15 to 25 m from the average sea level. The topsoils are sandy in texture, with sandy-clay-loam to sandy- clay textures in the subsoil. These deposits have mottling that results from the water table fluctuation, which is less than 1 m or tens of meters depending on the location along the slope. As a result of hylomorphism, the aeolian deposits can show colorings that vary from whitish grayish to yellowish. They are neither saline nor sodium, imperfectly drained to excessively well-drained.

According to existing studies, the region is characterized by a Tropical Rainy Savannah climate (Köppen classification). The average annual rainfall (Quelimane and Namacurra) surpasses 1,100 mm, with an irregular distribution. The most significant rainfall falls from November to April of the following year. It should be noted that variation is observed during the same year and from year to year.

Brief description of the irrigated lands

The areas of Empresa Agrícola Jorge A. Valente and Senhor Durão are irrigated lands belonging to the former Blocks I and II of the Empresa Agrícola do Licuari, which in turn integrated abandoned agricultural properties of former private farmers (settlers) as a result of their subsequent installment payment. After national independence, a considerable part of the area came under the management of former national liberation struggle fighters. Another part was distributed to private farmers without exhausting the fund of land belonging to the old company. Some traces of infrastructure show the existence of channels for water distribution for irrigation, with some sections in reinforced concrete channels, and the junction boxes and the platform of the pumping station next to the Teque-Teque lagoon.

The Teque-Teque lagoon is naturally fed by the high flow of the Licuari River, that is, only during the rainy season. It should also be noted that the distribution of the primary network of channels allows coverage of the current areas explored by Empresa Agrícola Jorge A. Valente and the adjacent areas of the family sector that are currently exploited under rainfed conditions, despite their high irrigation potential. The company irrigates only with water that accumulates in one of the abandoned channels of the Licuari River, whose flow is guaranteed by the water level of the Teque-Teque lagoon.

The most common method of irrigation is gravity, either by long furrows (>10 m) or intermediate ones (5 to 10 m) from the secondary network of channels on the land. Agricultural vegetable production (new season) depends on the supplementary rate due to the climatic characteristics of the region. The maintenance of the irrigation infrastructure after the disintegration of the Empresa Agrícola de Licores got little attention, resulting in its degradation and abandonment. The primary water source is the Licuari River, an abandoned river channel, and lagoons fed by the high flows of the river during the rainy season.

Water is usually transported to fields and plots by pumping from mobile diesel or gasoline motor pumps, mostly with small displacement. The leading brands of motor pumps are Lister, Yamaha, and Honda BW20. Galvanized Bauer and PVC tubing (1½ to 2 inches) transports water to the irrigation channel network, most of which is uncoated. Depending on the crops, irrigation is done by furrows (vegetables, legumes, and cereals) and by basins (banana, latch, mangoes, and ornamental plants). Irrigation efficiency, irrigation duration, and irrigation interval are not monitored or do not follow any recommendation; they are dependent only on the knowledge and experience of the irrigators and the water deficiency observed directly. The conservation status of the pumps is not favorable. Almost all of the infrastructure for capturing, conducting, and distributing water at the production unit managed by the Licuari Agricultural Company, particularly Blocks I and II, is inoperative and even partially destroyed, yet it is rehabilitated.

Small vegetable fields use manual irrigation concentrated in the Bati lagoon, belonging to several farmers (Augusto Ofinar Tambo, Alberto Virimio, Daniel Gonçalves, António Camião, Agostinho Ebue, Amélia Francisco, and Lisete Castiano). The water source for irrigation was registered with the following coordinates: Lagoa Bati, 17o38´00.9” S latitude and 36o43´12.8” E longitude.

Description of other infrastructure associated with irrigation

The secondary and tertiary road network is in relatively good condition, benefiting from some maintenance, although circulation is critical on secondary roads during the rainy season. Land preparation and other operations are guaranteed by their tractors (e.g., Jorge A. Valente company) and rented equipment and complemented by irrigation operations, motor pumps, and manual labor (using hoes and shovels). The markets for agricultural products are Licuari (local production), the village of Nicoadala, the markets in the city of Quelimane, the hotel industry, and the local health post (Nicoadala). The land is distributed by private farmers (former employees of the defunct company) and the family sector, thus benefiting agricultural wage workers in the region as labor.

Current irrigation scheme status

The Class A irrigation systems in this district are partially operational. The areas under production are smaller than those that constituted the former Licuari Agricultural Company and those explored by small private producers associated with the company.

Main crops

The main crops in the irrigated areas are vegetables (tomatoes, cabbage, peppers, onions, garlic, and cucumbers) and fruit trees (banana, litchi, papaya, mango, and coconut), ornamental plants, and trees. The seeds are obtained locally through SEMOC, PANNAR, and street vendors. Producers use the preparation and sowing of their nurseries for transplantation, sometimes using phytosanitary treatments and fertilizers. The production of vegetables is not intensive; it is limited only to the new season. The other season (hot and rainy) is reserved for producing paddy rice and maize for self-consumption and selling the surplus. The technical level of farmers concerning their knowledge of agricultural and agronomic practices

and water management seems more limited. Under current conditions, they could produce vegetables and supply the markets in Quelimane City, which practically depends on fresh produce from Angónia (Tete Province).

Technical opinion

The two blocks make up an area suitable for agriculture using irrigation, approximately 50 ha. The area currently irrigated is less than 10 ha, 17-20% of the total area with irrigation infrastructure in reasonable conditions of use, with its current intensity of use being about 50%. Some farmers (agricultural company Jorge A. Valente, properties of Durão and Lucas Miguel) are interested in expanding their current irrigated areas, considering the available area and credit availability. According to current conditions, farmers must be exposed to new challenges and technologies to improve and make irrigated agricultural areas viable, with high potential and potential far from being satisfied.

The farmers will have to have a different attitude when negotiating with the government to support agricultural development, moving from a situation of expectation to a more participatory and collaborative situation, considering their interests. Practically all conditions are in place for greater competition and the importance of irrigation. It is necessary to adapt the current agricultural production systems and technologies available to the management systems of

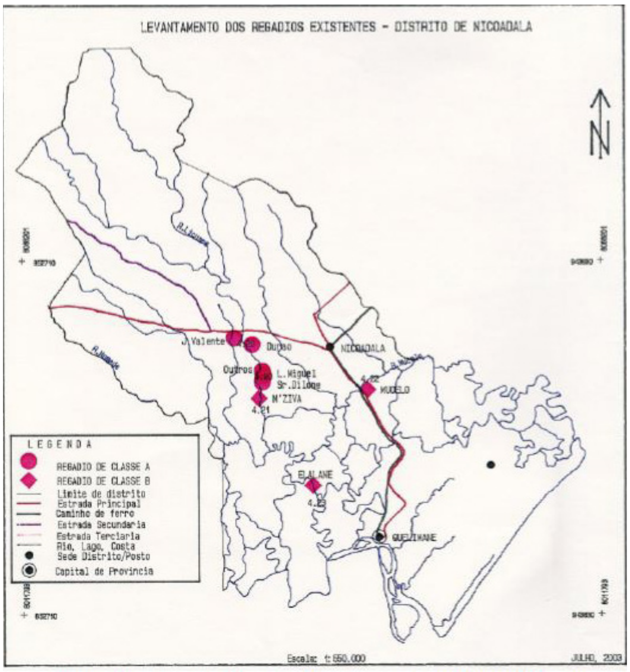


FIGURE 56.SPATIAL DISTRIBUTION OF IRRIGATION SCHEMES OF CLASS A (<50 HA) AND CLASS B (50-500 HA), NICOADALA DISTRICT, ZAMBÉZIA PROVINCE.

farmers, who need a lot of organization and planning to make feasible and enhance intensive agricultural production and the economic sustainability of irrigated agricultural production systems.

The block partially explored by Empresa Agrícola Jorge A. Valente has greater possibilities for resuming activity since only the restoration of the water pumping system next to the Teque-Teque lagoon (a safe source of water for irrigation throughout the year) is imperative, along with cleaning and rehabilitation of the main water conduction channel as well as the junction boxes located along the channel. In another block, only the resizing and installation of the pumping station, piping necessary for the transport of water, and the reopening of the onshore channels for the conduction of water to the different parcels were sufficient because the extent of irrigable land was relatively more minor.

Because of the costs involved in the purchase of new equipment, its maintenance, and operation, it is convenient to resize not only the irrigations established to find a balance between the operating costs and the benefits of the system but also the rehabilitation of current farmers: the current beneficiaries and managers of the irrigation infrastructure. This presupposes creating conditions for their access to credit and markets for agricultural products. The current strategy of organizing farmers into irrigation associations aims to increase farmers' credibility with banks, but the marketing problem remains unsolvable.

It is the prices of agricultural products that, at a particular time of the year, drop to levels that do not cover production costs; it is the lack of information from farmers about the best time, the best way, and the best place to sell their products; in some cases, it is the expense of farmers traveling to cities looking for information on updated prices and forecasting the demand for their products - it is all a chain of problems, for which irrigation cannot be made profitable without their solution. Hence, it is necessary to reflect on the positive impact of, for example, the rehabilitation of some local agro-industries and the implementation of a technological and market information system in the Quelimane City region.

Existence of maps and executive projects

Only the Provincial Directorate of Agriculture and Rural Development - Zambézia Province has information in the technical reports regarding the studies and performance of the former Licuari Agricultural Company (verbal communication with Eng. Brás, Hydraulic Nucleus of Zambézia).

- Gouveia, D.H.G. 1974. Outline map of the soils of Zambézia.
- Other sources of information: José F. Xavier, Silvestre D. Cinco Reis, Madeira S. Mendonça, Augusto
- O. Tambo, Alberto Virimio, Daniel Gonçalves, António Camião, João Guiniala, Agostinho Ebeu, Amélia Francisco, and Lisete Castiano.

5.5.2 M'ziva irrigation scheme (Regadio de M'Ziva) - Class B

River basin: Licuari/Zambezi River.
Area: total irrigated area: 400 ha; equipped area: 400 ha; operational area: 0 ha. About 25 ha of this area are irrigated by a group of motor pumps alternating with the flood points of the Licuari River. The 375 ha were irrigated from two sub-stations, each equipped with groups of motor pumps with a capacity of 500 L/s. The irrigable area was thus subdivided into two blocks: the North Block and the South Block. Additional information from the existing reports shows that irrigation still comprised an area of approximately 100 ha for expansion.

Brief description of the region

The area is on the flat land, with slopes of 0 to 1%, from the upper terrace of the Licuari River, consequently with soils of alluvial origin, deep to intense, clayey texture over clayey to sandy-clay, imperfectly drained, not salty, and no presence of lime or sodium. Fertility is moderately high with good nutrient and water retention capacity; only the pH is slightly low. The water table is 1.0 to 2.5 m deep, and the infiltration speed is from 5 to 10 mm/hour.

The region's climate is characterized by the occurrence of a Rainy Savannah - AW type (Köppen classification). The average annual rainfall for the nearest meteorological station (Quelimane) is 1,428 mm. Its distribution is irregular, with the maximum rainfall falling from November to April. It should be noted that variation is observed during the same year and from year to year. The average annual temperature is 25.6 oC. The maximum extremes occur from December to February, registering 32.9 oC. The highest evapotranspiration is in October and November, 185 mm and 173 mm, respectively.

Description of the irrigation scheme

The M´ziva irrigation scheme was built in the 1970s and later nationalized after national independence, passing to the state company, directed to rice production (Figure 56). According to statements collected in the field, about 160 ha of the total area were to be parceled out in the 1988-89 agricultural season and distributed to the war-displaced families, with each family having about 0.25 ha. The rest of the area was occupied by the local family sector. With the end of the civil war and the return of the displaced to their original regions, that is, in mid-1994, the National Association of Liberation Combatants (ACLLN) exploited a considerable part of the irrigation system. Two years later, this association suffered a disintegration for non-payment of quotas (fees), machinery without technical assistance or accessories, and the most influential members' appropriation of part of the means.

Since then, irrigation has been inoperative. The source of water for irrigation is the Licuari River. It should be noted that, given the region's high rainfall rate, irrigation was used only from January to April when

the river had a greater flow. Each pumping station (two in total) was equipped with a Niagara motor pump with a suction capacity of 500 L/s. The water was subsequently conducted through the main lined channels and later through secondary channels on land.

It should be noted that the junction boxes consisted of a concrete structure equipped with gates that allowed water control. Each station supplied about half of the total area. The irrigation method used was gravity and flooding in the rice crop. In the second season, particularly in vegetables, irrigation was done only by gravity through furrows.

The irrigation also included a machinery park, warehouses, and other facilities such as offices and

(a) Coated channel for water distribution

(b) Pumping station equipment

FIGURE 57. M'ZIVA IRRIGATION SCHEME, NICOADALA DISTRICT.

houses for technical staff (in degradation). The access roads are in poor condition and are not passable in the rainy season.

Current irrigation situation

Currently, the M´ziva irrigation system is not operational. From the pumping stations, only the pumps' installed platforms were left, some sections of the main lined channels are severely damaged, and the junction boxes are broken and without the respective gates. Some sections of the protection dikes and the secondary network of channels on land suffered leaks from a few meters to tens of meters in length. Onshore channels and drainage ditches are generally obstructed (by termite mounds and shrubs) and covered with vegetation (grass, shrubs). The irrigation scheme belonged to Monteiro and Giro Company, having been nationalized and passed to the state company to produce rice. Currently, the family sector and the National Association of Liberation Combatants exploit it on a rainfed basis.

Main crops

Irrigation was mainly designed for rice production. Vegetables and sweet potatoes were alternative crops produced in the cold season and irrigated by gravity/furrows by an alternative and mobile group of pumps covering a relatively small portion of the land. Rice was exported to South Africa, Malawi, and Zimbabwe, and sweet potatoes and vegetables were sold in the local markets of Quelimane City and to the hotel industry, health centers, schools, and the military.

Technical opinion

The irrigation has been paralyzed for a long time and the pumps were removed from the pumping stations. The main coated channels have some sections wholly destroyed, sometimes with (possible) cracks to be rehabilitated. The protection dikes and the secondary network of channels on land have suffered considerable leaks and drainage ditches are obstructed. Therefore, before any rehabilitation, it would be essential to assess the current physical conditions. The pumping station will need to be re-established. It would also be necessary to resize it according to the irrigated area and the type of users of the system, the type of crop to be exploited, and the actual requirements of the national and international markets.

Although it can be considered flat, the irrigated land is characterized by micro-topography irregularities, making the current gravity system operate with low distribution efficiency. To make the ongoing rehabilitation feasible, conducting a topographic survey to level the land would be necessary. Likewise, an approach is needed on the availability of water for irrigation because the river was without the necessary flow for any irrigation during the fieldwork period. However, in the region, many abandoned riverbeds of the Licuari River naturally conserve water accumulated in the rainy season, which can be boosted (their water storage capacity increased). As a result, these small functional irrigation schemes can be designed and projected, along with being efficient and easy to manage.

In fact, around these abandoned riverbeds, the family sector has been producing vegetables using manual irrigation. It should be recalled that the two pumping stations were only for taking advantage of the "peak" flows of the Licuari River for supplementary irrigation in the rice crop. The recovery decision should consider the current irrigation users and how they would be organized to manage an irrigation system collectively. The system's high operating and maintenance costs should not be ignored since the family sector is the beneficiary. Here, the long-term sustainability of the system is questioned. Therefore, it is crucial to ensure the existence of organized users capable of making the investment possible. The plan for the family sector using these areas under rainfed conditions is a viable alternative.

Existence of maps, executive projects, and other relevant studies

Most documents are available from the Provincial Directorate of Agriculture and Rural Development - Zambézia, the hydraulics sector.

- Gomes, F., Mihajlovich, D. 1986. Irrigated areas, Inventory and future possibilities. FAO/ MOZ/81/015, INIA, Department of Land and Water.
- Scholten, J.H.M. 1987. Soil Study at the Level of Recognition of the Quelimane Coastal Range. Communication Nº. 55. Earth and Water Series. INIA, Maputo.
- Serno, G. Brito, R. 1988. Technical visit to Zambézia. Technical Note No. 43. Land and Water Series. INIA, Maputo.
- Feasibility Study for the Provisional Rehabilitation of Three Small Scale Irrigation Schemes in Baixa, Zambézia (An emergency intervention in the irrigated areas of Mucelo, M´ziva, and Elalane). 1998.

5.5.3 Mucelo irrigation scheme (Regadio de Mucelo)

River basin: Mucelo/Zambezi.
Area: The total irrigated area is 250 ha. Equipped area: 250 ha; operating area: 0 ha. The rehabilitation work is in progress, including replacing the electricity transformer station and electric pump and cleaning and reopening the primary and secondary channels and the drainage ditches.

Brief description of the region

The Mucelo irrigation scheme is in the floodplain of the Mucelo River, characterized by a flat to an almost flat area, being more of a sediment deposition area of the river floods (Figure 57). Extensive grasslands of dense grassy strata dominate the plain. Geologically, it consists of alluvial formations and clays from the recent Quaternary. The soils are of fluvial origin, recent, thick, heavy, and imperfectly drained. Locally, the soils show contraction and expansion properties, in addition to cracking up to 100 cm depth, considered vertic properties. The hydraulic conductivity/infiltration of these soils is low. The salinity of the topsoil is generally low. However, the subsoil is slightly saline, increasing with soil depth and proximity to the water table level. The salinity increases even though the water table is quite salty. The topsoil is acidic (pH 4.9- 5.6) at 0-10-cm depth and slightly acidic to neutral at a depth of 20-30 cm (pH is 6.0).

FIGURE 58. MAIN WATER DISTRIBUTION CHANNEL AND THE RESPECTIVE ELECTRICITY TP SUPPLY TO THE PUMPING STATION OF MUCELO SCHEME.

Fertility is moderately high, with good nutrient and water retention capacity, but, because of acidity, the soils may show deficiencies in phosphorus content. There is evidence that soil sodicity may be more limiting than salinity. The topsoil shows a high percentage of exchangeable sodium. The robust structure, heavy texture, and subsoil remain saturated with water for a considerable part of the year, thus limiting biological activity and resulting in less nutrient availability, increased acidity, and salinity for the plants.

The climate is characterized by the occurrence of a Rainy Savannah - AW type (Köppen classification). The average annual precipitation for the nearest meteorological station (Quelimane) is 1,428 mm. Its distribution is irregular, with the most falling from October to April. The average annual temperature is 25.6 oC. The maximum extremes occur from December to February, registering values of 32.9 oC. The highest average evapotranspiration occurs in October and November and is on the order of 185 mm and 173 mm, respectively.

Description of the irrigation scheme

The Mucelo irrigation scheme covers 250 ha spread over five blocks, each block with 50 ha (1,000 m x 500 m). This irrigation scheme is seen as a development pole and is highly strategic for the food security of Quelimane City, as it serves about 500 families, each with a physical area of 0.5 ha. The entire irrigation system is served by a central channel from which the secondary channels derive, supplying water to approximately 25 ha on each side of the block. The primary, secondary, and tertiary networks of channels are earthen. Only the junction boxes are made of reinforced concrete. It should be noted that some needed rehabilitation and others needed complete replacement during the inventory. This irrigation was built in the 1960s by the Instituto de Cereais de Moçambique (ICM).

The ICM carried out irrigation management and the farmers covered their production costs with part of their harvest. The ICM also had equipment for husking the rice produced in this production unit. From 1986 to 1990, irrigation was managed by the Green Zones Office - Quelimane. Since 1990, the unit has been operated by the Farmers' Association 4 de Outubro. The irrigation system stopped operating in 1999 mainly because of constant power cuts, breakdowns of the electric pump, and the lack of payments for electricity to EDM. The irrigation method practiced in this production unit was gravity/flooding in the rice crops, complemented by the marachas system. Under normal operating conditions, water was pumped through a 37-kW (about 50 HP) electric pump, a 300-mm-diameter suction, and an approximate flow of 210-230 L/s along the Mucelo River, transported through the main channel and distributed in the blocks through the secondary network of channels. The water is conducted through the tertiary network of channels to the block irrigation plots. The irrigation also includes drainage ditches that drain excess water back to the Mucelo River.

The volume of water pumped was well beyond the real needs of the area, which is at least 1.5 L/s/ha. This volume is satisfied only when the suction is 400 L/s, while the old electric pump had a suction capacity of 210-230 L/s. This is the volume that is seen as being very low for the real needs of the irrigation. The irrigation is done by gravity with flood basins delimited by a system of marachas. However, it should be noted that irrigation here has always been considered supplementary, with irrigation in the most critical months when water stress is notorious or when dry periods occur during the regular growing season of

the crops in the rainy season. Despite the rainy season starting in October, there are rare occasions when farmers risk sowing, preferring to wait until November to sow with less risk. However, in December, the growth of crops begins (in a rainfed regime), coinciding with the cycle of rice cultivation usually observed by farmers.

Description of other infrastructure associated with irrigation

The irrigation is served by the paved road that connects Cidade de Quelimane and Nicoadala. Within the production unit, this is served by bits in good condition and passable. There is also a workshop park, warehouses, and other facilities, such as offices for technical personnel. In addition are tractors belonging to some members of the association used for hire to members of the Farmers' Association 4 de Outubro.

The irrigation system is being rehabilitated by replacing the PT, installing the electric pump with a slightly larger capacity, and cleaning the main channel. There was still a lack of cleaning of the secondary and tertiary channel networks and the drainage ditches, and the repair/replacement of the water junction boxes. Rehabilitation is carried out by the state in partnership with FAO within the scope of South-South cooperation. Irrigation was expected to return to operation in the 2002-03 agricultural season. This did not happen since the PT and the electric pump were not operative. Irrigation is owned by the state and currently benefits members. The state does management in partnership with the association.

Main crops

Rice is the only crop grown in this production unit. Sometimes sweet potatoes are grown in the cold season using residual soil moisture. The ICM absorbed part of the rice produced and the remaining was processed and exported to South Africa and other countries.

Technical opinion

Users have extensive experience in producing rainwater rice, so we do not know to what extent they would have greater or lesser difficulties in producing the same crop under irrigation conditions. Irrigation therefore takes on additional characteristics during the occurrence of dry periods throughout the crop growth cycle. since, at that time, irrigation was used from the pumping station installed on the Mucelo River. This period of the year coincides with a higher salinity of the river water, which is lower and allows the tidal waters to advance through the river, as the river level is also relatively low. This has only increased since January, with the intensification of rains in the catchment basin. From January, water quality improves due to the availability of rainwater, thus diminishing the need for irrigation water from the Mucelo River. Therefore, one of the essential assumptions in managing irrigation water is monitoring water quality according to the different tides to avoid irrigation periods coinciding with a higher concentration of salts in the river water.

The drainage system should also be updated to avoid the rise of salts by capillarity, resulting in secondary soil salinization. Farmers prefer sowing in November, crop growth begins in December, and farmers usually observe the rice cultivation cycle. Precipitation is adequate to produce a rice crop. However, much

rainwater is lost without any beneficial use. It is necessary to improve the water conservation system by raising the height of the marachas that limit the plots of each family, farmer, or sub-plot. It is essential to replace the pumping station, resize the main channel and the secondary and tertiary networks of onshore channels, and repair/replace the junction boxes and the drainage system.

The saline water intrusion can be controlled either through the floodgate control system during high tides or through the construction of a weir to prevent water flow from the tides into the river. This work was also done and installed on the Umbelúzi River. Because of the water salinity problem, it would be opportune to install an electronic conductive meter in the pumping system to monitor the concentration of salts in the irrigation water, thus avoiding the pumping of poor-quality water. However, this system's high operating and maintenance costs should not be ignored, considering that the family sector is the beneficiary. Here, the long-term sustainability of the system is questioned. What guarantees that the Farmers' Association can maintain the system even after losing support from DPADR/FAO? Therefore, it is crucial to ensure that the users are organized and capable of making the investment possible. The water quality can be guaranteed only for the second harvest for irrigation, and this quality depends on the assumptions discussed and presented above.

Existence of maps, executive projects, and other relevant studies

Some documents and maps show the exact location of the different irrigation infrastructure associated with irrigation. Further consultation can be made with the Provincial Directorate of Agriculture and Rural Development - Zambézia.

1. Marques, M.R. et al. 2002. Sampling and Assessment of Current Soil Toxicity. The Case of the Mucelo Irrigation, District of Nicoadala. INIA, Maputo.
2. Gomes, F., Mihajlovich, D. 1986. Irrigated Areas, Inventory, and Future Possibilities. FAO/MOZ/81/015, INIA, Department of Land and Water.

3. Scholten, J.H.M. 1987. Soil Study at the Level of Recognition of the Quelimane Coastal Range. Communication Nº. 55. Earth and Water Series. INIA, Maputo.
4. Serno, G., Brito, R. 1988. Technical visit to Zambézia. Report No. 43. Land and Water Series. INIA.
5. Feasibility Study for the Provisional Rehabilitation of Three Small Scale Irrigation Schemes in Baixa, Zambézia (An emergency intervention in the irrigated areas of Mucelo, M´ziva, and Elalane). 1998.

5.5.4 Elalane irrigation scheme (Regadio de Elalane)

River basin: Zambezi/Mucelo River.
Area: Total irrigated area: 200 ha; equipped area: 200 ha; operating area: 0 ha.

Brief description of the region

The area occurs in the flat zone, with 0 to 1% slopes. In the vast fluvial-marine plain where deep, clayey soils occur (55% to 85% clay fraction), imperfect drainage, inadequate bed expansion, and contraction characteristics resulting in the topsoil cracking are slightly saline, mainly underground. These are soils with a very high potential for rice production; however, they are tough to work when dry and moist. Soil fertility is moderately high, with good nutrient and water retention capacity and slightly low pH.

The average annual rainfall for the nearest meteorological station (Quelimane) is 1,428 mm. Its distribution is irregular, with the most rain falling from November to April. The annual average temperature is 25.6 oC. The maximum extremes occur from December to February, registering values of 32.9 oC. The average evapotranspiration occurred in October and November, 185 mm and 173 mm, respectively.

Description of the irrigation scheme

The Elalane irrigation scheme consists of four blocks, each with an area of 50 ha. An independent pumping station serves each block. In each block, the irrigation system installed in addition to the pumping station is equipped with a motor pump. It comprises a central channel partially lined (only next to the pumping station and in the junction boxes of the secondary channels), secondary and tertiary channels (all on land), and drainage ditches. A system of dikes protects the irrigation. Monteiro and Giro Company built the irrigation scheme in the 1970s with the primary objective of producing rice.

Irrigation occurs only in the months when the water flows most in the river channel: February, March, and April, when the rice fields' water depth is lower than the recommended level. The quality of the irrigation water is acceptable only during this period. The water is highly salty for the rest of the year and is not recommended for irrigation. This irrigation system, after national independence, started to be managed by the Office of the Green Zones of Quelimane under the technical care of the Hydraulic Nucleus of Zambézia. After 1994, the Women Farmers' Association of Elalane (AMCELA) was founded, benefiting from a donation of a tractor and its agricultural implements. Irrigation stopped operating in 1999 because of the poor management of resources (tractors, motor pumps, and other associated infrastructure), the weak water charging system, and the quotas of the constituent members. The same association currently exploits irrigated areas, but under rainfed conditions.

Description of other infrastructure associated with irrigation

The irrigation is served by a dirt road in a poor state of conservation, not allowing the passage of any vehicle without traction, particularly in the rainy season. The warehouses and the implement park were built at the time of the association, so they are still in good condition. The irrigation also includes protection dikes in need of rehabilitation. Rice is cropped in a single season (one harvest). Part of the rice produced was absorbed by the Monteiro and Giro Company and another part by the subsistence producers. Currently, production is carried out only for subsistence and sale of the surplus.

Technical opinion

Farmers are experienced in rice production under rainfed conditions or flood basins (water abstraction). Because of its geographic location, this irrigation scheme is more exposed to salinization risk than Mucelo. Given the sea's proximity, the river's level fluctuates depending on the height of the tide, and

TABLE 19. SUMMARY OF PROJECTED, EQUIPPED, AND OPERATIONAL INFRASTRUCTURE IN NICOADALA DISTRICT.

Nicoadala District	Projected	Infrastructured	Operational
Class A (<50 ha)	-	13.5	8.5
M'ziva	400.0	400.0	0.0
Mucelo	250.0	250.0	0.0
Elalane	200.0	200.0	0.0
Total for Nicoadala	850.0	863.5	8.5

saline water intrusion occurs, reaching critical levels that can be prohibitive for irrigation. Given the current state of irrigation deterioration, alternatives for its recovery are minimal. The repair of flood protection dikes and the rehabilitation of irrigation infrastructure destroyed over time require high costs. The recovery decision

should consider the current irrigation users and how they would be organized to manage irrigation collectively. The family sector's plan for using these areas under rainfed conditions is currently a viable alternative. The irrigation channels and drainage ditches, including the pumping station, could be scaled according to the irrigable area and the type of users who will manage the system day by day.

Taking advantage of the old channels' landfills and other irrigation infrastructure would be necessary. A solution for the irrigation operation would be to repair, clean, and deepen the drainage ditches and irrigation channels, repair leaks in the earthen channels, and install the floodgates of the main channel sockets for better control of the irrigation water against tides. The strategy consists of sensitizing the beneficiaries, providing them with repair materials and some repair tools (e.g., hand carts, picks, shovels, level, etc.), and ensuring technical supervision during rehabilitation. Thus, more information could be collected to allow the system to be resized. Table 19 summarizes the conditions in Nicoadala District.

Existence of maps, executive projects, and other relevant studies

Documents and maps show the exact location of the different irrigation infrastructure and that associated with irrigation. Consultation can be made with the Provincial Directorate of Agriculture and Rural Development - Zambézia Province.

- Gomes, F., Mihajlovich, D. 1986. Irrigated Areas, Inventory, and Future Possibilities. FAO/MOZ/81/015, INIA, Department of Land and Water.
- Scholten, J.H.M. 1987. Soil Study at the Level of Recognition of the Quelimane Coastal Range. Communication Nº 55. Terra e Água series. INIA, Maputo.
- Serno, G., Brito, R. 1988. Technical visit to Zambézia. Report No. 43. Land and Water Series. INIA, Maputo.
- Feasibility Study for the Provisional Rehabilitation of Three Small Scale Irrigation Schemes in Baixa, Zambézia (An emergency intervention in the irrigated areas of Mucelo, M´ziva, and Elalane). 1998.

5.6 Conclusions and Recommendations

- Improving irrigation and drainage infrastructure should be the top priority of the government's development strategy. Despite abundant water resources, their current use for agricultural production is still limited.
- This literature review was based on previous studies conducted by the Ministry of Agriculture in 2003. Some changes might have taken place in past years due to catastrophic events such as cyclone IDAI in central Mozambique or Kenned in northern Mozambique. A separate study is needed to assess the updated irrigation and drainage infrastructure status.
- Management of irrigation and drainage infrastructure by water user associations is a challenge for the sustainable use of infrastructure. Developing necessary competence through training is of paramount importance for enhancing agricultural productivity.
- This review of irrigated land, specifically for the districts selected (Moamba in Maputo Province and Nicoadala in Zambézia Province), must be complemented by field visits to update the current status of the referenced infrastructure and irrigated lands.

5.7 Country Summary and Recommendations

Agriculture plays a vital role in Mozambique's economy, contributing 23% to the GDP and employment of the population living in rural areas. Smallholder farmers cultivate 95% of the agricultural land and 70% of the population depends on subsistence farming. The country has 0.565 million ha of arable land with ample renewable freshwater resources for irrigation development. However, only 50,000 ha are used because of a lack of water management infrastructure. Most water flows into the Indian Ocean without beneficial use.

The majority of the farmers are carrying out rainfed agriculture. Because of climate change and variability, most farmers are vulnerable to catastrophic events such as drought and floods that significantly affect their livelihood. The government of Mozambique created the National Institute of Irrigation in 2012 as part of the strategy to expand irrigation facilities. Several development programs have been executed to improve irrigation and drainage infrastructure. The irrigation potential in Mozambique is estimated at 3.3 million ha, of which only 50,000 ha are being used. Moreover, 60% of the irrigated land is used for commercial sugarcane production. The major food crops in Mozambique are maize, sorghum, millet, rice, cassava, vegetables, and fruits, and the major cash crops are sesame, cotton, tobacco, pigeon pea tea, sugar, and cashew.

Only 8.8% of the smallholder farmers use any irrigation system. Smallholder farmers generally operate within an irrigation scheme individually or through associations of farmers or cooperatives. The water supply to these irrigation schemes is through small water pumps such as treadle pumps and other manual methods. These irrigation systems generally have low irrigation efficiency. The latest inventory showed 257 irrigated units with a total infrastructure area of 118,000 ha. The country's irrigation schemes with more than 500 ha are 21 units, representing 70% of the total irrigated land. Those of medium dimension (50-500 ha) are 77 units with a total area of 20,000 ha (17% of the total irrigated area). The irrigation schemes with less than 50 ha are 159 units and they cover 6,400 ha (13% of the total irrigated land). About 64% of the available irrigated land is in the southern region, 33% in the central region, and only 3% in the northern region.

The following are the main challenges to the irrigation sector in Mozambique:

- Abandonment of the irrigated production units, which were the properties of the former Portuguese citizens soon after independence, and the lack of skills and financial resources for maintenance of the irrigation infrastructure.
- Migration of the rural population from the vicinity of the production units to cities due to civil war.
- The lack of access to inputs, technical assistance, extension services, and maintenance of the irrigation infrastructure and markets.
- A gradual reduction in the public investment in irrigation infrastructure development, in addition to the increase in production taxes (fuel, energy, inputs, seeds, and agrochemicals).

The following can be recommended to overcome the challenges in the irrigation sector:

- Improving irrigation and drainage infrastructure should be the top priority of the government's development agenda in the agricultural sector. Despite abundant water resources, their current use for agricultural production is limited.
- Management of irrigation and drainage infrastructure by water user associations is a challenge for the sustainable use of infrastructure. Developing necessary competence through training is of paramount importance for enhancing agricultural productivity.
- This report is based on the literature review of previous studies conducted by the Ministry of Agriculture in 2003. Some changes might have taken place in past years due to catastrophic events such as cyclone IDAI in central Mozambique or Kenned in northern Mozambique. A separate study is needed to assess the updated irrigation and drainage infrastructure status.

6 ANNEXES

6.1 Annex I: Liberia Irrigation Infrastructure Profile

SMALLHOLDER AGRICULTURAL PRODUCTIVITY ENHANCEMENT AND COMMERCIALIZATION (SAPEC) PROJECT LIBERIA

LOWLAND DEVELOPMENT UPDATE

JARWODEE SWAMP, Grand Gedeh County

The SAPEC Project rehabilitated a 34-km rural feeder road to access the Jarwodee Swamp. The rehabilitated road connects Gbarzon Jarwodee to Zleh Town and several other towns. Additionally, the project is constructing an irrigation dam with water control structures and developing 75 ha in the lowland environment. The project was expected to be completed in December 2020. However, only 75% is completed.

Outstanding work in lowland development

- Embankment work
- Right intake
- Development of 35 hectares

Zwedru A&B Swamp, Grand Gedeh County

The SAPEC Project is intervening in lowland development: 65% has been developed and the irrigated dam construction is in progress. The contract is expected to develop 20 ha and construct an irrigation dam and diversion boxes. The contract was to be completed in December 2020.

Outstanding activities

- Provision and installation of three new gates
- Preparation of catchment area (1 ha)
- Development of 10 hectares
- Construction of diversion boxes (seven sets)

Zwedru Work and See Swamp, Grand Gedeh County

The Work and See Swamp has a dam that the ASRP constructed. To date, the dam gates are not functioning correctly. No water is found in the catchment area. According to the farmers, the field lacks water. The swamp has irregular plot sizes, with no standard design. The farmers cultivate a total area of 50 ha.

Activities to be considered before intervention

- Provision and installation of three new gates
- Preparation of catchment area (1 ha)
- Development of 75 hectares
- Construction of diversion boxes (35 sets)

TuoJallah Swamp, Grand Gedeh County

The SAPEC Project is intervening in lowland development: 65% has been developed and the irrigated dam construction is ongoing. The contract is expected to develop 50 ha and construct an irrigation dam and diversion boxes. The contract was to be completed in December 2020.

Outstanding activities

- Development of 20 hectares
- Construction of diversion boxes (eight sets)
- Construction of an irrigation dam

Flewroken Swamp, River Gee County

The SAPEC Project is intervening in lowland development: 85% has been developed and the irrigated dam construction is completed. The contract is expected to develop 50 hectares and construct an irrigation dam and diversion boxes. The contract was completed in December 2020.

Outstanding activities

- Development of 15 hectares and construction of diversion boxes (eight sets)

Fish Town Swamp, River Gee County

The SAPEC Project is intervening in lowland development: 60% has been developed and the irrigated dam construction is ongoing. The contract is expected to develop 20 hectares and construct an irrigation dam and diversion boxes. The contract was to be completed in December 2020.

Outstanding activities

- Development of 8 hectares
- Construction of diversion boxes (eight sets)
- Construction of an irrigation dam

Kaweaken Swamp, River Gee County

This swamp has a dam that the ASRP constructed. To date, the dam gates are not functioning correctly. No water is found in the catchment area. According to the farmers, the field lacks water. The swamp has irregular plot sizes. The total area is approximately 30 hectares.

Activities to be considered prior to intervention

- Provision and installation of three new gates
- Preparation of catchment area (1 ha)
- Development of 30 hectares
- Construction of diversion boxes (20 sets)

Philadelphia Swamp, Maryland County

This swamp has a dam that the ASRP constructed. To date, the dam intake gate is damaged. Water in the catchment area is overflowing in many directions. The fields are flooded with water and river sediment. Some of the swamp plots have been washed away by flood. The total area is 35 hectares.

Activities to be considered before intervention

- Provision and installation of intake gate
- Development of 20 hectares
- Construction of diversion boxes (15 sets)
- Construction of an embankment to protect the catchment area
- Construction of an embankment to protect from flood from the river

Pleebo Swamp, Maryland County

This swamp has a dam that the ASRP constructed. To date, the dam intake gate is damaged. Water in the catchment area is low. According to the farmers, the field does not have adequate water. The swamp has not been developed. The total area is approximately 15 hectares.

Activities to be considered before intervention

- Provision and installation of intake gate
- Development of 15 hectares
- Construction of diversion boxes (five sets)

Swamps with farmers' intervention but that lack a dam, regular plot sizes, and irrigation schemes

Name of swamp	No. of hectares	Location
Zleh Town	75	Zleh Town, Grand Gedeh
Jarkaken	25	River Gee

6.2 Annex II: Irrigated Units (Class A: <50 ha), Moamba District, Mozambique

Location: Administrative Posts: Moamba-Sede, Ressano Garcia, and Sábié, Moamba District, Maputo Province

Name	Administr. Posts/ Locality/ Community	River Basin	Area (ha) Infrastructure	Operational	Remarks
Paulo Ubisse	Ressano Garcia/ Chanculo 25°32´33,9´´ S 32°05´09.3´´ E	Incomáti	25	25	The expansion of the current irrigation area to another 60 ha is planned; there are two more coordinate readings for two more pumping stations. Gravity/furrow irrigation; water quality limits the use of drip irrigation.
Paulino Julai	Ressano Garcia/ Condene	Incomáti		<5	Irrigation has been abandoned since the floods of 2000; gravity/ furrow irrigation; has an operational pump but it is not on the site; it was not possible to visit the area due to lack of access.
Alberto Cherindza	Ressano Garcia/ Condene	Incomáti	5	3	Partially operational. The area is used for rainfed production - diesel pump in good working order.
Alberto Mouzinho	Ressano Garcia/ Condene 25°31´25.1´´ S 32°08´48.7´´ E	Incomáti	50	10	Gravity irrigation system/ furrows and basins for water conservation for irrigation transported through a channel on land with ±150 m of high length and built manually.

Name	Administr. Posts/ Locality/ Community	River Basin	Area (ha) Infrastructure	Operational	Remarks
João Sigaúque	Ressano Garcia/ Condene 25°31´26.3´´ S 32°08´58.6´´ E	Incomáti	3	2	Partially operational; gravity/furrow irrigation.
Albertina Chemo	Ressano Garcia/ Condene 25°31´49.7´´ S 32°10´00.7´´ E	Incomáti	40	15	Gravity/furrow irrigation; has three diesel pump groups.
Joshua Sitoe	Ressano Garcia/ Condene 25°31´58.2´´ S 32°10´53.4´´ E	Incomáti	2	0	Degraded, abandoned, and currently under rainfed crop production; damaged pumps.
António Medeiros	Ressano Garcia/ Condene 25°33´32.3´´ S 32°11´43.7´´ E	Incomáti	2	0	Not operational; area with natural vegetation; motor pump was not in place; water pumped from an abandoned river channel.
Elias Mulima	Ressano Garcia/ Condene 25°32´53.7´´ S 32°11´36.3´´ E	Incomáti	12	5	Gravity/furrow irrigation; operational pump.
José Bila	Ressano Garcia/ Condene 25°32´32.1´´ S 32°11´22.5´´ E	Incomáti	5	0	Partially operational irrigation; damaged motor pump; sucker and tubing lost during floods.
Silvestre Chemo	Moamba-Sede/J. Machel 25°33´50.3´´ S 32°10´58.9´´ E	Incomáti (braço do rio)	40	10	Gravity/furrow irrigation; operational pump although it lost other equipment in the floods.
Domingos Macaringue	Moamba-Sede/ Condene 25°33´41.5´´ S 32°11´45.7´´ E	Incomáti (braço do rio; rio M´Fute)	17	10	Gravity/furrows; piping for lifting and transporting water; can usually irrigate 10 ha in 2 days.
Pacheco I. Dai	Moamba-Sede/ Chinhangoanine 25°17´42.4´´ S 32°30´02.0´´ E	Incomáti	15	13	Gravity/furrow irrigation; operational pump with alternator; area currently in production 5 ha; 2 days to water.

Name	Administr. Posts/ Locality/ Community	River Basin	Area (ha) Infrastructure	Operational	Remarks
Maria Ubisse	Moamba-Sede/ Chinhangoanine 25°17´45.3´´ S 32°28´56,0´´ E	Incomáti	10	10	Gravity/furrow irrigation; diesel pump although it has already operated with an electric pump; abandoned lined canal and an old pumping station and lifting of water. It has capacity for expansion.
G.A. Seia	Moamba-Sede/ Chinhangoanine 25°17´35.1´´ S 32°26´39.5´´ E	Incomáti	<10	0	It currently produces rainfed crops; the state of the equipment and shrub invasion throughout the area do not indicate an immediate interest in irrigated agriculture.
Joaquim Ubawene	Moamba-Sede/ Chinhangoanine 25°17´55.8´´ S 32°29´17.8´´ E	Incomáti	5	2	Gravity/furrow irrigation; usually two waterings per week; water conducted partially through the land channel.
Carlos Machava	Moamba-Sede/ Malangane 25°21´18.2´´ S 32°19´33.7´´ E	Incomáti	25	5	Gravity/furrow irrigation; the old high pumping system with the main cement channel was temporarily abandoned due to the return of water and this damaged the turbine and sucker.
Sulemane Ngwenha	Moamba-Sede/ Malangane 25°21´18.2´´ S 32°19´33.7´´ E	Incomáti	2	2	Gravity/furrow irrigation; the coordinates are the same as those of farmer C.M. once the pumps are in the exact location.
Jaime Zita	Moamba-Sede/ Malangane 25°21´23.1´´ S 32°19´05.6´´ E	Incomáti	10	1	Gravity/furrow irrigation; operates with a borrowed motor pump although it has its equipment; intends to expand the current area to 15 ha with banana plantation.
Albai Dai	Moamba-Sede/ Malangane 25°21´21.5´´ S 32°18´42.2´´ E	Incomáti	16	2	Gravity/furrow irrigation; under normal conditions, it produces 16 ha, although at the moment only 8 ha are clean.

Name	Administr. Posts/ Locality/ Community	River Basin	Area (ha) Infrastructure	Operational	Remarks
Elmone Changule	Moamba-Sede/ Malangane 25°21´21.5´´ S 32°18´42.2´´ E	Incomáti	28	18	Gravity/furrow irrigation; it has five motor pumps, all damaged, and the rest of the agricultural equipment.
Francisco Nhumbate	Moamba-Sede/ Goane 25°24´44.4´´ S 32°13´28.4´´ E	Incomáti	10	2.5	The area belonged to Block III of the old agricultural company. Gravity/furrow irrigation. Partially operational; has a reservoir for water storage; because the motor pumps cannot supply the reservoir, they pump directly into the channel on land. The distribution of water by the plots is made from two valves that water the plots.
Elias Macuvele	Moamba-Sede/ Goane I 25°25´58.2´´ S 32°14´00.9´´ E	Incomáti	10	0	Currently an area for rainfed production; irrigation equipment lost during floods; abandoned area; usually gravity watering.
Nelson M´Bocota	Moamba-Sede/ Goane I 25°26´05.0´´ S 32°14´04.8´´ E	Incomáti	6	4.5	Partially operational irrigation; rainfed agricultural production; intends to resume irrigation (3-4 ha) in the second season with vegetable production; gravity irrigation.
Franisse Mucatchwa	Moamba-Sede/ Goane I 25°29´34.0´´ S 32°15´29.5´´ E	Incomáti	20	6	Gravity/furrow irrigation; area served by coated gutters inoperative; partially operational irrigation.
Judas Changule	Moamba-Sede/ Goane I 25°29´35.3´´ S 32°15´33.0´´ E	Incomáti	20	5	Gravity/furrow irrigation; water transported from the pumping station on the river to the production area through a ditch.

Name	Administr. Posts/ Locality/ Community	River Basin	Area (ha) Infrastructure	Operational	Remarks
Manuel Baptista	Moamba-Sede/ Goane I 25°29´52.6´´ S 32°15´59.1´´ E	Incomáti	75	50	The dominant irrigation is gravity/furrow; it has an experimental area of 2 ha with a drip irrigation method. It has equipment for a larger area; it irrigates from 7 a.m. to 5 p.m.
Bestino Jeque	Moamba-Sede/ Pondzela 25°31´58.7´´ S 32°15´31.6´´ E	Incomáti	50	15	Drip irrigation is dominant, although also irrigating by gravity; possibilities to increase operational area during the next campaign; maintains three pumping stations.
Simeão Nhombate	Moamba-Sede/ Mbocodo 25°30´29.6´´ S 32°16´15.1´´ E	Incomáti	85	15	Gravity irrigation; operating gutter system for water distribution across fields.
Pinina Mabuza	Moamba-Sede/ Wamogolombe	Incomáti	8	0	It was partially operational; gravity irrigation; it was impossible to register the coordinates.
Ezequiel Cossa	Moamba/Sábié 25°34´06.1´´ S 32°13´53.2´´ E	Incomáti	20	1	Gravity/furrow irrigation; water transport through ditches and pipes; partially operational.
Francisco Arone	Moamba Sábié	Incomáti			Abandoned area; used gravity irrigation; livestock production.
Zainadine Pale	Moamba/Sábié	Incomáti			Abandoned area; used gravity irrigation; rainfed production.
Queface M´Bocoda	Moamba/Sábié 25°33´12.7´´ S 32°11´59.7´´ E	Incomáti	3	3	Gravity/furrow irrigation; in addition to vegetables, bananas are produced.
Wilson Sewane	Moamba/Sábié 25°33´22.8´´ S 32°12´07.9´´ E	Incomáti	20	5	Gravity/furrow irrigation; old ditches destroyed by floods.
Solmone Chongo	Moamba/Sábié 25°33´01.2´´ S 32°11´51.2´´ E	Incomáti	2	0.5	Gravity/furrow irrigation; isolated operational area; only 2 ha deforested and still to be plowed.

Name	Administr. Posts/ Locality/ Community	River Basin	Area (ha) Infrastructure	Operational	Remarks
Elias Chongo	Moamba/Sábié	Incomáti	0	0	Abandoned area; rainfed production.
Wilias Fundzane	Moamba/Sábié 25°33´13.8´´ S 32°14´45.7´´ E	Incomáti	24	10	Gravity/furrow irrigation; water source in the dry months is critical.
Elias Mugube	Moamba/Sábié	Incomáti			Abandoned area; livestock production.
Wilson Milambo	Moamba/Sábié 25°34´06.1´´ S 32°13´53.2´´ E	Incomáti	10	10	Gravity/furrow irrigation; the coordinates are the same as 1.32.
Barbosa Milambo	Moamba/Sábié	Incomáti	10	0	Gravity irrigation; damaged motor pump.
Fenias Changula	Moamba/Sábié 25°26´42.7´´ S 32°13´31.7´´ E	Incomáti	50	0	Gravity/furrow irrigation; currently abandoned area; makes only 10 ha of rainfed production.
António Pequenino	Moamba/Sábié 25°20´09.4´´ S 32°13´54.4´´ E	Incomáti	100	50	Gravity/furrow irrigation; the water from the pumping station is transported through a concrete channel to the distribution boxes.
Gulamo Patel	Moamba/Sábié 25°20´09.4´´ S 32°13´54.4´´ E	Incomáti	100	6	The same as 1.44.
Jeremias D. Mutisse	Moamba/Sábié 25°25´02.7´´ S 32°13´21.1´´ E	Incomáti	20	10	Gravity/furrow irrigation; non- operational since the 2000 floods.
Tomás Catuane	Moamba/Sábié 25°19´57.8´´ S 32°14´10.2´´ E	Incomáti	50	30	Gravity irrigation: water pumped directly into the channel carried by piping; abandoned coated block channel; during the dry period, the river flow decreases, and saline intrusion occurs; tubing shows signs of rust.
José F. Mulhovo	Moamba/Sábié 25°14´12.9´´ S 32°08´48.8´´ E	Sábié	60	0	Gravity/furrow irrigation; non- operational; area used for rainfed production; coordinates correspond to a residential area.

Name	Administr. Posts/ Locality/ Community	River Basin	Area (ha) Infrastructure	Operational	Remarks
William		Sábié	4	4	The drip irrigation method: produces tomatoes and the plot is from 1.48 to 1.50.
Ezequias Mabatsana	Moamba/ Sábié- Missão 25°16´15.2´´ S 32°12´55.0´´ E	Sábié	25	0	Gravity/furrow irrigation; not operational since 2000 floods; irrigation infrastructure has not yet been recovered; rainfed production.
Jacinto Tivane	Moamba-Sábié	Incomáti	10	0	Gravity/furrow irrigation; has not been operational since the 2000 floods.
Armando Chauque	Moamba/Sábié 25°17´15.3´´ S 32°25´52.0´´ E	Incomáti	20	12	Gravity/furrow irrigation; old irrigation infrastructure destroyed; current piping along the gutter.
Siliasse Macala	Moamba/Sábié		2	0	Abandoned; rainfed production.
Francisco Dimande	Moamba/Sábié		5	0	Abandoned.
Elmone Mussique	Moamba/Sábié	Incomáti	25	10	Gravity irrigation; partially operational.
Cristina Moreira	Moamba/Sábié 25°15´17.1´´ S 32°15´40.7´´ E	Sábié	10	5	Gravity/furrow irrigation; served by a lined channel.
José João Chileleca	Moamba/Sábié 25°15´17.1´´ S 32°15´40.7´´ E	Sábié	0	0	Abandoned irrigation; submerged electric pump group was not repaired; litigation with the bank; drip irrigation and used the “dragline” method.
Velho Xai- Xai	Moamba/Sábié 25°18´44.4´´ S 32°21´17.3´´ E	Sábié	5	0	Abandoned.
Isaura Vuma	Moamba/Sábié (vila do Sábié/ zona comercial)	Sábié	4	1.5	Gravity/furrow irrigation.
Vicente A. Bila	Moamba/Sábié 25°16´57.5´´ S 32°16´23.6´´ E	Sábié	10	10	Gravity/furrow irrigation; water transported through tubes; intensive vegetable production.

Name	Administr. Posts/ Locality/ Community	River Basin	Area (ha) Infrastructure	Operational	Remarks
Henrique A. Bila	Moamba/Sábié 25°16´57.5´´ S 32°16´23.6´´ E	Sábié	5.5	5.5	A neighbor of farmer 1.60; gravity/furrow irrigation; water transported through tubes.
Jonas Muconto	Moamba/Sábié	Sábié			Abandoned irrigation.
Daniel A. Matusse	Moamba/Sábié 25°17´54.6´´ S 32°16´57.8´´ E	Sábié	20	5	Gravity/furrow irrigation; is partially operational; lack of equipment limits expansion of the irrigated area; you can irrigate only 5 ha at a time.
Geraldo L. Fulane	Moamba/Sábié 25°17´54.6´´ S 32°16´57.8´´ E	Sábié	20	16	Drip irrigation method. A major limitation of the system is the frequency with which sprinklers are blocked by sediment.
Azarias Quetena	Moamba/Sábié 25°17´58.1´´ S 32°16´58.9´´ E	Sábié	8	4	Gravity/furrow irrigation; piping for transporting water from the pumping station to irrigate the plots.
TOTAL			**1,248.50**	**434.5**	

6.3 Annex III: Irrigated units (Class A: <50 ha), Nicoadala District, Zambézia Province, Mozambique

Location: Administrative Posts (APs): Nicoadala-Sede and Maquival, Nicoadala District, Zambézia Province.

Name	Administr. Posts/ Locality/ Community	River Basin	Area (ha) Infrastructure	Operational	Remarks
Empres a Agrícola de Jorge A. Valente	Nicoalada Munhonha 17°35´17.1´´ S 36°40´51.5´´ E	Licuari/ Zambe ze	5	5	Gravity irrigation, furrows. Lister 1 diesel cylinder; Honda Bernard 1 cylinder gasoline. Production of vegetables, fruit trees. Expansion to 50 ha.
Regadio do Sr. Durão	Nicoadala Munhonha 17°34´50.3´´ S 36°42´03.2´´ E	Licuari/ Zambe ze	5	0.25	Manual irrigation (use of watering cans) has a pond with water throughout the year. Localized irrigation, horticultural and ornamental trees, and shade. It plans for drip irrigation in the two greenhouses, 100-150 m2 each.
Lucas Miguel	Nicoadala Munhonha 17°38´45.6´´ S 36°43´08.2´´ E	Licuari/ Zambeze	2	1.5	Gravity irrigation, 2-cylinder Lister motor pump, piping, and channels on land and grooves. Vegetables. Itione Lagoon water source abandoned channel of the Licuari River. The expansion area is 10 ha.

Name	Administr. Posts/ Locality/ Community	River Basin	Area (ha) Infrastructure	Operational	Remarks
Sr. Dilone	Nicoadala Munhonha 17°38´58.1´´ S 36°42´58.1´´ E	Licuari/ Zambeze	1.5	0.25	Gravity irrigation, 1-cylinder Yamaha motor, gasoline, piping (PVC type), inland channels, furrows. Paddy rice in an adjacent area.
Others	Nicoadala Munhonha 17°38´00.9´´ S 36°43´12.8´´ E	Licuari/ Zambeze	0	1.5	Gravity irrigation, manual watering, beds. Water source: Lagoa Bati (year-round water). Production of different vegetables. Destination: local production market and Quelimane City.
Total			**13.5**	**8.5**	**Vegetable production only in the cold season, paddy rice and maize in the hot and rainy season.**

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