



**CHARACTERIZATION OF FARMER-LED IRRIGATION
DEVELOPMENT IN CHAD**

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ACRONYMS

ANADER	National Agency for Rural Development Support (former ONDR)
APT-EMF	Chadian Professional Association for Micro Finance Institutes
ATPESFORC	Chadian Association for the Promotion of Specialized Low-Cost Drilling Enterprises
BAC	Commercial and Agricultural Bank of Chad
BEAC	Central Bank of the Central African States
CBLT	Lake Chad Basin Commission
CEC	Savings and Credit Club
CEMAC	Central African Economic and Monetary Community
CILSS	International Permanent Inter-State Committee against Drought in the Sahel
CNCPRT	National Concertation Board of Rural Producers in Chad.
COBAC	Central African Banking Commission
DEAFPR	Directorate of Agricultural Education, Training and Rural Promotion
DGGRHA	General Directorate of Rural Engineering and Agricultural Hydraulics
FAO	The Food and Agriculture Organization of the United Nations
FLID	Farmer Led Irrigation Development
EMF	Établissement de Micro Finance
MDA	Ministry of Agricultural Development
MEE	Ministry of Environment and Water
MFI	Micro Finance Institution
MPIEA	Ministry of Production, Irrigation and Agricultural Equipment
ONAPE	National Office for Employment Promotion
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
PNSA	National Food Security Program
SISAAP	Chadian Food Security and Early Warning Information System
UCEC	Union of Savings and Credit Clubs

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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), and potentially suitable sites for small-scale irrigation for the whole territories of Chad and Mali. This report is a continuation of this work. It aims to shine a light on the specific irrigation practices and technologies used and opportunities and challenges in the enabling environment to derive recommendations for effective supporting mechanisms. This was done through a desk study, interviews with 20 farmers in the Ouaddaï, Logone occidentale and Mayo-Kebbi Ouest regions, and key expert interviews with government officials, MFI institutes, farmer associations and equipment suppliers.

The study shows that FLID in Chad is very diverse, primarily due to differences in water resource accessibility. Flood-based farming practices are dominant in the inundated plains of the Logone and Chari river systems and around lake Chad. Horticultural production using petrol pumps to withdraw very shallow groundwater from ponds and hand-dug wells is the predominant irrigation mode in the very dynamic area around Moundou and Pala. Farmers in the Ouaddaï province use similar technologies but are limited to accessing shallow groundwater near temporary water streams. The study found that different strategies and economic results arise from different farmer typologies. For the economic analyses a distinction was made between vulnerable farmers, market-oriented vegetable producers, commercial fruit producers and farmer groups.

Strategies to accelerate FLID start with recognizing this diversity and increased attention for individual farmers instead of a sole focus on farmer groups. The main constraints and opportunities identified during this study are different in the two studied regions. In the southwestern provinces where water availability is high and markets are well developed, accessible finance for irrigation technology and well construction would be the principal intervention that could accelerate FLID. In the central eastern provinces where water is scarcer and markets less diverse and more volatile, the potential for FLID is smaller. Access to water, markets and finance would need to be addressed simultaneously to support FLID in this area. For both areas, an approach based on the recognition of simple and cost-effective technical set-ups, financial and technical support to private supply chain actors, earmarked long-term investments in MFIs and supporting knowledge exchange initiatives for farmers and government officials could contribute to an increasingly enabling environment for farmer-led irrigation development.

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 the irrigation development, natural resources, profile of farmers. Farmers can lead irrigation in any of these types. 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.. Government led initiatives are often more present in the other types given the higher level of complexity and the higher unit cost.

Table 1 Types of irrigation in the Sahel

Types of irrigation in the Sahel (CILSS, 2017)	Description of corresponding systems in Chad (MPIEA, 2017)
Type 1: Lowland development and controlled submersion	- Lowland schemes - Controlled flooding for rice production and residual moisture crops organized by farmer communities
Type 2: Small-scale private irrigation	- Private (individual or commercial) irrigation systems ranging from several to over a hundred hectares (CILSS 2017: private irrigated production systems of less than a hectare to a few dozen hectares)
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 Mali and Chad, farmer-led irrigation exists, but the extent and form are 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 Chad, and in particular in the Ouaddaï region in the East and the areas along the Logone and Chari rivers and tributaries in the South and West of the country (see Figure 1 Table 1). This report forms the second part of the assessment and aims to characterize Chad's FLID practices and constraints, and to provide an indication of strategies for the government to support FLID. The same assessment has been done for Mali 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 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 particularly 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 Chad and identify the challenges, opportunities and enabling factors relevant to each segment. Understanding the development process of FLID in the studied provinces could contribute to better target future interventions. 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.

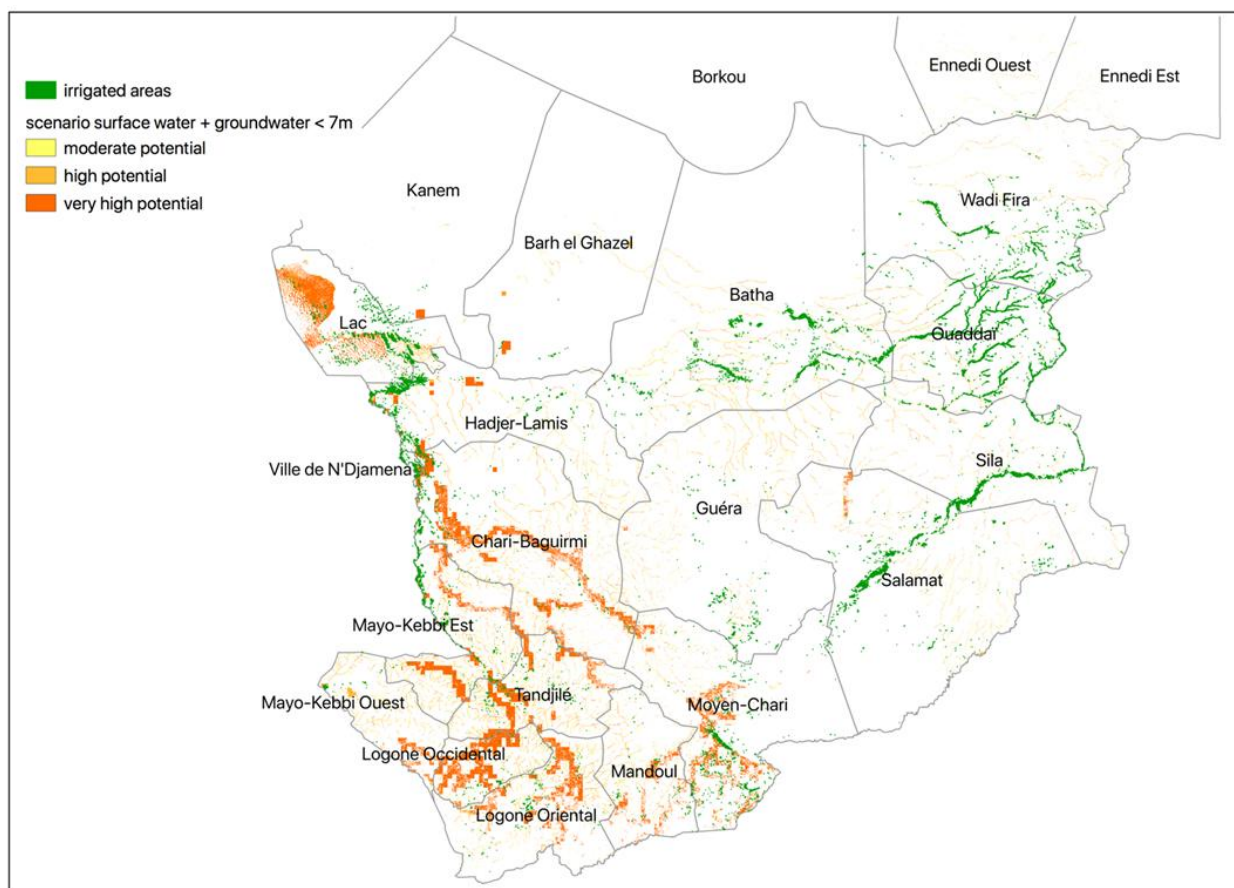


Figure 1 Currently irrigated areas (green) and high potential areas for irrigation (orange) (Westra, 2020)

The mapping of potentially 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. Then, the areas are assessed for 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 mapping 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 (2-5 meetings) - Maps, shapefiles, figures on irrigation schemes, agro-ecological zoning - 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 (5-10 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 - Local banks and microfinance institutions: type, access and conditions of loans for smallholder private farmers	Structured interviews and phone calls	- Capital - Regional towns: Pala, Moundou, Abéché
Farmer data (20 interviews) - Organization, land ownership, crop data, irrigated surface, location - Technology in use: water source, withdrawal, application - Access to information/technology/finance/markets	Structured interviews and observations with irrigating farmers	
Literature Online (grey) literature review on climate, agro-ecology, institutions and policies, technologies	Desk study	
Key stakeholder 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 resulting from the covid pandemic and the security situation a national consultant has been contracted to implement the study activities in Chad 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 Chad. Since the number of ZIPs in Chad is large, the PIU has advised focusing on the three sites representing two different agro ecological zones in the country with major differences in access to water, i.e. the Ouaddaï region in the eastern Sahelian zone and the Mayo Kebbi Ouest and Logone Occidental regions in the southwestern part of the Sudanian zone. These zones correspond in the following ways to the findings by Westra (2020) presented in Figure 1:

Ouaddaï region: Small private irrigation exists to a large extend along small streams

Logone Occidental: Large potential area for irrigation along the Logone river
Mayo Kebbi Ouest: tributaries and using shallow groundwater (<25m)

This confirms the recommendation of the PIU that the regions could show different realities influencing of the extent of FLID. As a result, the three regions have been selected for the field assessment and farmer interviews.

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. Knowledge

Chapter 6. Finance

Chapter 7. Market

Chapter 8. Technology

Chapter 9. Conclusions and recommendations.

2. RESOURCE POTENTIAL

This chapter aims to show how much water and land is (easily) available for irrigation to be developed by individual smallholder farmers. To this end it provides an overview of the agro-ecological zones (2.1), water availability and access (2.2), the cost of water mobilization (2.3) and the long-term trends and sustainability (2.1).

2.1. AGRO-ECOLOGICAL ZONES

Chad is a landlocked country located in central Africa with a total area of 1,284,000 square kilometers. The UN estimates its current population at 16.9 million people, with the largest share of the people living in the south western regions.

The National Water and Sanitation Master Plan 2003-2020 defines three major eco-climatic zones: the Saharan zone in the north, the Sahelian zone in the center and the Sudanian zone in the south of the country, see Figure 2 (HCNE, 2003). The three zones correspond roughly to the Köppen-Geiger climate classifications of desert, steppe and savanna and are mainly defined by the annual precipitation. As a result of its large impact on agricultural production, the eco-climatic zones also essentially correspond to specific livelihood zones (FEWS NET, 2001).

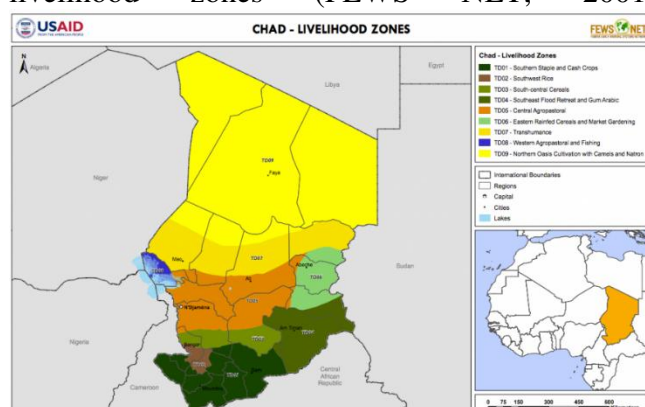


Figure 3 Chad Livelihoods zone map (FEWS NET, 2011)

Table 3 Eco climatic zones in Chad

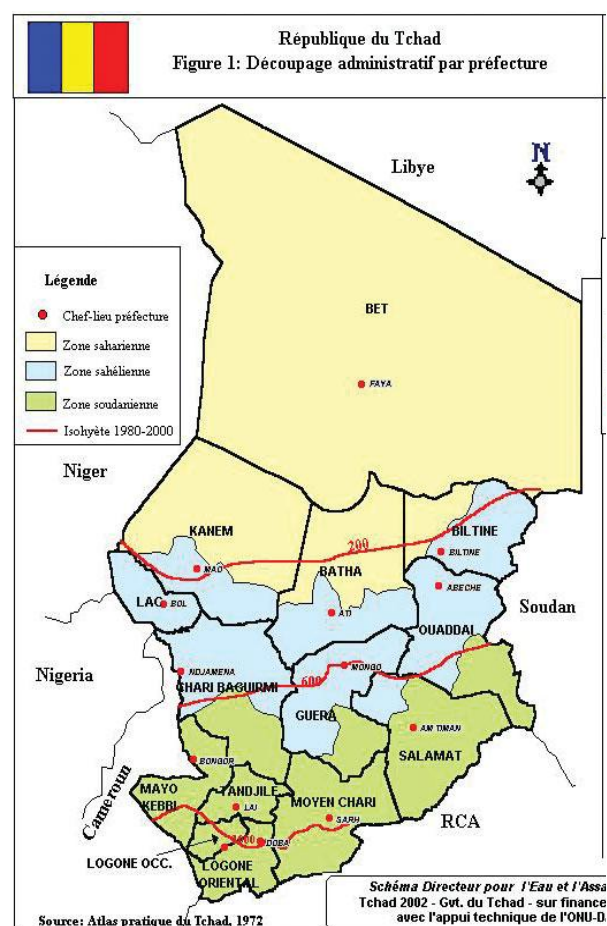


Figure 2 Eco climatic zones in Chad (HCNE, 2003)

HCNE eco-climatic zones	Köppen-Geiger climate zones	Average annual precipitation	Percentage Chadian Population	Livelihoods Zones
Saharan	Arid, desert, hot (BWh)	250 mm	3%	-Northern Oasis Cultivation, -Transhumance

Sahelian	Arid, steppe, hot (BSh)	300 – 650 mm	34% (42% if including N'Djaména)	-Central Agropastoral, -Eastern Rainfed Cereals and Market Gardening
Sudanian	Tropical, savannah (Aw)	650 – 800 mm	55%	-Southern Staple and Cash crops -South west rice -South central Cereals -Southeast Flood retreat

The PIU of the PARIIS project recommended to focus the field assessment on the two extremes of the project zone: the Ouaddaï region in the East of the Sahelian zone and the Mayo Kebbi Ouest and Logone Occidental provinces both situated in the South West of the Sudanian zone.

The Saharan zone

The Saharan zone includes the entire northern part of Chad and covers 61 % of the country's surface. The area corresponds to the Arid, desert, hot climate zone. It is characterized by deficient rainfall of less than 100 mm in the North to about 250 mm in the South, near permanent dry winds (harmattan), a low humidity (< 50%) and high temperatures (averages of 26°C in January to 42°C in October, with days up to 50°C.) Combined, these factors lead to maximum reference evapotranspiration (ET₀) of 9 mm/day in Faya. Agricultural production is limited to small-scale traditionally irrigated date palm cultivation in the oasis towns, as the area is too dry for other cultivation systems (CILSS, 2016). The southern stroke of the Saharan zone is mainly featured by transhumance or pastoralism (FEWS NET, 2011).

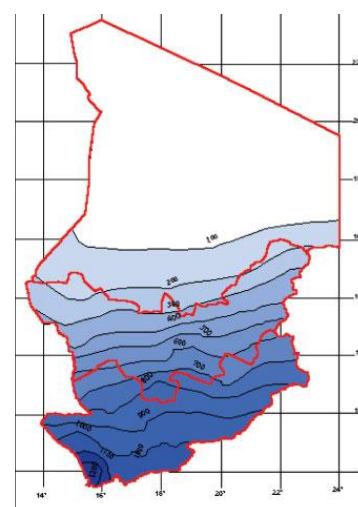


Figure 4 Average rainfall in Chad (1981 -2000 (HCNE, 2003)

The Sahelian zone

The Sahelian zone in central Chad covers 29% of the country. It is equivalent to the arid, steppe, hot climate zone. The annual rainfall ranges from 250 mm in the north to 800 mm in the south. The rainy season lasts from June to September. Average temperatures are 27-35°C from March to October and 20-27°C during the “cold period” after the rainy season, from November till February (World Bank, 2021). The reference evapotranspiration ET₀ ranges from 7.3 mm in Biltine (Wadi Fira) to 7.1 mm in Abéché (Ouaddaï) and N'Djaména, 6.8 mm in Ati (Batha) to 6.2 mm in Bitkine (Guéra).

Next to the marked North-South rainfall distribution, the elevation is a significant explanatory factor for the differences in water availability, agricultural potential and livelihoods strategies in the different agro-ecological zones. As shown in Figure 5, the central and western part of the country form a vast low plain. The altitude is below 500 m and the lithology consists mainly of loose sand and clay formations (HCNE, 2003). In contrast, the country's East is featured by the Ouaddaï mountain range, with ephemeral streams and dambos allowing for rain-fed cereal production and irrigated gardening. It is a major FLID cluster within the Sahelian zone.



Figure 5 Shaded relief map Chad (CILSS, 2016)

The rocky Gúera mountains constitute the South eastern belt of the Sahelian zone. With 600- 750 mm per year the region receives more rainfall than the rest of the Sahelian zone. As a result, Gúera is an essential region for Chad's rain-fed millet and groundnut production and cotton cultivation. According to CILSS (2016) "the transition area between the Sahel and Sudan climate zones is an area of steady encroachment by croplands, especially in the regions of Ouaddaï, Lake Fitri and around N'Djamena. In these regions, agricultural landscapes now dominate the savanna."

The Sudanian zone

The Sudanian eco climatic zones comprises 10% of the area of Chad and covers the southern regions. The climate corresponds to a Tropical, savannah (Aw) type and annual rainfall ranges from 650 mm/year in the North of the Sudanian zone to over 1200 mm/year in the extreme south west of the country (Logon Oriental region). The rainy season takes from May to October , two months longer than the Sahelian zone. Average temperatures in this period are 27-29°C (World Bank, 2021). The maximum daily reference evapotranspiration ET₀ ranges from 7.3 mm in in Lare (Mayo-Kebbi Ouest) to 6.6 mm in Gounu (Mayo-Kebbi Est), 6.3 mm in Goz Beïda (Sila) and Bouso (Chari-Baguirmi), to 5.5 mm in Maro (Moyen-Chari) and 5.3 mm in Baïbokoum (Logone Oriental).

The livelihoods strategies of people living in the Sudanian zone are diverse due to the differences in climatic and physical contexts. Typical landscapes include mountains, highlands and valleys as wells as the vast Salamat and Massénya floodplains (see Figure 10). The latter are inundated starting from June with the first rains until September/ October as the river flow entering Salamat reaches its peak (Whigham et al., 1993).

The dominant vegetation consists of savannas in the southeastern Salamat region, woodlands in the southern border of the Moyen-Chari region and vast plains in the southwestern areas. Nowadays, the southwestern plains are predominantly used for agriculture, as shown in Figure 6 (CILSS, 2016). The deep and fertile alluvial soils combined with the large water volumes coming in through the Chari and Logone rivers (see Figure 7) explain the large agricultural potential of the southwestern regions.

Except for Moyen-Chari and Mandoul, all regions in the Sudanian zone are priority regions (ZIPs) in the PARIIS project. According to CILSS (2016) the Moyen-Chari and Salamat plains are home to scattered communities engaged in subsistence farming, fishing, and raising livestock. Agricultural production through FLID is concentrated in the southwestern regions.

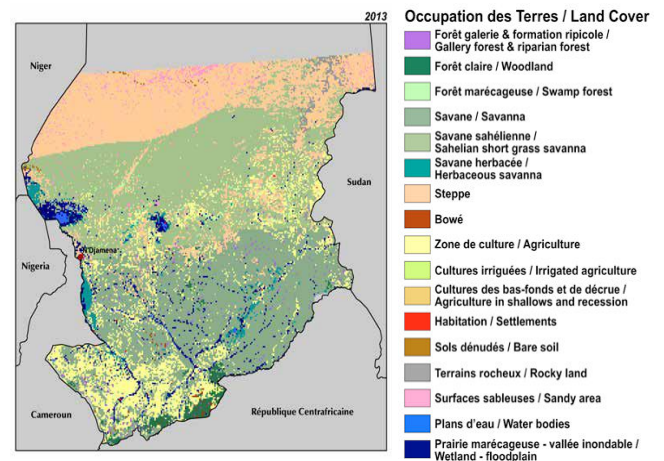


Figure 6 Land use map of Chad (CILSS, 2016)



Figure 7 The Chari and Logone river basins (Kmusser, 2010)

2.2 WATER AVAILABILITY AND ACCESS

Surface water

Chad counts a large number of permanent and seasonal rivers. The vast majority of the country (81.5%) is within the lake Chad basin (see Figure 8). Next to this, the Mayo Kébbi river in the south west drains into the Niger river basin, while the Wadi Howa in the northeast ultimately drains into the river Nile.

Nearly 95% of the water in the Lake Chad basin originates from the Chari-Logone river system in the South of Chad (FAO, 1997); see Figure 8 The Logone river has tributaries in Cameroon: the Vine and Mbere rivers, and in the Central African Republic: the Pende river. It flows northwards, marking the border with Cameroon and feeding the extensive 400km long Logone / Ba Illi floodplain, until it merges with the Chari river in N'Djamena.



Figure 1. The Lake Chad Drainage and "Conventional" Basins.

Figure 8 Lake Chad basin (Odada et al., 2006)

The Chari river has many tributaries entering the country from Sudan and the Central African Republic. The streams from the East: the Barh Aouk which marks the border with the CAR, and the smaller Barh Azum, delineate the vast Salamat floodplain. After merging with its largest tributary: the Bahr Sara or Ouham river from the South, the Chari river flows northwest towards N'Djamena. At times of high water, the Chari may overflow its west bank starting 100 km below Bousso, inundating the area between the Chari and Logone rivers up to N'Djamena. From there the Chari river ultimately drains into Lake Chad. The average flow of the Chari river at N'Djamena is estimated at 22 billion m³/year¹ (HCNE, 2003) (MPIAE, 2017).

Because of the large river discharges, plain areas and low river slopes (0.1 m/km for the Chari river and 0.14-0.25 m/km for the Logone), Chad counts important floodplain and wetland areas (HCNE, 2003). The most important swamp areas include Lake Chad, Fitri, and Massenya, Salamat, Logone / Ba Illi, and the Toubouri (Binder-Léré) wetlands, which are the six designated Ramsar wetlands in Chad, i.e. wetlands of international importance as convened by the Ramsar Convention on Wetlands. The floodplains start getting inundated during the rainy season and reach their maximum size when the river discharges peak around October. The inundated zones slowly recede to reduced wetland areas after the rainy season. HCNE (2013)

¹ Hughes (1992) estimates the discharge of the Chari river at 38.7 billion m³/year in N'Djamena after the convergence with the Logone river which contributes an average of 12.6 billion m³/year to this. HCNE (2003) and MPIAE (2017) report that the discharge of the Chari river has substantially decreased comparing the 1950-1971 period (39.1 m³/y in N'Djamena) and 1972-2000 period (21.8 m³/y in N'Djamena).

estimates the total inundated area at 95,000 km², although the actual size varies considerably from one year to another.

Table 4 shows the characteristics of Chad's main lakes and floodplains. It combines data from HCNE (2003), Odada et al. (2006), Whigham et al. (1993) and Hughes (1992). The corresponding areas are shown in Figure 10. A detailed account of the swamps and temporary reservoirs in the northern Ennedi, Borkou and Tibesti regions is not included due to its scattered character and a lack of available data (HCNE, 2003).

Some floodplains border and temporarily expand permanent lakes, the most important one being Lake Chad. The size of the permanent water body of lake Chad has reduced from 19,000 km² in the sixties to 7,500 km² (HCNE, 2003) or 1,350 km² (Odada et al., 2006) around the year 2000. Contrary to what could be expected for a sinking lake in an area with high evaporation rates, the water of Lake Chad is not extremely salty: 60-120 mg/l in the southern pool to 250-400 mg/l in the northern pool. This is because of an underground outflow of salts into the aquifer, as demonstrated by the many boreholes in the area yielding salty groundwater (Odada et al., 2006).

The smaller lake Fitri fed by the seasonal Batha river and streams from the Guera Massif has similar characteristics as lake Chad. It is also a sinking lake with relatively low salinity (below 80 mg/l). Its typical area is 500 km² (Hughes, 1992) to 800 km² (HCNE, 2003), while the complete Batha de Lieri floodplain system ranges from 11,000 km² (Hughes, 1992) to 46,000 km² (HCNE, 2003). However, according to CILSS (2016), unlike lake Chad the area of lake Fitri did not change substantially between 1975 and 2013.

The third natural lake, lake Iro, is substantially smaller with 100 km². The Toubouri lakes in the Mayo Kebbi depression have 170 – 320 km² (Hughes, 1992).

Table 4 Principal lakes and floodplains in Chad

Water body	Region	Source	Inundation Period	Description	Area
Lakes					
Lake Chad	Lac	Rivers from the lake Chad basin (see Figure 8)	Permanent	Average permanent water body of the lake	1,350 – 7,500 km ²
Lake Fitri	Batha	Batha river	Permanent	Average permanent water body of the lake	500 - 800 km ²
Lake Iro	Moyen-Chari	Bahr Salamat river	Seasonal	Lake within the Salamat floodplains	100 km ²
Toubouri lakes (lake Fianga, Ngara, Tikem, Trene Léré)	Mayo Kebbi Est (Fiango Ngara, Tikem), Mayo Kebbi	Logone river (overflow during peak)	Permanent	Series of 2-5m deep lakes in a depression marking the start of the Mayo Kebi river	40-140 km ² per lake. Max total size 170 – 320 km ²

	Ouest (Trene Léré)				
Floodplains					
Lake Chad floodplains	Lac	Rivers lake Chad basin	Seasonal	Maximum size in Jan, Minimum in July. Average depth of 1.5m, max 8m.	4,000 to 11,000 km ²
Kanem lakes	Lac	Rainwater and groundwater	Seasonal	Hundreds of small lakes and temporary pools of < 2m depth	100 m ² to 2 km ² per lake.
Salamat floodplains	Salamat, Moyen-Chari	Various Chari tributaries and rainfall	Sep – Jan (peak in Oct),	228 km wide plain between the Barh Aouk (Chadian border) and Bahr Salamat rivers.	50,000 km ²
Massenya floodplains	Chari-Baguirmi	Chari river (permanent)	Aug - Nov	470 km long plain on the east bank of the Chari reaching till N'Djamena, Generally 1-1.5 m deep.	15,000 km ²
Logone / Ba Illi floodplain	Chari-Baguirmi, Mayo Kebbi Est	Logone river (permanent)	July - Dec	400 km floodplain between the Logone and Ba Illi (also called Marba) river	21,000 km ²
Batha de Lieri	Batha, Hadjer-Lami	Batha river (Aug-Oct) and streams from Guera Massif		System including the floodplains and around Lake Fitri and a smaller one east of the Guera Massif.	11,000 km ² (Hughes, 1992) to 46,000 km ² (HCNE, 2003)

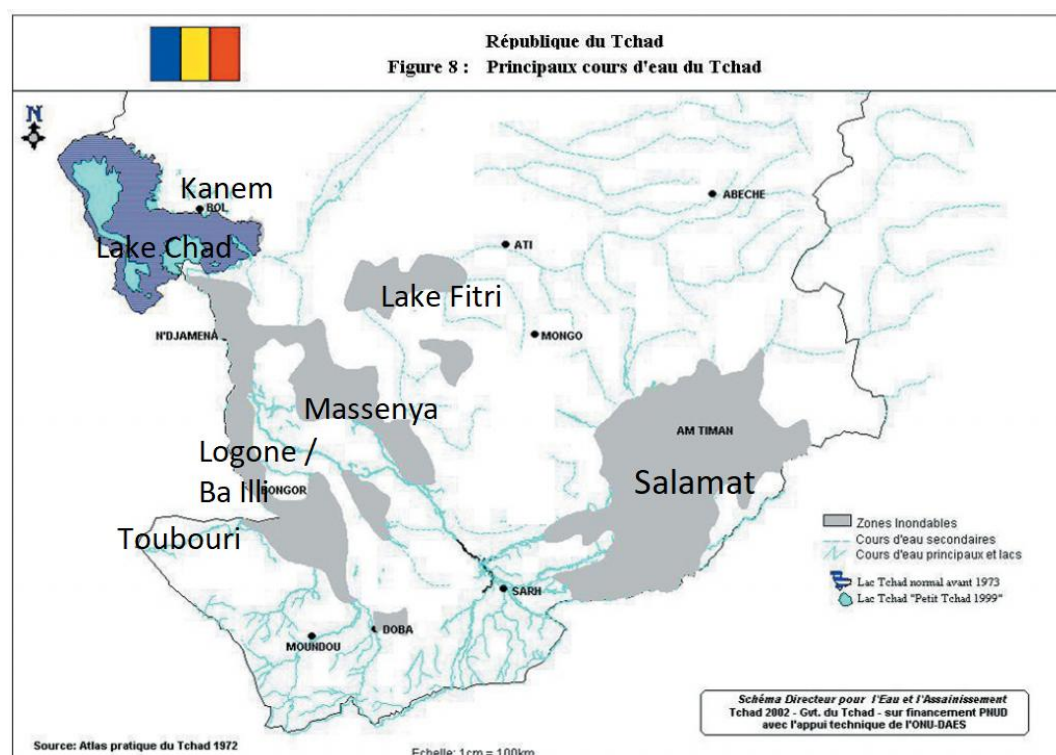


Figure 10 Main surface water bodies and floodplains in Chad (adapted from HCNE, 2003)

Groundwater

Unlike surface water, of which 84% of the resources is concentrated in the Sudanian zone, the available renewable groundwater resources are more equally distributed between the Sahelian zone (42%) and Sudanian zone (58%) (HCNE, 2003). The groundwater is generally of good quality (ibid). The map in Figure 9 shows the distribution of Chad's main aquifers and their productivity. Table 5 provides a corresponding overview and some background related to these aquifers including the typical yield, description of the formations and its accessibility for FLID.

The central and western part of the country and the areas around the rivers (see blue zones on the map) are covered by unconsolidated sediments, the so-called Chad formation. These are the easiest formations to dig or drill and therefore have the lowest drilling cost per meter. The same applies to the unconsolidated alluvium in river valleys in the north and east of the country (light blue). The sandstone continental terminal aquifer (green) in the southern and mid-northern areas can be artesian, providing a substantial yield. Yet drilling in these formations comes at a higher cost. The Palaeozoic and Lower Mesozoic continental sandstone in the north (purple) has high productivity in fractures, but identifying and reaching these is very expensive. Little is known about the igneous formation in the north (pink). The

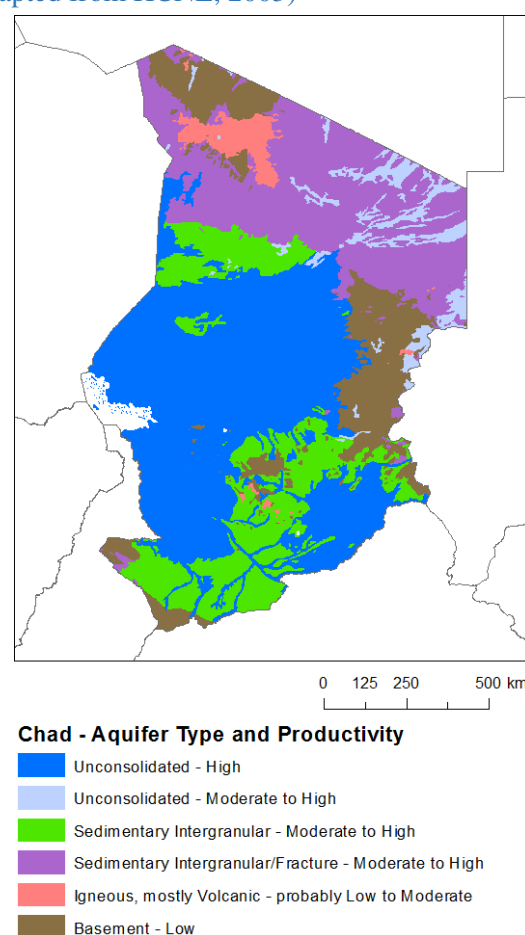


Figure 9 Aquifer type and productivity (BGS, 2019)

basement rock formations in the east, extreme south and north (brown) are not productive. However, pockets of unconsolidated sediments can be found in its valleys, which farmers could use to access shallow groundwater.

It should be noted that pockets of alluvial material with accessible shallow groundwater could be encountered as a local overlaying layer on top of any of the aquifer formations described above. The map reflects the dominant aquifer type. The indicated aquifer yield is based on a borehole of an “appropriate depth”, which depends on the type of aquifer, according to BGS (2019). The average depth of the boreholes used to create the aquifer productivity map is more profound than the economically viable depth for groundwater mobilization for individual smallholder farmers participating in FLID. As a result, one could find thick clay deposits with a low permeability and yield in the blue and green zones on the map, since most farmers will not reach the depth on which the aquifer productivity map is based. It is not the dominant aquifer type as shown in Figure 9, but the groundwater depth that forms a more precise indicator of the accessibility of groundwater for FLID.

The productivity of the shallow aquifer is also important as it needs to provide enough water for the pump. This depends mainly on the soil formation in the first twenty meters (sand or clay) which is not visible in the generic description of “unconsolidated sedimentary formation”. Once the groundwater is not too deep, farmers dig more wells (or in some cases deeper wells) to increase the water storage in order to counteract the low aquifer productivity.

Table 5 Overview of aquifer characteristics (Adapted from BGS, 2019)

Aquifer map category Figure 9	Formation	Bore-hole productivity	Description	Aquifer accessible for smallholder farmers
Unconsolidated – High	Sedimentary - Quaternary-Pliocene Chad formation	5-20 l/s	Unconsolidated sediments of lacustrine, alluvial and deltaic origin. Deposits range from pure sand to clay.	Yes where groundwater is not too deep (<25m) ²
Unconsolidated – Moderate to High	Sedimentary – Quaternary undifferentiated	2 – 20 l/s	Alluvium in river valleys; aeolian sand in the north. Likely to be permeable and to have high groundwater storage potential, and shallow water tables.	Yes where groundwater is not too deep (< 25m)
Sedimentary Intergranular – Moderate to High	Sedimentary – Tertiary – Continental Terminal	2 – > 30 l/s	Artesian aquifers of sandstone, confined by overlying clay bands. The water is not replenished by recharge. General depth is 400-700m, but the Continental Terminal rocks crop out at the ground surface in the southern	Potentially, but reported drilling costs are high. Hand-dug wells in overlaying clay formations possible when groundwater not too deep (<10m).

² Provided that low-cost manual drilling services are available. This is the case in N'Djamena, but not throughout the country.

			regions, shown on the geology map. Groundwater is abstracted for drinking water, but extraction costs are considerable.	
Sedimentary Intergranular or Fracture – Moderate to High	Sedimentary – Mesozoic and/or Palaeozoic	2 – 20 l/s	The Nubian Sandstone aquifer system contains large volumes of fossil groundwater. Groundwater flow is largely through fractures but also by the intergranular flow. Little specific investigation has been done on the aquifer in Chad	Aquifers in fractures not accessible due to high cost of well siting and construction. Shallow wells in overlaying formations possible when groundwater not too deep
Igneous, mostly Volcanic – probably low to moderate	Igneous – Mesozoic to quaternary	0.5 – 2 l/s	Little is known about the aquifer properties of volcanic or other igneous rock aquifers in Chad.	No : low yield, complex formation, mainly deep groundwater
Basement - Low	Precambrian Basement	0.1 – 0.5 l/s (0.5 - 2 l/s in valleys)	In deep valleys in the granitic massifs, the upper parts of the rocks can be heavily weathered. When overlain by sands, these weathered basins form low to moderate productivity aquifers, which supply additional groundwater storage.	Basement aquifer: No. Shallow wells in overlaying formations possible when groundwater not too deep, especially in weathered valleys

Figure 11 shows the static water level of registered water points in Chad:

In blue : less than 10m

In green : 10-25 m

In red : more than 25m

It shows that most very shallow groundwater can be found in the southwest of the country, along the Logone river, around N'Djamena, and along the wadis and streams in the Ouaddaï, Wadi Fira and Guéra regions. The main parts of the Hadjer-Lami and Batha regions are featured by deep groundwater tables (>25m) and therefore less favorable for FLID. This is also the case for the Chari-Baguirmi region. However this region has a large irrigation potential along with the Chari river (see Westra 2020). The most plausible explanation for this potential not being visible in Figure 11 is that the water points constructed in this area have not been placed directly near the river.

The feasibility study for manual drilling in Chad (UNICEF, 2010) confirms that the highest potential to mobilize shallow groundwater is found in the western and southwestern regions. The most feasible areas correspond to the alluvial sediment deposits along the Logone, Chari, Bahr Azoum and Batha rivers, and the Lac, Kanem and Bahr el Ghazal regions. The corresponding methodological report adds to this that even though the eastern regions are not favorable on the map, experiences from UNICEF and Practica have demonstrated that manual drilling is possible around temporary water streams in these regions (UNICEF, 2010).

Chad is one of the countries in Africa with most manual drilling capacity and experience, dating back to its introduction in 1965. According to an interviewed driller, between 3,000 and 10,000 boreholes have been drilled manually in N'Djamena alone between 2005-2014, and 200 manual drilling enterprises were reported to be active in the capital (RWSN, 2015). Hand-dug wells are also common in N'Djamena, which confirms the ease of access and low cost of groundwater mobilization in this area. Manual drilling in Chad is increasing, mainly due to the increased demand for boreholes in the drinking water sector. The same companies offer their services for both drinking water and irrigation purposes and adapt the depth and cost accordingly.

2.3 COST OF WATER MOBILIZATION

The available water resources, including rain, rivers, floodplains, and groundwater, have shaped of the country's agricultural production systems and irrigation practices. Table 6 shows the agricultural water consumption per source within the different eco-climatic zones. For example, while groundwater is vital in the Saharan zone and accounts for a third of the water use in the Sahelian zone, irrigation in the Sudanian zone relies almost entirely on surface water.

Static water level in registered water points

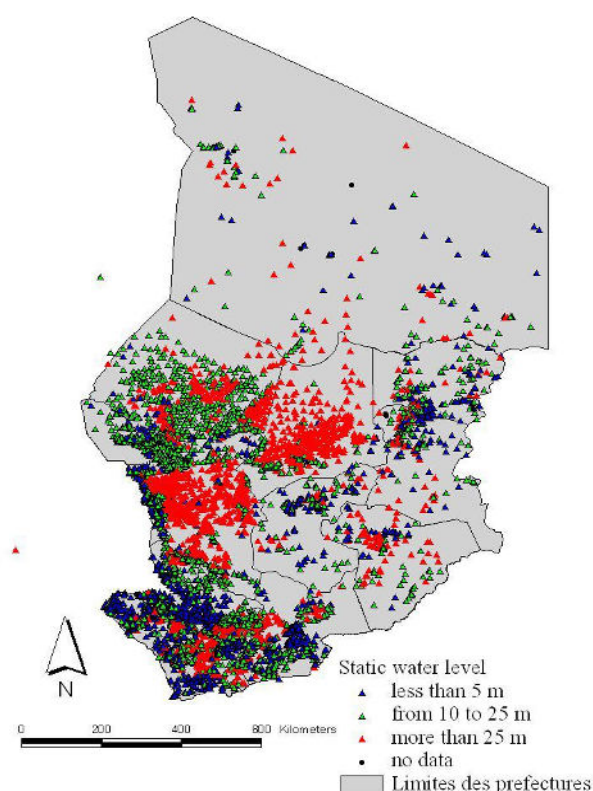


Figure 11 Static water levels in Chad (UNICEF, 2010)

Table 6 Source of agricultural water per zone (adapted from HCNE, 2017)

Agro Ecological zone	Surface water use (million m ³ /year)	Groundwater use (million m ³ /year)	Percentage surface (SW) / groundwater (GW)
Saharan zone	0	127	0% SW / 100% GW
Sahelian zone	117	63	65% SW / 35% GW
Sudanian zone	683	20	97% SW / 3% GW
Total	800	210	79% SW / 21 % GW

The source is the primary determinant of the required infrastructure and cost to mobilize water for irrigation. The following table shows an overview of the primary water sources used for irrigation in Chad, the possible technologies and its investment cost per farmer and per hectare. The cost of operation and labor is not included in this overview. The water sources can be traced back to different locations in Chad using Figure 9 and Figure 10. A more detailed description of the technologies and their implications can be found in chapter 8 Technology. The procedure to determine the indicative suitable area per water source is explained in Annex A. It is important to realize that the indicated suitable area per water source does not indicate the sustainable potential in terms of how much water is available.

Table 7 Water sources and cost of mobilization³

Water source	Water depth	Required Infrastructure	Average cost USD ⁴ per farmer	Average cost USD per ha ⁵	Indicative suitable area (1000 ha)
Flood water	Surface water, residual moisture	None Controlled flooding infrastructure	Participation to the construction and maintenance	Up to 5,000 to 7,000 USD/ha	1,039
Rivers, streams, lakes	Surface water	Buckets / Fuel pumps	Bucket 5 Fuel Pump 150-930 + pipes 170-1,200 = 5 – 2,500 USD	N.A. Fuel Pump 240 + pipes 410 = 650 USD/ha	926

³ HD is Hand Dug well, TW is Tube Well, MD is Manual Drilling, RW is Reinforced open Well, MDB is Machine Drilled Borehole

⁴ 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.

⁵ Cost for a simple set-up. Costs increase when adding water and time saving technologies, see difference between simple and promoted set-up explained in chapter 8.2.

Alluvial aquifers or pockets	Very shallow groundwater (<7m)	Hand-dug well / Pond / Tube well + Fuel pump + pipes	HD Well 140 / Pond 330 / TW 200 + Pump 150-930 + pipes 170-1,200 = 460 - 2,500 USD	HD Well 350 / Pond 140 / TW 580 ⁶ + Pump 240 + pipes 410 = 1,000 USD/ha	1,601
Alluvial aquifers or pockets	Shallow groundwater (7-25m)	Manual drilling / Reinf. well / Machine drilled borehole + Submersible pump	MD 900-1,300 RW 14,000 MDB 8,400 + Sub solar Pump 2,800-3,400 + pipes 410 = 4,000 - 17,000 USD	MD 1,100 RW 14,000 MDB 5,600 + Sub solar pump 4,600 + pipes 410 = 6,000 USD/ha for GW at 15m depth⁷	1,812
Alluvial aquifers or pockets	Deep groundwater (35-60m)	Manual Drilling / Machine drilled borehole + Submersible pump	MD 1,500 – 3,000 MDB 9,900 (60m) Sub solar pump > 4,000 Total > 6,000-15,000	> 9,000 USD/ha	0
Sandstone aquifers (intergranular)	Artesian, groundwater	Machine drilled borehole			516
Sandstone aquifers (intergranular)	Shallow to deep groundwater	Machine drilled borehole Electric/solar pump	MDB 17,400 USD (60m)		
Sandstone aquifers (fractures)	Deep groundwater	Machine drilled borehole			0

⁶ While the cost of a tube well in the wadi is higher than a hand-dug well or pond, the great benefit is that it provides a permanent source that does not dry out. All ponds and 80% of the simple hand-dug wells sampled run dry in February.

⁷ This is the cost of a system in the Ouaddaï province including manually drilled borehole of 25m depth and a solar-powered pump system of 1kW sufficient for 0.67 ha at a TDH of 20m. The required capacity and cost of the solar pumping system depends on the water depth. It can be cheaper in zones that have a higher water table, e.g. in the Logone Occidental province, or more expensive where the water is deeper.

		Electric/solar pump			
Total					5,894

2.4 LONG-TERM TRENDS AND SUSTAINABILITY

The use of surface water in Chad in the year 2000 was estimated at 861 million m³/year, including 800 million m³ for agricultural use 57 million m³ for livestock ①. The total surface water use envisaged for the year 2020 was 1,850 million m³/year including 1,727 million m³ for agricultural use, i.e. a projected growth of 114% (HCNE, 2003).

The total envisaged groundwater use for agriculture in 2020 is 373 million m³/year, leading to a total envisaged agricultural water use of 2.1 billion m³/year in 2020 (HCNE, 2003) ②. The numbers are based on a projected 100,000 ha of the cultivated area in 2020 including all types of irrigation, taking an average water consumption of 15,000 m³/ha/year which leads to a total water need of 1.5 billion m³/year, and an additional 600 million m³/year for other types of systems (HCNE, 2003). The numbers form a sharp contrast with the 20,000 ha of irrigated area envisaged for 2020 based on a review of strategic documents in the sector, which is explained by the lack of coordination and clear policy frameworks (ibid). In 2017, the realized irrigated area in Chad was estimated at 18,000 ha (MPIAE, 2016) to 35,000 or 43,000 ha (CILSS, 2017)⁸. MPIAE (2017) proposes that another 4,350 ha of newly irrigated land will be added to this using funds from the PARIIS project, resulting in a projected total irrigated area of 22,000 to 47,000 ha by the end of the PARIIS project in 2023. Using the same water need per hectare as HCNE (2003), would result in **agricultural water demand of 330 ③ to 705 million m³ per year ④** in 2023. According to HCNE (2003) the total water demand for all other human activities combined (village, urban, pastoral and industrial) is estimated at 512 million m³/year in 2020. This brings a total estimated **human water demand of 0.8 to 1.2 billion m³/year**. The environmental water need is not included because it is unknown (HCNE, 2003).

⁸ MPIEA (2017) reports that the irrigated area in 2017 is 35,000 ha. CILSS (2017) adds to this that a recent inventory shows that the developed irrigation areas in Chad cover 43,000 ha.

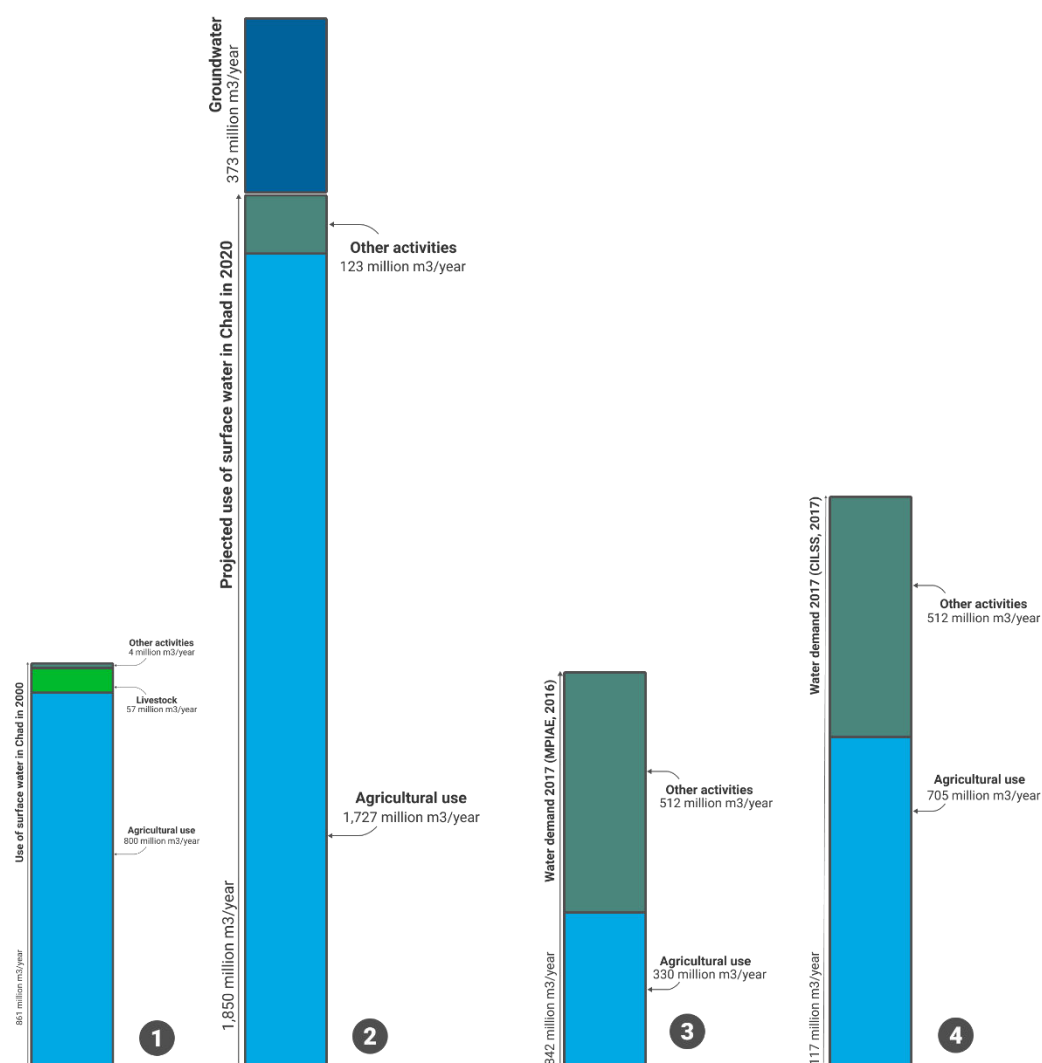


Figure 12 Actual and projected water use in m³/year for different scenarios (see 1,2,3,4 in text above)

Chapter 2.2 shows that the total river discharge in N'Djamena is estimated at 22 billion m³/year. The country's total estimated surface water resources are **26.7 billion m³/year** (HCNE, 2003). As a result, the government of Chad (HCNE, 2003) (MPIEA, 2017) and many others (USAID 2010) (FAO 2005) consistently argue that Chad has sufficient water resources to increase its agricultural production through irrigation substantially. HCNE (2003) highlights that its ambitious plans for 2020 including 100,000 ha of irrigated land require only 7% of the available surface water sources and 4% of the renewable groundwater sources, and that this will not have significant impacts on the environment, even though the environmental water need is difficult to quantify. It also concludes that water does not put a break on the social and economic development of Chad. USAID (2010) indicates that Chad has significantly more water resources available than the other Sahelian countries, a volume that is sufficient to increase the irrigated area to 5.6 million ha. MPIAE (2016) also speaks of 5.6 million ha of "potentially irrigable lands", of which 335,000 ha can be irrigated "easily" as this area is situated close to the country's water bodies.

Yet, research suggests that these figures may be too optimistic. Walker et al. (2016) estimate the irrigation potential for SSI in Chad at 94,000 ha. Furthermore, these ambitions go against the agreements made in relation to transboundary water management. As an example, a bilateral agreement between Chad and Cameroon limits dry season irrigation from the Logone river to 3,000 ha of rice cultivation in each country (see chapter 4). Moreover, the projections above do not take into account the potentially large effects of increased water abstraction on the ecology. Hence, a cautious approach based on a local water resource assessment is critical when planning large-scale irrigation development.

Large regional differences exist: 84% of the available surface water and 58% of the renewable groundwater resources are situated in the Sudanian zone. In contrast, the Saharan zone relies on a mere 1% of the country's surface water and almost no renewable groundwater resources (HCNE, 2003). In the Sahelian zone, available water for irrigation is linked to the presence of rivers and streams with a potential of 4 billion m³ of surface water and 8 billion m³ of renewable groundwater.

HCNE (2003) does mention the following constraints when it comes to increasing the consumption of water for irrigation:

- Water withdrawal and the use of pesticides affect the areas around the sink lakes (Lake Chad, Lake Fitri)
- Reduced and more intensive rainfall and increased evaporation due to climate change could affect the rain-fed and spate irrigation systems.
- Increased water consumption within Chad may affect the transnational water resources
- Depending on the water source and its characteristics, mobilizing water could become a considerable cost.
- The lack of information about the aquifer systems and their transboundary impact poses some limitations to sustainable management. Yet the main issue with groundwater mobilization is of technical, qualitative and economic order.

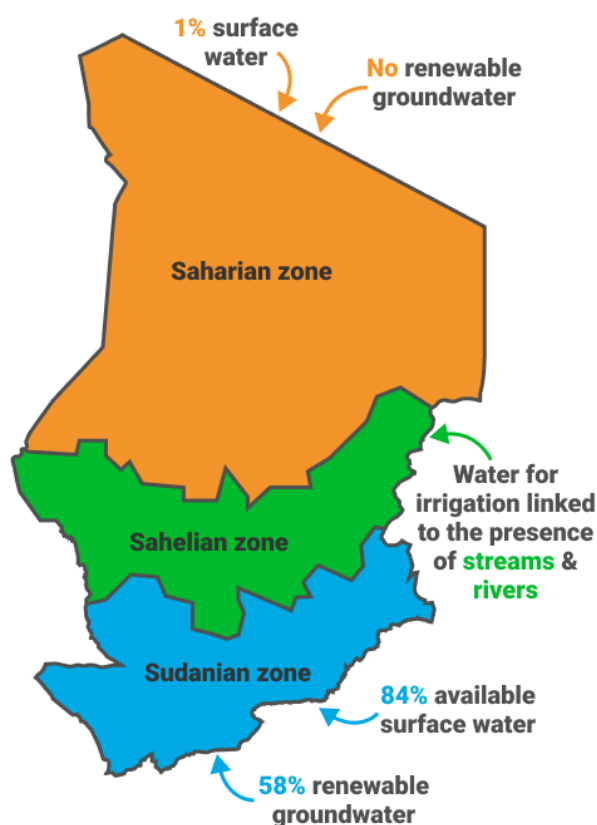


Figure 13 Percentage of Chad's available water resources situated in each agro-ecological zone

Next to this it is essential to note that especially large-scale water withdrawals and river embankments for irrigation schemes have a large environmental and socio-economic impact on a local level. Ngatcha et al. (2005) report that the construction of the Maga dam (100-300 km²) and river embankments implemented in 1979 to enable large-scale gravity-fed rice irrigation, reduced the groundwater table in the area downstream of the irrigation scheme by 3-10 m. UNEP (2004) mentions that the large irrigation projects on the Chari river: SONASUT (4,000 ha) and on the Logone river: Casier A, B, C at Billiam Oursi, Bongor (7,120 ha) and Lai, have all underperformed in terms of agricultural production and seriously affected the local population, since the reduction of flooding also reduced the available farmland for spate irrigation. UNEP (2004) citing Nami (2002) stresses that the increase of food insecurity in the

region directly resulted from the reduction of available floodplain areas for agricultural production.

The same article also mentions that agriculture in the downstream regions of lake Chad is very dependent on the water level in the river and that this segment is most affected by surface water shortages and increased abstraction. MPIEA (2017) mentions that billions of hectares of agricultural and pastoral land cannot be used anymore if the lake Chad inundated area continues to shrink. According to Odada et al. (2006) the shrinking trend of lake Chad is expected to continue due to population growth and increased irrigation in the basin. The water use efficiency of irrigation schemes is estimated at a mere 11% (ibid). CILSS (2016) also indicates that rainfall shortages, heavy use of the lake and rivers for irrigation purposes and population growth are the main contributing factors to reducing the lake's area. The severe effects on fishing and gardening has already sparked migration to Chad's urban areas. In a contrasting case, the total area of the lake Fitri wetlands did not change much between 1975 and 2013, despite increasing agricultural water consumption. While the northern wetlands decreased, the southern wetlands actually increased, causing migration to the southern side of the Batha de Lieri system (ibid).

As stated by HCNE (2003), the condition to increased agricultural water consumption is to understand the water resources better and manage them carefully, to protect the ecosystems on which the majority of Chad's population and biodiversity rely. Special care should be taken in the semi-arid hill valleys and the arid oasis systems where the balance between the available water resources and their usage is fragile (ibid).

3. FARMER BENEFITS

This chapter has the objective to answer the question: What are the benefits for farmers from irrigation? To answer this question, the different manifestations of irrigation and FLID in Chad have been described (3.1), four segments of farmers have been identified based on the field work (3.2) and the farmer business cases and non-monetary benefits have been assessed (3.3).

3.1 CHARACTERIZATION OF FLID IN CHAD

Over 80% of Chad's population works in the agricultural sector (EIB, 2020). Chad is known for its flood recession agriculture which makes an essential contribution to food security. It is a form of water management that is not always easy to define or quantify. FAO (2019) indicates that Chad has an irrigated area of 26,200 ha, plus 21,400 ha of cultivated wetlands and 125,000 ha of flood recession cropping⁹. The National Water Directive by the Government of Chad (HCNE, 2003) differentiates between seven types of irrigation systems, based on the size of the system, level of control of the water and the type of crops grown (see Table 8).

⁹ Data irrigation and flood recession from 2002, data cultivated wetlands from 1988.

Table 8 Overview of irrigation types in Chad

Irrigation type	Crop	Water source	Technology	Estimated area	Departments	Equivalent PARIIS type
Traditional irrigation with partial water control	Berbéré, maize, vegetables	Flood water from rivers and streams : Logone, Barh Azoum		70,000 – 100,000 ha	Mayo Kebbi, Chari Baguirmi, Ouaddaï, Salamat, Lac	Type 1
Low land rice production	Rice	Run-off water				Type 1
Traditional small-scale irrigation with total water control	Vegetables, fruits, cereals	Shallow ground-water from open wells and surface water	Chadouf, small petrol pumps	8000 ha	Ouaddaï, Biltine, Kanem, Lac, Batha	Type 2
Modern small-scale irrigation with total water control	Vegetables	Shallow ground-water from wells or boreholes, Surface water: Chari, Logone	Petrol or diesel pumps Systems typically 0.5 - 10 ha also < 100 ha	2000-3000 ha around N'Djamena only	Hadjer Lamis, Chari Baguirmi, (+ Ouaddaï, Biltine, Kanem, Lac, Batha, + N'Djamena)	Type 2
Large-scale irrigation with partial water control	Rice, wheat, maize	Surface water: Logone, lake Chad				Type-4
Large-scale irrigation with total water control	Sugarcane, rice, wheat, maize	Surface water: Chari, Logone, lake Chad		20,000 ha but only a small part cultivated		Type-4
Oasis systems	Date palms, vegetables, cereals, fruit	Shallow ground-water	Chadouf, small petrol pumps			Type-2

Next to this overview, the Ministry of Production, Irrigation and Agricultural Equipment (MPIAE, 2017) mentions the following additional types of irrigation:

Irrigation type	Crop	Water source	Technology	Estimated area	Departments	Equivalent PARIIS type
Small to large (10-50 ha) village schemes	Rice, vegetables			220 ha (small) + 1200 ha (large)		Type-3
Micro dams	Berbéré, tomato	Residual moisture in floodplains	N.A.	600 ha	Ouaddaï (barrages de Matar, Ouéré, Tarbaka, Malanga, Bokoy) + 18 new works in Guéra, Ouddaï, Biltine	Type-3
Modern polder systems	Maize, wheat, potatoes	Lake	Hybrid: gravity + pumping when low water level	4000 ha (without valves + 1000 ha (with valves) + 3000 ha (with pumps)		Type-1
Industrial irrigation	Sugarcane	Chari river	Sprinklers, pivots	<6000 ha	S	

This study focuses on Farmer-Led Irrigation Development (FLID). Except for the two large-scale irrigation types (Type 4), which are state-managed, and the Type-3 systems: the village schemes and micro dams which rely mostly on government and NGO support, all other types could be considered a form of FLID. The assessment of farmer benefits in this section will focus on individual smallholder farmers, i.e. Type-2 irrigation.



Figure 14 Type-5 Commercial sugarcane irrigation near Sarh, Moyen-Chari (Google Maps, October 2019)

The modern and traditional versions of the irrigation types defined above as “irrigation with total water control”, are typical examples of private smallholder farming, or Type 2 irrigation within the PARIIS framework. The “irrigation with total water control” types refer to private smallholder irrigation systems using petrol pumps, buckets or chadoufs to withdraw groundwater or surface water. According to MPIAE (2017), clusters of the traditional irrigation type with total water control can be found in the departments of Ouaddaï, Biltine (Wadi Fira), Kanem and Lac while the modern type is encountered in the Kanem, Lac, Ouaddaï, Batha, Biltine, Hadjer-Lamis and Chari Baguirmi departments. The economic activities depend on the availability and control over water resources and that horticulture is encountered along rivers and streams. Irrigated horticultural production during the dry season is also reported in the Logone floodplains in the Mayo Boneye (Bongor), Tandjilé-Est and Tandjilé-Ouest departments, where farmers focus on the production of lettuce, tomato, okra, eggplant and carrots after the rain-fed rice and berbéré production have finished (MPIAE, 2017).

The area around N'Djamena can also be considered a cluster of FLID development. The National Water and Sanitation Master Plan from 2003 (HCNE, 2003) already mentioned the “success of the modern private smallholder irrigation in the region of N'Djaména”. Farmers irrigate small plots using buckets or large plots using motor pumps (0.5 to 100 ha) to withdraw water from the Logone and Chari rivers which merge in N'Djamena. The total irrigated surface by private farmers around N'Djamena is estimated to be between 2,000 to 3,000 hectares.

The World Bank (1992) already mention that: “In Chad, cheap tube wells to tap shallow aquifers, used in conjunction with small pumps that individual farmers purchase from the private sector, which also provides maintenance, are beginning to supplement manual water lifting. As a result, almost all successful irrigation occurs on plots owned and managed by individuals with individual water supply control.”



Figure 15 FLID Type-2
Manually irrigated plots near
Chari river, suburbs of
N'Djamena (Google Earth, May
2021)

Yet another major cluster of farmer-led water management is the Lake Chad region, which is the final recipient of the rivers in the large lake Chad basin. The vast flooded areas are used for rice cultivation during the rainy season. Flood-recession farming is used to extend the growing season and range of crops. Farmers have developed a diversity of controlled flooding mechanisms to make optimal use of the water and land to produce cereals and vegetables. The main agricultural products clusters are found around Bol, where farmers construct small rice polders (CILSS, 2017) and just around Baltram (LCBA, 2015). According to LCBA (2015) the natural resources are not overexploited, but a lack of labor limits further farmer-led agricultural development and support services for family farming, including credit, improved value chains and extension services.

The following chapters of this report will focus on the “irrigation with total water control” types defined above; the most common production systems found in the focus provinces: Ouaddaï, Logone Occidental and Mayo Kebbi Ouest.



Figure 16 FLID Type-2 :
Irrigated farms along a wadi
near Ouadi Galenge (Wadi Fira)
(Google Earth, March 2013)

3.2 TYPOLOGY OF FLID IN THE OUADDAÏ, LOGONE OCCIDENTAL AND MAYO KEBBI OUEST PROVINCES

The cultivation of horticultural crops irrigated by hand was a common practice in the Ouaddaï since more than twenty years ago. The horticultural producers were mainly poor farmers from the area. In the past ten years, however, irrigation has increased considerably, following the arrival of refugees and the comeback of Chadian people who worked in Sudan and came back with irrigation knowledge and financial resources. The main model imported from Sudan was the tube well technique, called soumbouk in local Arab, and the use of small petrol pumps. Those returning invested in irrigated production systems and benefitted from high sales prices in Abéché town, motivating other farmers to do the same¹⁰. The provincial ANADER office estimates the number of farmers practicing horticulture in the Ouaddaï province at 50,000 covering a total of 750 to 1,100 ha of irrigated onions, garlic, tomato, okra and other vegetables. The small area per person (0.02 ha) indicates that this data is mainly based on farmer groups and that the total irrigated acreage including individual private farmers is expected to be considerably larger. It was also noted that there is no official register at the province level and that the estimations are based on the national statistics database. The Ministry of Agriculture in N'Djamena reports that 500 farmers are practicing irrigation individually in the Ouaddaï province covering 80 ha. The first part of our study by Westra (2020) estimates the total irrigated area in the Ouaddaï province at 18,270 ha.

¹⁰ Information following from farmer interviews.

In the Logone Occidental province, the appearance of irrigated production is more recent. Here too, irrigation was started by farmers who had learned about irrigation techniques abroad. The first producers started irrigating around the rivers using fuel pumps. Some benefitted from training and finance by external funders. Right now there are a lot of irrigated fields and the number keeps on increasing. Two reasons are mentioned: the lack of job opportunities for young people in other sectors and the high demand and profitability of horticultural crops, which requires irrigation. Next to this, the erratic rainfalls and poor soils reduce the productivity and increase the risk of harvest failure related to rain-fed agriculture¹¹. As a result, some farmers transform their rain-fed land into irrigated land.

In Mayo Kebbi Ouest farmers indicate to have shifted from sugarcane to horticultural crop production because of the higher revenues. The use of irrigation is still increasing however it is becoming increasingly expensive to expand once areal. ANADER in Pala region reports 1,005 individual producers covering 156, 167 and 108 ha in the Gagat, Pala and Lamé sub region, respectively. The resulting average of 0.4 ha corresponds to that of a typical individual vegetable producer. The PARIIS-UGL in Mayo Kebbi Ouest reports over 1,000 ha of irrigated production including 500 ha by individual farmers. The local Rural Engineering department from the Ministry of Agriculture indicated that most farmers are not registered and therefore the number of farmers or hectares is unknown. Westra (2020) estimated a total irrigated area of 260 ha in the Mayo Kebbi Ouest province.

Irrigated production systems in the three provinces now focus on vegetable or fruit production using surface water (Logone Occidental and Mayo Kebbi Ouest) and/or shallow groundwater (Ouaddaï, Logone Occidental and Mayo Kebbi Ouest). The rainy season starts in May and finishes in October. For most farmers October marks the start of the season. The main horticultural crops grown in order of importance are onions, garlic, tomato, okra, jute mallow, eggplants, melons, cabbage, paprika, pepper and potatoes. Some farmers in the southwest also grow bananas and papayas.

From the 20 farmers interviewed, 65% have two irrigated crops per year, whereas 15% grow 3 cycles and 20% only grow one irrigated crop. As for the latter, all have these farmers used wells that dried up at the end of the dry season. In Abéché, having a well that dries up means you can only grow one horticultural season per year. In the Logone Occidental and Mayo Kebbi Ouest however, 70% of the farmers with wells drying up in February still managed to grow two horticultural crop cycles through various strategies, including continuing horticultural crop production during the rainy season.

Based on an analysis of 20 interviewed farmers, their access to support, technology, water and markets, the objectives and organization of the production system, as well as the costs and benefits of the production systems, the typology in Table 9 has been developed.

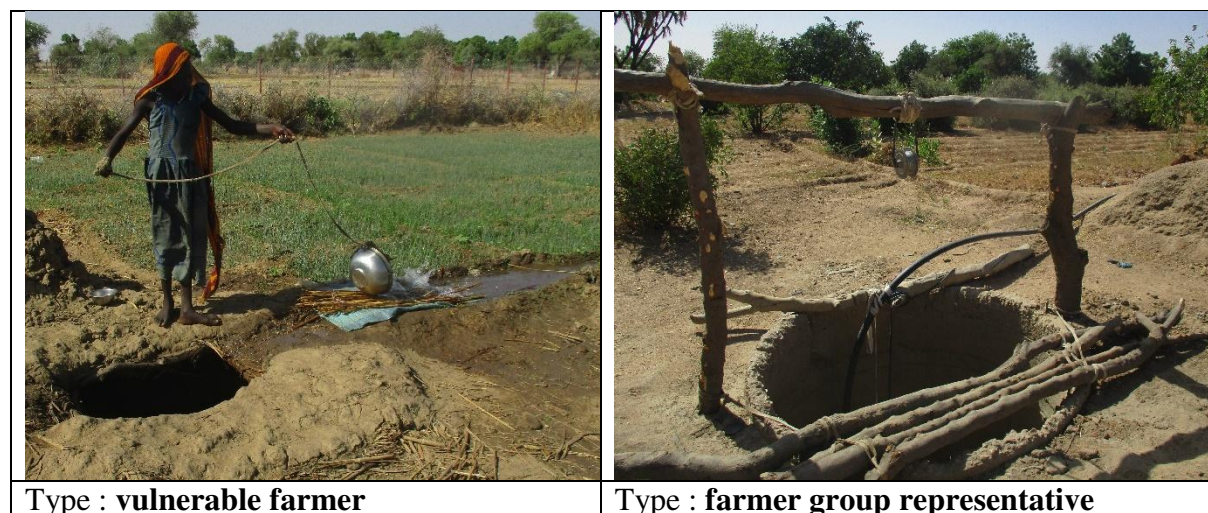
¹¹ Information provided by Dr. Molengar Ngoundo, Agriculture expert at FAO Chad.

Table 9 Typology of FLID in Ouaddaï, Logone Occidental and Mayo Kebbi Ouest

Type	Vulnerable farmers	Market-oriented vegetable producers	Commercial fruit producers	Farmer groups
Objective crops	Vegetables mainly for sales	Vegetables mainly for sales	Fruit (banana and papaya) for sales	Vegetables mainly for sales
Organization	Private	Private	Private	Groups of about 15 family members
Access to water	Hand-dug well – non-permanent	Hand-dug wells, ponds, streams	Hand-dug wells, ponds, streams	Reinforced wells or boreholes – permanent
Technology	Buckets or small petrol pump	Petrol pump	Petrol pump	Solar, diesel or petrol pump
Funding of water source and equipment	Private	Private	Private	Government or NGO
Risk tolerance	Low	Medium	High	Low
Main market	Farm gate and provincial capital	Provincial capital, Commercial farmers	Buyers from N'Djamena	Provincial capital
Irrigated area	< 0.25 ha	0.3 – 3 ha	> 1.5 ha	0.5 – 1 ha

The risk tolerance is illustrated by the ability and willingness to invest in a few crops with volatile prices (high risk, e.g. bananas and papayas), towards a more risk-spreading approach (medium risk: 3-4 different vegetables), to increasing importance of crops for consumption (lower risk, lower profit). Risk tolerance is also related to farmers' resilience to agronomic or financial shock events.

The following pictures and information concern four interviewed farmers, each of them corresponding to a different type. The total investment refers to the water source and irrigation technology only.



Type : vulnerable farmer

Type : farmer group representative

Gender : female	Gender : male
Age : 37	Age : 66
Started irrigation: 30 years ago	Started 18 years ago
Location : 60km from Abéché town	Location: near Abéché town
Crops : garlic, onions	Tomato, okra, cucumber, lettuce, etc.
Irrigated area : 0.135 ha	1 ha
Water source : hand-dug well	Reinforced open well 25m
Technology: rope and bucket	Solar submersible pump
Total investment : 10,000 FCA	Total investment 7,850,000 FCA
Total revenue : 480,000 FCA/year	Revenue : 2,850,000 FCA/year
Total margin : 75,000 FCA/year	Total margin : 500,000 FCA/year



Type : market-oriented vegetable producer	Type : commercial fruit producer
Gender : male	Gender : male
Age : 40	Age : 38
Started irrigation: 2 years ago	Started 7 years ago
Location : 25km from Moundou town	Location: near Moundou town
Crops : tomatoe, capsicum, potato, cabbage	Crops: bananas, papayas
Irrigated area : 2 ha	Irrigated area: 4 ha
Water source : hand-dug wells and ponds	Water source: large excavated ponds
Technology: petrol pump	Technology : two large petrol pumps
Total investment : 985,000 FCA	Total investment : 1,700,000 FCA
Total revenue : 3,800,000 FCA/year	Revenue : 46,000,000 FCA/year
Total margin : 2,619,000 FCA/year	Total margin : 44,026,000 FCA/year

3.3 FARMER BUSINESS CASES AND NON-MONETARY BENEFITS

The following chapter discusses the business case of the irrigated production systems. Almost all farmers grow additional rain-fed crops during the rainy season, mostly maize, rice and groundnuts in the southwestern provinces and sorghum, millet, groundnuts, sesame, and niébé in the Ouaddaï province. About 85% of the interviewed farmers have no other income sources, while 15% earned additional income through poultry or pig breeding or providing plowing or transport services with a tractor.

The following figures on the cost of inputs and labor are based on full costing accounts provided by 13 farmers, including 4 in Ouaddaï, 7 in Logone Occidental and 2 in Mayo Kebbi Ouest.

Table 10 Overview input use and cost per crop season

Input	Seed	Fertilizer	Chemicals	Fuel	Maintenance pump & irrigation system	Total inputs
Cost range (FCA)	10,000 - 250,000	10,000 - 88,000	10,000 - 83,000	36,000 - 241,000	6,000 - 160,000	82,000 - 792,000
Average cost/ha (FCA)	76,397	53,846	23,385	119,479	44,846	31,7954
Average cost/ha (USD)	142	100	44	223	84	593

For those using fuel pumps, the cost of fuel and maintenance of the pump and irrigation system amounts to 53% of the total input expenditures. The cost of seed is the second most expensive input, followed by fertilizer and chemicals. For the farmers renting the land an additional renting cost of 23-65 USD per hectare applies in the Logone Occidental and Mayo Kebbi Ouest provinces for a field with access to hand-dug wells that provide water for one irrigation season (till Jan-Feb).

The cost of labor is difficult to evaluate as farmers use a mixture of paid and family labor activities. Farmers were simply asked to provide their labor expenses without accounting for the input of family labor. Table 11 compares the cost of irrigation and agronomic labor, i.e. all the production activities that are not irrigation. The labor cost related to irrigation constitutes 9 to 44% of the total labor costs of the irrigated production systems, with an average of 24%.

Table 11 Cost of irrigation and agronomic labor per crop season

Labor type	Irrigation labor	Agonomic labor	Total labor
Cost range (FCA)	40,000 - 280,000	0 - 1,125,000	10,000 - 1,333,333
Average cost/ha (FCA)	99436	251910	351346
Average cost/ha (USD)	185	470	655

The price yield and price figures shown below in Table 12 are based on interview data from 20 farmers. It shows that the yield per hectare can vary a lot from one farmer to another based on the quality of the seed, use of inputs, water, duration etc. The factor length of the season is well illustrated by the okra yield outlier of 20,000 kg/ha (see Table 12), resulting from a very long harvest season by a farmer who opted to focus on one instead of two crop cycles. The produce prices vary even more in place and time, especially for perishable cash crops like tomatoes and papayas. The indicated prices are those received by the interviewed farmers.

Table 12 Yield and price of product sold by farmers¹²

Crop	Yield ¹³ (kg/ha)	Price Mayo- Kebbi Ouest	Price Logone Occidental	Price Abéché	Average revenue (FCA/ha)
Garlic	2,500- 3,600			330 - 830 FCA/kg	1,769,000
Onions	12,000 - 29,600	360 FCA/kg		190 - 310 FCA/kg	5,200,000 ¹⁴
Tomato	3,600 - 12,000	250 FCA/kg	250 FCA/kg	170-500 FCA/kg	2,613,000
Capsicum			300 FCA/kg		
Potato			300 FCA/kg		2,984,400
Okra	2,000 - 20,000	250 - 300 FCA/kg	200 FCA/kg	330 - 800 FCA/kg	3,300,000
Cabbage	3,100	300 FCA/kg	250-300 FCA/kg		852,000
Eggplant	2,000	200 FCA/kg			400,000
Chilies	15,000	700 FCA/kg			10,500,000 ¹⁵
Cucumber		200 FCA/kg			
Bananas	75,000 ¹⁶		133-1,000 FCA/kg		
Papayas	60,000		10 - 750 FCA/kg		
					357,000
Maize	1,700		210 FCA/kg		
Groundnuts	2,700		300-375 FCA/kg		

Table 13 provides an overview of the average production costs, revenue and profit per farmer type, based on figures from two vulnerable farmers, nine market-oriented vegetable producers, two commercial fruit producers and seven representatives of farmer groups. The original data

¹² All prices are selling prices reported by farmers. Most farmers sell at various locations: at the farm gate, in the village and in the provincial capital.

¹³ The yields correspond relatively well to the 2019 yields for Chad indicated by FAOSTAT:

Onions 12,375 kg/ha; tomatoes 8,100 kg/ha; potatoes 9,948 kg/ha; maize 1,263 kg/ha; vegetables 10,488 kg/ha
<http://www.fao.org/faostat/en/#data/QCL>

¹⁴ The figures for onions are based on three farmer group sites of 0.5 ha each, yielding respectively 80, 180 and 200 bags of 80 kg.

¹⁵ This figure is based on the production of chilies on one plot with a size of 0.01 ha. It is therefore not a representative yield or revenue for a hectare.

¹⁶ While FAOSTAT does not have banana productivity data for Chad, the 75,000 kg/ha is considerably higher than the long-term average banana productivity in Mali (55,000 kg/ha) or Senegal (18,000 kg/ha). Online accounts from another company in Moundou, Chad, report that “Yields are quite variable depending on the variety and the degree of intensification of the exploitation, i.e. respect of the standards. Yields vary from 20T (1000 feet per ha), 75T (2500 plants per ha), 150 T (5000 plants per ha)”
https://wapex.org/fr/system/files/presentation_bananes.pdf Hence, a yield of 75,000 kg/ha is realistic in this area. Furthermore, FAO mentions that it is difficult to compare production data on bananas as some report in terms of bunches, in which case the stalk is included in the weight. <https://www.fao.org/waicent/faostat/agricult/prod-e.htm>

from the individual farms are shown in Annex C. The results show that the revenue from vegetable production ranges from 3,000 USD to 6,000 USD per hectare depending on the farmer type and their corresponding access to water, money for inputs, paid labor and markets. While these numbers informed the farmer typology, they cannot be used as representative values for irrigated production in the region. The number of farmers interviewed is too small especially considering the large variety of crops

In reality, most farmers count on about 6 family members that contribute to the production system - which are not included in the costs per hectare. Therefore, the indicated profit should be considered on family basis and not as profit generated on the account of one person.

Table 13 Average economics per farmer type (per season)

Farmer type	Total irrigated area (ha)	Total production cost (USD)	Total revenue (USD)	Total profit (USD)	Profit margin	Cost/ha (USD)	Revenue /ha (USD)	Profit /ha (USD)
Vulnerable farmers	0.2	262	587	465	64%	1,050	3,111	1,859
Market-oriented vegetable producers	1.5	2,006	8,210	6,204	72%	1,386	6,059	4,674
Commercial fruit producers	2.8	2,791	54,528	51,737	94%	1,094	18,487	17,393
Farmer groups	1.2	2,156	5,313	3,157	61%	1,597	4,008	2,411

The vulnerable farmers growing on average 0.2 ha were constraint by access to water, either due to the lack of a pump or because the water table in the hand-dug wells is relatively deep (8m) and the small water column only allows for one irrigated crop cycle before drying up. Therefore, the absolute values are lower for this farmer type and also the revenue and profit per hectare as they apply less water and inputs than the market-oriented vegetable producers.

The market-oriented vegetable producers irrigating on average 1.5 hectares make average revenues of about 8,200 USD per farmer of which 6,200 USD is profit. They make the highest revenue and profit margin per hectare amongst the vegetable producers. Farmer groups have a lower sales revenue per hectare. The two farmers growing a couple of hectares of bananas or papayas are of a different kind. These production systems led to a profit of over 18,000 USD per ha in 2020 and a profit margin of 94% (!).

It is important to note that the revenues and profit margins indicated here mainly concern the 2020 produce prices, which was a good year. Prices in 2021 are considerably lower. Farmers in the Ouaddaï province mention that the price of a bag of onions went down from 15,000 to 25,000 FCA in 2020 to less than 10,000 FCA in 2021. The reason was a spike in production of mainly tomatoes, onions and garlic following abundant rainfall, which caused the prices to go down. The price drop has been even more dramatic for the banana and papaya producers in the southern provinces, who reported reductions by a factor 5 and 75 for bananas and papayas respectively after the oil exploitation had stopped and the economy went down.

Next to the economic figures, there are non-monetary benefits to the irrigated production systems with more or less importance depending on the farmer type. The number one most important non-monetary motivation mentioned by farmers is being self-employed and having a continuous income source. Food availability for the household was another important benefit mentioned by all vegetable producers, irrespective of the land size or farmer type. Yet all farmers interviewed indicated that profit is the most important benefit of irrigated production for them. Compared to rain-fed farming, farmers in the southwest indicated that a big advantage of irrigated production is that less land is required to get a good income, which is important considering the increasing pressure on farmland in the area.

4. POLICY AND LEGAL

This chapter aims to answer the question whether the policy and institutional environment is conducive for individual smallholder farmers who have water nearby to take action in irrigation or not. First the regulations and practices of access to water (4.1) and land (4.2) are described, followed by corresponding policies that could support farmer-led irrigation development.

4.1 REGULATIONS AND PRACTICES OF ACCESS TO WATER

The development and implementation of water management policies in Chad is the Ministry of Environment and Water Resources (MEE) responsibility. Under the guidance of MEE the government has brought together numerous public stakeholders to develop its Master Plan for Water and Sanitation (2003-2020). The national master plan, referred to as HCNE (2003) in this report, has shaped the policies, strategies and targets for water management over the past decades for drinking water, sanitation, pastoral and agricultural water use. The organizational framework for water management is also detailed in the master plan. The plan describes that the General Directorate of Rural Engineering and Agricultural Hydraulics (DGGRHA), which is part of the Ministry of Agriculture (MDA), is responsible for designing and implementing irrigation policies concerning public irrigation systems and other agricultural water use programs. To this end the DGGRHA has offices in most provinces. The other national agencies with a formal role in the irrigation sector according to the national master plan (HCNE, 2003) are the National Rural Development Office (ONDR), responsible for the implementation of agricultural development programs and the Lake Development Society (SODELAC) in charge of the overall development in the Lac province. End of 2016 the ONDR, SODELAC and PNSA were replaced by establishing the National Rural Development Support Agency (ANADER).

Chad is a member of the international Lake Chad Basin Commission (CBLT) together with Cameroon, Central African Republic, Niger and Nigeria. In 1998 the countries adopted a strategic action plan to regulate and control water use in the basin. Next to this a bilateral agreement was signed in 1970 between Chad and Cameroon. This agreement limits the withdrawal of water from the Logone river and its tributaries to 10 m³/s between May and December and 5 m³/s from January to April. In addition, this agreement limits dry season irrigation from the Logone river to 3,000 ha of rice cultivation in each country. Yet the Lake Chad Water Charter signed in 2012 established the potential withdrawal from the entire lake Chad basin at 6 km³ and allowed for a potential of 80,000 ha of irrigation development in Cameroon (World Bank, 2019). However, interviewed experts indicate that the agreement between Chad and Cameroon has not been implemented in practice. The withdrawal of water is subject to traditional rule only, without any control from the state. MPIAE (2017) describes private irrigation development as anarchy resulting from the absence of practical policies to implement the water code.

The National Water Code of 1999 defines the rules related to water access for domestic, pastoral and agricultural use. The code states that all surface water and groundwater belong to the public domain. Water rights are linked to land rights. In practice, the traditional leaders control water rights and oversee that water use and access correspond to the local and Islamic laws (USAID, 2010). The customary and Islamic laws prescribe that everyone has the right to access a water source. This right comes with the obligation to use water efficiently and avoid comprising water access for other people and damaging the environment. Surface water is accessible to everyone. However, changing water courses or interfering with downstream rights requires approval from

the local authorities. The right to a water source, like a spring, can be inherited. Rainwater or groundwater access and use are linked to the ownership of land. Land owners are entitled to construct wells on their land (USAID, 2010). There are no permits required for (manual) borehole drilling either (RWSN, 2015). Interviews with ANADER in Abéché and Pala and the PARIIS-UGL in Pala confirm that no permits are required to withdraw water and that access to water is free for everyone. The Ministry of Agriculture refers to the agreements between countries when asked about the rules and regulations regarding water abstraction.

4.2 REGULATIONS AND PRACTICES OF ACCESS TO LAND

Formally the Ministry of Land Affairs is responsible for land right policies and titles. The Chadian Civil Code includes a supporting policy on private property rights. Yet, a Household Living Standards Measurement Study by IDA (2018) indicated that only 7,000 land titles are registered in Chad. According to this assessment, the formal land title registration process requires 30 steps, and payments adding up to hundreds of USD in a process that takes over 5 years' time. In reality, most farmers consider land as a communal resource. Therefore, they rely on customary systems and traditional authorities. Land rights in Chad result from a complex coexistence of overlapping formal, customary and religious laws. The vast majority of land tenure in rural areas is structured through customary rights. Land rights are predominantly based on Islamic tenure law (IDA, 2018). The government of Chad recognizes traditional and customary land rights (MPIEA, 2017).

According to the Chadian law, land ownership can be obtained through registration (formal right) or usage (customary right). However, non-registered lands are officially considered vacant unless one can demonstrate that the land is under his or her usage ("mise en valeur"). Land owners are entitled to use and sell their land. However, the state can always claim rights over any natural resource including land if this is within the public interest. MPIAE (2017) highlights that land rights are always linked to its usage or exploitation (MPIAE, 2017). Land ownership can be inherited or purchased. In customary law, land ownership is connected to the first occupants who passed on the rights through inheritance. Individual access and land use rights are assigned by a traditional leader, following the principle that land belongs to the collective. Access is linked to the usage of the land.

Over the past decades the customary system has evolved towards more family-based inheritance as lands have become more scarce. This implied that land ownership had been linked to family names which are passed on to male descendants (USAID, 2010). As a result, women have less access to land than men, which is one factor that limits the perspectives of female farmers in irrigation development. Formal tenure laws make no difference between men and women. Yet, the majority of land rights are based on customary laws and traditions. USAID (2010) calls for donors to assist the government in formalizing land rights for female farmers to provide an alternative to "discriminatory principles of customary and religious law". Women in Chad have limited access to land in general and specifically to productive and irrigable lands (ibid). One of the strategies by the PARIIS project to address this issue is to develop specific tenure agreements for female farmers (MPIAE, 2017). ANADER in Pala (Mayo Kebbi Ouest) confirmed that women could only access land through their husbands, since they inherited the land from their parents. According to USAID (2010), women get access to land through short-term use agreements with community members in some areas.

In the Ouaddaï, Mayo Kebbi Ouest and Logone Occidental provinces, access to irrigated land can be obtained through inheritance, purchase and leasing. Inheritance from father to son or daughter is the most common form of land ownership. Some producers have purchased irrigable land, but according to experts from ANADER this is rare. Pressure on irrigable land is increasing throughout the country. MPIAE (2017) mentions that small fields of 0.25 ha are standard and motivate farmers to consider their irrigated production as a secondary activity. The demand and price of irrigable land is exceptionally high in the Ouaddaï province, where prices range from 7,500 to 11,000 USD/ha. Most farmers indicate that renting land is more accessible due to the high cost of buying land. Rental fees vary from zone to zone and cost about 50-60 USD per season per acre. ANADER confirms that renting is an increasingly frequent practice to access irrigable lands in the Ouaddaï province.

4.3 POLICIES TO SUPPORT FLID

The government of Chad aims to adapt development policies to match the potential and constraints of the different regions. In the drylands, priority is given to the intensification and diversification of traditional irrigated agriculture, particularly flood recession agriculture, and the extension of rainfed agriculture. In the wetlands, the priorities are the rehabilitation and reorganization of large perimeters; modern or supplementary irrigation of small perimeters along perennial rivers; increasing the irrigated areas (PARIIS project); and improving yields and increasing agricultural production.

The Regional Support Project for the Sahel Irrigation Initiative (PARIIS), initiated with the objective to significantly increase the irrigated area within five years, is the main governmental project focusing on FLID. The project provides opportunities to technically and financially support private smallholder farmers, since Chad has opted to focus on developing irrigation types 1, 2 and 3. The awareness of the importance of FLID within the government of Chad is not new. In the National Water Master Plan (HCNE, 2003), it is already mentioned that the majority of irrigated lands are cultivated by traditional practices. The large-scale systems are very costly compared, which does not justify public investments. Therefore, the master plan called for the state's withdrawal from investments in large public irrigation systems, leaving this to private investors. The investment by the state in small-scale irrigation systems was not considered successful either. Despite its "marginal surfaces", the plan mentions the success of the private smallholder irrigation development around N'Djamena. (HCNE, 2003).

Interviews with local government agencies showed that not much financial or technical support had been received from the national government. One officer mentioned that the National Master Plan of MEE has never been implemented. In contrast, most others said that there are no national support strategies for developing private irrigation. The only public support mechanism for FLID that was noticed at the local government level is the National Food Security Program (PNSA) supported by the FAO that was implemented from 2006 to 2015. The program provided materials to support individual horticultural producers, e.g. by funding and installing boreholes and motor pumps. More recently, in the Ouaddaï province the PARIIS program has financed the construction of open wells with concrete rings, generally of 4 to 8 meters' depth. The wells were constructed exclusively for farmer groups.

Some observers question the justness of the procedures to establish a group or cooperative and note that some groups are serving just one household or family. Establishing a cooperative to benefit from government or NGO support is generally only feasible for those who have

resources to contribute to the investment. The vulnerable farmers who need support are often unable to join a cooperative and thereby remain deprived of support. Yet, the strategy to strengthen producer groups and link these to associations and unions is considered an important strategy that could offer a more durable alternative to the ad hoc project-based support initiatives. The establishment of multi-stakeholder platforms is supported by the PARIIS program to contribute to knowledge sharing and capacity building.

5. KNOWLEDGE

5.1 PUBLIC SECTOR CONTRIBUTIONS TO FURTHERING FLID KNOWLEDGE

Chad is featured by a low level of schooling and high youth illiteracy rates. Secondary education is comprised of two tracks. The general education track, which is open to the highest-scoring primary school graduates, leads students to the secondary education license and university access. After following the general tracks, the percentage of youth subscribing at a university is 3.6% for men and 0.9% for women (UNICEF, 2014). An alternative more frequented track is the Technical and vocational education and training (TVET) route. The TVET institutes covering irrigation aspects are the responsibility of the Directorate of Agricultural Education, Training and Rural Promotion (DEAFPR) from the Ministry of Agriculture. The operational institutions include the college of agriculture, a rural development training center and 33 training and rural promotion centers throughout the country.

Interviews with five government officials involved in irrigation, see Figure 17, showed that the main topic included in professional agricultural education is the design of gravitational irrigation systems. Other topics mentioned are agricultural input management, motor pumps' operation and maintenance, drip irrigation and Californian systems. Other topics including solar irrigation or access to land and water are not included in the curricula. Some officials indicated that the content and theory taught is not linked to its application in practice.

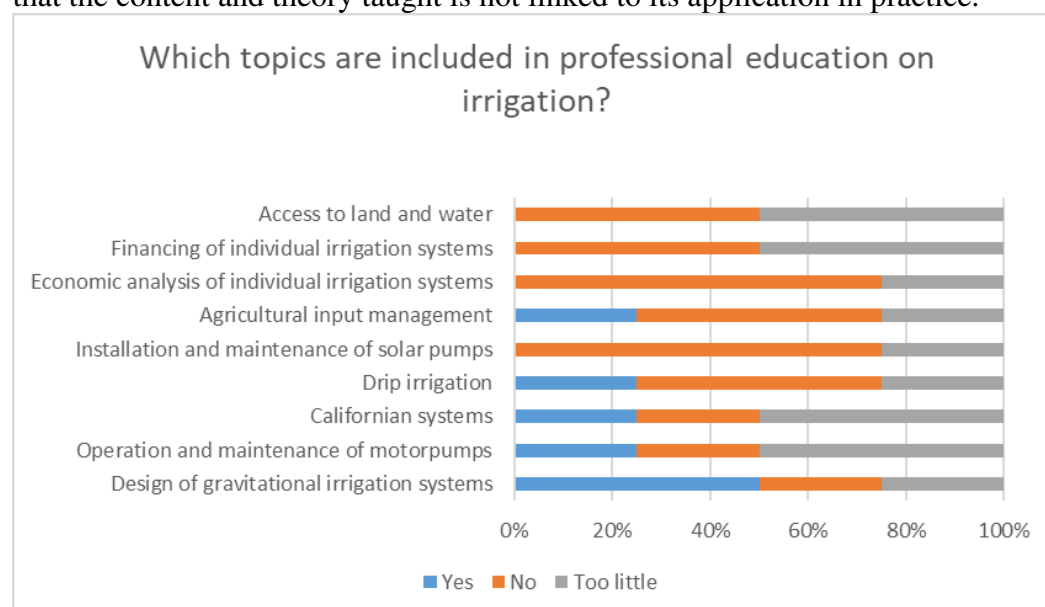


Figure 17 Irrigation topics included in professional education

Public extension services

Access to information and technology remains uncertain in all of the provinces visited, as traditional channels of dissemination such as state development agents (ONDR in the past and ANADER today) are practically absent in the field. In fact, the producers surveyed are unanimous in stating that they no longer receive support, advice or technical supervision from ANADER agents at all levels since the disappearance of the ONDR. Only development projects provide occasional support to market gardeners in the zones, although a few producers mentioned that they had received advice from certain technical service agents. The most prominent producers receive assistance from the projects on several occasions, while the most vulnerable and needy are not considered or given adequate assistance.

Since 2016, ANADER is the state agency responsible for agricultural extension services, structuring, and training farmer organizations, and supplying agricultural inputs (fuel, seeds, etc.) to farmers. Four axes shape the work of ANADER:

Water control and management: Provision of pumps to small producers, maintenance of polders and pump stations, supply of inputs

Intensification and diversification of agricultural production: Promotion, demonstration and awareness-raising on innovations and the diversification of production systems; providing agricultural inputs and land preparation materials (animal traction)

Capacity building of producer organizations: Capacity building needs assessments, surveys to develop farmer typologies, training extension workers on good agricultural practices and soil fertility, farmer support and the use of digital information channels.

Promotion of promising agricultural value chains: Identification of promising crops and production systems, realization of assessments and workshops. (ANADER, 2020).

The website of ANADER suggests the organization is under-budgeted and understaffed, as it states that the extension services have been introduced but limited due to a lack of support. Information exchange within ANADER and between ANADER and DGGRHA is limited. While some governmental technical services mentioned manual drilling as high potential technology, others, including the extension services representative, are not aware of the technology and its potential. Yet ANADER is considered the state agency that is the closest to the farmers, with its ten provincial branches, 70 sub-sectors and 380 extension zones throughout the country. The organization counts 739 extension workers in total.

The appreciation of the public extension services varies amongst farmers and regions, as shown in Figure 18. For example, in the Logone Occidental and Mayo Kebbi Ouest provinces the majority (88%) of the farmers considers the advice of extension workers useful or completely useful. In comparison, in the Ouddaï province only 45% of the farmers is of this opinion, and another 45% indicates that their advice is not useful to them at all.

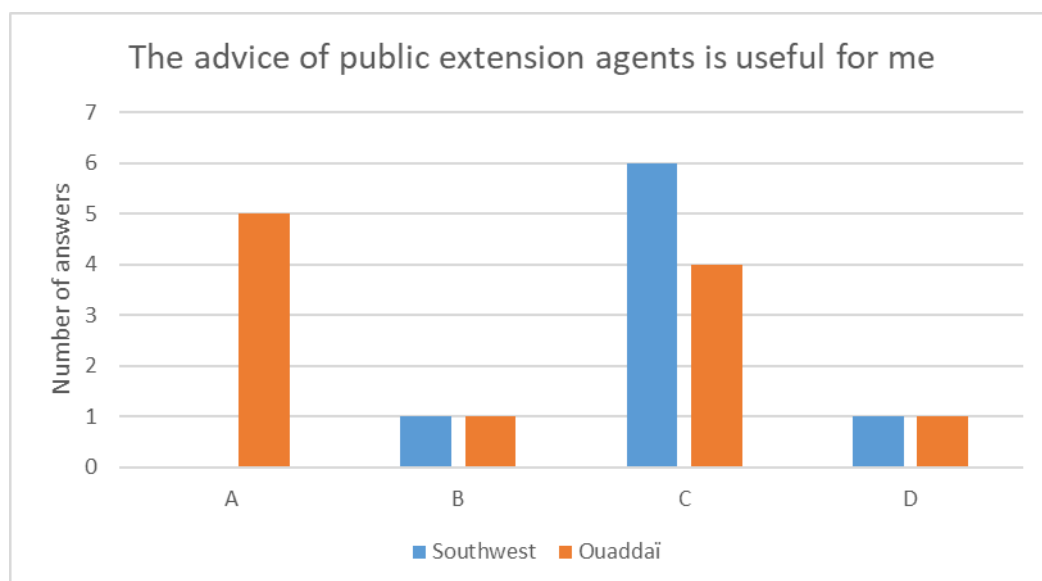


Figure 18 Farmers' opinion on public extension agents

A = Not at all; B = A little bit; C = useful; D = completely useful

Next to ANADER, another relevant government platform mentioned by farmers is SISAAP. One farmer and some of the cooperatives indicated the SISAAP (Système d'Information sur la Sécurité Alimentaire et d'Alerte Précoce du Tchad) platform is a useful source FOR produce prices and yield information.

Farmer cooperatives and associations

The government and NGOs mainly support farmer groups and associations. The umbrella associations receive access to offices and are consulted for government activities. The national and provincial associations are generally linked to specific crops. In 2020 the Ouaddaï province counted 700 farmer groups, Mayo Kebbi Ouest 851 local cooperatives, and Logone Occidental 974 local cooperatives¹⁷.

At local (sub prefecture) level, farmer cooperatives or groups ranging from 9 to 105 members support their members with several activities as detailed in Figure 19. The two cooperatives interviewed in Mayo Kebbi Ouest province operate individually without linkages to a larger association or union. The only support they receive from the government is the extension services provided by ANADER. The two cooperatives interviewed in the Logone Occidental province are linked to a larger cooperative and sell to the state. In addition, the government provides these cooperatives with seeds and the possibility to use a tractor for field preparation.

In the Ouaddaï province, the regrouping of cooperatives into an umbrella organization is a strategy in progress. The CNCPRT, the National Producers Board in the Ouaddaï province now representing 1,300 groups and cooperatives, provides their members with non-subsidized sales of seeds and sometimes also with agronomic support. However, there is no credit provision for inputs or equipment, joint marketing or transport organized by the association.

¹⁷ Data provided by respectively the Ouaddaï Multi Actor Platform and the ANADER offices in Pala and Moundou.

At the moment the cooperative model is not always inclusive in the sense that farmers who are not a member cannot benefit from government or other support mechanisms. The requirements and other barriers to join an association need to be carefully considered when promoting this model.

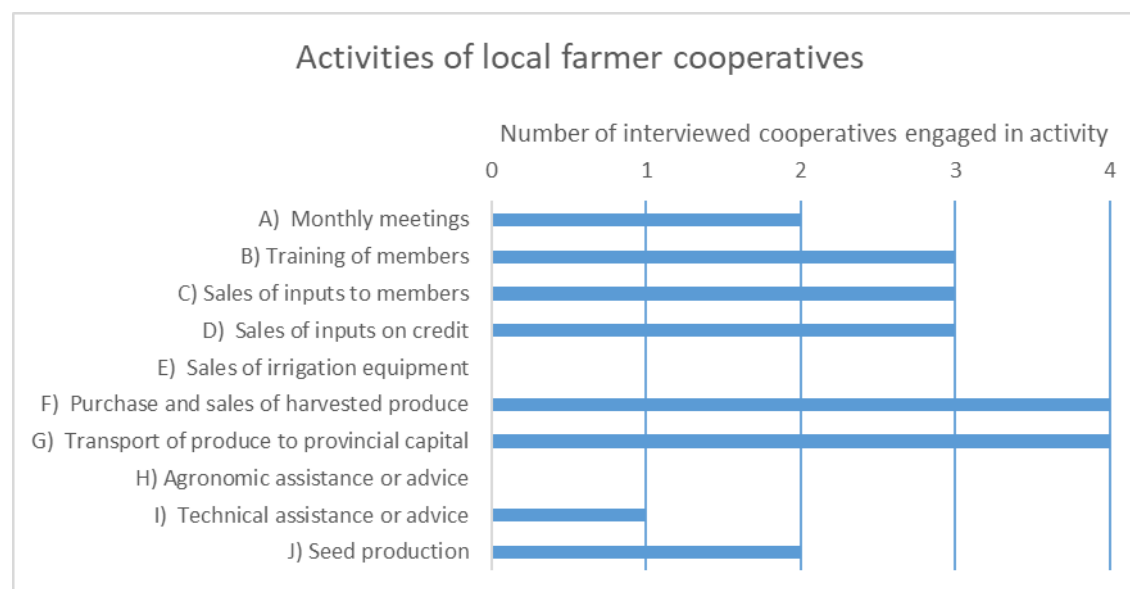


Figure 19 Activities of local farmer cooperatives

5.2 KNOWLEDGE SHARING BY PRIVATE ACTORS

Farmers have a strong preference to use information by other farmers, either from individuals or farmer associations, as shown in Figure 20. Any other source of information is a lot rarer. MPIEA (2017) indicates that the youth in Chad is increasingly interested by the benefits that could be gained in the agricultural sector. They manage to access information on market prices and demand, pest management, agricultural practices, irrigation technologies and finance solutions through the internet and mobile applications. They also use such tools to communicate with peers and exchange knowledge and practices. Next to this, some farmers in the Ouddaï province pointed at people from Sudan as a reference on which agricultural inputs and chemical products to use. It confirms the importance of (re)migration from Sudan bringing technologies, agricultural practices, products, and knowledge as a major factor accelerating FLID in eastern Chad.

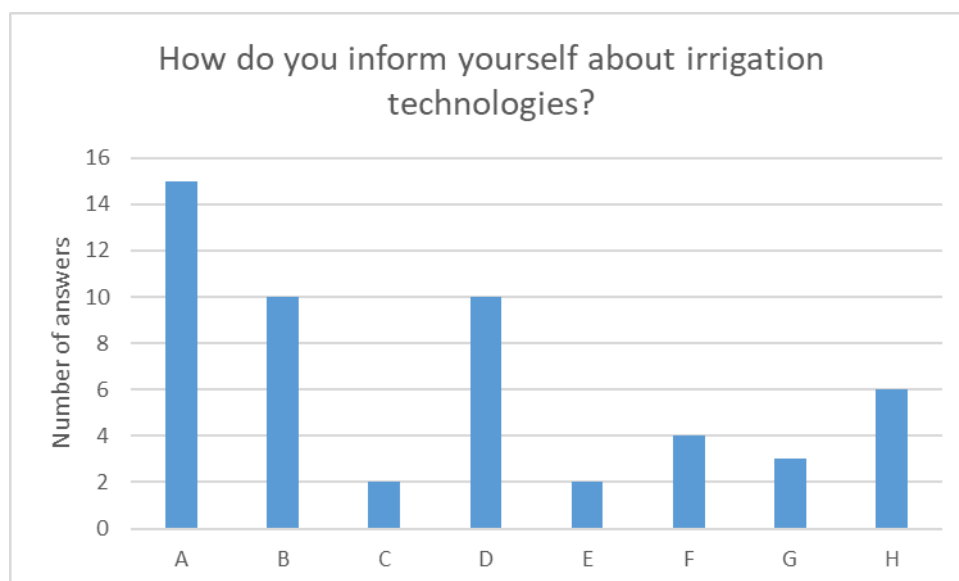


Figure 20 Farmers' information sources

**A = other farmers in the village; B = other farmers elsewhere; C = information from suppliers
D = farmer associations E = radio F = internet G = whatsapp H = other**

As for the agricultural input suppliers there is a major difference between the Ouaddaï province, where all farmers indicate that no advice is provided, and the Southwestern provinces, where 64% of the farmers mention that suppliers do provide advice on the selection, usage, dosage and/or application frequency of the products. Figure 21 shows that equipment suppliers in the southwestern provinces also offer more services compared to the equipment suppliers in the Ouaddaï province.

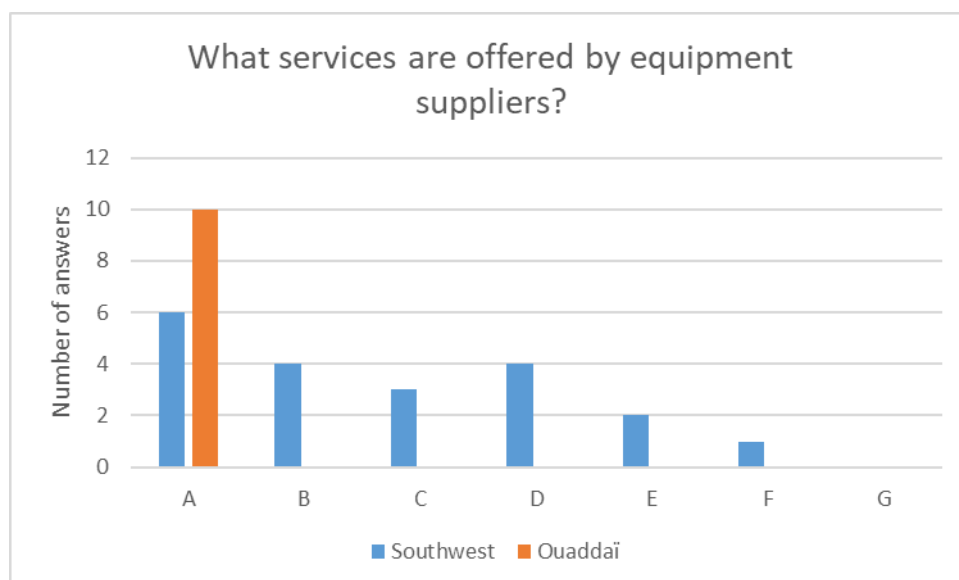


Figure 21 Services offered by equipment suppliers

**A = sales only; B = advice on selection and sizing; C = installation; D = maintenance;
E = warranty; F = credit; G = other**

Asking farmers to what extent the advice of equipment suppliers is useful for them, 29% of the farmers in the southwestern provinces indicated that the advice is not useful to them at all, while the other farmers mentioned it is either useful (57%) or completely useful (14%). Farmers appreciate their advice on the required maintenance of the technology. All of the five

interviewed technology suppliers showed they have brochures about their products. However, suppliers in Moundou indicated that 15-40 % of their clients use websites or apps (including whatsapp) to inform themselves about the products and prices, whereas the suppliers in Pala and Abéché indicated that only 0-5% of their clients uses such communication technology.

A different example of private knowledge sharing in Chad is the ATPESFORC: the Chadian association to promote specialized low-cost drilling enterprises. Manual drilling has been introduced in the Lake Chad area around 1960. Yet it was around the year 2005 that its development started to accelerate, after the introduction of the jetting or wash boring technique by drillers from Nigeria. This technique takes considerably less time than the auger or sludge techniques that were used previously, and allows to drill a 20 to 45 meters' well in one day in sandy soils. UNICEF, Practica and other NGOs equipped and trained about 45 manual drilling enterprises. Later this has grown to over 100 enterprises that united themselves in the ATPESFORC association to advocate and promote the manual drilling technique for the construction of drinking water wells (RWSN, 2015). The enterprises have been particularly successful around N'Djamena. The same companies currently drill wells for private irrigators at reduced prices compared to the drinking water wells.

6. FINANCE

This chapter discusses the question to what extent smallholder individual farmers are able to mobilize the money to develop irrigation. Before answering this question (6.2) an overview is provided of the available public finance incentives for FLID (6.1).

6.1 PUBLIC FINANCIAL INCENTIVES FOR FLID

According to the provincial representative of the CNCPRP producers' association in the Ouaddaï there are no public subsidies available for farmers. They also indicated that none of their members benefit from any form of credit for inputs or irrigation equipment. The two cooperatives interviewed in Mayo Kebbi Ouest indicate the same: zero percent of their members benefit from subsidies or credit for inputs or equipment. On the other hand, the two cooperatives in the Logone Occidentale mention that the government provides subsidies for agricultural inputs, including seeds, fertilizer, and phytosanitary products.

Both cooperatives also mention that the National Office for Employment Promotion (ONAPE) provides agricultural credit to farmers, yet it was added that only 1% of the farmers manages to make use of this scheme. Since 2020, ONAPE manages three programs to reduce youth unemployment, focusing on providing agricultural credit for anyone who produces agricultural raw materials. The role of ONAPE as an agricultural credit provider in the southern provinces (Chari Baguirmi, Logone Occidentale, Logone orientale, Mandoul, Moyen Chari, Mayo Kebbi Est, Mayo Kebbi Ouest, Tandjilé) dates back to 2012. More provinces including the Ouaddaï were added to its intervention area more recently. The total value of agricultural credit made available by ONAPE for the 2021-2022 season is 2,274,000 USD. The credit will be distributed amongst 27 cantons and over 314 farmer groups and individual farmers. ONAPE applies a zero percent interest rate and in the previous season a payment recovery rate of 91% was noted (Al-Khabar, 2021).

The implementation of a shared finance mechanism for agricultural inputs and small equipment (including irrigation pumps) is also included in the National Investment Plan for the Rural Sector in Chad 2014-2020 (PNISR, 2014). PNISR is defined as the strategic framework for coordination and sectoral planning framework for rural development. The strategy is to establish public private partnerships (PPPs) to develop sustainable finance and supply mechanisms (PNISR, 2014). However, no accounts or cases of the PNISR mechanism have been identified during this study.

Due to difficulties to implement the PNISR program, the MPIEA initiated the writing of an updated plan resulting in the PNISR 2019-2022. The updated plan critically reflects on the PPP approach and indicates that the investments made by the government have not encouraged the realization of public-private investments. The updated approach concerning access to finance for farmers is to strengthen the country's different financial institutions, including microfinance institutions, financial agricultural cooperatives and agricultural banks. Some specific components include supporting commercial banks to open up to the private sector in rural areas, and establishing shared finance mechanisms for small producers. The total budget to implement the PNISR 2019-2022 program is 1,914 million USD of which 66% had been secured when the plan was launched (PNISR, 2019).

Another public financial incentive to FLID is the sales of subsidized inputs. In the 2019-2020 season over 7,500 ton NPK and 7,100 ton urea were sold to farmers¹⁸. Over 65% of the available NPK and 40% of the urea were not sold after the end of the season (MPIEA, 2020). ANADER, with support from the FAO, also donates seed and agricultural inputs to vulnerable farmers and refugees. In the 2018-2019 season, about 1110 kg of horticultural seeds were distributed in addition to much larger volumes of seeds for rain-fed crops through the PUCAE2 project in the south of Chad. The project also donated fencing and motor pumps to about 100 farmer groups. Other support programs for horticultural farmer groups have been supported by IFAD (2018), GIZ and others.

6.2 COMMERCIAL FINANCE SOLUTIONS

Chad's access to finance is ranked the lowest amongst the CEMAC countries, and the quality of information on credit provision is evaluated at zero points out eight, along with only the Central African Republic (World Bank Doing Business analysis, shown in EIB 2020). Five percent of Chad's population uses banking services, while the target set by the BEAC was to reach 20% in 2016 (PNISR, 2019). However, the number of MFIs and their visibility and use amongst farmers within the studied areas are limited. None of the 18 farmers interviewed in the Ouaddaï and Logone Occidental provinces uses any credit to finance his/her activities. In Mayo Kebbi Ouest however, both interviewed farmers use credit from the local Savings and Credit Club (CEC), which is a specific and widespread credit facility to both of the Mayo Kebbi provinces. In the Ouaddaï none of the farmers knows about mobile applications for sending or receiving money, whereas in the Logone Occidental province, five out of seven farmers could mention at least two providers of such services. It is an indication of the different dynamics encountered in the eastern and southern provinces.

¹⁸ The total volumes are larger since the data from two out of six regional branches was not yet available when MPIEA (2020) report was published.

The PNISR (2014) indicates that the Agricultural and Commercial Bank of Chad (BAC) is the principal bank investing in agriculture and providing credit for inputs, equipment and irrigation systems. However, the reviewed PNISR (2019) states that commercial banks in Chad do not offer financial products to people in the informal sector or to small-scale farmers. Different forms of Micro Finance Institutions (MFIs) have aimed to fill this gap and offer adapted financial products to entrepreneurs and farmers with small revenues. According to PNISR (2019), the currently operating microfinance networks include the UCEC based in Pala, ASDEC in Moundou, PARCEC in Sarh and PARSAT in Mongo, which cover the Southwestern and Guéra provinces. The well-known URCOOPEC based in N'Djamena has gone bankrupt. The organizations comply with the COBAC norms and are referred to as EMF (Établissements de Micro Finance) within Chad PNISR (2019), (Guemdje, 2008). Its statutes allow EMFs to collect savings and distribute credit to its members or third persons. It is used to acquire agricultural inputs, small agricultural equipment and processing materials. In 2015, 116 EMFs were registered in Chad, serving 200,000 people with a total credit volume of 33.6 million USD. In 50% of the Chadian provinces, there are no EMFs available (PNISR, 2019).

FINADEV is a private MFI that offers a number of financial products to small entrepreneurs including farmers. The company has 15 branches in Chad including in Abéché (Ouaddaï), Pala (Mayo Kebbi Ouest), and Moundou (Logone Occidentale). The company offers saving accounts as well as group loans, individual loans, and salary-based loans. In 2003 FINADEV became the first entity established as an MFI in Chad. Nowadays, it is the largest provider of financial products for small entrepreneurs in N'Djamena, Moundou and Abéché (FINADEV, 2021). As for the interviewed FINADEV branches in Pala, Moundou, and Abéché, respectively, 30, 55 and 6 % of its clients are farmers. FINADEV Abéché just initiated credit provision to 20 farmers in 2020, which is why the percentage is still low. For the interviewed CEC branch in Pala (see below) farmers' share amongst its members is 90%. The percentage of female clients ranges from 10 to 30% across the four interviewed MFI branches.

The Union of Savings and Credit Clubs (UCEC) is the umbrella organization of ten local CECs, including 7 in Mayo Kebbi, 1 in Moundou (Logone Occidentale), 1 in Kelo (Tandjilé), and 1 in N'Djamena. In total the UCEC has 37 client counters. UCEC is organized as a cooperative and offers credit, savings, bank transfer and, through its partners, mobile money services to its members (UCEC, 2020). The UCEC collaborates with ANADER and is a member Chadian Professional Association for Micro Finance Institutes (APT-EMF) which was established to represent, defend and strengthen the capacities of MFI organizations in Chad. Member institutions of the APT-EMF are the privileged partner for projects financed by Technical Financial Partners (PNISR, 2019).

At FINADEV and CEC the interest rate for farmers is 2% per month and the payback period varies from 3 to 8 months for agricultural inputs to a maximum of 18 to 24 months for equipment. All payments are made in cash except for Moundou, which has partnerships with phone companies and therefore has enabled payment with mobile money. At FINADEV in Moundou, clients from other sectors could benefit from a 1.5% monthly interest rate, yet the high risk and lack of serious collateral in the agricultural sector has obliged them to issue higher interest rates for farmers. The criteria to obtain a loan include an assessment of the farmer's character (sometimes based on endorsement), his/her access to agricultural land, the capacity to pay back timely and the viability of the investment. However, when it comes to farmers some branches do not require a hard collateral.

In the season 2018-2019 the Union of Savings and Credit Clubs (UCEC) in Pala, Mayo Kebbi, has provided 7.4 million USD of credit to 12,506 individuals and 389 farmer groups. From this amount, 64% was lent to farmers and livestock producers and 25% to people working in commerce. The average loan issued to individuals across all sectors was 500 USD (UCEC, 2019). On the other hand, the FINADEV branch in Moundou consistently issues loans of around 300 USD per client, yet the total credit value decreases (see Table 1). According to the branch manager, FINADEV currently faces a lack of long-term (3 to 5 years) financial resources needed to satisfy the large demand for credit from the agricultural sector. This remark is in line with the PNISR (2019) which mentions that MFIs face a lack of capital to respond to the credit demand of smallholder farmers to purchase equipment and technology.

Table 14 Credit provision by FINADEV Moundou

Year	Total credit provided (FCA)	Total credit provided (USD)	Number of clients	Average loan per client (USD)
2018	411220000	766,601	2,498	307
2019	287810000	536,539	1,812	296
2020	198805000	370,614	1,213	306

With respect to credit provision by equipment suppliers, three out of five interviewed shopkeepers indicated they do not provide any credit to their customers. The remaining sellers sometimes provide short-term discounts to known customers that need to be paid back later in money or harvested produce. None of the suppliers has made use of bank loans to finance their business, neither could they make use of government subsidies or tax exemptions. The suppliers indicated that the majority (on average 97%) of the farmers do not use credit and buy their equipment using cash from produce sales.

7. MARKET

7.1 ACCESS TO INPUT MARKETS

All inputs including seeds, fertilizers, plant protection products, etc. are readily available in Abéché, Pala and Moundou. The interviewed farmers are ready and able to invest in inputs, yet there are important differences amongst the identified farmer types (see chapter 3). Farmers in the south mention that input prices have increased recently due to the closing of borders. In the Ouaddaï province, the seeds and pesticides come from Sudan, while the NPK fertilizer comes from southern Chad. In the southwestern provinces most seeds and pesticides are imported from Cameroon or Nigeria. According to a key irrigation expert, due to a lack of information, farmers use phytosanitary products that are inappropriate for horticultural production. The lack of safe spraying technologies has led to health issues for both the producers and consumers of horticultural produce. According to farmers, the PNISR (2016) indicates that adapted inputs for horticultural production are not always available and are too heavily taxed according to farmers.

Most farmers buy their inputs in shops in the provincial towns, see Figure 22. Next to this, over 60% of the interviewed farmers in the Ouaddaï province buy inputs from commercial farmers. Over 40% of farmers in the southwestern provinces get their inputs from contracted buyers. About a fifth of the interviewed farmers in the south buys subsidized inputs from ANADER (see chapter 6.1). None of the farmers buys inputs from itinerant traders.

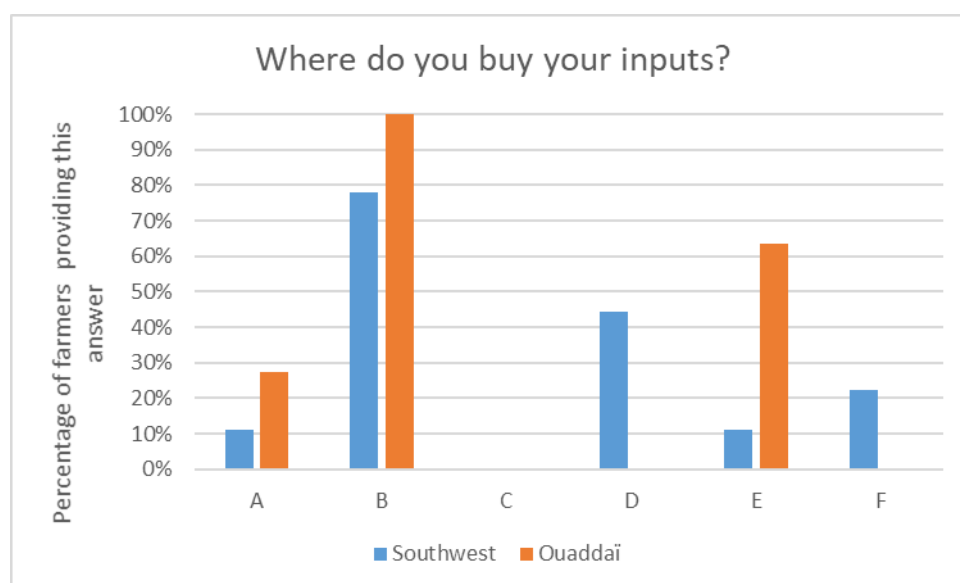


Figure 22 Source of agricultural inputs per area

A = in a shop in the village; B = in a shop in town; C = from itinerant traders; D = from contracted buyers; E = from commercial farmers; F = from a public agency (ANADER)

7.2 ACCESS TO OUTPUT MARKETS

Many producers in the Ouaddaï province indicated that they had recorded major capital losses in the 2020-2021 season due to the overproduction of onions and garlic¹⁹. The overproduction was the result of abundant rainfall leading to larger cultivated areas and a peak harvest. As the supply exceeded demand, prices had dropped drastically and parts of the production could not be sold. Key experts mention the lack of conservation or processing options for horticultural produce is mentioned by key experts as a reason for the losses related to these crops. Another reason is the poor diversity of crops grown in the Ouaddaï, where ten out of eleven producers grow garlic and onions. The contrast with the southwestern provinces is large, where seven out of nine producers grow at least four different horticultural crops at a time and where over 12 different irrigated crops have been observed. A specific market problem to the southwestern provinces was the extreme price drop of bananas and papayas as the Chadian economy suffers from reduced oil incomes. Detailed accounts of input and production costs, produce yields and revenues, as well as price variability experienced by the interviewed farmers, can be found in chapter 3.2.

As for produce selling strategies, the answers of different farmer types have been compared. Figure 23 shows that most farmers apply diverse strategies to sell their produce, i.e. at the farm gate in retail or bulk, in the village and, predominantly, in the provincial capital. Some market-oriented vegetable producers also sell to commercial farmers. Farmer groups behave slightly differently as besides selling in bulk from the farm gate and in town, almost 80% also sells to contracted buyers. Farmer groups practically don't engage in petty sales from the farm gate or in the village. Commercial fruit producers are the only type of farmers selling to buyers from the capital N'Djamena.

¹⁹ This was not the season on which the produce prices in chapter 3 are based, but the season after.

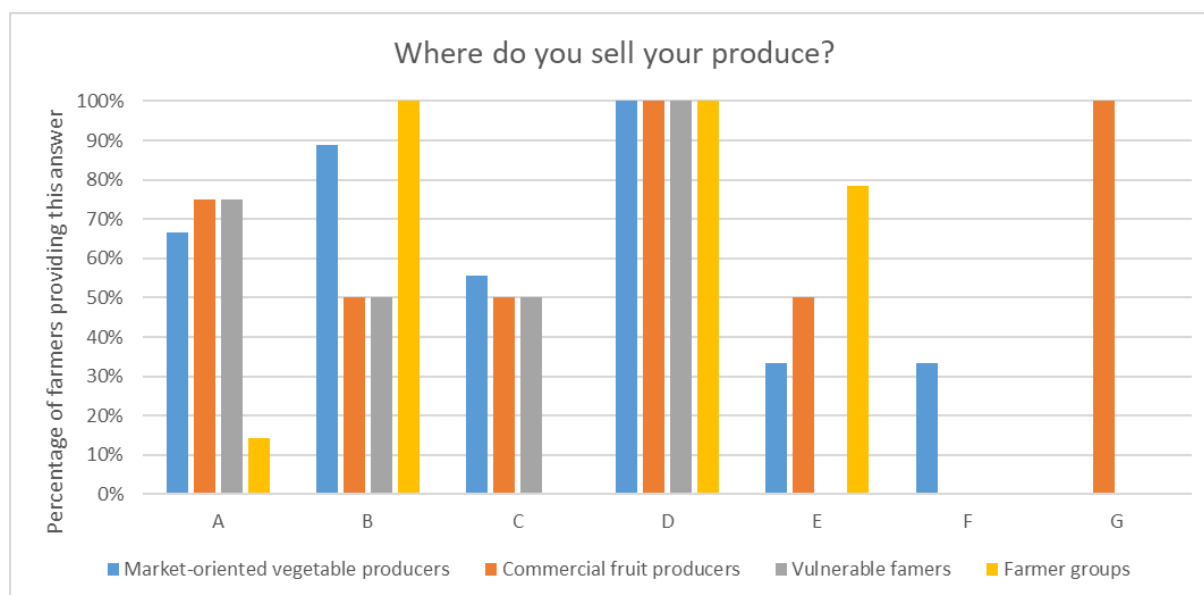


Figure 23 Produce market per farmer type

A = At the farm gate in retail; B = at the farm gate in bulk; C = in the village = D = in the provincial capital; E = to contracted buyers; F = to commercial farmers; G = to buyers from N'Djamena

The main crops providing the best revenue according to the interviewed farmers are, in order of importance: garlic, onions, tomatoes and okra in the Ouaddaï province and capsicum, cabbage, onions, tomatoes, potatoes, papayas, watermelon, cucumber and bananas in the southwestern provinces. In addition, farmers obtain information on market prices through a range of sources, including traders, sellers on the market, producer organizations, or government (SISAAP). More information on information sources used by farmers is presented in chapter 5.

8. TECHNOLOGY

8.1 SET-UP AND COST OF IRRIGATION SYSTEMS

Water sources

The following overview shows the cost and capacity of the different irrigation water sources encountered during field visits at 20 farms in April. Since April marks the end of the second irrigation season it shows the worst conditions in terms of water availability. In the Abéché province irrigation depends primarily on shallow groundwater found in the lowlands and temporary streams or ouadis. The groundwater can be accessed by open wells and traditional tube wells installed in the dry streams. The tube wells provide farmers with water access all-year round. The PARIIS program and international NGOs have supported the construction of open wells with concrete rings that in most cases reach deeper (generally till 8m) and thereby increase the percentage of wells with permanent water availability to 80%. Manually drilled boreholes and reinforced open wells that reach beyond the very shallow groundwater are rare and only constructed with support from donors. Manual drilling is mainly used to construct drinking water points, sometimes will small gardens on the side. While over a hundred manual drilling enterprises exist in N'Djamena, the Ouaddaï province counts about 10 enterprises that provide manual rotary drilling services and the technology is not known widely. Manual drilling

for irrigation is done using a smaller diameter (100 mm instead of 125/140 mm) and depth (15-25m instead of 30-60m) compared to manual drilling for drinking water purposes to reduce the costs. Water availability is considered to be the main limiting factor to irrigation development in the Ouaddaï province.

Surface water is more widely available in the Logone Occidental and Mayo Kebi Ouest provinces, and some farmers have year-round access to water from permanent streams or marshes. Other farmers dig multiple hand-dug wells and ponds going from a few cubic meters to cases over 15m³ and one case going up to 50m³. The general cost is 5,000 FCA/m³ and the excavated volume is directly linked to the size of the irrigated field and the corresponding water need. Most hand-dug wells and ponds dry up after February and therefore do not allow for a second irrigated crop cycle. People interviewed in the southern provinces had no examples of manual drilling for irrigation purposes as the costs exceed farmers' investment capacity.

Table 15 Water source types and cost

Source + depth	Water volume stored (m ³)	Cost range (USD)	Average Cost (USD)	Irr area (ha)	Cost (USD)/ha	Water availability	Funder	Region
	NA							
Streams		0	-	2.3	-	Permanent	Farmer	Logone Occ
Pond 0-4m		150-500	330	2.4	139	Nov-Feb	Farmer	Logone Occ
Hand-dug well 0-5m		20-60	36	0.06-0.4	95 -600	80% Nov-Feb	Farmer	Logone Occ, Mayo Kebbi
Tube well 4m		150-250	203	0.4	579	Permanent	Farmer	Oue, Abéché,
Well with concrete rings 0-8m		3,500-6,100	5,204	1.2	4,337	80% Permanent	Donor	Abéché
Reinforced well with stones 25m		14,000	14,000	1.0	14,000	Permanent	Donor	Abéché
Manual drilling 25m		900-1,300	1,100	> 1ha	< 1,100	Permanent	N.A.	N'Djamena, Abéché
Machine drilling 40m		7,500-8,400	8,000	0.5-1.5 ha	8,000	Permanent	Donor	Abéché

Pumps

In the Ouaddaï, Logone Occidental and Mayo Kebbi Ouest provinces, petrol pumps with gravitational irrigation are the most common irrigation set-up. The technology that is used depends mainly on the means of a farmer and whether he/she has benefited from support by the government or an NGO. Farmers irrigating without project support use either buckets or cans on a rope, and petrol pumps. The farms supported by projects have been equipped with fuel pumps (petrol or diesel) as well as electric submersible pumps with generators or solar submersible pumps. The submersible pumps are typically installed in boreholes or open wells

in which the water is beyond suction depth (>7m) and therefore inaccessible for fuel pumps. Solar pump suppliers can be found in N'Djamena and provincial towns, most of them focusing on installation services and providing solar pumps amidst other agricultural technologies. About 10-20 installers offering solar pumps have been identified in Abéché town (Ouaddaï). Prices are very high since the market is donor-driven and not yet developed. The purchase and promotion of solar pumps is increasing amongst investors, NGOs and government projects.

The price range of petrol pumps is large. The common low cost brands range from 3HP 2" pumps for 150 USD to 4-5 HP 3" pumps for 560 USD. The average cost of fuel pumps purchased by projects instead of farmers is about twice as high. Some brands seem to be preferred, e.g. PTM and KIPOR (diesel), yet there is no clear relation between the price of the pump and the expected lifespan, or the price and the irrigated area per pump, see Table 24 in Annex B. For example, the same pump model was used to irrigate 0.25 ha on one farm and 2.5 ha on another farm. The reason is that the capacity and cost of the water source is the main determining factor for the irrigated area with fuel pumps. The table below shows the cost range per pump technology.

Table 16 Overview of pump types and costs

Pump type	Cost range USD	Average cost USD	Average ha / pump	Cost/ha USD	Expected lifespan (years)
Bucket	10	10	0.1	N.A.	N.A.
Petrol pump (private purchase)	150-930	354	1.5	234	2.4
Petrol pump (donation)	230 – 1,300	781	1.3	600	2.4
Diesel pump	370	370	1.1	350	2.5
Submersible pump (electric) ²⁰	560	560	1.5	373	2.5 ²¹
Submersible pump (solar) 1kW (6.7 m ³ /h at TDH 20m)	2,800 - 3,360	3,100	0.67	4,600	2-10 ²²

The additional cost for the suction hose and the pipes and tubes to convey the water to the field ranges from 170 USD for farms of about 0.5 ha to 1,200 USD for farmers irrigating 2-4 ha. In terms of cost per hectare, it ranges from 140 to 670 USD/ha with an average of 411 USD/ha. Hence for farmers using fuel pumps the cost of pipes may well exceed the cost of the pump.

²⁰ For the electric submersible pump the total well depth is 25m, the SWT is unknown. The price includes the cost of the generator that is needed to power the electric pump.

²¹ Expected lifespan indicated by the farmer using it. Potential lifespan could be longer, depending on the usage and water quality.

²² The expected lifespan for the other pumps is based on the experience of farmers. Since for solar pumps such accounts were not available, a lifespan of 2-10 years is indicated as it depends on the pump type, usage and water quality. For the cost-benefit analysis in chapter 8.2 an average lifespan of 6 years will be used.

From the 20 farms visited in the different provinces, all application systems are gravitational through basins or short furrows. As a result, no additional investment costs are incurred for the application systems. Three farms that received support from a government project had a Californian system with buried PCV pipes. The cost of a Californian system installed by a project ranges from 1,500 to 9,300 USD/ha. The cost for digging and connection pieces to install a Californian system is not included in the conveyance pipes costs shown above. The PARIIS project promotes the use of Californian systems in the Ouaddaï province. Farmers are positive and consider it an adapted solution for the area.



Table 17 Farmer in Fadjal Hala (Ouaddaï) using a diesel pump and californian system

Private smallholder farmers in Chad barely use other water efficient application technologies such as drip, sprinklers, or spray tubes. Some suppliers sell drip kits in N'Djamena, with links to regional hardware shops, yet they only sell to government or NGO projects. In the studied areas, no suppliers of drip, spray tube or sprinklers have been encountered.

8.2 COST BENEFIT ANALYSIS

Technical set-up and investment cost of irrigation systems

As explained above, except for one farmer irrigating manually, all farmers interviewed for this study use a fuel pump and pipes for gravity irrigation. Most of them pump water from open hand-dug wells. This is the simplest system that comes at a total investment cost by the farmer of about 1,000 USD to irrigate one hectare.

The PARIIS program and other government initiatives promote the use of Californian systems to increase irrigation water, fuel and time efficiency. As an alternative to hand-dug wells generally falling dry in February, the use of tube wells is increasing in the temporary streams in the Ouaddaï province, providing water access until the rainy season. Both add-ons have been included in the technical set-up referred to as “Fuel pump system promoted” in Table 18 resulting in a total investment of 2,300 USD/ha²³. It should be noted that these two innovations do not need to be introduced simultaneously and that a Californian system alone could be introduced at a limited additional costs if installed by informal service providers. No interviews have been held with farmers using solar pumps as this technology is still relatively rare in Chad. Based on the unit prices and assuming equal production costs and benefits as petrol pump systems, two set-ups for solar-powered submersible pump systems have been included in the cost benefit analysis. These set-ups provide an option for farmers in areas with groundwater that is not accessible by fuel pumps. A distinction has been made between a simple set-up of

²³ The investment cost of only a petrol pump and Californian systems adds up to 1,732 USD. This price and the price for a simple set-up are relatively similar to the price mentioned by HCNE (2003), i.e. respectively 1,300 and 1,860 USD/ha for a simple petrol pump system with pipes and a petrol pump with Californian system.

around 6,000 USD including pipes only, which requires continuous presence in the field, and a promoted set-up of about 9,000 USD including the construction of basins, a commonly implemented solution for farmer groups. Both solar systems are combined with a manually drilled borehole. In practice, most solar irrigation systems constructed with donor support are more expensive due to the additional construction of reinforced concrete wells and/or the installation of drip irrigation systems.

Table 18 Investment and depreciation cost of four technical set-ups

Technical set-up	Investment cost (USD/ha)	Estimated Lifespan (years)	Depreciation cost (USD/season) (based on 2 seasons per year)
Fuel pump system simple			
Hand-dug wells (0-5m)	350	1	175
Petrol pump	240	2.4	50
Pipes	410	2	103
Total investment	1,000		328
Fuel pump system promoted			
Tube Well (4m)	580	1	290
Petrol pump	240	2.4	50
Californian system	1,492	5	149
Total investment	2,312		489
Solar pump system simple			
Manually drilled borehole (25m)	1,100	10	55
Submersible solar pump	4,600	6	383
Pipes	410	2	103
Total	6,110		541
Solar pump system promoted			
Manually drilled borehole (25m)	1,100	10	55
Submersible solar pump	4,600	6	383
Basins and pipes	3,357	5	336
Total	9,057		774

Cost benefit analysis per technical set-up

In Table 19 a cost benefit analysis is made for the four different set-ups. The investment costs for each set-up are based on a one-hectare irrigated field. The production costs and revenues correspond to one irrigation season. Thus, farmers with access to a permanent water source could grow two, or in a rare case three, irrigated crop cycles per year.

Table 19 Cost benefit analysis of four technical set-ups

System	Fuel pump system simple	Fuel pump system promoted	Solar pump system simple	Solar pump system promoted
Water table	0-7m	0-7m	7-25m	7-25m
Investment (USD/ha)	1,000	2,312	6,110	9,057

<u>Production costs (USD/ha/season)</u>				
Depreciation cost	328	489	541	774
Agricultural inputs	286	286	286	286
Fuel ²⁴	223	167	-	-
Pump maintenance ²⁵	84	63	84	84
Labor agronomic	470	470	470	470
Labor irrigation ²⁶	185	139	370	278
<u>Costs + benefits (USD/ha/season)</u>				
Total cost (USD/ha/season)	1,576	1,614	1,751	1,892
Gross revenue (USD/ha/season) ²⁷	5,064	5,064	5,064	5,064
Net revenue (USD/ha/season)	3,489	3,450	3,313	3,172
<u>Return on investment (seasons)</u>				
Rol Revenue scenario above (5,064 USD/ha)	0.3	0.7	1.8	2.9
Rol Low revenue scenario (2,568 USD/ha) ²⁸	1.0	2.4	7.5	13.4
Rol High revenue scenario (7,553 USD/ha)	0.2	0.4	1.1	1.6

The cost benefit analysis shows a positive return on investment for all technical set-ups with a return on investment of less than one season for both fuel pump set-ups and nearly two or three seasons for respectively the simple and promoted solar irrigation set-ups. The chosen gross revenue scenario of 5,064 USD/ha is based on sales during a good year taking a cross section from the different farmer types. Yet, the high volatility of agricultural produce prices requires the consideration of different sales scenarios. The low and high revenue scenario based on the tomato price range mentioned by the farmers shows that the return on investment changes drastically when produce prices are different. This is an important concern especially when equipment is purchased on credit. The cost of interest (2% per month) associated to the promoted solar-powered system would add 543 USD of additional costs to the first cycle if the full investment were made on credit. This would increase the total cost of the first season to a level of 2,423 USD, which is almost equal to the gross revenue in the low price scenario and leaves the farmer with net revenue of only 133 USD/ha. Considering that farmers need to make use of their net income to fulfill a multitude of domestic or social charges, implies that the positive returns on investment presented above should be handled with care.

²⁴ The pumping charges including fuel, maintenance and labor decrease by 25% when using a Californian system (Abric et al., 2013). This explain the lower cost for the set-up “Fuel pump system promoted”.

²⁵ Solar pumps need less maintenance than fuel pumps, but if a technician needs to intervene the mobilization costs are higher since there is no maintenance capacity at local level. Therefore, the maintenance costs for fuel and solar pumps are assumed to be equal.

²⁶ The flow of the 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. The promoted set-ups for fuel and solar systems are both featured by a 25% reduction in labor costs since the system is more efficient and less time consuming.

²⁷ The gross revenue of 5,064 USD/ha is the average of all interviewed vegetable producers. The revenues from commercial fruit producers have been excluded because these systems are not representative or accessible for most farmers.

²⁸ The low and high revenue scenarios correspond to the lower and upper ends of the tomato price range mentioned by farmers, i.e. 170 and 500 FCA/kg. A yield of 8,100 kg/ha has been used, which is the average yield for tomato production in Chad indicated by FAOSTAT.

9. CONCLUSIONS AND RECOMMENDATIONS

The situation of FLID in Chad

Chad is widely known for its large water availability as a result of the Logone-Chari river system, which contributes 95% of the water resource volume in the complete lake Chad basin. Many highlight that unlike other countries in the Sahel, Chad has the potential to substantially increase its irrigated area without having to compromise the environment (HCNE, 2003) (USAID, 2010) (FAO, 2005) (MPIEA, 2017). However, there are large differences between regions, as 84% of the available surface water resources and most of the very shallow groundwater is situated in the southern provinces, also known as the Sudanian zone. Most of Chad's population and water resources can be found in the southwestern provinces, including in Logone Occidental and Mayo Kebbi Ouest provinces. Surface and very shallow groundwater is also abundant along the Logone river up to N'Djamena and lake Chad. In the Ouaddaï, and Wadi Fira provinces in central Chad, farmers rely on shallow groundwater available in lowlands and in the surroundings of (temporary) rivers and streams. It is in the areas mentioned here that important clusters of FLID can be encountered. Other regions are featured by deep groundwater tables and, therefore, less favorable for FLID at scale.

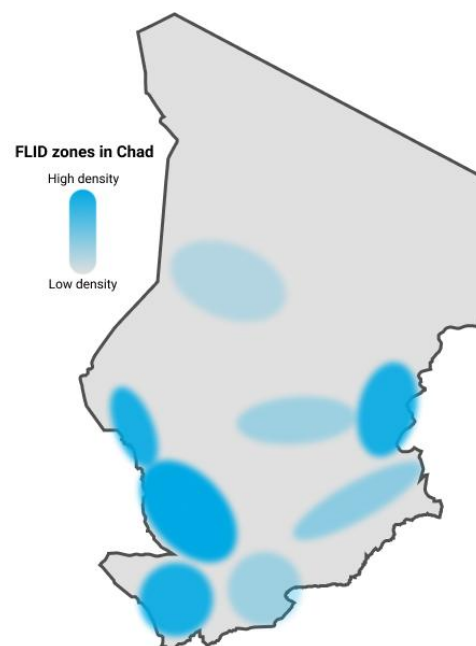


Figure 24 Location of main FLID zones in Chad

FLID in Chad has a diverse character and includes an important variety of flood-based farming techniques besides the pump-based irrigation systems. The fieldwork in this study has focused on private farmers' activities using irrigation systems with full water control, i.e. pumped irrigation systems. The field visits in the Ouaddaï (eastern Chad), and the Logone Occidental and Mayo Kebbi Ouest provinces (southwestern Chad) showed important differences between the eastern and southwestern regions. The situation around Moundou is more dynamic and developed compared to the Ouaddaï province in terms of market development, finance and support mechanisms. Farmers in the Logone Occidental province grow a much wider variety of crops than farmers in the Ouaddaï, which reduces the risk of sudden price declines resulting from overproduction of one or two particular crops. In the case of the Ouaddaï, ten out of eleven interviewed producers grow garlic and onions. Farmers around Moundou are also more connected, since the rate of farmers using websites or apps to inform themselves about products or prices or make mobile payments is substantially larger than the farmers interviewed in the Ouaddaï province. Next to this, MFIs in the southwestern provinces have a large track record in providing financial products to farmers, whereas in the Ouaddaï such services have only commenced recently. As an example, the different branches of the private MFI FINADEV in Abéché, Pala and Moundou respectively count 6, 30, and 55% of farmers amongst their clients. The extension services by ANADER are also more developed and appreciated in the two southwestern provinces where 88% of the farmers considers the advice of extension workers useful. In contrast, in the Ouaddaï province half of the farmers indicate that their advice is not useful to them at all.

The reasons for this clear difference in FLID development are plural, but the easy accessibility of water in the southwestern provinces is a major enabling factor that has allowed farmers to develop their irrigation systems without external support. The current supporting environment with a diverse output market, technology suppliers, accessible finance solutions and practical extension workers have resulted from and continue to accelerate FLID in the southwestern provinces. In the Ouaddaï province, where knowledge, technologies, inputs and financial resources have arrived following the migration from Sudan, the limited water accessibility is the major limiting factor to irrigation development. The following diagrams summarize which enabling factors are the main constraints to FLID in order to prioritize potential supporting interventions.

Table 20 FLID scoring in the two regions

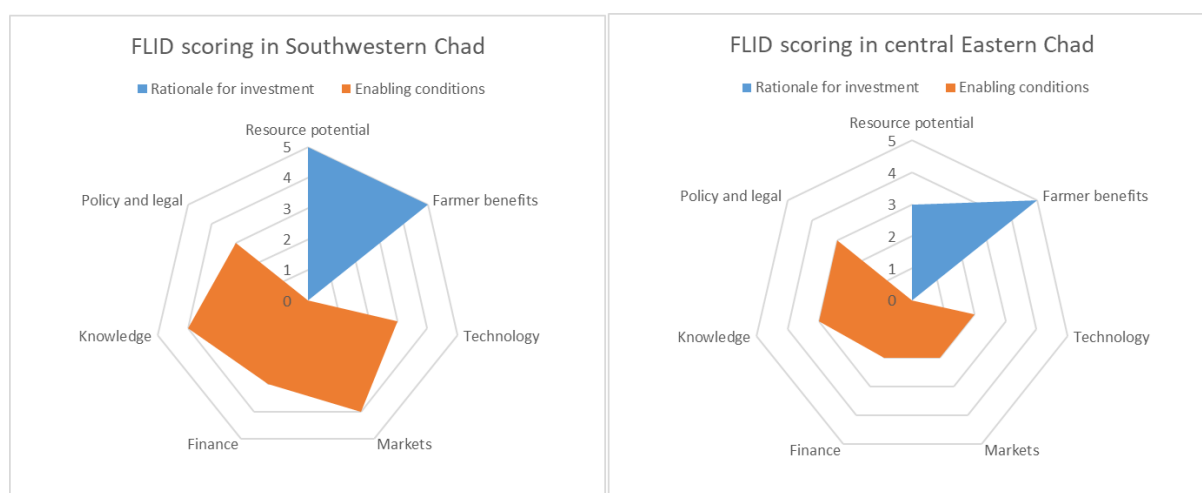


Table 21 Scoring of enabling conditions for FLID

	Southwestern provinces		Central Eastern provinces	
Factor	Score	Argument	Score	Argument
Resource potential	5	Surface and very shallow groundwater widely available	3	Shallow groundwater available in pockets
Farmer benefits	5	Variety of farmer types that benefits from irrigation	5	Very long dry season and potentially a high added value
Technology	3	Lack of transformative technologies for wells and irrigation	2	Few suppliers, lack of transformative technologies for wells and irrigation
Markets	4	Regional market for large variety of produce and inputs	2	Lack of variation, coordination, information
Finance	3	Some MFIs providing small loans to farmers	2	Practically no MFI or supplier based finance for farmers
Knowledge	4	Farmers appreciate the services form extension workers and suppliers.	3	experience from Sudan, but extension workers and suppliers fail to provide acequate support
Policy and legal	3	Land access limited for women	3	Land access limited for women

Strategies to accelerate FLID

A case study on Chad by the World Bank (1992) already concluded that “Almost all successful irrigation occurs on plots owned and managed by individuals and where the individual controls the supply of water”. Almost thirty years later there is still a lack of policies and support initiatives that target individual farmers. Most NGOs and government programs continue to focus on farmer groups, even though questions are posed at both the justness and effectiveness of this approach. Vulnerable farmers that merit support from NGOs do not qualify for joining a farmer group if they cannot bring in a contribution, while wealthier farmers manage to benefit from multiple projects. Individual market-oriented fruit or vegetable producers make higher revenues and profit per hectare compared to farmer groups, whereas the investment cost of their irrigation infrastructure is considerably lower. The results point at the need to consider the diversity of farmer types and develop accessible and inclusive support mechanisms for each instead of focusing primarily on farmer groups.

The constraints to FLID mentioned by farmers and other experts in order of importance are: access to water, stable markets, finance and knowledge. The following paragraphs present potential strategies to increase the accessibility of each of these four topics. Government support to enhance the enabling environment supporting FLID could potentially be a practical strategy with a large and sustainable impact on agricultural productivity and food security.

The key challenges in the enabling environment highlighted above could be addressed by a range of strategies. To open the door for co-creation, co-ownership and co-design of the interventions, this study does not provide a blueprint or road map to accelerating FLID. Yet, the following paragraphs do provide some ideas for activities that could potentially contribute to improving specific aspects of the enabling environment.

Enhancing reliable water access by enhancing financial services for well drilling.

Water in southern and central Chad is a problem of accessibility rather than availability. The vulnerable farmers encountered during this study were primarily constrained by access to water. The promotion of adapted manual drilling techniques using the vast experience in local manual well drilling could be spread to the Ouaddaï and the southwestern provinces, while considering the potential risk of failure in unfavorable soil formations. Similar technologies could also unlock groundwater at intermediate depth (10-25m) in the Lac, Kanem and Barh el Ghazel regions.

Pressure on irrigable land is increasing throughout the country, especially along surface water bodies. Many farmers indicate they are renting land at about 125 to 150 USD/ha. Increasing access to shallow groundwater could be a strategy to decrease dependency on irrigable land along surface water bodies. Chapter 8.2 shows that the investment in a manually drilled borehole and a simple solar pump set-up to withdraw water from 15 meters' depth could potentially be returned within two seasons. With an average interest rate of 2% and a maximum loan duration of 18-24 months, the current financial products offered by MFIs in the studied provinces do allow for investments in petrol pumps or small equipment, but not for solar pumps. In fact, the current financial resources of MFIs to scale up loans to farmers are limited.

The investment costs calculated in chapter 8.2 are slightly below the costs mentioned in the HCNE (2003) master plan from the Government of Chad. According to this document, the average investment cost for private irrigation systems is 2,800 USD/ha, compared to over

26,000 USD/ha for the large-scale modern irrigation systems (HCNE, 2003)²⁹. Therefore, it confirms that the decision by the government to withdraw from public investments in large-scale schemes is justified and that the prices related to private irrigation systems continue to decrease.

Despite the positive effect on groundwater accessibility, introducing innovations like solar powered irrigation also increases farmers' investment risk compared to technologies with a lower cost. The cost effectiveness and accessibility of most promoted solar systems are lower compared to petrol pump systems. The promotion of simple and cost-effective technical set-ups for solar-powered irrigation is essential if one aims to grasp the interest of private farmers. Next to this, there is an increasing number of farmers that makes use of rental arrangements to access irrigable land. While most promoted solar technologies are fixed installations, only mobile solutions (petrol or solar suction pumps) are attractive for this segment of farmers.

The Californian system is a simple solution to reduce the fuel, time and water spent using fuel pumps. This solution has been promoted in the Sahel for many years, yet its use is not widespread amongst farmers in Chad. Since fuel costs constitute over 50% of farmers' total input expenditures, and Californian systems could reduce this cost by at least 25%, the investment pays back and could attract the interest of private farmers. In general, farmers will purchase water-efficient irrigation technologies, including spray irrigation, once the benefits in terms of reduced out-of-pocket costs or time input are demonstrated. Unfortunately, the availability of such technologies is currently very limited, if not nonexistent in Chad.

Market and supply chain development for inputs, technologies and agricultural produce is a main enabling factor and a result of FLID. Sustainable mechanisms to encourage market development require a careful approach that builds on the private sector and does not counteract its development by donating products rather than increasing farmers' interest and capacity to invest. One specific measure could be the reduction of taxes on inputs for horticultural production, which are too heavy according to the PNISR (2016). Furthermore, as a result of the limited availability of adapted products and a lack of information, many farmers currently use unsafe products that could compromise their health.

Farmer associations could be strengthened and extended, enabling them to purchase and sell seeds, inputs and irrigation equipment to more farmers. Joint seed purchase by a farmers' union could also contribute to more coordination to ensure crop diversity, and avoid overproduction of one or two crops as happened in the Ouaddaï province last year. The government also has programs in place for the subsidized sales of seeds. This could be tailored to vulnerable farmers that are constraint by money to buy inputs. Since more than 50% of the subsidized seeds have not been sold last year, the accessibility or timing of this distribution could be improved.

Finance to purchase inputs or equipment is an important enabling factor for FLID. The commercial banks are not accessible for farmers, but MFIs of private or associative nature serve large numbers of farmers in the southwestern provinces with small loans. Accessible financial products for farmers are still scarce in the Ouaddaï province. Yet also in the Logone Occidental, the MFIs face a lack of long-term financial resources to expand their services to more farmers. It is recommended to provide earmarked guarantees and funds to MFIs with the specific aim to provide loans to farmers wishing to procure inputs and equipment. Since climate or market-

²⁹ Exchange rate fluctuations not taken into account.

related risks cannot be avoided in the agricultural sector, MFIs could use such guarantees to provide a tolerant approach when applicable. Rather than monthly backpack schemes, the moments should be tailored to the harvest periods, as already done by some MFIs. Supporting MFIs should come with conditions, different targets, and technical support to encourage them to provide finance for irrigation. However, it should be taken into account that to manage risks, MFIs often create procedures and criteria that are only accessible to larger commercial farmers. This is especially the case when loans are larger, as is the case for irrigation equipment.

An alternative route to increase access to finance is to explore a potential role for the farmer cooperatives. Strong farmer cooperatives in Senegal and Burkina Faso already import agricultural inputs and provide these to their members on credit. The risk of payment defaulting is low since they know their members and they can deduct the loans when they pay farmers for their produce, as it is marketed collectively. Strategies to build upon this strong local capacity would be to support the farmers' cooperatives to become more independent and sustainable and to provide them with funds that are earmarked to develop inclusive finance solutions for irrigation technology acquisition by their members.

Knowledge sharing amongst farmers and traders has been at the base of FLID in both the Ouaddaï and southwestern provinces. Farmers have indicated a strong preference to learn from other farmers, either from individuals or farmer associations. Approaches that connect farmers could be explored or strengthened, ranging from traditional investing strategies to farmer associations to more innovative solutions such as digital exchange platforms or Whatsapp groups linking interested farmers from different regions or countries. As such, farmers could learn about the manual drilling activities for irrigators in N'Djamena, the Californian systems installed in the Ouaddaï province, the diversity of cropping systems in the Logone Occidentale, or even the increased uptake of spray tubes by farmers in Benin.

Knowledge exchange is also a recommended strategy for government staff working on FLID. More communication between the Rural Engineering department and ANADER could increase ones' awareness of problems experienced by farmers and the potential for different technologies. A visit of ANADER extension workers from the Ouaddaï province to the Logone Occidental, where 88% of the farmers is positive about the services of ANADER, could bring ideas on the content and methods of extension work. Because as expressed well by a key expert from the government: "There is a clear need for different sectors and stakeholders to learn from each other. This in turn fosters an inclusive ecosystem that is conducive to the formulation and implementation of policies, plans, and interventions for the sustainable scaling up of FLID".

Access to irrigable land is an increasing problem that mainly affects women, as they benefit less from inheriting since land ownership is increasingly linked to family names. To increase the perspectives of female farmers in irrigation development, specific tenure agreements for female farmers could be promoted.

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ANNEX A ESTIMATION OF INDICATIVE SUITABLE AREAS PER WATER SOURCE

The indicative areas per region and water sources can be found below in Table 23. This table is based on three data sources:

- The overview of suitable areas for irrigation per region by Westra (2020), which differentiates between areas with surface water, very shallow groundwater (0-7m) and shallow groundwater (7-25m)
- The potential area for manual drilling per region (UNICEF, 2010), see Table 22 below.
- The overview of floodplain areas in Chad (HCNE, 2003) and Table 4.

The areas suitable for surface water irrigation as presented by Westra (2020) have been divided into suitable floodplain areas and suitable areas around rivers and streams. This has been done by adding the floodplain areas per region to the overview below. Since all floodplain areas are much larger than the identified suitable areas for irrigation, the total suitable area for surface water irrigation has been counted as “floodplain” for those regions in which the main floodplains are located. The surface water in the remaining regions has been counted as suitable areas around rivers and streams.

The very shallow groundwater (0-7m) category has not been modified. The shallow groundwater (7-25m) category has been divided into suitable and unsuitable areas for manual drilling. In most areas the suitable area for manual drilling largely exceeds the suitable area for irrigation using shallow groundwater. In those regions all areas referred to as suitable for shallow groundwater by Westra (2020) have been counted under suitable manual drilling or alluvial areas.

For those regions in which the suitable area for manual drilling was smaller than the suitable area for irrigation using shallow groundwater: Logone Oriental, Logone Occidental and Biltine (former name of Wadi Fira), the suitable area for manual drilling was taken to provide an indication of the suitable alluvial areas, whereas the remaining suitable area was counted as sandstone areas suitable for machine drilling.

Table 22 Suitable area for manual drilling per region (UNICEF, 2010)

	% suitable MD	area suitable MD (10 ³ ha)	Total area
LAC	99.40%	1,972	1,984
KANEM	66.80%	8,282	12,398
MAYO KEBBI	57.50%	1,759	3,059
TANDJILE	49.00%	859	1,753
CHARI BAGUIRMI	28.60%	1,316	4,603
MOYEN CHARI	26.90%	1,116	4,147
LOGONE ORIENTAL	18.10%	429	2,372
LOGONE OCCIDENTAL	13.20%	116	881
BATHA	9.60%	868	9,041
SALAMAT	9.00%	612	6,796
GUERA	3.70%	226	6,104
BET	2.90%	1,655	57,073
OUADDAI	2.30%	151	6,545
BILTINE	0.00%	0	5,412

Table 23 Indicative suitable area per region and water source

Region	Total area (1000ha)	Surface water			Very shallow groundwater (0-7m)	Shallow groundwater (7-25m)			Total area suitable for FLID	Floodplain area
all areas in 1000 ha		total	floodplain	rivers/ streams	total	total	manual drilling	machine drilling		
Barh el Ghazel	5,631	0.29		0.29	15.04	20.61	20.61		35.94	
Batha	9,041	151.86	151.86		0	1.47	1.47		153.33	550
Borkou	25,623	0.71		0.71	0	0	0		0.71	
Chari-Baguirmi	4,603	183.76	183.76		397.57	0.79	0.79		582.12	2,550
Ennedi Est	7,737	10.69		10.69	0.13	0	0		10.82	
Ennedi Ouest	11,105	18.92		18.92	0	0	0		18.92	
Guéra	6,104	120.02		120.02	1.81	161.42	161.42		283.25	
Hadjer-Lamis	3,044	95.1	95.1		54.15	11.66	11.66		160.91	550
Kanem	6,767	1.65	1.65		11.89	0	0		13.54	100
Lac	1,984	369.69	369.69		2.43	0	0		372.12	400
Logone Occidental	881	70.9		70.9	208.15	470.39	116	354	749.44	
Logone Oriental	2,372	122.31		122.31	184.5	572.07	429	143	878.88	
Mandoul	1,744	72.95		72.95	75.88	95.64	95.64		244.47	
Mayo-Kebbi Est	1,805	139.37	139.37		173.52	24.8	24.8		337.69	1,050
Mayo-Kebbi Ouest	1,254	62.98		62.98	56.84	229	229		348.82	
Moyen-Chari	4,147	78.13		78.13	209.1	115.43	115.43		402.66	
Ouaddaï	2,975	88.2		88.2	0	51.7	51.7		139.9	
Salamat	6,796	97.16	97.16		17.45	43.96	43.96		158.57	5,000
Sila	3,570	72.45		72.45	0.31	227.59	227.59		300.35	
Tandjilé	1,753	144.26		144.26	185.43	282.28	282.28		611.97	
Tibesti	12,608	0.03		0.03	0	0	0		0.03	
N'Djamena	40	0.99		0.99	7.06	0	0		8.05	
Wadi Fira	5,412	62.18		62.18	0	18.85	0	18.85	81.03	
Total	126996	1965	1039	926	1601	2328	1812	516	5894	

ANNEX B UNIT COSTS TECHNOLOGY, INPUTS AND PRODUCE

Table 24 Fuel pumps sorted by price

Brand and some details of the pump	Price pump (FCA)	Irrigated area (ha)	Estimate Lifespan (year)
motor pump 3"	80000	0.4	2
motor pump 3"	90000	0.3	2
Honda 3"	120000	2.5	3
Honda 3"	120000	0.25	2
Honda 3"	120000	0.75	3
PTM 3"	125000	2	2
PTM 4"	200000	1	2
Diesel Kipor KDP20	200000	1	2.5
Diesel Kipor KDP20	200000	1	2.5
Diesel Kipor KDP20	200000	1	2.5
Robin 3"	300000	2	2.5
Brand motor pump 3"	500000	1	2
Djongdong 4"	650000	1.2	2.5
Djongdong 4"	700000	1	3

ANNEX C PRODUCTION COSTS, REVENUE AND PROFIT PER FARM PER SEASON

Province	Farmer type	Crops*	Total irrigated area (ha)	Total production cost (FCA)	Total revenue (FCA)	Total profit (FCA)	Profit margin	Cost/ha (FCA)	Revenue/ha (FCA)	Profit /ha (FCA)
Log Occ	MO	Cab, Cap	2.5	205000				92000		
Log Occ	MO	Tom, Cap, Cab	2	1097000	4700000	3603000	77%	548500	2350000	1801500
Log Occ	MO	Tom, Cap, Cab, Pot	2	1181000	3800000	2619000	69%	590500	1900000	1309500
Log Occ	CF	Pap, Ban, Tom, Cab	4	1974000	46000000	44026000	96%	493500	11500000	11006500
Log Occ	MO	Okr, Cab	1.5	302000	642250	340250	53%	201333	428167	226833
Log Occ	CF	Pap, Ban, Veg	1.5	1020000	12500000	11480000	92%	680000	8333333	7653333
Log Occ	MO	Cab, Tom	3	1508000				502667		
Mayo K Oue	VU	Okr, Egg, Pep, Cab	0.25	140750	390000	249250	64%	563000	1560000	997000
Mayo K Oue	MO	Okr, Cuc, Oni	1	250800	5052000	4801200	95%	250800	5052000	4801200
Ouaddaï	FG	Tom, Oni	1		2375000				2375000	
Ouaddaï	FG	Tom, Oni	1.5	525000	1650000	1125000	68%	350000	1100000	750000
Ouaddaï	MO	Tom, Oni, Gar	0.4		850000				2125000	
Ouaddaï	MO	Oni, Gar	0.3		975000				3250000	
Ouaddaï	FG	Oni, Garl, Tom	2	1450000	3100000	1650000	53%	725000	1550000	825000
Ouaddaï	FG	Oni, Tom	1		4350000				4350000	
Ouaddaï	FG	Oni, Okr	1		2850000				2850000	
Ouaddaï	FG	Gar, Oni	1	1495000	3800000	2305000	61%	1495000	3800000	2305000

Ouaddaï	VU	Gar, Oni	0.135		240000				1777778	
Ouaddaï	FG	Gar, Oni	1		2475000				2475000	
Ouaddaï	MO	Gar, Oni, Okr	1.2	2550000	5275000	5275000	675%	2125000	6520833	4395833
AVERAGE FCA				1,124,463	5,754,125	7,043,064	72%	662,869	3,339,781	3,167,587
AVERAGE USD				2,097	10,731	13,134	0	1,236	6,228	5,907

* Crops: Cab = cabbage, Oni = onion, Cap = capsicum, Pot = potatoes, Pep = peppers, Okr = okra, Gar = garlic, Ban = bananas, Pap = papaya, Cuc = cucumber, Veg = vegetables.