THE WORLD BANK

Characterization of farmer-led irrigation development in Mali

PRACTICA FOUNDATION

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Front image: Smallholder irrigation near the Niger river in Mali, in the commune of Pelengana in the Ségou region.
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Acronyms

ATI	Agency for Land Development and Irrigation Water Supply
BNDA	Banque Nationale de Développement Agricole
CILSS	International Permanent Inter-State Committee against Drought in the Sahel
DNA	Direction Nationale de l'Agriculture
DNGR	Direction Nationale du Génie Rural
FAO	The Food and Agriculture Organization of the United Nations
FLID	Farmer Led Irrigation Development
PARIIS	Regional Support Project for the Sahel Irrigation Initiative
PARIIS-UGP	National Project Implementation Unit of the PARIIS project
PARIIS-UGL	Local Implementation Unit of the PARIIS project
PASNDI	Projet d'Appui à la Stratégie Nationale de Développement de l'Irrigation
PCDA	Programme de Compétitive et de Diversification Agricole (2006-2015)
PIV	Périmètres Irrigués Villageoises
PNIP	Programme National d'Irrigation de Proximité (2012-2021)
PPM	Petits Périmètres Maraîchèrs
SFD	Decentralised Financial Systems of Mali
SIIP	Sahel Irrigation Initiative Program

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Executive summary

This work forms part of the project “Diagnostic and future directions for Farmer Led Irrigation Development (FLID) in Chad and Mali”, which aims to assess the current extent of farmer-led irrigation in Chad and Mali, and assess the areas that are suitable for further growth. FLID is the process by which farmers drive irrigation development. It is about how farmers initiate and develop their irrigated productions systems and how they acquire the necessary resources and markets. In both countries, farmer-led irrigation exists, but the extent is not well known. As a first step towards the characterization of FLID, Westra (2020) identified the distribution of currently irrigated areas (both small-scale and large-scale), as well as potential suitable areas for small-scale irrigation for the full territories of Chad and Mali. This report is a continuation of this work and aims to shine a light on the specific irrigation practices and technologies used and opportunities and challenges experienced by individual farmers. The report aims to inform and contribute to the development of effective supporting mechanisms in the frame of the PARIIS program. The FLID assessment was done through a desk study, interviews with 10 farmers in the cercles of Ségou, Baraouéli, Dioïla and Koulikoro, and interviews with government officials, MFI institutes, farmer associations, equipment suppliers and well drilling companies.

The results of the study show that FLID in central Mali is widespread along rivers and in lowlands. Farmers pump directly from the river or use hand-dug wells to access shallow groundwater. A classification of individual farmer categories was made to differentiate between farmers’ abilities to invest in their irrigated production system. Identified categories are: constraint farmers, market-oriented farmers, intensive producers and investors. Access to finance is the biggest constraint for individual farmers in Mali, followed by access to water. The low income earned by constraint farmers does not allow them to purchase pumps, and as a result they get stuck in manual irrigation with limited growth perspectives. The other farmer categories make considerable revenues which allows them to invest in simple irrigation technologies without using credit. Finance solutions by banks or MFIs are not accessible for most farmers.

Strategies to accelerate FLID start with increasing access to finance. A range of elements could be addressed including the provision of guaranties to lower the risks of MFIs, and disseminating transparent information. Strengthening farmer associations to increase their involvement in the sales and/or storage of products could decrease price volatility, which could reduce farmers’ risk profile. Secondly, water scarcity is increasing which calls for catchment-based approaches when planning future irrigation investments, as well as subsidies on efficient irrigation technologies. Effective knowledge sharing on irrigation and agricultural practices mainly happens informally. These processes could be facilitated and funded to increase its reach and volume. Policies to support irrigation are traditionally focused on large-scale and communal systems, however there is a promising interest from the government of Mali to develop support mechanisms for individual farmers in the frame of the PARIIS program.

1. INTRODUCTION

1.1 BACKGROUND

Farmer-led irrigation development (FLID) is the process by which farmers, alone or as a collective, drive irrigation development, i.e. the establishment, improvement or expansion of irrigated agriculture by acquiring the necessary irrigation technologies and skills and developing output markets (Izzi et al., 2021). FLID forms a contrast with state or donor driven approaches in the sense that the farmers take the lead in developing the irrigated production systems and in accessing the necessary land, water, financial, technical and human resources and markets. The importance of FLID in increasing productivity and enhancing food security is now widely recognized. FLID is generally a more sustainable, economic and inclusive process than state or donor driven initiatives. Supporting FLID starts with a thorough, local understanding of the current extent, suitable areas, and overall potential for farmer-led irrigation. Currently, the World Bank is supporting country-level diagnostics of the extent and forms of farmer-led irrigation development and potential strategies to accelerate FLID in a range of countries in Africa.

A major initiative to support irrigation development including FLID is the Support Project to The Sahel Irrigation Initiative (PARIIS) (2018-2024). This project aims to support the states and irrigation stakeholders of Burkina Faso, Mali, Mauritania, Niger, Senegal and Chad to increase the areas under agricultural water control to one million hectares while ensuring the viability, performance, and environmental sustainability of existing and future irrigated systems, and the associated agricultural development (CILSS, 2017). It does so by establishing and funding diverse irrigation solutions adapted to the Sahelian context to enable the development of irrigated agriculture that is sustainable, suited to the environment, competitive and inclusive. The project support five types of irrigation (Table 1), defined based on the scale of irrigation development, natural resources and the profile of farmers. Farmers can lead irrigation in any of these type. However, FLID is mainly observed under Type 1 where farmers jointly construct systems to retain water in floodplains or dambos for the production of rice, maize and vegetables, and under Type-2 where farmers take the initiative in small-scale private irrigation development mainly focused on horticultural crop production, and to some extent also type 3 where farmers come together to take the initiative with additional support. Government-led initiatives are often more present in the other types given the higher level of complexity and the higher unit cost. For the purpose of the report we are focusing on farmers individually taking the initiative in irrigation, i.e. Type 2 irrigation.

Table 1 Types of irrigation in the Sahel (CILSS, 2017)

Types of irrigation in the Sahel	Description of corresponding systems
Type 1: Lowland development and controlled submersion	- Lowland schemes or controlled flooding - Managed by village communities or municipalities
Type 2: Small-scale private irrigation	- Private (individual or commercial) irrigation systems
Type 3: Community Irrigation	- Communal irrigation systems < 100ha - External funding but community participation - Village irrigation schemes (PIV) and small horticultural schemes (PPM)
Type 4: Large-scale public irrigation	- Schemes > 100 ha till > 1,000 ha - Public funding but beneficiary participation - Beneficiaries: traditional farmers organized in producer organizations

Type 5: Commercial PPP Irrigation	- Schemes > 100 ha till > 1000 ha - Financed and realized by private companies, sometimes with use of public funded infrastructure

Purpose of the work
In both Mali and Chad, farmer-led irrigation exists, but the extent and form is not well known. The assessment "Diagnostic and future directions for Farmer Led Irrigation (FLID) in Chad and Mali" was launched to assess the current extent, suitability and practice of FLID in Mali and Chad. In the first phase of this assessment, Practica conducted a mapping study showing that existing individual irrigation and the potential for FLID development are widespread in several regions of Mali (see Figure 1). To complete the diagnostic, this report forms the second part of the assessment and aims to characterize the FLID practices, constraints and potential supporting mechanisms in Mali. The same assessment has been done for Chad which is presented in a separate report.

Problem statement
Farmer-led irrigation development (FLID) is a widespread irrigation development process driven by farmers. The World Bank has commissioned a country-level diagnostic study in Mali and Chad to confirm the potential and formulate concrete recommendations for FLID enhancing mechanisms. A characterization of FLID types and corresponding challenges and opportunities is needed to better understand the situation in the identified areas. The learnings should serve as a reference and contribute to the discussion whether government support could accelerate FLID and make it more inclusive. The obtained insight could also serve as a base for the prioritization and formulation of support measures that target strengthening the enabling environment to support farmers in developing their irrigation systems and practices. The recommendations will be addressed in particular to the authorities that provide technical and institutional support to contribute to an enabling environment for FLID, implemented under the PARIIS project.

Objective
This study aimed to characterize the existing types of FLID in Mali and to identify the challenges, opportunities and enabling factors relevant to each segment. The focus of this study will only be on Type-2 irrigation, i.e. private smallholder irrigation or individual irrigation development, as this segment is not well documented and tailored supporting mechanisms for individual farmers are generally scarce.

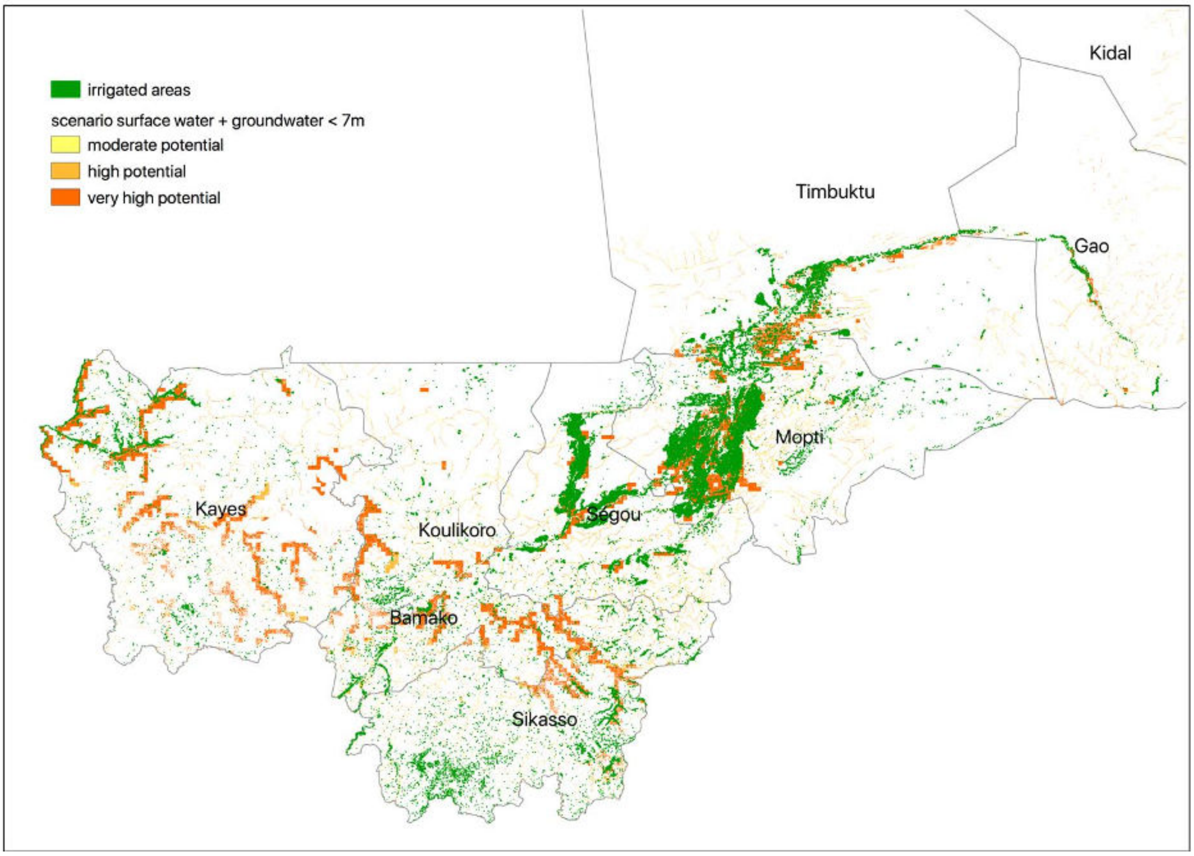


Figure 1 Currently irrigated areas (green) and high potential areas for irrigation (orange) (Westra, 2020)

The mapping of potential suitable areas prepared by Westra (2020) is an adaptation of the methodology described by Schmitter (2018). The method by Westra consists of excluding areas that are not suitable for agricultural production: high slopes, protected zones, water bodies and non-agricultural land followed by a multi-criteria scoring model. The areas are scored in terms of its suitability for irrigation according to six parameters: slope, distance to water, groundwater depth, storage and productivity, and access to cities. This analysis is done for three situations: surface water, very shallow groundwater and shallow groundwater. The result is a mapping of suitable areas (medium, high and very high potential) per water scenario. Figure 1 shows the scenario for surface water and very shallow groundwater (<7m).

1.2 METHODOLOGY AND GEOGRAPHICAL FOCUS

The following data and study methods have been employed:

Table 2 Data and study methods

Data to collect	Method	Source/Location

Government data (3 meetings) - Maps, shapefiles, figures on irrigation schemes - Relevant and recent study reports and policy papers - Farmer registration data: type, organization form, crops, technologies, surfaces, area, financial and technical support (if available)	Meetings and phone calls	-Ministry of Agriculture -Regional technical services
Private sector data (9 interviews) - Technology distributor sales data: technologies, numbers, clients, areas, local branches, finance solutions - Local technology supplier data in a selected towns: numbers, products, services, cost - (Manual) drilling enterprise data: areas, numbers, cost - Banks and microfinance institutions: type, access and conditions of loans for smallholder private farmers	Structured interviews and phone calls	- Capital - Regional towns: Ségou, Koulikoro
Farmer data (10 interviews) - Organization, ownership, crops, irrigated surface, location - Technology in use: water source, withdrawal, application - Access to information/technology/finance/markets	Structured interviews and observations with irrigating farmers	Ségou (3), Baraouéli (2), Dioïla (3) and Koulikoro (2).
Literature Online (grey) literature study on climate, agro-ecology, institutions and policies, technologies	Desk study	
Key expert insights (5 interviews) In-depth interviews on plans, challenges and recommendations from: - Ministry of Agriculture - Representative farmers union - Representatives private sector	Semi-structured interviews	

Due to travel restrictions as a result of the covid pandemic and the security situation a national consultant has been contracted to implement the study activities in Mali in close collaboration and with remote support from Practica.

Since one of the objectives of this study is to support the implementation of the PARIIS project, the geographical zones have been aligned with the priority regions (ZIPs) defined by the Project Implementation Unit (PIU) of the PARIIS project in Mali. The PIU has advised to focus on the two priority zones of the project, i.e. Zone 1 : the cercles of Ségou and Baraouéli in the Ségou region, and Zone 2: the cercles of Koulikoro and Dioïla in the Koulikoro region. For the field assessment, farmer interviews have been realized in the cercles of Ségou (3), Baraouéli (2), Dioïla (3) and Koulikoro (2). For the location of the four cercles see Figure 2.

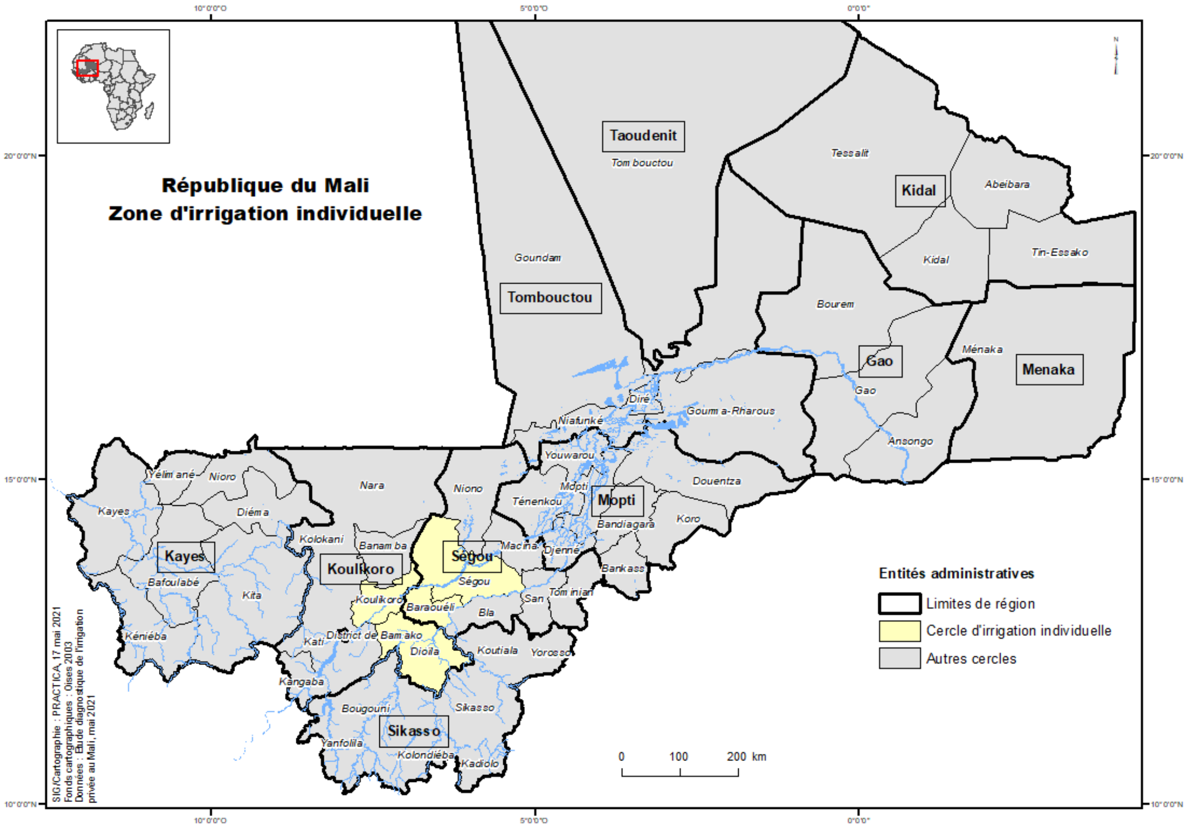


Figure 2 Priority zones of the PARIIS project. Zone 1: Ségou, Baraouéli, Zone 2: Koulikoro, Dioïla

Structure of the report
The structure of the report follows the main steps of the FLID Guide as described by Izzi et al. (2021).:

Chapter 2. Resource potential

Chapter 3. Farmer benefits

Chapter 4. Policy and legal

Chapter 5. Market

Chapter 6. Knowledge

Chapter 7. Technology

Chapter 8. Finance

Chapter 9. Conclusions and recommendations

2. Resource potential

2.1. Principal agro-ecological zones and FLID clusters

Mali is a landlocked country located in West Africa with a total area of 1,241,138 square kilometers (TRAGSATEC et al., 2016). The UN estimates its current population at 16.9 million people, with the largest share of the population living in the south western regions.

In its large majority the country is flat with an average altitude of 340m (TRAGSATEC et al., 2016). Some highlands are located in the Southern part of the country, in the middle-East, and in the North-East, at the border with Algeria. The highest altitude of the country is the Mount Hombori with 1,155 meters. Also in the middle of the country, but West of this elevation, a depression corresponds to the "lower Niger Delta". It is a major agriculture area with large floodplains (UNICEF et al., 2010).

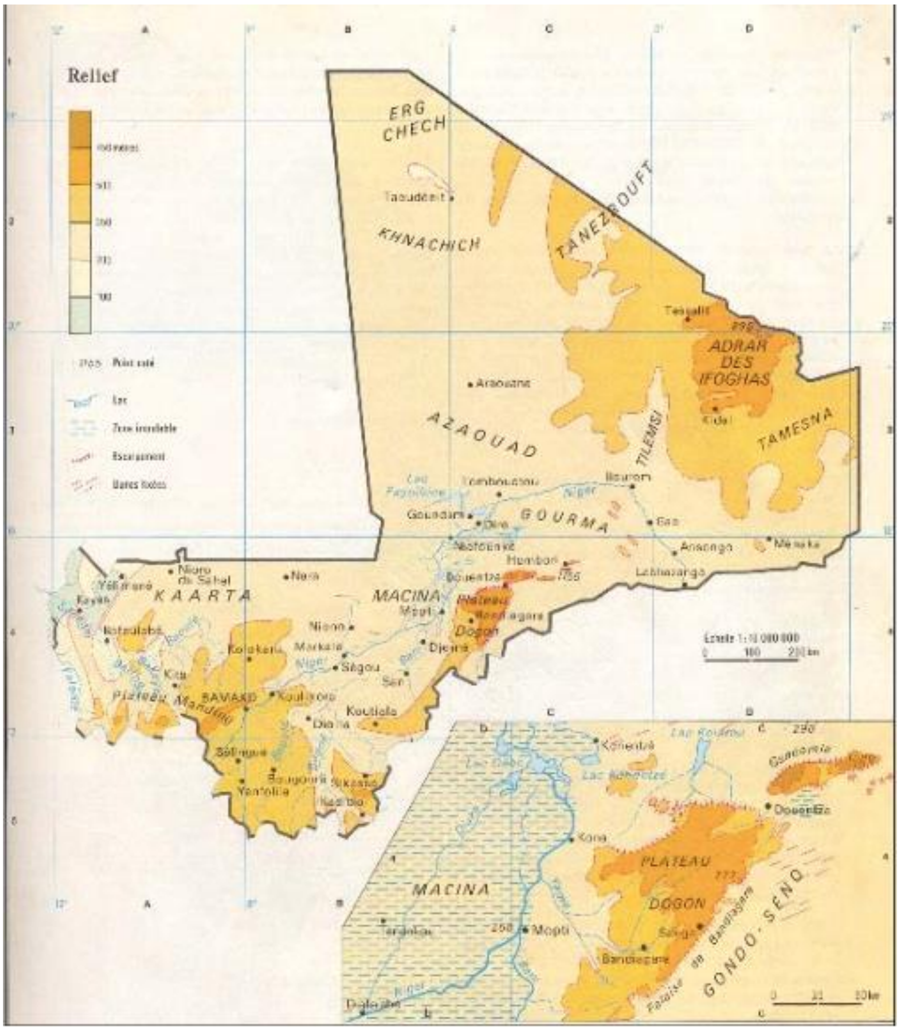


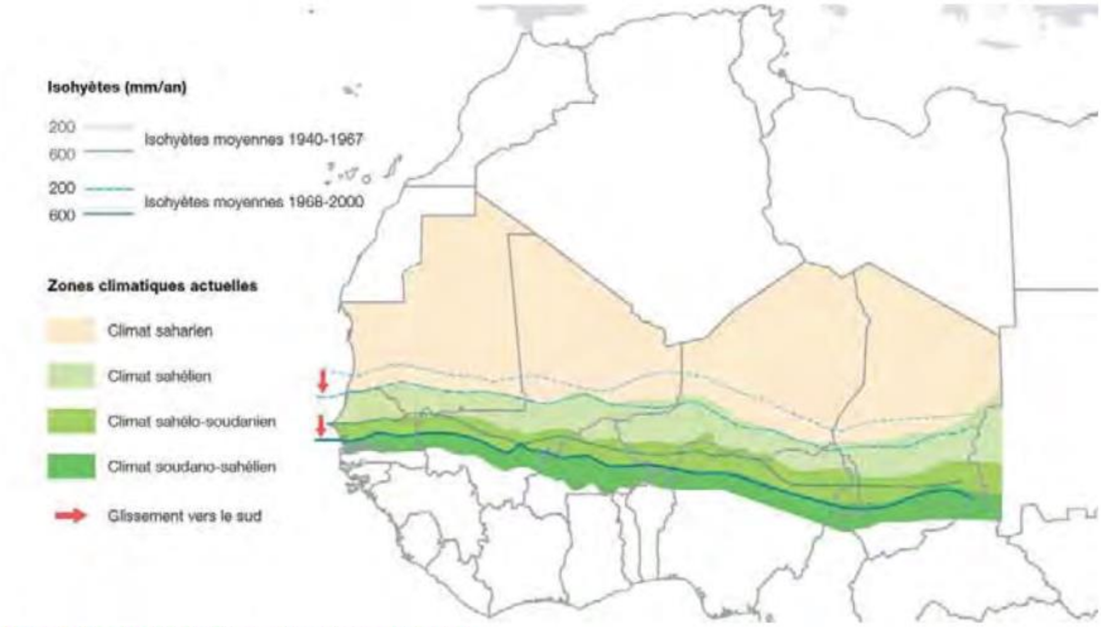
Figure 3: UNICEF et al., 2010 "Map of the topography of Mali"

The climate is defined as tropical, and it is marked, especially in the South of the country, by a rainy season with the West African monsoon coming from Guinea from June to September. The dry season usually lasts from six to nine months (FAO, 2015).

Even if average temperatures are considered to be very high all over the country, it is possible to specify two types of regimes: the north usually experiences a maximum peak of temperatures between June and August; while in the South this period of high temperatures is interrupted by the rainy season, therefore two slightly smaller peaks occur in April-May and in September-October.

The amount of precipitation received varies greatly depending on the latitude. The South of the country can receive up to ten times more rain per year than the Northern regions which are desertic. The volume of precipitations constitutes one of the main delineators between the four main agro-climatic areas that are distinguishable.

The country can be divided from North to South into four of these agro-climatic areas which also correspond to specific climatic areas at the scale of the Sahel.



Carte 2. CSAO, 2009. «Zones climatiques du Sahel».

Figure 4: TRAGSATEC et al., 2016 "Main Agro-climatic areas in the Sahel region"

Table 3: Agro-climatic areas in Mali and characteristics (FAO, 2015)

HCNE eco-climatic zones	Köppen-Geiger climate zones	Average annual precipitation	Percentage Country surface	Livelihoods Zones (FEWS NET, 2015)
Saharan	Arid, desert, hot (BWh)	<200 mm	51%	Nomadism & trans-saharian trade
Sahelian	Arid, steppe, hot (BSh)	200 – 700 mm	26%	Livestock, millet
Sudanian	Tropical, savannah (Aw)	700 – 1200 mm	17%	Sorghum, remittances, millet, maize
Sudano-guinean / pre-guinean	Tropical, savannah (Aw)	>1200 mm	6%	Maize, cotton, fruits

The Saharan zone

The Saharan zone includes the entire northern part of Mali and covers 51 % of the country's surface. The zone corresponds to the Arid, desert, hot climate zone. It is characterized by extremely low rainfall of less than 100 mm in the North to about 200 mm in the South, nearly permanent dry winds (harmattan), a low humidity (< 50%) and high temperatures (FAO, 2015). These factors combined lead to a maximum reference evapotranspiration (ETo) of 7.2 mm/day in Kidal in April (FAO, 2021). Most of the area is without vegetation. Agricultural production is limited to small-scale traditionally irrigated cultivation of cereals and vegetables, as the area is too dry for other cultivation systems (TRAGSATEC et al., 2016). This area is the less populated of Mali because of its limited water resources that constraints agricultural production.

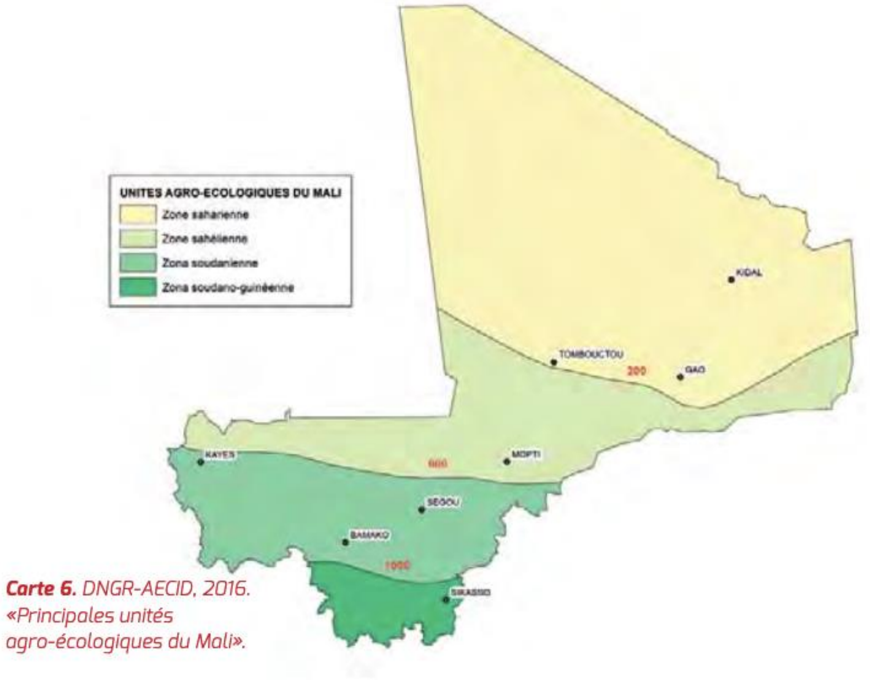


Figure 5: TRAGSATEC et al., 2016 "Main agro-climatic areas in Mali"

The Sahelian zone

The Sahelian zone in central Mali covers 26% of the country. It is equivalent to the arid, steppe, hot climate zone. The annual rainfall ranges from 200 mm in the north to 700 mm in the south (FAO, 2015). This zone covers most of the Niger Delta, thus also covering a very a specific agro-ecological area with swamps that are usually flooded for a part of the year. During the rainy season, flooded irrigation is practiced a lot, allowing the cultivation of rice and similar crops. It is one of the main agricultural areas of Mali, along with the Senegal valley.

The reference evapotranspiration ETo in April is also 7.2 mm both in Tombouctou (at the border with the Saharian zone) and in Mopti (in the South of the zone, and the swamp area of the Niger Delta) (FAO, 2021).

The Sudanian zone

The Sudanian eco climatic zone comprises 17% of the area of Mali. The climate corresponds to a Tropical, savannah (Aw) type and annual rainfall ranges from 700 mm/year in the North of the Sudanian zone to over 1200 mm/year in the South. The maximum daily reference evapotranspiration ETo in April ranges from 6.7 mm in Kayes (West of the Country) to 6.3 in Ségou (East) (FAO, 2021). This zone hosts a denser and wider diversity of vegetation than the previous one, with bushes and trees spread across the space (FAO, 2015). Up to 90 days of rain per year generally occur in this area, which is 2 to 3 times more than in the North of the country. The West of this agro-climatic area covers the river basin of the Senegal which is the second area of the country offering the most opportunities for irrigation after the Niger delta.

Most of the Malian population lives in rural areas, mainly in the South of the country and along the river Niger. Livelihood strategies are strongly linked to the availability of water, and the ability to practice agriculture and animal husbandry. The Sudanian agro-ecological zone offers diverse opportunities to make a living: along the rivers Niger and Senegal, their affluents, as well as from groundwater. Thus, it is also the zone which hosts most of the country's population.

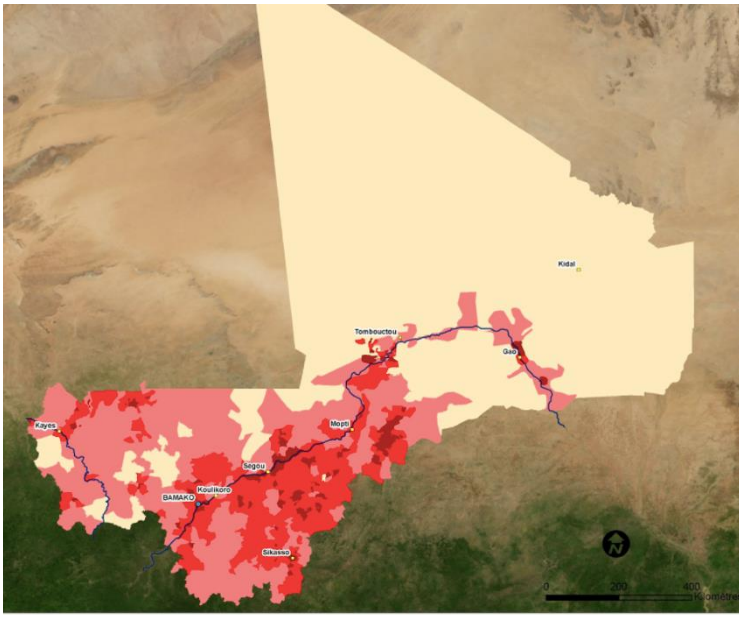


Figure 6: UNICEF, 2012 "Density of Malian population per municipality"

The Sudano-guinean zone

The Sudano-guinean eco climatic zones comprises 6% of the area of Mali and covers the southern region. The climate also corresponds to a Tropical, savannah (Aw) type but annual rainfall can provide from 1200 up to 1500 mm (FAO, 2015). The maximum daily reference evapotranspiration ETo is 5.8 mm in Sikasso (FAO, 2021). This zone is also qualified of 'sub-humid'. It hosts an even denser vegetation with some wooden savannah and forests.

The type of livelihoods and economic activities also evolve according to these agro-climatic zones. Nomadism and livestock are frequent in the North. In the Sudanian zone, sorghum and similar types of cereals are usually cultivated. In the extreme south (soudano-guinean zone), field crops with higher water requirements, such as maize or fruits are cultivated. The Inferior Niger Delta marks a disparity in the concordance of the agro-climatic areas with the types of livelihoods. Rice cultivation, cattle and fishing are practiced in the Delta in the center of the country (FEWS NET, 2015).

2.2 WATER AVAILABILITY AND ACCESS

Surface water

Mali is a landlocked country. Despite not benefiting from any access to the sea, the country is crossed by two of the biggest rivers in West Africa: the Senegal and the Niger. Both originate from Guinea and enter through the Southern border of Mali. The Senegal travels 850 km before entering Senegal from the West of Mali. The Niger travels 1700 km in Mali and enters Niger at the North Eastern border of Mali (UNICEF et al., 2010). Both rivers and their tributaries constitute one of the biggest water resources for the country.

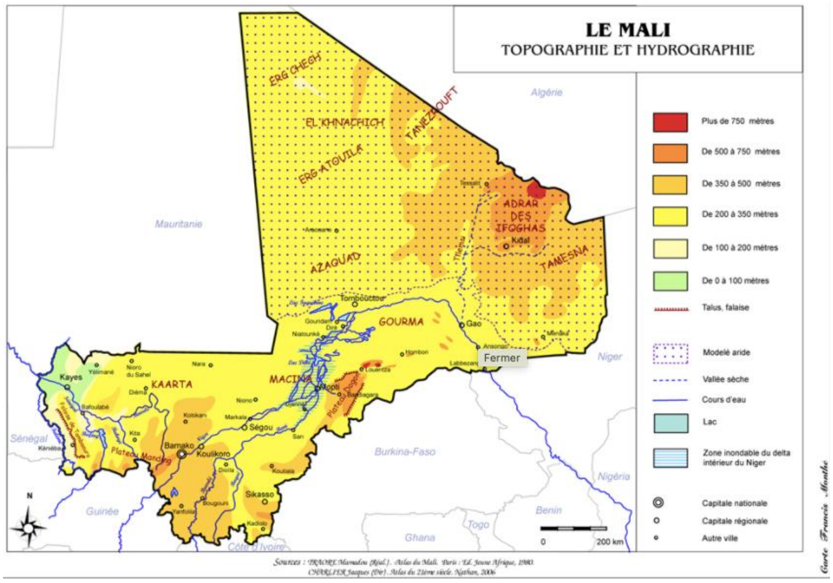


Figure 7: DNH, 2006 "Rivers in Mali"

The main tributaries in Mali of the Senegal they are the Bafing, the Bakoye and the Baoulé. For the Niger river are the Bani, the Sankarani and the Baoulé (same name but different river than for the Senegal). All the tributaries of the Niger river, are for topographic reasons located at the South of the Niger (UNICEF et al., 2010).

Five dams along the course of each of these water ways also allow to store 13.8 km³ per year (FAO, 2015).

Altogether, the Niger, Senegal and their tributaries provide 50 km³ of renewable surface water per year to Mali. In addition to this, a number of other rivers coming from Guinea and Ivory Coast, including the Volta River, carry about 40 km³ of water per year to the country. In comparison, 30 km³ are available from groundwater which includes km³ originating from surface waters. In total, Mali disposes annually of about 100 km³ of renewable water resources (FAO, 2015).

Mali knows a few zones that are rich in water resources. The most remarkable is the Inferior Delta of the Niger river because of its size (4 million of hectares) and its economic importance. During the rainy season, this part of the Niger river floods creating swamps and flood plains, which allow for practices of flooded irrigation, for instance for the cultivation of rice, and animal husbandry on the pastures. A lot of agriculture and irrigation practices take place in this area, as even when the land dries after the rainy season, the water remains accessible at relatively small water depths.

The second water abundant area in size is the flood plain of Sourou with 56 500 Ha. The lake Magui covers 24 740 Ha, and the lake Wegnia 3 900 Ha.

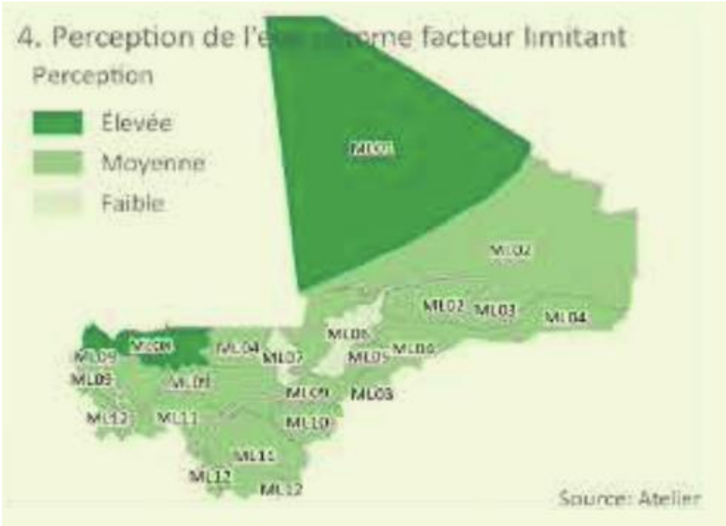


Figure 8 : FAO, 2015 “Perception of the water as a limiting factor” (Dark green: high, Green: medium, Light green: low)

As shown above, the main share of Mali’s available water comes from surface water. However, the resource is distributed very unequally over the surface of the country. While most of the rivers, dams and floodplain areas are located in the South of the country, the North is very dry and desertic. While it represents more than 60% of the surface of the country, 10% of its inhabitants live in the desertic zone (UNICEF et al., 2010). It is due to the lower precipitation in the North and the location of the rivers that the biggest part of the population lives in the South of the country where the water is less scarce, and therby facilitating livelihood activities such as agriculture.

Groundwater

BGS (2019) differentiates between eight different aquifers in Mali, see Figure 9. A corresponding overview of the characteristics of the aquifers is presented in Table 4. For each aquifer an indiciation of its accesiblity for individual farmers is provided based on the water depth, aquifer productivity and hardness of the formation. The analysis shows that farmers can only tap directly from the Unconsolidated – High (dark blue) aquifer and possibly some parts of the Sedimentary Intergranual aquifer (in purple), provided that the water is not too deep. Both aquifers can be considered as productive and renewable groundwater resources, predominantly recharged by respectively surface water and rainfall (BGS, 2019). Wells can be dug or drilled manually in the unconsolidated soils, and motorised or machine drilled in case of the sedimentary aquifers.

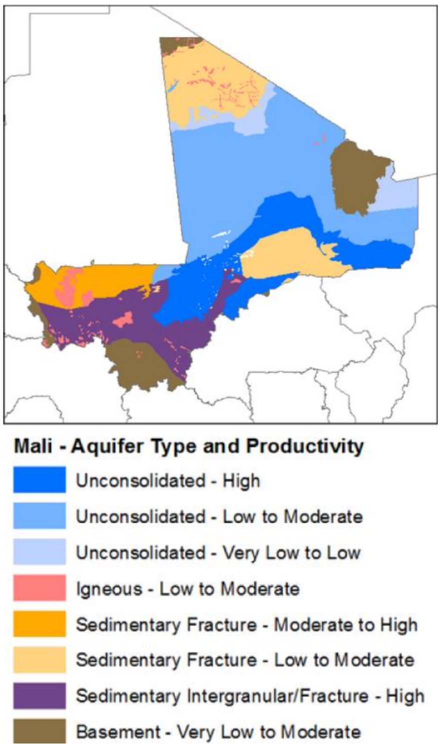


Figure 9 Aquifer type and productivity (BGS, 2019)

It is important to note that throughout the country, pockets of unconsolidated quaternary sediments can be found as alluvium along rivers and in the inner Niger delta, or in the form of sand dunes. These sediments of varying thickness are not shown on the map of Figure 9, yet they constitute important volumes of easily accesible groundwater. On the other hand, parts of the Unconsolidated – High aquifer are actually inaccesible since the groundwater can be too deep. In fact, the feasibiliy map for manual drilling is a better representation of the accesibility of groundwater, as it is based on the geological and hydrological maps in combination with water levels and logs from existing boreholes. The map in Figure 10 shows that groundwater is mainly accesible along the Niger and Senegal rivers and in the inner Niger Delta. Sikasso in the south also represents an important potential, although success rates for manual drilling are lower compared to the riverine areas. Because of this, the cost of groundwater mobilization is the lowest in the riverine and inner delta areas.

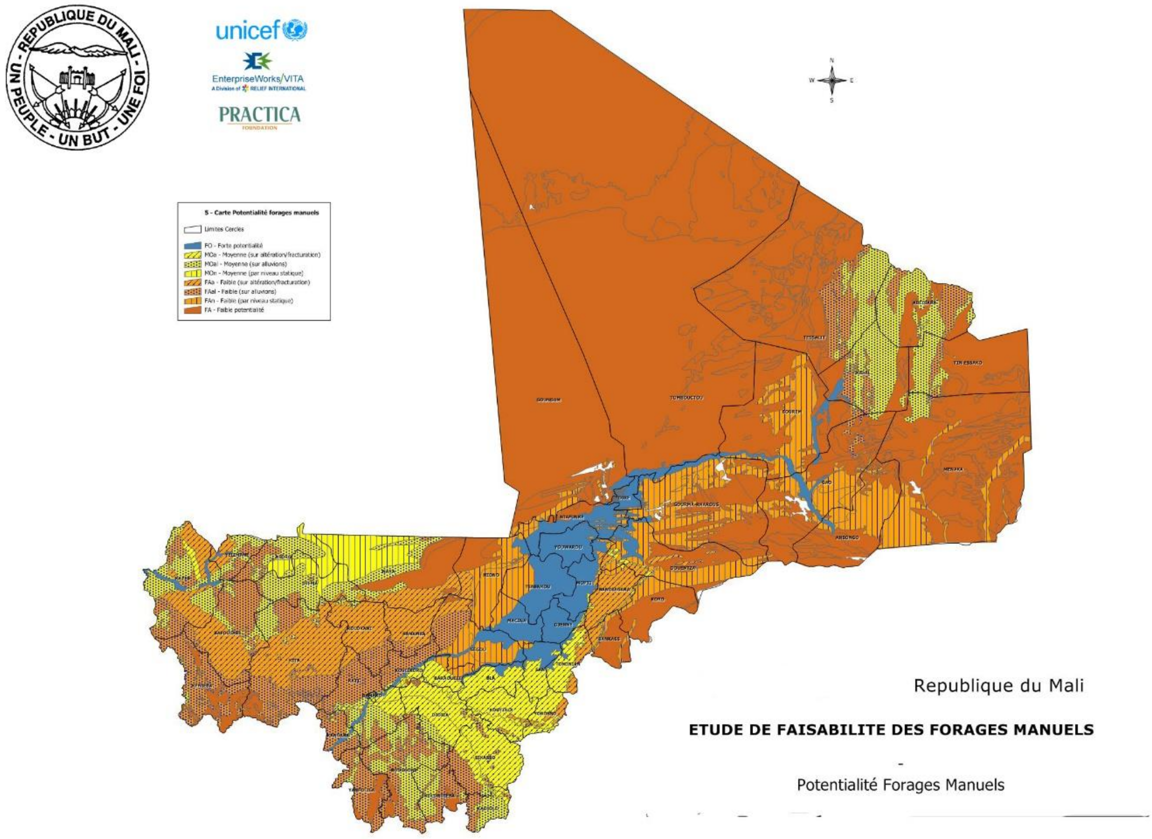


Figure 10 Feasibility map for manual drilling in Mali (UNICEF, 2010)

Table 4 Overview of aquifer characteristics (Adapted from BGS, 2019)

Aquifer map category Figure 9	**Formation**	**Borehole productivity**	**Description**	**Aquifer accessible for smallholder farmers**
Unconsolidated – High	Sedimentary – Tertiary (Continental Terminal)	Generally 8-23 m³/h for boreholes 50-150 m. Recharged by surface water.	Unconsolidated sands overlaying sandstone. Water table 0 – 80 m.	Yes, suitable for manual drilling. Accesibility depending on water depth.
Unconsolidated – Low to Moderate	Sedimentary – Upper Cretaceous – eocene (Tertiary)	7 m³/h for boreholes from 110-165 m depth.	Sandstone and clay on top of limestone. High salinity.	No, poor water quality and water too deep.
Unconsolidated – Very Low to Low	Sedimentary – Lower Cretaceous (Continental Intercalaire)	9-12 m³/h for boreholes from 45-450 m.	Rocks made of sandstone, conglomerate, clay. Water table around 40m.	No, water too deep.
Igneous – Low to Moderate	Igneous – largely volcanic	4-6 m³/h for boreholes from 40-80m.	Volcanic rocks.	No, hard to penetrate.
Sedimentary Fracture – Moderate to High	Sedimentary - Palaeozoic	6 m³/h for boreholes from 50-80 m.	Semi-confined discontinuous fractured sandstone and limestone. High salinity.	No, machine drilling success rate less than 50%.
Sedimentary Fracture – Low to Moderate	Sedimentary – Palaeozoic / Precambrian Metasedimentary	6.5-8 m³/h for boreholes from 70-100 m. Recharge from niger river.	Semi-confined discontinuous fractured sanstone and limestone. Water at 20-100m.	No, machine drilling success rate less than 50%.
Sedimentary Intergranular /Fracture – High	Precambrian Metasedimentary	5-10 m³/h for boreholes from 55-75 m. Recharge during the rainy season.	Semi-confined motamorphosed sandstone aquifer with high permeability in fractures. Water 10-17m (south) to > 50m (north)	Difficult, but depending on water depth and hardness of layers.
Basement – Very Low to Moderate	Precambrian Craton	4-6 m³/h for boreholes from 40-80 m.	Basement rock, groundwater in fractures. Water	No, hard to penetrate.

			generally 8-20m, max 70m.	

2.3 Long-term trends and sustainability

Irrigation accounts for 90% of all water use in Mali (USAID, 2020). While large volumes of surface and shallow groundwater are relatively easily accessible in Mali's riverine and floodplain areas, the sustainable potential for water extraction is much lower. Yet, various organizations continuously stress the potential to increase the irrigated area. FEWS NET (2019) reports that Mali is using 34% of its irrigation potential. USAID (2020) estimates Mali's potential for irrigation is around 2.2 million hectares, of which 18% or 370,000 ha is currently developed. This includes 167,000 ha in fully controlled perimeters of which 100,000 ha are located in the Office du Niger scheme. According to USAID (2020) based on FAO (2015), 650,000 ha (!) of land in the Office du Niger has been assigned to foreign investment entities for the development of new perimeters. About 70,000 ha of irrigated land has been developed in Mali between 2014 and 2018 (USAID, 2020).

Due to the increased water withdrawal for irrigation and changing rainfall patterns, water scarcity is on the rise as well. One of the interviewed experts[1] confirms that in various areas water depths in open wells are increasing due to limited rainfall, which increases the cost and effort for farmers to access the water and irrigate. Based on water accounting research on in the upper Niger basin, IWMI (2021) estimates that groundwater resources can support 80,000 ha of irrigated area in Ségou and 270,000 ha in Sikasso. The surface water yield in the dry season is almost zero, hence limited to water stored in dams or ponds. The areas above compare to respectively 145,000 ha and 655,000 ha of suitable land for irrigation in Ségou and Sikasso using water up to 7 meters' depth (ibid). The difference shows that studies on irrigation suitability, including the study by Westra (2020), should always be combined with studies on the sustainable potential for abstraction. The numbers above indicate that in the case of the upper Niger basin, the sustainable potential is a factor 2-3 lower than the suitable area for irrigation development. Once the analysis of the suitable area for irrigation is not limited to surface and very shallow groundwater, the difference with the sustainable potential would be even larger.

As a result, IWMI (2021) recommends that any large-scale investment in irrigation in Ségou or Sikasso should be informed by an assessment of the local water availability and accompanied by guidelines to increase water productivity. Several technical and financial partners start to become aware of this issue. As an example, in 2017 kfW commissioned a study on the impact of the village irrigation schemes developed by the IPRO-DI project on water levels in the Niger river downstream of the inner delta. The study showed that in the scenario that the village irrigation schemes would be expanded from 27,000 to 61,000 ha in 2026, a maximum impact of 11% reduction of the river flow could be expected. It shows that the combined sum of small-scale irrigation developments could still have a significant impact on the available water resources in Mali.

[1] Sidy Cheick Diallo, irrigation expert based in Bamako.

3. FARMER BENEFITS

3.1 CHARACTERIZATION OF FLID IN MALI

Mali counts 6.4 million hectares of arable land, of which 90% is cultivated by smallholder farmers. 58% of its population lives in rural areas and the majority relies on rain-fed agriculture and pastoralism. Yet, small-scale irrigation is on the rise in both urban and rural areas (USAID, 2020). In fact, most irrigated agriculture in Mali takes place by family farming. As a result, even the community schemes along the rivers and tributaries, around ponds and in the lowlands or plains are in reality operated under individual irrigation of horticultural crops. In addition to these, there private horticultural and fruit tree cultiviation systems built with farmers' own funds or with the support of Mali's partners.

Irrigation in general, and individual irrigation in particular, is practised everywhere in Mali along rivers, on plains and around large ponds. The state, through its National Programme of Proximity Irrigation (PNIP), has focused its efforts on community irrigation. This means that there is no data exclusively on individual irrigation at the level of the state services. The available figures are those of the PCDA and PARIIS, but the number of producers in these directories is insignificant compared to what actually exists.

Information on irrigation areas for horticultural production, as well as the main crops and their level of development, is provided by the state's technical services. In recent years, the area under market gardening in Mali, outside the areas developed by the state offices, is estimated at over 200,000 ha. This estimate gives an idea of the importance of the practice of individual irrigation in Mali with areas of concentration indicated in the table below. These figures vary from year to year but the trend has been almost the same in recent years. The main crops grown in these areas are tomatoes, shallots, onions, potatoes, chillies, melons, watermelons and green beans, and fruit trees. The table below is based on small-scale horticultural production and does not include the irrigation schemes developed by the state. In the state irrigation schemes such as the Office du Niger, the main irrigated crop is rice, completed with diversified produce (USAID, 2020).

Table 5 FLID clusters in Mali (National Directorate of Agriculture, 2020)

Région	**% of national surface**	**Main FLID clusters**	**Main crops** (in order of importance)
Sikasso	54%	Sikasso cercle	Potato, sweet potato, eggplant, tomato
Bamako-Koulikoro	22 %	Cercles of Kati (Bamako), Koulikoro (3,188 ha), Dioïla (2,710 ha)	Onion, , shallots, tomato, cabbage, letuce
Ségou	13%	Cercle of Ségou (1,079 ha)	Shallots, cabbage, tomato, potato, melon
Kayes	3%	Cercle of Kayes, Kita	Okra, tomato, onion, cucumber

Mopti	3%	Interior Delta: cercles of Mopti, Djenné, Youwarou Dogon plateau: cercles of Bankass, Bandiagara, Douentza, Koro	Shallots, okra, tomato, onion Onion, shallots, garlic, chili
Tombouctou	3%	Cercles of Diré, Goundam	Onion, shallots, zuchini, tomato

In Mali Mali farmer-led irrigation can take many forms. It is commonly associated with the PARIIS irrigation type 2: small-scale private irrigation, but also with invididuals within type 3: community irrigation schemes, and type 1: lowland development and controlled submersion. The irrigation typology overview in Table 6 by DNGR (2016) shows considerable overlap between the different types, and links individual smallholder irrigation to all classical and PNIP irrigation types, and including to small village irrigation schemes (PIV), small horticultural schemes (PPM). Though PIV and PPM have been estblished with external support, farmers have in some cases taken the lead in its further development. Similar developments are visible within and around large-scale irrigation systems, where invidual farmers have taken up irrigation activities using some of the available land, water, infrastructure and market resources. As a result, in many cases there is no hard border between the different irrigation types or between strictly farmer- or government initiated irrigation development.

Table 6 Correlation between irrigation typologies in Mali (DNGR, 2016)

Classic irrigation typology (Azouggagh, 2001)	DNGR-PNIP typology (PNIP, 2012)	Dakar forum typology 2013	Initial SIIP typology
I. Gravity or surface irrigation	Group 1: River irrigation systems - Village Irrigation schemes (PIV) - controlled flooding	T4. Large public systems	T1. Public irrigation systems
			T2. Village irrigation schemes (PIV)
	Group 2: lowland irrigation (bas-fonds)	T3. Small village irrigation schemes	T2. PIV
			T3. Small collective schemes
	Group 3: pond systems		T4. Individual smallholder irrigation
	Group 4: oueds and oasis water retention	T2. Individual irrigation schemes	T4. Individual smallholder irrigation
			T5. Small and medium agrobusiness
II. Pressurized irrigation A. Drip	Group 5. Small horticultural schemes (PPM)	T1. Improved rainwater management	T7. Spate irrigation T8. Controlled riverbank flooding T9. Controlled lowland flooding

B. Sprinklers		T3. Small village irrigation schemes T2. Individual irrigation schemes	(T4. Individual smallholder irrigation) T10. Oasis schemes

In fact, the infrastructure and market development around government initiated schemes often creates an enabling environment for FLID that attracts individual farmers to develop irrigated production. Around the Office du Niger rice cultivation scheme near Ségou, many farmers started to develop horticultural production on the side using drainage canals. In 1992, workers from the COMATEX textile factory in Ségou successfully requested 50 ha of irrigable land from the government to grow horticultural crops as a side activity. The area has now grown to over a 100 ha as farmers started to produce vegetables around this scheme.

This study focuses on smallholder farmers that manage their plots invidually to grow crops that require investment in technologies for total water control, i.e. not depending on rain or flood water. Following this criteria, ten farmers have been interviewed in the Ségou and Koulikouro regions, which are the priority intervention zones for the PARIIS project. While all farmers interviewed managed their own irrigated parcels and had access to a private well, in some cases the fields were situated on a collective site for rice production with micro dam infrastructure to recharge the aquifer. Farmer's irrigated dry season production on these sites however is managed invidually and relies on a farmer's own investment in wells and pumps.

Farmer typology

Based on ten farmer interviews four types of farmers were identified: constraint and market-oriented farmers, intensive producers and investors. All interviewed farmers explained that they grow a range of horticultural crops, sometimes combined with fruit trees. The most frequent crops are tomatoes, cultivated by 70% of the farmers cultivate, onions (50%), followed by potatoes, okra, chili, cucumber and fruit, each cultivated by 30% of the farmers.

The typology has been developed based on the extent to which farmers are able to develop and invest in their production system. The constraint farmers lack access to water, either because their well dries up by February, because they cannot afford a pump, or both. Market-oriented farmers use motor pumps to grow 2 to 3 cycles per year, yet their level of investment is relatively low as they still cultivate a relatively small surface, spend little on agricultural inputs and rely on family labour only. Intensive farmers on the other hand are in the position to invest by hiring labour, purchase technology and cultivate their fields all year round. Finally one investor was interviewed who benefited from a PCDA loan to invest in solar-powered drip irrigation of large fields of oranges, papayas and melons.

Table 7 : Characteristics of each typology

Farmer type	Crops	Number of campaigns	Irrigated area (ha)	Labor source	Operation costs	Constraint
Intensive producers	Mainly vegetables	Mostly 4	0.81	Hired + Family	High	Information, land
Market oriented	Vegetables	2 to 3	0.65	Family	Medium	Finance
Constraint producers	Vegetables	1 to 2	0.43	Family	Low	Water, finance

Investor	Papaya, oranges, melon	2	3.50	Hired	Medium	Finance

Constraint producers

The constraint producers mainly cultivate small perimeters since they irrigate by hand and do not have a permanent water source. The average irriagted area in Table 7 is not representative due to one outlier who cultivates a large area with a very large family, but faces similar barriers as the constraint farmers. Farmers in this category cultivate the land with family labour during the dry season only, as the rainy season is required for staple crop production. Due to financial constraints farmers could not invest in permanent water sources or pumping equipment. Operational expenses are low since this is limited to the purchase of seeds. Fertilizer are self-produced on the farm in the form of manure and labour comes from the family, so that no out-of-pocket costs are involved. The main constraint for this type of farmers is access to water and finance.

Market-oriented producers

The market-oriented producers can be characterized as low input high output vegetable producers. Farmers in this categoary use a petrol pump to grow 2 to 3 cycles of vegetables per year. Their operational expenses are higher than the constraint producers due to the cost of petrol and maintenance, yet their overall expenses remain relatively low. This is because the market-oriented producers produce their own fertilizer, purchase a limited amount of chemicals and rely completely on family labour to irrigate and cultivate the crops. Despite the low operational expenses their turnover and productivity per hectare are high, which points at good technical and market knowledge. Market-oriented farmers cultivate a larger surface than the constraint farmers (0.65 ha on average), but a smaller area than the intensive producers and investor, and only during the dry season. The main constraint for this type of farmers is finance.

Intensive producers

The intensive producers are featured by intensive year-round production of irrigated vegetables, in some cases combined with fruit trees. Farmers in this category invest a lot in their production system and cultivate larger surfaces than the finance constraint market-oriented producers. Operational expenses are high as they invest heavily in labour, inputs for farming and irrigation. The intensive producers irrigate mainly with petrol pumps or, in one case, with an electric submersible pump powered a generator. Due to the intensive usage, irrigation comes with high petrol and maintenance costs. This type of farmers is the only type that purchases fertilizers instead of producing it. The intensive farmers cultivate irrigated vegetables during 4 campaigns per year, including during the rainy season. According to the four interviewed intensive producers, the main barrier to expand their production system are a lack of information and irrigable land.

Investor

The investor has obtained a large amount of capital and used this to invest in the planting of 3 ha of fruits trees and the purchase of high-end technology: a deep reinforced well (22m), Grundfos solar submersible pump, elevated tank and drip irrigation system. The cost of the well, pump and tank combined was 8M FCA or 15,000 USD. This type of irrigation technologies is a typical set-up provided by support projects. In this case the farmer had obted for a loan from the PCDA program in 2008 and reimbursed the amount through installments over a three years' period. The farmer has used the acquired infrastructure to develop a high value production system that generates high revenues. Instead of a range of vegetables as cultivated by the other producer types, this farmer focuses on commercial production of papaya, oranges and melons. The main contraint according to this farmer is finance.

Besides to the differences, the different farmer types actualy show a lot of similarities in terms of their crops grown and production systems as a whole. In practice, both the constraint producers, market-oriented producers and intensive producers self-consume a part of their production. Furthemore there was no difference in relation to the sales strategy between farmer types, and all farmers except the investor use furrows to irrigate. The marketing strategy is expected to differ more amonsgt different farmer types in areas that are farther away from Bamako, as in that case more resources would be required to access the capital or regional markets.

Figure 11 Application of manure and straw as an alternative to purchased fertilizer

3.2 Farmer business cases and non-monetary benefits

This chapter shows the inputs and outputs of the irrigated production systems per identified farmer category. Table 8 presents the costs of agricultural inputs, irrigation expenses and hired labor. The implication of family labor has not been accounted for since the objective was to analyze the out of pocket costs as an element to differentiate between farmer types. The results indicate that important differences exists with respect to farmers' strategies and means of investment.

Table 8 : Costs per hectare according to the farmer's type

USD[2] / Ha	Seeds	Ferti-lizer	Chemicals	Petrol	Mainten-ance costs	Labour irrigation	Labour production	**Total expenses (USD/ha)**
Intensive farmers	590	447	182	346	36	605	299	2,505
Market oriented	226	-	13	264	6	-	-	509

[2] A rate of 1 USD = 536.42 FCA (https://www1.oanda.com/ visited 02/06/21) has been used for all USD/FCA conversions in this study.

Constraint producer	72	-	250	36	1	-	-	360
Investor	89	186	-	-	-	149	93	518
Average	**344**	**222**	**184**	**159**	**121**	**273**	**716**	**1,404**

In Table 9 the productivity (kg/ha) is shown for seven farmers. The very high chili production by farmer number 9 was obtained through a long crop season from June till December, i.e. partially during the rainy season. Apart from this specific case, the productivities correspond relatively well to the historic FAO records for Mali[3], with maximum a factor three difference.

Table 9 Productivity (kg/ha) of different crops per farmer

Farm	Onion	Potato	Chili	Okra	Tomato	Capsicum	Cucumber	Melon
1	20,000	12,000	20,000					
2			12,000	6,000	6,000	14,000		
3	16,667							
4		40,000						
5				8,000	12,800		19,200	
7								14,000
9			41,667	8,889			26,667	
10	24,000	40,000						
FAO Mali	19,444	19,705	7,257	10,972	12,647	N.A.	12,171	5,025

Table 10 shows the average, maximum and minimum revenues per crop per hectare based on the data of ten farmers. The full overview per farmer is available in Annex B. The table shows that the revenue per hectare is featured by a larger variation than the productivity per hectare, as a result of volatile market prices. For okra the market price varied fom 150 to 750 FCA/kg, for chilis from 200 to 1,250 FCA/kg and for tomatoes from 120 to 800 FCA/kg. Combined with differences in productivity, see the example for chilies in the paragraph above, this can lead to very large differences in revenue per hectare from one season to another. The results per hectare are high, however it should be noted that except for the investor type, farmers generally irrigate areas that are much smaller than one hectare. The figures per farm as presented in Table 11 correspond a lot better to the reality. Yet, the high revenues and profit per hectare are a good indication of the potential of FLID compared to large-scale systems. Because of the large variety of crops, farmers can respond to market trends and benefit from higher prices. However, this is likely to be different in areas that are farther away and less connected to markets as the studied areas.

Table 10 Revenue per crop per hectare (USD/ha)

Rev USD/ ha	Onion	Potato	Chili	Okra	Tomato	Capsicum	Watermelon	Cucumber	Melon	Average[4]

[3] https://www.fao.org/faostat/en/#data/QCL

[4] Average of the presented crops excluding chili as its high revenues are not representative for one season considering the large growing and harvest period (7 months) by some of the farmers.

Average	11,733	16,902	44,234	7,536	4,834	5,872	8,948	3,187	15,659	9,334
Low	10,486	7,830	6,711	2,517	746		746	2,436		4,127
High	13,422	24,235	97,094	10,771	10,976		17,151	3,937		13,415

In Table 11 the average revenues, expenses and profit per season per farm are presented for each farmer category. The results show clear differences both in overall results per farmer as well as per hectare. In terms of total revenue it is clear that constraint producers make a very low revenue due to the small fields or a very extensive production strategy. Investors have the highest revenue, followed by the market oriented farmers. The high revenue of the market oriented producers results from the fact that farmers in this category could sell chilies at a high market price. In terms of operational expenses it is clear that intensive producers invest most in their sytem, which goes at the expense of their profit per season. Since the market oriented farmer rely entirely on family labor that has not been accounted for, in reality the economic results of the market-oriented and intensive producers do not differ as much as shown below. The investor is a one-of-a-kind in the sense that his expenses are very low because he uses a solar-powered instead of a petrol-powered irrigation system. As a result the profit per hectare of this category is the highest, although this could change once depreciation costs of the system are taken into account, as shown in chapter 7.2.

Table 11: Financial overview according to the farmer type, per season

	Revenu/farm USD	**Expenses/farm USD**	**Profit/farm USD**	**Profit/ha USD**
Intensive farmers	4,533	1,784	2,749	5,216
Market oriented	7,402	341	7,061	10,668
Constraint producer	399	79	389	3,449
Investor	8,203	259	7,943	15,887
Average	**4,234**	**915**	**3,760**	**7,221**

Non-monetary benefits

The development of irrigated production in the studied areas illustrates the importance of non-monetary benefits. An important reason to start irrigated crop production is to have a job and income source when there are no other stable opportunities, and to follow the market. In Ségou many people turned to horticultural production after the tobacco factory closed and the market for tobacco produce disappeared. In Koulikoro the closure of the cotton oil factory HUICOMA drove many people into horticultural production. These events show that FLID can be an important safety net in case of economic shocks.

Irrigated vegetable production is also an important strategy to complement existing economic activities. As explained in chapter 3.1, it was the workers of the COMATEX textile factory in Ségou that advocated for access to an irrigation scheme. After obtaining this they developed their horticultural production systems to complement their salaries with additional income and food. Interviewed farmers indicated that they irrigate in order to increase their income and have food available for consumption. In fact, all interviewed farmers have other income sources next to their agricultural production system. Figure 12 shows that farmers mainly work on animal husbandry and other activities related to agriculture, such as seedling production or agricultural trade. As shown in chapter 9, additional income sources could also be an important enabling factor for farmers to start irrigated production.

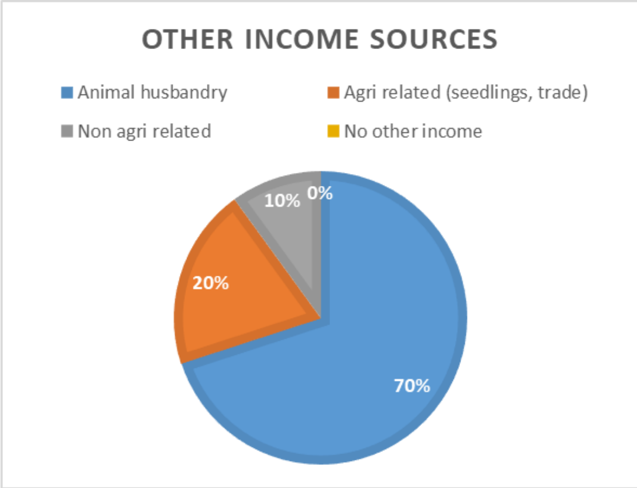


Figure 12 Other income sources of interviewed farmers

4. Policy and legal

This chapter focuses on the policy and institutional environment that shape farmers' access to water and land, followed by an overview of specific support initatives for farmer-led irrigation. Other policy and institutional aspects related to access to finance, technologies, knowledge and markets are discussed more extensively in the next chapters.

4.1 Access to land and water

Irrigation accounts for 90% of all water use in Mali. The allocation of agricultural water is the responsibility of the Ministry of Agriculture. According to the 2002 Water Code all surface and groundwater resources are owned by the state, with the exception of small surface water bodies. Permits are required for the extraction of water for non-domestic purposes above a certain volume. In the formal irrigation schemes the payment of permits is generally enforced. Apart from the permits, access to water is mainly linked to the rules and customs that determine access to land.

The Malian constitution recognizes private land ownership, which can be secured through a formal registration process. Yet, in rural areas the registration of land is practically non-existent, and land is owned by the state by default. Access to rural land is governed through customary use rights. The Land Code formally recognizes customary land rights, amidst the following plural forms of recognized land tenure arrangements. 1) Formal ownership can be obtained through registering a private land title. 2) Lease arrangements between companies and the state for periods of 50 years. 3) Rural concessions by the government. In this case customary users may get compensated for expropriation. 4) Permit rights issued by the state or local governments for residential use or for the use of irrigated land. Permits are a common tenure construction in publicly funded irrigation schemes. 5). Customary rights to land for housing or farming for groups or individuals. Customary rights can be issued through a range of arrangements including loans, leasing, pledging and inheritance, but not through sales. 6) Open access rights of communal pasture and fallow land for pastoralists (USAID, 2020).

Customary rights cover the large majority of rural land in Mali. Land rights can be inherited by male members of the family only. The male head of the group or family decides how to allocate land according to the above arrangements. In some communities, women are granted access to small gardens, yet as a result of the male inheritance principle and the importance of the continuation of patriarchal lines, USAID (2020) mentions that overall access to land for women is limited under customary arrangements and shows an estimate that only 20 percent of women engaged in agriculture have access to land. In general, sociocultural factors make that women in Mali face a very high workload, low access to productive assets and limited participation in decision-making. As a result, Mali ranks 50 out of 52 countries in the ADB Gender Equality Index (Sy and Niaré, 2017).

The constitution of Mali specifically prohibits gender discrimination and states that everyone has equal rights and obligations. Yet less favored groups have difficulties to access the formal legal system. First of all, literacy rates of men and women in Mali are respectively 50 and 27 percent (UNESCO, 2019). This low literacy not only affects access to the legal system, but also access to knowledge and finance for a large part of Mali's population. Furthermore, the formal legal system is difficult to access for people who don't know the functioning of these institutions and don't have the resources to travel and claim their rights. Women are especially affected by this skewed access to the former legal system and therefore rely on the customary rules and practices, which limit their access to land and water resources (USAID, 2020).

In contrast, Nkonya et al. (2020) conclude that women in Mali (and Uganda) are as likely as men to inherit land or to get land assigned by a village chief. The conclusion is based on an analysis of the LSMS-ISA (2017) survey dataset covering 5,013 and 4,482 plots managed by respectively male and female farmers distributed over the eight regions of Mali. The data show that men and women make use of similar acquisition strategies for irrigated plots, i.e. inherited land, or land provided by a customary chief, family member, or government. A slightly smaller percentage of female farmers could benefit from land allocation from farmer groups compared to men. The study also showed similar irrigated plot sizes, respectively 2.5 and 2.2 ha for men and women[5]. Nevertheless, despite the similarity in land acquisition strategies there is still an important difference, as 5% of the male respondents indicated to have irrigated plots, compared to 3% of the female respondents. Yet we can conclude from this study that while women's access to land in general is very limited (see USAID, 2020), access to irrigated plots is less gender skewed.

The main lesson on access to land provided by Nkonya et al. (2020) is that farmers use different strategies to acquire plots for irrigation compared to plots for rain-fed crops, see Figure 13.

[5] Since the survey was implemented through sampling households and all corresponding male and female managed irrigation plots were surveyed individually, there is no reason to believe that female irrigators were targeted more than male irrigators and that the indicated share of male and female farmers is not representative. However, it is unclear from the study whether female respondents responded to the question about plot acquisition on their own behalf or on behalf of the household.

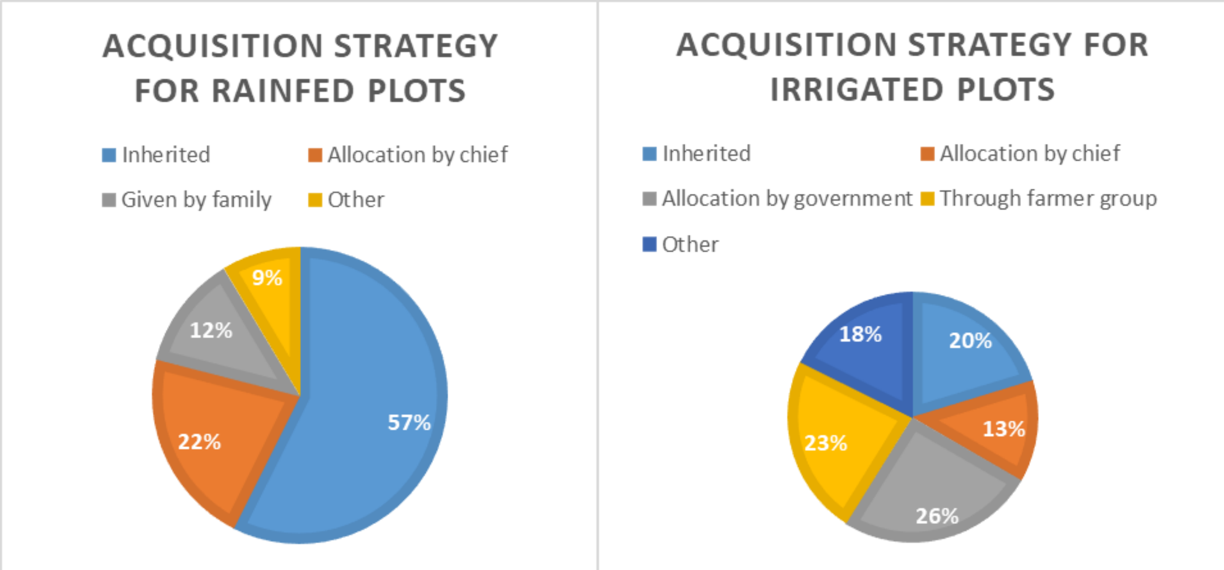


Figure 13 Acquisition strategies for rain-fed and irrigated plots. Adapted from Nkonya et al. (2020)

This diverse set of strategies that can be used to acquire irrigated land is likely the reason that women are less affected by unequal land rights for irrigated fields than for rainfed fields. The fact that the largest share of acquisition is through government allocation points at the large role of government investments in large-scale gravity schemes for rice production, which have been made colonial times and continue to date. Leasing contracts between the government and farmers are typical in these schemes, and more equally accesible for men and women than the inheritance arrangements which are common for rain-fed plots. The allocation of irrigable land by the government is therefore an opportunity for more gender-inclusive rural development.

Furthermore, sociocultural factors weigh heavily on women's status in the family and in society, and limit their capacities to make decisions and participate to community life on the same level as men. Thus, Mali ranks 50th out of 52 in the Gender Equality Index in Africa conducted by the African Development Bank (ADB). On the global level, according to the United Nations Development Programme (UNDP), in 2011 it was classified 143rd out of 146 countries.

Leasing arrangements of irrigated land depend on the area, plot size and parties involved. In the scheme of the Office du Niger, companies have been allocated lease contracts for 30 to 50 years, while individual farmers are offered yearly lease contracts with gravitational water allocation, as well as simple farming permits. The payment of water fees is included in the lease contracts (USAID, 2020) and its management is assured by the Office du Niger state agency. One of the interviewed intensive producers indicated he rents land from the government at a cost of 30,000 FCA/ha (56 USD/ha) per season.

Access to land and water resources is a common cause for conflicts between crop farmers and pastoralists. Land and water rights are formally assigned by local governments. The fact that the outcomes are not always in line with customary laws and practices, sometimes creates confusion and exacerbates the conflict (USAID, 2020).

4.2 Policies to support FLID

Various policies and projects to secure inclusive access to land and water have promoted by the government and NGOs. The Agricultural Orientation Law has the objective to promote stable, modern and competitive agriculture based on family farming (Government of Mali, 2006). The law looks to create equitable access to land resources and contains a focus on support for women, youth and vulnerable farmers. The Agricultural Land Law (Government of Mali, 2017) states that at least 15 percent of the land in state managed irrigation schemes must be allocated to women and youth. Yet, as the communes have limited resources to facilitate or enforce the allocation of land or water rights, the use of customary rights prevails in rural areas.

USAID supports a range of initiatives that strengthen land tenure rights in order to increase agriculture growth and gender inclusion. Part of the strategy relies on strengthening the local government to register customary land rights and manage land tenure issues. Next to this USAID advocates for education about the rights of women in formal laws in an attempt to change customary norms and practices (USAID, 2020). Furthermore, USAID programs focus on the development of markets and sustainable intensification of smallholder farming.

The Malian government as well as most NGOs including GIZ and USAID to focus on investments gravitational irrigation schemes to improve agricultural production food security. Though government-led, it is individual farmers that decide to lease land in these schemes, make use of the gravitational infrastructure and develop their production systems. Due to the government or donor managed nature, these projects can have beneficial impact on access to land for female farmers, which might be more difficult to achieve in FLID approaches.

An example is the Alatona Irrigation Project by the Ministry of Agriculture and the World Bank and supported by the Millennium Challenge Corporation (MCC) which aims to reduce poverty by economic growth through an increased irrigation scheme north of the Office du Niger area. In the first phase 5,200 ha were developed of which 37 percent was allocated to women. In the follow-up phase 9,000 ha were covered. The project has an innovative component to strengthen land tenure rights as farmers will receive formal land titles and right to sell the land, as an alternative to the lease arrangements in the Office du Niger. Next to this, the infrastructure and water permits are managed by farmer associations instead of the government, which have been strengthened through the project[6].

Other recent irrigation scheme initiatives are the National Program for Small Scale Irrigation (PNIP), which has developed 37,000 ha of irrigated land in Tombouctou and Mopti regions from 2015-2018 and planned another 19,000 hectares in the 2019-2022 period (DNGR, 2019), and the IPRO-IRRIGAR Koulikoro project that developed 3,300 ha of small-scale irrigation projects in the Koulikoro Region between 2015 and 2018.

To date, the interventions of the state and its partners are primarily based on the community approach through the development of lowlands/plains, village irrigation schemes and community market gardening schemes for women. However, PAPAM, PCDA and PARIIS, funded by the World Bank, have components based on individual irrigation. PCDA and PAPAM have already completed their first phase. In the PARIIS, Mali is moving from the pilot phase to the implementation phase with a specific interest and commitment to develop support mechanisms and subsidies targeting individual irrigators.

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[6] https://www.poverty-action.org/study/irrigation-and-property-rights-farmers-mali

5. MARKETS

5.1 INPUT MARKETS

Farmers' investment in inputs for their farms depends on their financial capacity. Inputs needed are seeds, fertilizers, and crop protection products. Various types of qualities are available on the market for different prices. Farmers with more financial means are able to purchase inputs of better quality. All interviewed farmers indicate that they buy their agricultural inputs in the regional towns. Seeds are available in several shops in most towns. Some seeds are produced in Mali, but the majority is imported from abroad via international companies that have branches in multiple countries. Different seed types for the same crop offer different degrees of resistance to pest and diseases. Similarly, different types are more or less adapted to the Malian context which impacts on the productivity and vulnerability to pests.

Chemical fertilizers can also be purchased in shops in the main cities, yet experts[7] indicate that most farmers consider this type of input as too expensive and that they prefer to use organic material from animal production. Farmers who own animals usually produce their own manure. Pesticides are normally purchased only when pests arise and if the farmer's financial capacity allows for it. Vegetable production usually takes place during the dry season because disease and pest pressure are more manageable from the farmers. Nevertheless, plagues can still occur during the dry season, sometimes with a high impact on a farmer's yield.

Farmers sometimes group themselves in an association in order to reduce the cost for purchasing inputs. This way, even farmers with limited financial capacity could get access to inputs as joint purchasing in bulk enables them to benefit from lower prices. Next to this, associations are in a better position to receive government or donor support to purchase inputs. Being member of an association also opens a way to access loans that would be inaccessible for individual farmers. In this case, the association is the warrant of the loan towards the financial institution.

5.2 OUTPUT MARKETS

Experts indicate that in most situations, farmers self-consume a small part of their production (5 to 10%) and sell the rest. As for the interviews, 80% of the farmers answered that they sell most of their production at the farm-gate in bulk. At the period of the harvest, traders come to the main production areas with small trucks and buy the products directly from the farmers' fields or at a place in the village. Farmers usually sell their production individually. Location is more important than the farmer category for the place of selling. Farmers with plots close to urban areas sell their products directly on the market, while others sell to traders from the farm-gate and a small portion at the village markets.

The consulted experts mentioned that the price variation of vegetables on the market in very high, and linked to the season. Many small-scale farmers do not have access to storage and transformation facilities. As a result, a lot of perishable products become available on the market at the same time which makes prices temporarily going down drastically. Farmers who

[7] Experts interviewed for this section are Sidy Cheick Diallo, a Malian small-scale irrigation expert working in the PARIIS project, and Huub Muntstege, a senior small-scale irrigation specialist based in Mali.

are forced to sell during such moments receive a very low revenue for their production. This marks a large contrast with the few farmers who manage to store their produce and sell once the harvest period is over and prices are higher again. Sy and Niaré (2017) indicate that even for nonperishable crops like cereals, farmers face difficulties storing produce due to the high costs of the infrastructure and guarding. They add that there are also very little product transformation facilities in Mali, which large consequences for the price of perishable products like mangoes and vegetables. The lack of finance is mentioned as the main reason for the lack of development of the agro-industrial sector.

5.3 Farmer associations

According to the interviewed experts, farmer associations currently play a limited role in the market. The number of farmer associations in Mali is limited compared to other countries in West Africa. However, some associations exist for specific types of farmers or products. Associations for individual farmers are mainly established when farmers perceive an immediate common economical interest. For instance, farmers set up an association to purchase farming inputs, or to obtain a loan. Most associations set up by farmers that each have their own land, are short-term structures. The organizations remain unstructured and activities rarely develop further than its initial common economic interest.

This is different in areas where farmers need to share a piece of land, a water source, or a pumping technology, since in such a context associations become essential. Associations can form a tool for the farmers to organise themselves and be a prerequisite to obtain and manage the land they use or the technology they share. In this case, associations are very common and often serve multiple purposes including organisational, economic and social ones.

Finally, there are some farmer organisations structured around a certain type of crop. They intend to provide extension services and financial advantages to farmers. One example is the “Potato interprofession”, which has been established and institutionalised by the PCDA project that ran until 2015. However, some experts criticise its success and point at the absence of replication of the structure in other areas or for different types of crops as an argument for their scepticism.

Hence, farmer associations in Mali exist either to make use of an immediate opportunity or as a long-term structure to obtain and manage shared land and infrastructure. A role of farmer associations in the output markets, to support knowledge exchange, or to provide access to storage and transformation facilities is lacking. Examples of strong farmer associations that import agricultural inputs and provide training and services to their members exist in Senegal and Burkina Faso, but are absent in Mali. Strengthening farmer associations to increase its added value could be an opportunity to improve the enabling environment for individual farmers, especially with regards to market and knowledge aspects.

6. Knowledge

6.1 Informal communication

No matter their situation, farmers need to remain aware of the evolutions in the sector, including the market, the available technologies and practices to remain competitive. According to the two experts interviewed, most farmers keep themselves updated on the current farming practices, and technologies available by observing their neighbors. Most farmers know about market prices through informal interactions, by asking the prices to other farmers and vendors.

As a result, information and market insights remain very local, and only spreads slowly around the country. Some curious individuals manage to travel to other regions to observe the practices and inspire themselves. These kind of innovators play an active role in informal knowledge sharing, which has an importance that may exceed formal communication channels.

The radio is another medium for farmers to obtain information on a national or local level about crops and farming. Some farmers use radio programs on topics such as pest management or irrigation technologies to inform themselves on the developments in the sector. Yet, the experts indicated that the impact of this type of diffusion remains limited because of the large diversity of farming types and landscapes in Mali, which makes it difficult to air nationally relevant information.

6.2 Institutional/formal processes

The government and farmer associations are not much involved in knowledge sharing processes, see also chapter 5. The notable exception to this situation are the farmers' associations organized around products, like the "potato interprofession". Even if their success is criticized, they certainly play a role in gathering and capitalizing on the experience of potato farmers in the area and are one of the only recognized institutional sources of information.

Extension workers from the state are present in the field with the role to support small-scale farmers. Nevertheless, the number of agents and available resources for transportation and salaries are limited. Next to this, the focus of the extension services is traditionally oriented towards rain-fed crop production. Sy and Niaré (2017) add that extension services do not take into account women specificities and their lack of time due to the overload of household work, which results in the fact that men provide and receive most of the trainings. Hence, the contribution by the extension service to inclusive farmer-led irrigation development is limited.

Knowledge exchange amongst farmers effectively happens in a rather informal way. Despite its merits in driving FLID, experts highlight that it also comes with a certain number of limitations. Disinformation and old habits could become an obstacle to the introduction of innovative farming practices or technologies. Despite the attempts to institutionalize the spread of information to farmers, currently most farmer associations and extension workers do not have the resources to inform and reach the farmers. It is the contribution by certain individual farmers and informal local interactions that prevail in knowledge development and information sharing amongst farmers in Mali.

7. Technology

7.1 Irrigation technologies in use

Water sources

Irrigation in the four visited zones mainly takes place around the Niger river and its tributaries. While a lot of farmers pump directly from the river after the rainy season, shallow groundwater is the main water source for invidual farmers. Even farmers with fields next to the river use hand-dug wells to irrigate during the hot season, as an alternative or complementary to using water from the receding river. Table 12 shows the principal water sources used by farmers in the four studies cercles.

Table 12 Water resource used per studied zone

Cercle	Water resource	Infrastructure
Ségou	River, drainage canals, groundwater	None, hand dug wells, shallow boreholes
Barouéli	River, groundwater	None, hand dug wells, shallow boreholes
Koulikoro	River, groundwater	None, hand dug wells, shallow boreholes
Dioïla	Low land areas with groundwater at 4-7m.	Hand dug wells and shallow boreholes

Through a country-wide study, Nkonya et al. (2020) showed that surface water is in fact the most commong water resource used for irrigation in Mali, especially in the regions of Ségou, Mopti, Kayes, Tombouctou and Gao, see Table 13. The region of Sikasso is an exception as it relies mainly on groundwater. Based on the findings in Koulikoro and Dioïla, both situated in the Koulikoro region, the use of shallow groundwater for irrigation in Koulikoro, and possibly also in Ségou, seems underestimated[8].

Table 13 Source of water for irrigation per region (Nkonya et al., 2020)

Region	Rivers	Dams	Groundwater	Lakes and ponds	Other
			Percent		
Kayes	0.0	0.0	0.0	66.7	33.3
Koulikoro	0	0.33	0	0	0
Sikasso	5.6	5.6	83.3	5.6	0.0
Ségou	20.8	73.6	3.1	0.0	2.5
Mopti	84.6	6.2	1.5	7.7	1.5
Tombouctou	96.2	3.8	0.0	0.0	0.0
Gao	87.5	0.0	0.0	12.5	0.0
National	54.0	35.5	5.8	3.0	1.9

The interviewed farmers using groundwater made use of a variety of hand-dug well types. In stable clayey soils simple wells are dug without reinforcement, ranging from 1 meter up to 15 meters depth with a diameter from 0.5 to 1.5 meters. In other zones reinforcement is needed which increases the cost of the structure. The simple wells often need to reconstructed every year. For both the simple and reinforced wells the water column in the dry season is generally not more than 1 or 2 meters which points at a limited water storage volume. As a result, farmers using motorpumps need to dig various wells on one field in order to have sufficient water available: 5 wells per hectare is no exception. Table 14 shows the technical and financial characteristics of different water sources that could be used for irrigation. Since the size, materials and yield of hand-dug wells depend on the local soil and aquifer characteristics, the cost and irrigated area per well varies a lot from one place to another.

[8] In fact the figures for Koulikoro in Nkonya et al. (2020) contain an error as it does not add up to 100%.

Table 14 Technical and financial characteristics of water sources for irrigation

Source + depth	Water volume stored (m³)	Cost range (USD)	Average Cost (USD)	Irr area (ha)	Cost/ ha (USD)[9]
River, stream, pond	N.A.		0		0
Simple hand-dug well 10-15m	0.4-3.5	90 - 160	128	0.03-0.5	350
Reinforced hand-dug well 5-15m	0.2-2	65-560	364	0.03-0.5	1719
Large diameter reinforced well 15m	3	6525	6525	0.5	13049
Manual drilling 15m	N.A.	280	280	1	280
Motorized (auger) drilling 15-25m	N.A.	730 - 913	820	1	820
Machine drilling 100m	N.A.	8389	8389	0.5	16778

The large diameter reinforced wells or boreholes were not encountered on the studied farm fields, so data has been collected from suppliers to complement the overview. Manual drilling services are available in the Office du Niger area in Ségou and in the internal Niger delta in the Mopti region. The main focus of these enterprises is on well contruction for drinking water purposes. Though there are some examples of manually drilled wells used for irrigation in Niono (Office du Niger area), most farmers use hand dug wells. In general, only farmers with more than 0.75 ha of irrigated land invest in boreholes. The relatively low price and suitability for the soil and water characteristics around rivers and in the interior delta make manual drilling a high potential alternative for smaller fields too. On average, manual drilling is featured by the lowest construction costs per hectare and a longer lifespan than hand dug wells.

Figure 14 Reinforced well of 4-5m depth (cost 35,000 FCA) and spray cans to irrigate

[9] The cost per ha was calculated based on the average construction cost and actual irrigated surface indicated by farmers using this type of water source and/or based on data from service suppliers and experts.

Pumps

Nkonya et al. (2020) show that on a national level, most irrigation takes place through gravity systems, with the Office du Niger accounting for the largest part. It shows that motor pump irrigation is the most common option in the Mopti, Tomboctou and Gao regions, while irrigation in Koulikoro and Ségou relies mainly on gravity systems. However in Mali, including in Koulikoro and Ségou, the systems that are created and fully managed by individual farmers rely on manual water withdrawel or pumps to get water on the field during the dry season.

The choice of the pumps and irrigation technology mainly depends on the water source, size of the field and the financial capacity and preference of the farmer. In the past, farmers started to irrigate manually right next to the rivers and streams, using calabashes, buckets, spray cans, jerrycans, etc. Currently most of the farmers use petrol pumps in order to irrigate larger areas and areas farther away from the river. From the interviewed farmers, most of the constraint producers irrigate manually, while the market-oriented and intensive producers use a motor pump and the investor uses a submersible solar pump. Next to this, one of the intensive producers uses a submersible pump with a generator. The manual and motor pump irrigators are concentrated in the zones close to the river and streams and in the low lands with very shallow groundwater. The solar submersible option combined with a large diameter well or borehole is mostly encountred in drier zones close to the city.

The study by Nkonya et al. (2020) shows that in Sikasso 83 percent of the irrigators use bucket irrigation and concludes that: “with regard to type of irrigation technology, the predominance of bucket irrigation in Sikasso is puzzling”. It should be noted that the potential use of irrigation technology is highly dependent on the available water source. A potential reason for the low use of motorpumps in Sikasso could be the fact that the primary water source is groundwater from hand-dug wells (also in 83% of the cases). As the water column is generally not more than a meter, the yield of these wells is often not sufficient to sustain a motorpump during multiple hours. As a result, purchasing a motorpump would only enable a farmer to increase his irrigated area if he can increase the number of wells too.[10] The fact that there is a clear relation between the water source and the irrigation technology is also demonstrated by the fact that in all areas where the use of motor pumps is predominant, i.e. Mopti, Tomboctou and Gao, river water is the major source for irrigation.

In Table 15 an overview is provided of the purchase costs, average area and expected lifespan per pump type, based on its actual usage indicated by farmers and the information from technology suppliers. The full list of technologies used to compile this table is available in Annex A. The purchase cost and cost per hectare are the lowest for manual irrigation and fuel powered pumps. The cost of solar-powered submersible pumps increases with the depth of the water and the required output and capacity. The expected lifespan for solar pumps depends on the quality of the water and installation.

[10] Another factor that could explain the choice of technology is the water depth. As shown by Westra (2020) the largest potential for irrigation in the Sikasso region is through groundwater beyond suction depth (7-25m), which is generally not accessible for motor pumps.

Table 15 Purchase cost and irrigated area per pump type

Pump type	Cost range USD	Average cost USD	Average ha / pump[11]	Cost/ha USD	Expected lifespan
Bucket	10	10	0.14	71	N.A.
Motor pump (3-5 HP)	350 - 560	445	0.61	729	2-3 year
Solar surface pump (120W)	1,120	1,120	0.21	5,227	5 year
Solar submersible pump 10m (250-750W)	1,000 - 3,000	1,766	0.44	4,053	1-3 year
Solar submersible pump 30m (1 – 2.5 kW)	3,500 - 4,500	3,912	0.66	5,952	1-3 year
Electric submersible pump	750	750	0.5	1,500	1-2 year

Irrigation equipment

The fuel powered irrigation systems visited during this study are all combined with a furrow system or hose, see Figure 15. In most cases farmers use PVC pipes to guide the water into the furrow system. None of the farmers uses a fixed buried pipe system which is referred to as Californian irrigation. Next to this, the manual irrigators use spray cans and the investor uses a drip system with elevated tank. Mamary et al. (2018) report the use of drip, sprinklers, californian systems, canal and manual irrigation in Mali. The interviews with technology suppliers confirmed the availability of exactly this range of technologies and systems. Some technologies that are available in surrounding countries like Senegal or Burkina Faso are not yet available in Mali. This is the case for the spray tube technology, as well as a larger variety of solar irrigation pumps. Considering the recent rapid market development of these technologies in other countries, it is expected that both will also become available in Mali soon.

Figure 15 Irrigation with a hose

Table 16 Cost and lifespan of irrigation application systems

Application system type	Cost range USD	Average cost USD	Average ha / system	Cost/ha USD	Expected lifespan

[11] The average area for solar pumps was calculated using the provided yield by the supplier for the given total head and a gross water need of 70 m^3/day, which is the gross water need in Ségou in the most critical month (May) based on the average water efficiency of sprinkler and drip irrigation.

Furrows and pipes	10-470	233	0.5	466	2 years
Californian system	650-1,200	932	0.75	1243	5 years
Sprinkler	15-5,600	5593	1	5593	3 years
Drip	560 - 10,250	6245	0.53	10719	3 years

In Table 16 the available irrigation technologies in Mali are listed, with corresponding cost information. The detailed list of prices and specifications can be found in Annex A. According to Nkonya et al. (2020) access to irrigation technologies in Mali is quite low. On the other hand, compared to the outcomes of the FLID assessment in Chad, suppliers in Mali offer a much larger variety of technologies, including various types of solar pumps, different manual drilling services as well as a range of sprinkler and drip technologies.

7.2 Cost benefit analysis

Farmers interviewed within this study mainly irrigate using motor pumps and almost all practice furrow irrigation. Yet technology and service providers in Mali offer a much wider range of technologies. The full overview of the available technologies, specifications and prices is presentented in Annex A. This chapter shows a cost benefit analysis of five complete irrigation set-ups that could be used in different farming contexts in Mali, according to the water access, field size, investment capacity and preference of the farmer. It should be noted that in reality, a farmer may already have some of the water sources or technology, purchase only one technology at a time, or make different combinations. The exercise is therefore a theoretical one, with the objective to show the different costs of water mobilization according to the water depth and technology choice. As a first step in this analysis, Table 17 shows the investment cost per farmer for each technology, as well as the investment and depreciation costs per season, assuming two seasons per year. With the exception of spray tubes that are not yet on the market in Mali, the different set-ups are based on technologies that are currently available in the country.

Table 17 Investment and depreciation costs of five irrigation set-ups

Technical set-up	Investment cost (USD/farm)	Investment cost (USD/ha)	Expected lifespan (years)	Depreciation cost (USD/farm/ season)	Depreciation cost (USD/ha/season)
Fuel pump simple 0.5 ha					
Simple hand-dug well	175	350	1	87.38	175
Motor pump	365	729	2.5	72.94	146
Pipes	233	466	2	58.26	117
Total investment	**772**	**1,545**		**219**	**437**
Fuel pump promoted 0.5					
Reinforced hand dug wells	860	1,719	10	42.98	86
Motor pump	365	729	2.5	72.94	146
Californian system	621	1,243	5	62.14	124
Total investment	**1,846**	**3,691**		**178**	**356**
Solar surface pump 0.2 ha					

Simple hand dug wells	70	350	1	34.95	175
Solar surface pump	1,120	5,227	5	112.00	523
Pipes	93	466	2	23.30	117
Total investment	**1,283**	**6,042**		**170**	**814**

Solar submersible 0.4 ha

Manual drilling 15m	280	280	10	14.00	14
Solar submersible pump	1,808	4,218	3	301.30	703
Californian system	497	1,243	5	49.71	124
Spray tubes (unavailable)	522	1,305	3	87.00	218
Total investment	**3,107**	**7,046**		**452**	**1,059**

Deep solar pump 0.4 ha

Machine drilling 100m	8,389	16,778	10	419.45	419
Solar submersible pump	3,398	7,928	3	566.25	1,321
Drip irrigation	4,288	10,719	3	714.61	1,787
Total investment	**16,074**	**35,425**		**1,700**	**3,527**

The results of the table above show that the investment needed for fuel pump systems is lower compared to solar-powered systems, although for small solar surface pumps with less requirements on the quality and quantity of the water source the total investment cost could be in the same range as petrol pump systems. Due to the lower output however, the investment costs per hectare are higher for solar powered systems in all situations. While the simple petrol pump set-up has the lowest investment costs, the depreciation costs for the promoted fuel pump system and solar surface pump system are actually lower.

The solar submersible pump system is featured by a higher cost. However, this set-up enables the pumping of groundwater beyond suction depth (>7m), which is normally not possible for fuel pumps and solar suction pumps. As shown by one of the interviewed farmers, generator-powered submersible pumps could achieve the same. Finally a solar submersible pump on a deep borehole combined with a drip system requires the highest investment. The high cost of this set-up is even more pronounced when expressed per hectare, as the yield of a deep borehole in Mali generally does not provide more water than what is required to irrigate half a hectare.

The investment costs and depreciation costs provided above serve as an input for the cost-benefit analysis in Table 18. This table shows the expenses and revenues per farm based on the output and size of each irrigation set-up. This means that the expenses and revenues have been corrected for the irrigated area. The reference expenses and revenue data used for the analysis follow from the farmer business cases presented in chapter 3.2.


Figure 16 A Robin petrol pump and pesticide spray kit ready to be taken home

Table 18 Cost-benefit analysis of five irrigation set-ups

System	Fuel pump system simple 0.5 ha	Fuel pump promoted 0.5 ha	Solar surface pump 0.2 ha	Solar submersible pump 0.4 ha	Deep solar pump 0.4 ha	Ref data per ha
Water table	0-7m	0-7m	0-7m	7-25m	>25m	
Size irrigated area (ha)	0.5	0.5	0.2	0.4	0.4	
Investment (USD)	772	1,846	1,283	3,107	16,074	
Production costs (USD/season)						
Depreciation cost	219	178	170	452	1,700	
Agricultural inputs	375	375	150	300	300	750
Fuel[12]	80	60	0	0	0	159
Pump maintenance[13]	61	45	24	48	48	121
Labor agronomic	358	358	143	286	286	716
Labor irrigation[14]	137	102	109	164	109	273
Costs + benefits (USD/season)						
Total expenses	1,228	1,118	597	1,251	2,444	
Gross revenue [15]	4,667	4,667	1,867	3,734	3,734	9,334

[12] The pumping charges including fuel, maintenance and labor decrease by 25% when using a Californian system (Abric et al., 2013). This explains the lower cost for the set-up “Fuel pump system promoted”.
[13] Solar pumps need less maintenance than fuel pumps, but if a technician needs to intervene the mobilization costs are higher since there is often no maintenance capacity at local level. Therefore, the maintenance costs for fuel and solar pumps are assumed to be equal.
[14] The flow of a solar pump is about half the flow of the average petrol pump. Therefore, it is assumed that the irrigation labor costs for solar systems are twice as high as for fuel powered systems. For the set-ups: fuel pump promoted and solar submersible a 25% reduction in labor costs was used as the Californian systems and spray tubes required less time. For the set-up deep solar pump irrigation labor costs have been reduced by 50% as since the associated drip system is more efficient and less time consuming.
[15] The gross revenue of 9,334 USD/ha is the average of the different crops as shown in Table 10. (chapter 3.2)

Net revenue	3,439	3,549	1,270	2,483	1,289	
Return on investment (seasons)						
RoI Average revenue scenario above (9,334 USD/ha)	0.2	0.5	1.0	1.3	12.5	9,334
RoI Low revenue scenario (4,127 USD/ha)[16]	0.9	2.0	5.6	7.8	(20.3)	4,127
RoI High revenue scenario (13,415 USD/ha)	0.14	0.33	0.62	0.75	5.50	13,415

The results show that in the average revenue scenario all set-ups lead to a positive net revenue. The return on investment for simple and promoted petrol pump systems are less than one season, whereas for as for the solar surface and solar submersible system the return on investment is respecitively 1 or 1.3 seasons. It is important to note how strongly this is linked to the revenue scenario, as the low revenue scenario which is about half the average scenario, leads to an increase of the return of investment by a factor 6. This can be problematic if a technology is purchased on credit, especially because prices of invidual crops can fluctuate even more. For the deep solar-powered system, the return on investement is 12.5 seasons in the average revenue scenario and negative in the low revenue sceario. Hence, from a purely economic point of view this could be a risky investment, which explains why in practice this kind of set-ups relies on external support.

8. Finance

8.1 Farmer strategies to mobilize money for irrigation

This chapter discusses how and to which extent farmers manage to mobilize money to develop their irrigation systems. The main set-up that is used (in case of market oriented and intensive producers) or aspired (in case of constraint producers) is a simple fuel pump set up. If a farmer would need to invest at once in the hand-dug wells, a fuel pump and the pipes to start irrigating 0.5 ha, an investment of 772 USD would be required, see Table 18 above. The Table 11 in chapter 3.2 shows that this is a lot less than the profit made by market-oriented farmers, intensive producers or investors during one season. This implies that they could renew their technology within one season, as is also indicated by the return on investment which is less than one season in all accounted revenue scenarios.

For the constraint farmers however, the required investment for a simple fuel pump system is almost twice the sum of their average net revenue of 389 USD. Since farmers need their net revenue for a wide range of household expenses too, the income from the manually irrigated production system only does not provide constraint farmers with sufficient financial resources to invest in this full system at once. Even more so, since the cost of family labor has not been accounted for, the actual net revenue is even lower. Adding the very volatile produce prices to the equation explains why many constraint farmers do not manage to purchase technology that would increase their production and income.

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[16] The low and high revenue scenarios correspond to the low and high averages for the different crops combined as shown in Table 10 (chapter 3.2)

To invest in an upgrade of the irrigation system, petrol pump users would need to mobilize 621 USD to install a Californian system on 0.5 ha of land. As the average net revenue of the market oriented and intensive producers is respectively 7,061 and 2,749 USD per season, such investments could be made without credit or subsidy support. This investment would save them about 71 USD[17] per season on fuel, maintenance and irrigation labor. Considering that this investment would take 9 seasons to recover might explain why at the current price level, most farmers do not invest in Californian systems by themselves.

The cost of a solar surface pump and simple pipes comes at a cost of about 1,200 USD in Mali. This is less than the average net revenue of market oriented and intensive producers, which means that adding solar powered pumps could be possible without taking a loan. The maximum loan sum offered by MFIs are insufficient to cover such investments. Solar submersible systems with a manually drilled borehole and spray tube system would come at a cost of 3,100 USD, which might be possible for few farmers, but is out of reach for most. Finally, a deep submersible pump with drip system (16,000 USD) is beyond the financial capacity of any of the identified farmer types.

As explained in chapter 3.2, the use of additional income sources in an important factor that could allow farmers to invest in their irrigation system. The results of Nkonya et al. (2020) also underscore the importance of non-farm income in increasing smallholders' income for investing in irrigation. All farmers had other revenue sources next to their agricultural production system, which may have contributed to the fact that eight out of ten farmers have been able to purchase motorized pumps and irrigation tools. Except for the investor, all farmers have funded their equipment by themselves without a loan or other external financial support.

While the investor is the only farmer who has taken a loan to finance his irrigation equipment, this is different for agricultural inputs. Two of the intensive producers and one of the constraint producers indicated that they often take a loan to buy agricultural inputs at the start of the season, which they pay back after three to six months. The six other farmers did not use any form of loan.

8.2 Available finance solutions and incentives

The PARIIS program in Mali is exploring finance solutions comprised of partial subsidies, bank loans and a contribution by the farmers. The percentage of each component will depend on the producer category, which is linked to the size of the farm: A: < 0.25 ha, B: 0.25 – 1 ha, and C: > 1ha. The option with a partial bank loan has not been implemented to date.

The banking and micro finance sector in Mali is relatively well developed compared to other countries in the region (Sy and Niaré, 2017). However, the financial sector mainly targets urban rather than rural investments and has limited knowledge of the agricultural sector. Major banks in Mali focusing on agriculture are the National Agricultural Development Bank (BNDA), and CORIS bank. The current conditions set by banks to obtaining a loan exclude many small farmers, and women in particular, as they are not in the position to provide the required guarantees e.g. land titles deposits, etc., nor are they able to complete the loan application process, or to submit a business plan. Even investors have difficulties to obtain loans for

[17] See Table 18 : a reduction of 20 USD on fuel, 16 USD on maintenance and 35 USD on labor.

agricultural investments, as banks require land property titles whereas most entrepreneurs do not have these. It is an expression of the prudency of banks to invest in the agricultural sector which according to Sy and Niaré (2017) "can be explained by the fact that it is very hard for them to collect bad debts because of an ineffective judicial system". As a result, the number of agro-business in Mali is relatively low.

Micro credit for agricultural purposes is available through the Decentralised Financial Systems (SFD) networks. In 2015, almost one million people in rural areas made use of the SFD savings and credit services, which equals 7 percent of the rural population (Sy and Niaré, 2017). In 2014, about SFDs were operational. Five networks account for the major part (>80%) of the credit supply: Kafo Jiginew, Soro Yoriwasso, RMCR, Nyesigiso and CAECE-Jigiseme. While ten years ago agricultural credit predominantly served the low-risk cotton sector, low market prices have driven the financial institutions to open up to irrigated production systems as well. Financial services therefore have been expanded to irrigation zones, e.g. to the Office du Niger area. The SFDs have increased access to credit for women, however as shown in Figure 17, the majority of SFD clients are male (Sy and Niaré, 2017).

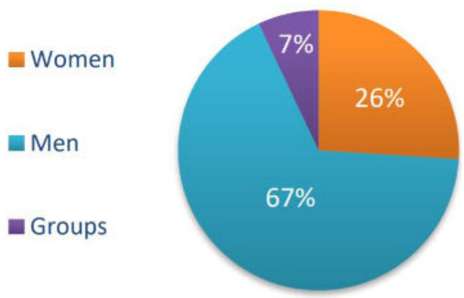

Figure 17 Clients of SFD services in 2015 (Sy and Niaré, 2017)

According to Sy and Niaré (2017), the main reasons for the low access rate of the SFD services is the limited financing capacity of the SFDs, the difficulties for farmers to provide guarantees, as well as distrust. Furthermore, relatively high illiteracy rates and a lack of simple and transparent communication impedes many people from understanding and opting for financial services. From the SFD clients, only 22% are satisfied with the provided services, due to the low credit amounts that are allocated, the duration of the loan request process, the required guarantees, the high interest rate and the distance to the service points (Sy and Niaré, 2017). It shows that SFDs still have limited capacity to provide accessible and attractive financial services to farmers in Mali.

Interviews with SFDs in Ségou show that the interest rate for agricultural inputs varies from 12-18% (Nyesigiso) and 12-22 % (Soro Yiriwaso) depending on the client profile. Conditions to obtain a loan are a warranty (usually animals), a storage room, pro forma invoices and a bank account with at least 15% of the total sum. NGOs play a key role in organizing the farmers into associations and linking these to the SFDs. Payments need to be made in cash in the branch office. This is different for the banks, e.g. CORIS nowadays offers the option Coris Money to transfer money by phone. While the large majority of loans provided by SFDs concern agricultural credit for a maximum duration of 6 months, some SFDs do have a credit line for equipment with loans up to 500,000 FCA (932 USD) to be reimbursed in 1-2 years. In practice however, the large majority of farmers cannot comply with the SFD criteria, especially regarding the required collateral. The interviewed financial institutions indicated they are willing to increase the sum and duration of the equipment loans in case a partner can serve as an interface and reduce the risks of financing agriculture.

Sy and Niaré (2017) also show that farmers in Mali mainly request loans for agricultural inputs and equipment. However, financing equipment is almost inexistent with SFDs (ibid), due to a lack of mid and long term financial resources and the high risk associated with larger investment and longer durations in the absence of adequate guarantees. This corresponds to the findings of Merry and Lefore (2018) who conclude based on many studies, that financial institutions are particularly reluctant to provide smallholder farmers with credit for expensive equipment like irrigation pumps.

Merry and Lefore (2018) recommend governments to support financial institutions to explore models that reduce risks and transaction costs of loans while serving large numbers of farmers. One option to support this is the provision of low-cost credit guarantees to local financial institutions offering credit for irrigation equipment to smallholder farmers, as well as the necessary financial training, marketing and service provision. Furthermore, a particular focus on gender-inclusive finance solutions is recommended (Merry and Lefore, 2018). A major initiative to support access to finance for smallholder farmers in Mali was launched by IFAD in 2018 with contributions from the SFDs and the government of Mali. The program called INCLUSIF has a cost of 105.5 million USD and aims to provide financial services to 440,000 farmers and 360 agricultural organizations[18].

Asset finance by irrigation equipment suppliers is a finance solution that could remove some of the barriers related to conventional finance, in particular the need for collateral and the distance to the service point. The essence of such approaches is that the irrigation technology serves as collateral, while farmers pay back over time. The integration of technology and finance services reduces the risk of the farmer, e.g. in the case of technology failure. Merry and Lefore (2018) indicate that Rent-to-Own plans could increase access to finance for female farmers in particular, as women have generally less collateral than men.

Various rural asset finance solutions have been developed by solar home kit providers in East Africa, facilitated by the widespread use of mobile money transfers. In West Africa and the Sahel, the off-grid solar companies have grown from almost zero in 2013 to over 2 million systems sold in 2017 (ECREEE, 2019). Mali is amongst the largest off-grid solar markets in the region, together with Nigeria, Ghana, Cameroon and Senegal, and offers favorable conditions such as an exemption on import taxes for solar appliances, and a solar training organization (ibid). The range of products, financial services and business models is diverse, with at least two solar companies, EMICOM and PEG, now also providing solar irrigation pumps to farmers in Mali. PEG offers farmers a solar pump and PAYGO solution for a payback duration up to 18 months[19].

Mali is featured by one of the highest mobile penetration rates in the Sahel, with 4 million people in Mali using mobile payment services made available by Orange and Malitel (Sy and Niaré, 2017). Mobile payments could allow for quick money transfers in rural areas and potentially a reduction of loan interest rates. Hence Mali has potential for supplier-based mobile

[18] https://www.ifad.org/en/web/latest/-/news/increased-access-to-finance-could-help-thousands-of-smallholder-farmers-while-improving-mali-s-agriculture-sector
[19] https://pegafrica.com/peg-africa-has-emerged-as-the-largest-provider-of-financed-solar-water-pumps-in-west-africa/

finance solutions for irrigation equipment, however so far only a few companies manage to attract resources to make the necessary upfront investments. To reduce the risk for farmers to default on PAYGO payments in case of adverse weather or market events, some organizations are exploring combinations with insurances[20]. In Mali however, insurances for farmers have not been developed to date (Sy and Niaré, 2017).

9. Conclusions and recommendations

Based on interviews with 273 farmers in Koulikoro and Mopti regions, Mamary et al. (2018) found that the high cost of irrigation equipment is the main challenge in irrigation (36%), followed by the unavailability of water (25%) and the unavailability of irrigation equipment (21%). The results of the farmer and expert interviews and the analysis of enabling conditions for FLID undertaken in this study confirm that access to finance is the main limitation to for invididual farmers in Mali to develop their irrigated production systems. The results and arguments for the scoring of enabling conditions are presented in Figure 18 and Table 19 below.

Figure 18 FLID scoring in central Mali

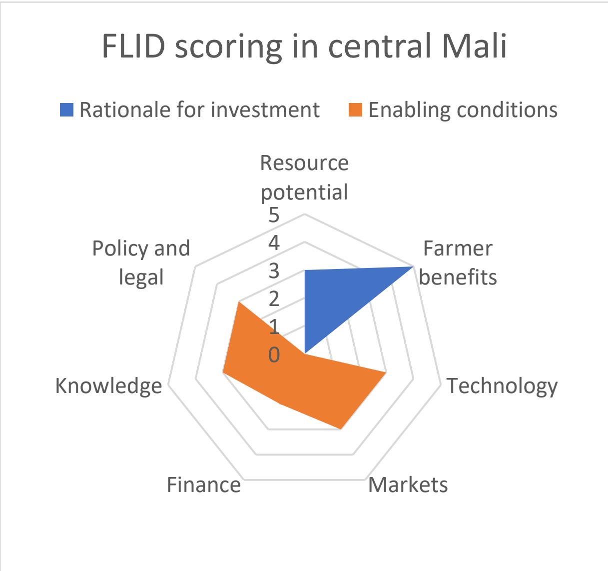

Table 19 Scoring of enabling conditions for FLID

Factor	Score	Argument
Resource potential	3	Water accesible in riverine areas, but limited sustainable potential
Farmer benefits	5	Very long dry season and potentially a high added value
Technology	3	Range of suppliers including transformative technologies for wells and irrigation
Markets	3	Access to input and output markets, limited role of associations
Finance	2	Finance not accesible for most farmers. Asset finance solutions still in a very early stage.
Knowledge	3	Lot of irrigation experience. Limited role of extension workers and farmer associations.
Policy and legal	3	Limited access to land for women. Institutional support for FLID anchored in PARIIS program.

The main issue related to finance is that the average constraint farmer, who often irrigates manually, does not make enough money in one or two seasons to purchase a pump and increase his or her production. If it takes the net revenue of a full year of work to buy a petrol pump, while there are many household expenses, it is almost impossible to invest and step up. A contribution from other income sources has allowed many farmers to make this shift, yet such resources are not evident for every farmer. Once a farmer uses a motor pump, investments in additional irrigation equipment could be made from the earned revenue, however the added value to make such investments is not convincing for all farmers. Finance solutions for equipment exist on paper, yet the SFDs, and banks even more so, consider the risk of providing credit for equipment to farmers as too high and therefore require collateral and other guaranties that farmers cannot provide. Financial institutions are open to support farmers if they receive the necessary guaranties. It is recommended to explore to what extent these institutions are

[20] https://www.findevgateway.org/blog/2021/09/can-insurance-make-small-scale-solar-energy-more-accessible

willing to simplify procedures and lower their requirements in exchange for public support and guaranties. Next to this, a strategy to restore trust between farmers and SFDs, provide transparent information and increase the use of mobile payment options would be required to increase the interest of farmers.

The second most important barrier to irrigation mentioned by Mamary et al. (2018) is access to water. In fact, water in Mali is relatively easily accesible in large areas along rivers and in floodplains. However, the sustainable potential for large-scale irrigation developments is limited and farmers report increasing water scarcity and deepening groundwater tables. As a result, it is recommended to use a catchment-based approach for developing future irrigation initiatives, and include investments in water management, water harvesting and retention solutions. Next to this, IWMI (2021) recommends to increase water productivity, which could be realized by promoting water efficient irrigation technologies such as spray, sprinklers, drip or Californian systems. Since efficient water use serves the common good, it is recommended to partially subsidize such systems in order to increase farmers' interest. Most efficient irrigation technologies (except spray tubes) are already available in Mali, yet the cost is currently prohibitive for many farmers.

According to Sy and Niaré (2017), an important constraint that contributes to the high risk profile assigned to farming by banks and SFDs, is the high price volatility of agricultural products, and of perishable crops in particular. Farmers indicate that they can access a variety of input and output market in towns and in the capital, and sell to traders buying at the farm-gate. However, farmers have no control over the timing to sell and therefore risk making a considerable loss when prices are low. Farmer associations are barely involved in the input and output markets, and strenghening the long-term associations in this regard is an opportunity to increase farmers' coordination and negotiation position. Storage facilities, currently absent in most of Mali, could be managed to farmer associations too, and so could finance for inputs or equipment. Existing strong farmer associations in Burkina Faso and Senegal could serve as an example to develop this model in Mali.

Knowledge about irrigation is widespread in central Mali, yet knowledge sharing by extension services or associations is very limited. Farmers rely on informal information sources, mainly the other farmers in the community, which makes that information, practices and beliefs often remain at a local level. Traveling curious farmers and the radio are reported to play the biggest role in intercommunity knowledge sharing. Such processes could be supported by facilitating and financing exchanges between farmer representatives, especially when linked to a shared crop and biophysical context.

In relation to policies and support, traditionally individual farmers have not received much attention from both the government and international donors, both of which focused on large-scale schemes or communal gardens. The World Bank supports through the PARIIS program an initiative with a specific target to develop support mechanisms for individual farmers. The government of Mali has shown interest to develop this approach in the upcoming years.

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ANNEX A : COSTS OF TECHNOLOGIES PROVIDED BY FARMERS AND SUPPLIERS

Type	Brand and specs	Total price (FCA)	Total price (USD)	Irrigated area (ha)	Estimate Lifespan (year)	Cost (USD/ha)
FARMER DATA						
Surface water	River	0		0.7		
Surface water	River	0		0.6		
Surface water	River branch	0		1		
Surface water	River branch	0		0.25		
Surface water	Permanent stream	0		0.25		
Hand dug wells	4 wells: depth 10m, SWT 5-8m, diam 1.5m, no reinforcement: stable soil	350000	652	2		326
Hand dug well	4-5m	35000	65	0.03		2175
Hand dug wells	2 wells: depth 15m, SWT 4m	300000	559	0.5		1119
Hand dug well	1 well: depth 22m	2530000	4716	0.5		9433
Hand dug wells + river	Various wells: depths 6-15m	250000 for 15m well		0.5		
Bucket				0.03		
Bucket				0.25		
Motor pump	Honda 320 l/min at TDH 8m	200000	373	0.6	2-3 year	621
Motor pump	Robin 3 HP	250000	466	0.7	2-3 year	666
Motor pump	Robin 320 l/min at TDH 8m	250000	466	0.5	2-3 year	932
Motor pump	Robin 320 l/min at TDH 8m	250000	466	0.25	2-3 year	1864
Motor pump	Unknown 5 HP	300000	559	1		559
Submersible electric pump	Pump	50000	93			
	Generator	350000	652			
	Total set	400000	746	0.5	1-2 year	1491
Submersible solar pump	Grundfos 20 m³/h	1250000	2330			

	3kW panels including installation	1200000	2237			
	Total set	2450000	4567	0.5	1-3 year	9135
Drip system	Elevated tank 20 m^3	3000000	5593			
	Drip lines	1250000	2330			
	Total set	4250000	7923	0.5		15846

SUPPLIER DATA

Type	**Brand and specs**	**Total price (FCA)**	**Total price (USD)**	**Estimated area (ha)**	**N.A.**	**Cost (USD/ha)**
Simple hand-dug well	Depth 15m, diam 0.5m	50000	93	0.25		373
Reinforced hand-dug well	Depth 15m, diam 0.5m	250000	466	0.25		1864
Large diameter well	Depth 15m, diam 1.4m	3500000	6525	0.5		13049
Manual drilling (auger)	Depth 4-12m, diam 50-140 mm	150000	280	1		280
Motorized (auger) drilling	Depth 15m	390000	727	1		727
Motorized (auger) drilling	Depth 25m	490000	913	1		913
Manual drilling (rotary jetting)	Depth 12m diam 140 mm	120000	224	1		224
	Depth 15m, diam 140 mm	150000	280	1		280
Machine drilling	Depth 100m, diam 140 mm	4500000	8389	0.5		16778
Motor pump	4 HP Robin	220000	410			
	4 HP Honda	220000	410			
	4 HP Kochin	190000	354			
	5 HP Robin	300000	559			
	5 HP Honda	300000	559			
	5 HP Kochin	275000	513			
			0			
	3 HP, 8 m3/h	250000	466			
	3-4 HP, 36 m3/h	275000	513			
	4-5 HP, 66 m3/h	300000	559			
Solar surface pump	SF2 120W, 15 m3/d at 6.5m	600000	1119	0.21		5220

Solar submersible pumps Lorentz including panels and installation	PS2-100 250W 12 m3/d at TDH 10m	541500	1009	0.17		5889
	PS2-100 500W, 20 m3/d at TDH 10m	666750	1243	0.29		4350
	PS2-150HR, 500W, 30m3/d at 10m	969750	1808	0.43		4218
	PS2 1800, 750W, 60 m3/d at 10m	1611000	3003	0.86		3504
	PS2 1800, 1kW, 30 m3/d at 30m	1822500	3398	0.43		7928
	PS2 1800, 1.5 kW, 40 m3/d at 30m	2007500	3742	0.57		6549
	PS2 1800, 2kW, 50 m3/d at 30m	2155500	4018	0.71		5626
	PS2 1800, 2.5kW, 64 m3/d at 30m	2407500	4488	0.91		4909
Submersible solar pump	Lorentz, Grundfos pump without panels	600000	1119			
	250W panel	75000	140			
	Installation cost	150000	280			
	Total set 0.5 kW	985000	1836	0.29		6427
	Total set 1 kW	1750000	3262	0.43		7612
	Total set 1.5 kW	1950000	3635	0.57		6362
PVC pipes	50 mm evacuation type, 6m	2750	5			
	75 mm evacuation type, 6m	5000	9			
	50 mm pressure type, 6m	6500	12			
	75 mm pressure type, 6m	12500	23			
	90 mm pressure type, 6m	17500	33			
	Total set up 150m of 75mm evacuation pipe	125000	233	0.5		466
	32 mm, 100 m	75000	140			
	50 mm, 100m	150000	280			
	0.25 ha	350000	652	0.25		2610
	0.5 ha	650000	1212	0.5		2423
	10 m3, 10m	1500000	2796			
	1 ha for horticultural crops	5250000	9787	1		9787
	1 ha papaya trees	4250000	7923	1		7923
	1 ha orange trees	3250000	6059	1		6059

	Netafim Kit 500 m^2 including installation	300000	559	0.05		11185
	Total set 1 ha including installation	5500000	10253	1		10253
	Sprinkler 0.3-0.6 m3/h	8000	15			
	Total set 1 ha including installation	3000000	5593	1		5593

Annex B Farmer production data

Revenue per farmer (FCA/ ha)

Farm	Onion	Potato	Chili	Okra	Tom-ato	Cap-sicum	Water melon	Cucumber	Melon
1	6,500,000	4,200,000	15,500,000						
2			3,600,000	1,350,000	1,750,000	3,150,000			
3	5,625,000								
4	5,850,000	13,000,000			3,328,000				
5				5,000,000	5,888,000			2,112,000	
6					400,000		400,000		
7							9,200,000		8,400,000
9			52,083,333	5,777,778	1,600,000			1,306,667	
10	7,200,000	10,000,000							
Average FCA/ ha	6,293,750	9,066,667	23,727,778	4,042,593	2,593,200	3,150,000	4,800,000	1,709,333	8,400,000
Average USD/ ha	11,733	16,902	44,234	7,536	4,834	5,872	8,948	3,187	15,659

Low USD/ ha	10,486	7,830	6,711	2,517	746		746	2,436	
High USD/ ha	13,422	24,235	97,094	10,771	10,976		17,151	3,937	