Feasibility Study Report

Potential for Water Management in Chad

Submitted To
Idh -The Sustainable trade Initiative
Netherlands

Submitted By

Action for Food Production (AFPRO)
25/1A, Institutional Area, D-Block,
Janakpuri, New Delhi (India)
Email -ed@afpro,org, aro.anr@afpro.org
www.afpro.org

Acknowledgement

At the outset, we express our gratitude to IDH for giving us this opportunity to conduct the field assessment to establish the potential and feasibility of water resources development in southern Chad. We would like to specifically thank Ms Catalina Diaz, Programme Manager, Materials, Textiles and Manufacturing and Mr Guilherme do Couto Justo, for their continued support and constant encouragement during the entire duration of this study. We are also thankful to Mr Pramit Chanda, Global Director, for his valuable guidance and feedback.

Thanks, are especially due to Mr Didier Mbaitelem Djekounro, Programme Coordinator, IDH, Chad for his continued support during the entire assignment especially for sharing necessary information, documents and arranging logistic support.

We are grateful to the entire team of Société Cotnonniere du Tchad (CotonTchad) Société Nouvelle for their excellent support and facilitation of the study in the field. We are particularly thankful to Mr Ibrahim Malloum, Secretary Genenral and the Director for their valuable insights and guidance. We are thankful to all Regional Managers of CottonTchad and their teams for providing excellent guidance and support during the field visits.

We would like to place on record our gratitude to the officials and experts from various government institutions and para-statal organisations, research institutes and other development agencies.

This study was possible because of the help of our translators, Mr Opportun. We owe a great deal of gratitude to them.

This study would not have been complete without the help of the village community from the villages we visited. We will always remain grateful to them for their valuable inputs and insights, and for their warm hospitality.

Last but not least, we acknowledge the sincere efforts and hard work of Mr Yugandhar Mandavkar who led the study team and the members of AFPRO Regional Office, Maharashtra particularly Mr SG.Salunke- Director Programme and Ravindra Sathe-Sr Civil Engineer

Dr Jacob John
Executive Director
AFPRO, New Delhi

Abbreviations

AFPRO	**Action for Food Productions, New Delhi, India (a Civil Society Organisation)**
ANADER	**L'Agence Nationale d'Appui au Développement Rural (National Agency for Support to Rural Development)**
BGRM	**Bureau de Recherches Géologiques et Minières**
LCBC	**Lake Chad Basin Commission**
CRIPT	**Centre for Research, Innovation and Technological Production**
CNRD	**National Development Research Centre**
CTSN	**Société Cotnonniere du Tchad (CotonTchad) Société Nouvelle**
CV	**Coefficient of Variation**
DRE	**Direction des Resources en Eau (Directorate of Water Resources)**
DCRE	**Directorate for Water Knowledge and Regulation**
ENTRAG	**Entreprise des Travaux Agricoles**
FIT	**Inter Tropical Front**
GIZ	**Deutsche Gesellschaft für Internationale Zusammenarbeit (German Internation Cooperation; GTZ or German Technical Collaboration, in the past)**
IGN	**National Geographic Institute**
IRD	**Institute of Research for Development**
ITRAD	**Institut Tchadien de Recherche Agronomique pour le Developpement**
MATHU	**Ministry of Land Management, Housing and Urban Development**
ND-GAIN	**Notre Dame Global Adaptation Initiative index**
ORSTOM	**Office of Scientific and Technical Research in Overseas France**
UNDP	**United Nations Development Programme**
SDEA	**Water and Sanitation Master Plan**
P-SIDRAT	**Information System for Rural Development and Land Management Programme Territory**

Table of Content

	Acknowledgement	I
	Abbreviations and Acronyms	II
1	**Introduction**	**1**
1.1	Background of the study	1
1.2	Scope and Limitations	1
1.3	Structure of the Report	6
2	**Observations from the Field**	**7**
2.1	About Chad	7
2.2	Overview of the study area	9
2.3	Prevailing water use practices	13
2.4	Agriculture and livelihoods	16
2.5	Recent climate trends	17
2.6	Problem analysis	18
3	**Proposed Strategy**	**19**
3.1	Prioritisation of villages	19
3.2	Drinking water solutions	19
3.3	Water and agriculture	
3.4	Setting up a pilot	29
4	**Immediate Actions**	**31**
4.1	Conceptual foundations	31
4.2	Key performance indicator	35
4.3	Cost implications	34
4.4	Groundwork to launch the pilot	35
4.5	Livestock development	37
4.6	Social acceptance and ownership	38
4.7	Long term interventions and strategy	38
Appendix		
A	Field visit schedule	39
B	The Big Picture	40
C	Technical details of the interventions	41
D	Bibliography	48

1. Introduction

IDH is an international trade organisation for inclusive and sustainable market-driven solutions for people through private sector investment and support for new business models. Textiles and cotton being one of the important commodities of interest, IDH has been addressing some of the key issues in the cotton value chain including production support and service delivery. In Chad, IDH has been working in partnership with Cotontchad Société Nouvelle (CTSN) to provide better incomes for smallholder farmers and a better environment through sustainable farming practices.

1.1 Background of the study

Having realised that the poverty and agricultural production challenges of Chadian farmers are intricately liked to the availability and quality of natural resources, especially water resources, IDH commissioned a study on assessment of water resources in southern Chad. IDH invited Action for Food Production (AFPRO), a Civil Society Organisations from India with substantial experience in water and Natural Resources Management. AFPRO has also been a long-time partner of IDH in a variety of development projects including Better Cotton Initiative (BCI) in India and abroad.

Action for Food Production conducted the study with the help of the local office of IDH and its local partner, Cotontchad (CTSN) during the month of December 2022. It was an extensive assessment covering large geography of southern Chad, broadly known as the Sudanian region, covering 33 villages from 22 cantons belonging to seven prefectures[1]. The main purpose of the study was to assess the potential of augmenting and conserving water resources for ensuring drinking water security in the first place, and improving availability and access of water resources for productive purposes (agriculture and livestock), as a bonus.

1.2 Scope and Methodology

Geographic Scope : The assessment was limited to the southern part of Chad, also known as the Sudanian region, which is a source of origin of the main rivers Logone and Chari, the lifelines of Chad and the main contributors to the waters of lake Chad. The area has a good rainfall of over 1000 mm per year and hydrologically a water surplus area that supports agriculture and biomass production for about two agricultural seasons. The study covered 33

1 While some old literature, and even colloquial references, call these units as prefectures, some of which were subsequently sub-divided. After this re-organisation, these administrative units were called provinces. This report will refer to the geographic unit as a province, mainly to maintain the official geographic definitions prevailing. However, new nomenclature based on climatic zones is gradually coming in vogue.

villages from 22 cantons and eight provinces as per the follows (Table 1). These represented the main agro-climatic regions of Chad that presented the typical challenges and potential.

Table 1 : Villages covered under the study

S No	Province	Name of the villages covered
1	Logone Occidental (Moundou)	N'Gandjibien, Mouppon, Pogru, Koilele-I and Doubtou (All in M'Baikoron Canton)
2	Logone Oriental (Doba)	Koro-I, Bewala and Koundou (All in Bedjal Canton)
3	Mandoul (Koumra)	Koro-I (in Bedaya)?
4	Moyen Chari (Sahr)	Benguebe and Congosarah (Band Canton)
5	Mayo Kébbi West (Department Pala)	Dfgufouno-II, Mahouin-II, and Menda Midjigit (All in Pala Canton)
6	Mayo Kébbi West (Department Gaya)	Djodo Gassa, Tagal-II, Tagal-I, Golonhoubou, Gounouka, and Gounou Gembou/ Gaskala (All in Gounou Gaya Canton)
7	Mayo Kébbi East (Department Kelo-Defra)	Ngette-II, Ngette-III, Mangsou Bougrou, Boudo M'Bongue (All in Kelo Defra Canton)
8	Tandjilé (Department Lai)	Bologo, Mongsou Bougrou, Boudo MBongue (all in Lai Canton)

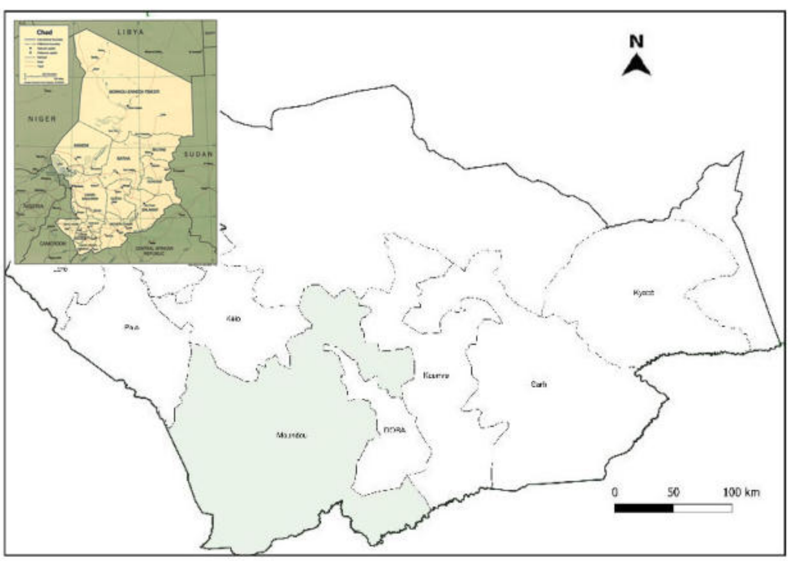


Fig 1 : Map of Sudanian zone showing location of the study area

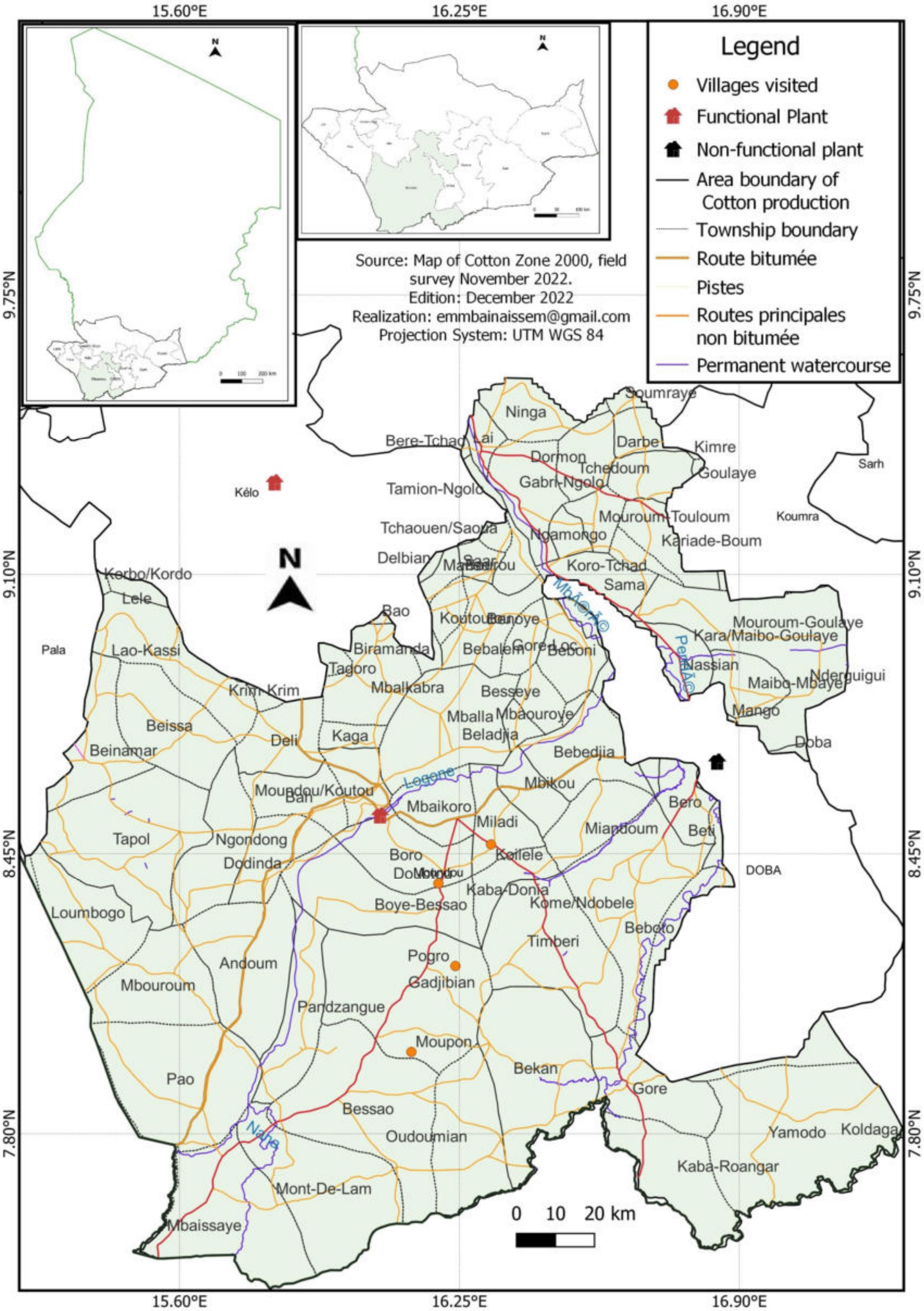


Fig 2 : Location of the study villages in Logone Occidental

Methodology : The feasibility study was conducted using a rapid assessment approach relying partly on the interaction with various stakeholders and partly on physical observations in the field. It comprised site or field visits to the area for physical observations, in combination with interactive sessions or meetings with the community, structured interviews with key relevant informants (local partners, institutions, government departments and other development agencies). The field observations were also used for validating the phenomena narrated by various stakeholders.

Photographs of village meetings and community interaction in the field

Photographs of open wells used as drinking water sources

Tube wells fitted with foot pump (Hydropompe) and hand pump (India Mk-II)

The assessment was dynamic, with the initial questions of enquiry designed on the basis of review of available secondary literature, information, maps, etc, and these were refined and area of enquiry shaped up as the newer information got collected during the field work.
The study undertook the following specific activities and tasks:

- Interaction with Cotontchad SN, the local partner of IDH, to understand their experiences and perception on water management and its implications for agriculture and livelihoods of the local community.
- Identification of study area (representative villages to be visited), in consultation with the project staff of CTSN, with a view to get comprehensive idea about the prevailing situation.

- Study of prevailing land and water management practices, together with an inventory of prevailing traditional practices of the community for in-situ moisture conservation, water harvesting and farming.
- Broad assessment of land and water resources (soil type, spoil texture, depth, erodibility, topography, drainage pattern, hydrogeology, cropping pattern, land use and prevalent farming systems)

Based on the findings and analysis of the above aspects, pragmatic options for land and water management were identified for various regions in the study area.

- Identifying suitable technological options for soil moisture conservation, surface water harvesting, groundwater recharge and possible irrigation management
- Assessment of capacity of the local community and partners for carrying out the water management and livelihoods improvement interventions
- Developing perspective plan for pilot implementation of the above options

1.3 Structure of the report

This report presents the findings of the study, organised according to the following structure. This first chapter briefly describes the study in terms of its objectives, scope and methodology including the steps and tasks carried out by the study team during the course of investigations.

The second chapter presents the observations from the field in terms of assessment of the land and water resources, its implications for agriculture and livestock. It also refers to the prevailing and traditional methods of soil and water conservation prevailing in different eco-regions and its contemporary relevance.

The third chapter presents to potential development actions and the possible soil and water management activities that can be taken up to increase and stabilise the incomes of smallholders in region. The technical details and broad cost implications are given in appended at the end in form of Appendix C.

The fourth chapter provides suggestions on immediate actions that can be taken up on priority. It dwells mainly on setting up a pilot project and pragmatic steps in its implementation and monitoring, including key performance indicators. In addition, it briefly charts out the actions and options from a long term perspective.

A separate appendix is added at the end (Appendix B) presenting a brief conceptual treatise on the larger picture of socio-economic reality of Chad and raises some fundamental dilemmas on technological and strategic choices that need to be addressed in course of any development interventions in Chad.

2. Observations from the field

This chapter presents the main findings from the field observations about the land and water resources, its current situation and its implications for agriculture and livestock. It also presents the observations on various soil and water conservation prevailing in different eco-regions and its contemporary relevance.

2.1 About Chad

About the country : Republic of Chad is a landlocked country in central northern Africa located between 7° to 23° North latitude and 13° to 24° East longitude. It is one of the largest country in Africa spread over 1,284,000 square kilometres with 13.5 million inhabitants. Chad has different climatic zones, varying from arid in the north to tropical in the south. Chad is made up of three major climatic zones, namely, Saharan, Sahelian and Sudanian. Southern part of Chad, the Sudanian region, is fertile land with good water resources availability and is the traditional food bowl of the country. The north of Chad extends well into the arid Sahara desert, dominated by pastoralist rearing cattle, horses, donkeys and camels. with whilst the south has a much wetter, and typically tropical, climate.

Land and Geology : The occurrence of groundwater and its quantity and quality are closely related to geology of the region. Large inland depressions in the basement rock, having been filled with sedimentary layers of continental origin, form important groundwater reservoirs in southern Chad. Lake Chad Basin is composed mainly of late Cretaceous, Tertiary and Quaternary sandy or sandstone formations, which have built up an average 300-metre elevation plain, underlain by a Precambrian crystalline basement (Fig. 4). The Continental Terminal period, a regression in which the sea level fell in relation to land, led to continental sediments being deposited mainly in the Miocene period in Chad. It discordantly overlies the marine sandstone and clay cretaceous series and the basement complex. In the southern and western fringes, it outcrops the Koros zone, with Pala sandstones and Kelo sands. Composed of a sandy or clayey sandy formation that is 100-130 m thick, with moderate hydraulic characteristics and yields, values generally lower in the east toward Batha.

Southern Continental Terminal covering over 145,000 sq km, it outcrops in the western and eastern Logone, Tandjile, Mayo Kebbi, Moyen Chari and Salamat areas. It constitutes the most important aquifer in this part of Chad. As a confined or unconfined aquifer, it presents important lithological heterogeneity. When the aquifer is superficial and is not confined, it is composed generally of sandy lenses, when the aquifer is confined by deep sandstone and clayey sandstone. Thickness is variable and ranges from 70 m to 250 m, but from 150 m to 900 m in Doba to Salamat, and from 150 m to 300 m in the Bousso basins. Its hydraulic characteristics are acceptable (specific yield is around 4 cum/h/m). Water quality is good (salinity is generally lower than 100 mg/L), but presents high iron concentrations and an acidic reaction. Flow is northward and is drained by the rivers Logone and Chari. The aquifer is recharged by precipitations and rivers during floods (World Bank, 2020; pp. 50-51).

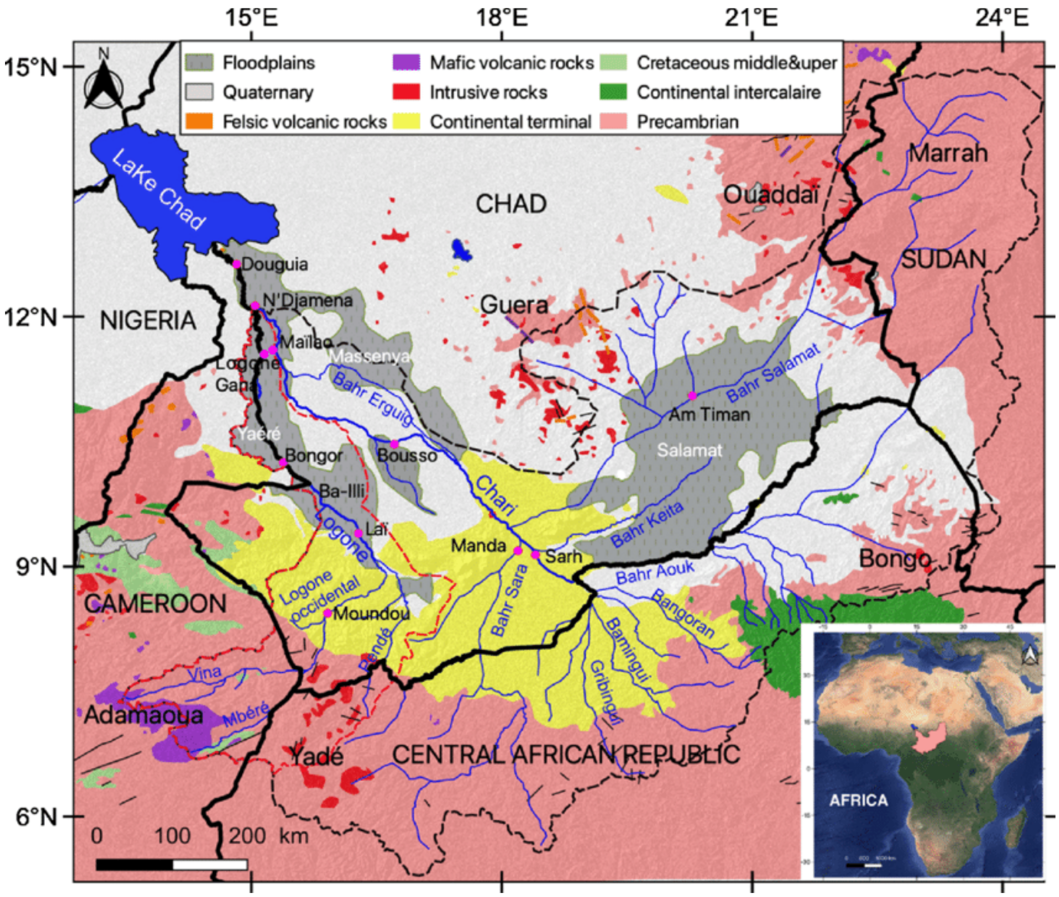


Fig 3 : Geological Map of South Chad (Source : The World Bank)

Rainfall and climate : Rainfall is brought to Chad by a tropical weather system known as the intertropical front, which crosses Chad from south to north, bringing a wet season that lasts from May to October in the south, and from June to September in the Sahelian region. The northern, desert regions of Chad receive very little rainfall all year round (annual average of less than 350 mm). The southern, tropical savannah regions of Chad experience a wet season between May and October (receiving 150-300 mm per month), whilst the central sub-tropical regions have a shorter wet season between June and September (receiving 50-150 mm per month). The remaining months between November and March have almost no rain.

Annually, mean temperatures are similar across most of the country at 25°-30°C, and only differ substantially in the cooler mountainous regions of the north at 15°-25°C. However, seasonal variations are large, and differ in their patterns for different parts of the country. In the north and central regions, summer and winter temperatures are distinct at 27°-35°C in summer and 20-27°C in winter. In the south, less seasonal variation is evident, but the rainy season (July to September) is the coolest (22°-25°C) due to the cooling effects of rain at this time of year.

Economy : Chad's economy is based mostly on agriculture and pastoralism, engaging nearly 80 percent of the country's economically active population. Another 8-10 percent worked in industry, and 12-14 percent engaged in services, including government employment, trade, and other service activities, which are concentrated in a limited number of cities. Cotton ginning and sugar milling are the main industrial activities in Chad. Since the beginning of this century, the economic importance of oil has grown and is now the main source of government revenue.

Development challenges : Chad is facing multiple interdependent challenges. The country struggles with insecurity, entrenched poverty and stagnated economic growth. It faces a problem of food security, malnutrition and underemployment of young people. It has one of the highest child mortality and maternal death rates in the world. Chad faces natural hazards like drought, desertification, floods and dust-storms.

Chad has one of the highest levels of hunger in the world, with 42% of its population living below the poverty line. Chad ranks very low in the Global Hunger Index (113th out of 116 countries) and the Gender Inequality Index (160th out of 162 countries). Chad ranks 181 out of 181 countries in the Notre Dame Global Adaptation Initiative (ND-GAIN) index, which designates its vulnerability to climate change and other global challenges in combination with readiness to improve resilience. This ranking indicates that Chad has extremely high vulnerability levels and low levels of readiness to adapt to climate change.

2.2 Overview of the Study Area

The Sudanian zone in the southern part of Chad is the mainstay of rural economy. Because of its favourable resource endowment, it has very high population density of 52.4 per square kilometre, as against 0.1 in the Saharan Borkou-Ennedi-Tibesti region of the North and 7.3 in the Sahelian region in the centre. About half of the nation's population lives in the southern fifth of its territory, making this the most densely populated region (Wikipedia, 2023). Chad's major rivers, the Chari and Logone flow through the southern savannas from the southeast into Lake Chad. The study covered the provinces of Mayo-Kebbi, Tandjile, Logone Occidental, Logone Oriental, and Moyen-Chari.

Topography and drainage : South Chad is mostly flat with an average altitude of 400 m, is served by two major rivers: The Chari and Logone, both of which originate in the Central African Republic (Fig 4).

River Logone is a major tributary of River Chari and the two rivers jointly contribute about 95% of the inflow into Lake Chad. It has its source in Cameroon from the Mbere and Vina Rivers rise in the Adamawa Plateau. In Lai, it is joined by Rivers Lim and Pende from the Central African Republic. On the left bank, it is joined by River Tandjile and Nya.

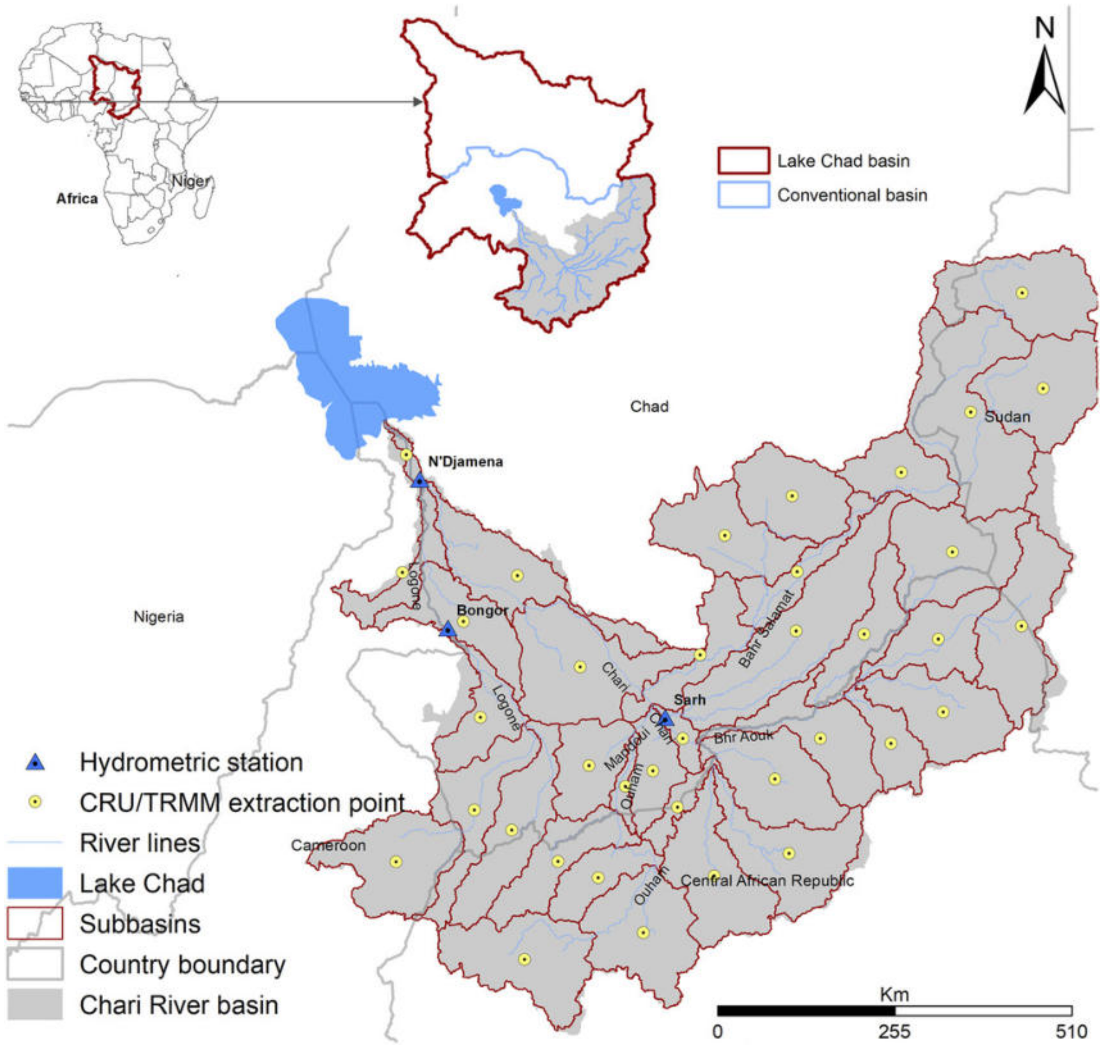


Fig 4 : Drainage of rivers Logone and Chari (Source : The World Bank)

River Chari, upstream of its confluence with the Logone, receives the tributaries of Bahr Salamat and Bahr Keita from the East and Bahr Aouk from South. On the left bank, it is joined by Bahr Illi (also called Padjouek) and Bahr Sara. The total catchment of rivers Chari and Logone at their confluence in N'Djamena is about 600,000 sq km.

Climate and rainfall : The southern part of Chad, is predominantly plains covered with tropical or subtropical grasses, shrubs and bushes. The growth is lush during the rainy season but turns brown and dormant during the five-month dry season between November and March. The Sudanian region receives an average annual rainfall ranging from 900 mm to 1250 mm falling mostly during May to October.

Based on the data of the last 30-50 years (compiled by the authors from various sources), it was found that the average annual rainfall (AAR) for two stations was 969.3 mm falling in 86 rainy days for Sahr and 1082.8 mm falling in 85 rainy days for Moundou. Out of this, the seasonal rainfall (May-September) was 861.7 mm (88.9% of AAR) falling in 70 rainy days and 980.2 mm (90.5% of AAR) falling in 68 rainy days, respectively. Up North in the Sahelian region, N'Djamena receives average annual rainfall (AAR) of 510.0 mm falling in 60 rainy days. Out of this, the seasonal rainfall (June-September) was 453.5 mm (88.9% of AAR) falling in 46 rainy days.

Table 2 : Month-wise rainfall distribution in three cities

Month	Sahr		N'Djamena		Moundou	
	Rainfall	Rainy Days	Rainfall	Rainy Days	Rainfall	Rainy Days
Jan	0	0	0	0	0	0
Feb	1.6	1	0	-	0.2	1
Mar	9.5	2	0.3	1	4.6	2
Apr	37.4	5	10.3	3	39.2	5
May	82.2	9	25.8	6	89.8	9
Jun	135.9	12	51	9	147.7	12
Jul	234.4	15	143.8	13	257.8	15
Aug	243.7	18	174.4	15	284.8	19
Sep	165.5	16	84.3	9	200.1	13
Oct	55.8	7	20.3	3	57.1	7
Nov	3.3	1	0.1	1	1.5	2
Dec	0	0	0	0	0	0
Total	**969.3**	**86**	**510.3**	**60**	**1,082.8**	**85**
Seasonal	861.7	70	453.5	46	980.2	68

(Source : Compiled by the author from multiple sources).

Agriculture : Sedentary agriculture is the main occupation in this region, with farmers growing millets, legumes and oilseeds mainly for self-consumption. Cotton is the main commercial crops grown of Chad, and sugarcane is grown in some regions, mainly Moyen-Chari province. Corn, rice and wheat are relatively recent arrivals. These are grown on a very small area in the flood plains of lake Chad and its receding waters, as well as around lake Fitri in Sahelian region. In the South, rice is cultivated in the lowlands around Bongor, Kelo and Lai in Chari-Baquirmi and Tandjile provinces.

Water resources : Water resources of Chad, especially in the Sudanian zone, is central to the livelihoods of the people and an interesting phenomenon to study because of its seasonality and variability. Because of its topography, this region with relatively flat lands and very gently rolling topography is subjected to seasonal flooding in the rainy season and water scarcity in the dry season.

Surface water : Owing to the flat topography, and abundance of sandy soils, large parts of southern Chad have poorly defined drainage pattern. In almost two-third of the villages covered under the study, the surface runoff takes place merely a sheet flow on vast tracts of grasslands and farmlands, and any well-defined water courses are hardly visible. These areas are prone floods due to large catchment areas and high rainfall (more than 1000 mm with more than 60 rainy days). Near absence of well-defined drainage pattern is an important factor contributing to floods during rainy season, sometimes causing damage to crops. In villages close to the seasonal streams or rivers, only few of those were covered under the study, shallow and wide gullies were visible, which carry runoff only during the rainy season. Often such gullies are used as roads for internal transport and as cattle tracks.

Limited potential of augmenting surface water for drinking and for irrigation is also underscored by the Ministry of Water and Sanitation. In an undated presentation made by Councillor Abakar Ramadane, the drinking water coverage figures indicated that only 288 surface water structures were in service to provide drinking water in entire Chad, as against 17,991 structures (mainly wells) based on groundwater (please refer to the following box).

Box 1 : Drinking water supply situation in Chad

IV- Achievements in the water sector

The implementation of the national water and sanitation strategy with the support of the sector's technical and financial partners has enabled Chad to significantly improve the rate of access, rising from **21%** in 2000 to **53%** in 2015. This is reflected in the following achievements:

- **14,227** human-powered pumps;
- **342** drinking water supply systems;
- **3,422** pastoral wells;
- **267** ponds;
- **21** micro-dams;
- **38** pastoral pumping stations;
- **1000** km of marked transhumance corridors.

Source : Ministry of Water and Sanitation, Republic of Chad

Groundwater : The southern part of Chad is mostly alluvial, which is prominently spread over the Logone Occidental, Logone Orientale, Mandoul, Tandjile, Mayo Kebbi, Moyen Chari and Salamat areas. It constitutes the most important aquifer in this part of Chad and presents important lithological heterogeneity. When the aquifer is superficial and is not confined, it is composed generally of sandy lenses, when the aquifer is confined by deep sandstone and clayey sandstone. Thickness is variable and ranges from 70 m to 250 m, but from 150 m to 900 m in Doba and Sahr, and from 150 m to 300 m in the Bousso basin of Chari Baguirmi. It is believed to have abundant water of very good quality. In the western part, water showed presence of iron in a few villages of Moundou, Kelo and Pala.

The Groundwater Challenge : Falling in the alluvial tracts, with occasional sandstone outcrops, the terrain is capable of recharging large quantities of water in shallow to deep aquifers. Yet, ensuring year round availability of water for domestic uses sometimes poses a challenge because of the regional variations, and thus drinking water security becomes the top priority in such areas. While literature has reported small outcrops of a coarse-grained conglomerate surmounted by sandstone in the southwestern parts (Dedzo *et al*, 2017), but occasional lateritic outcrops were found in a few locations during the visit. There, too, the formations did not hint at any underground dykes of intrusions that would suggest groundwater location. Making water available for irrigation (or other productive purposes) assumes secondary importance. The occurrence and behaviour of water varies widely across regions, thus calling for multiple strategies for diverse areas. It also calls for addressing multiple objectives to meet the consumption and production needs of the community to the extent possible.

2.3 Prevailing water related practices

Water use in Chad largely goes into domestic consumption (drinking, cooking and livestock). Irrigation, which is more or less stagnant at 5-10% of the net cropped area, and industries (the three majors like Banda Sugar Mill, Tchad Brewery in Moundou and about 22 ginning mills of CTSN), accounts for about 15% of total water use in Chad (World Bank, undated).

Topographic limitations : Flat topography and deep alluvial deposits in large parts of southern Chad limit the potential of augmenting surface water, because of poorly defined drainage and high infiltration rate. Due to very low drainage density, augmentation of runoff in streams or gullies is not feasible in most of the villages covered under the study. Occasional surface water structures like ponds or runoff basins were found in some villages. These were used mostly for livestock and for washing and bathing. The only surface water source used for drinking and cooking was the rivers, both seasonal and perennial, in the lower valley portion.

Use of river water

Surface water pond

Preference for groundwater : Communities have depended on groundwater for meeting their domestic needs for a long time. Water for drinking and cooking is collected mostly from open wells and tubewells in all the villages studied. In places where groundwater is scarce (meaning where the wells tend to dry up in summer), the villagers use the perennial streams or rivers. Such streams, where available within reach, serve the source of water for other domestic uses and for animals throughout the year. In places where the streams dry up in summer months, the villagers dig little pits in the stream beds to fetch water for all uses.

Photograph of an open well

A shallow pit in farmland

A shallow pit in River Bed

Open wells : The local community classifies the open wells into two main types, namely **traditional well** and **modern well**, the only difference is that the modern well is constructed (lined) and has a platform and parapet wall. Often a pulley or two is provided to run the rope and bucket. Traditional wells are sometimes lined with wooden logs and provided with platform of the similar material.

Photograph of a traditional open well

Photograph of a modern open well

Photograph of a tube well with manual pump

Photograph of a tube well with power pump

The water sources and seasonality in various study villages is presented in the following table.

Table 3 : Water sources and their characteristics

S No	Village	Location (Lat, Long, Alt)	Open Wells	Tube Wells	Av Depth	SWL	OW-Season	Source summer
1	Mouppon	7.989682 / 16.136217	2+15	1 (7km away)	15-20	3-5m	Up to Jan	
2	Pogru	8.189707 / 16.240261	3	No	<25m	10m	Up to Jan	
3	Koilele-I	8.433347 / 16.268732	1		80m	Not sure	Perennial/ low	Stream (7 km)
4	Doubtou	8.383241 / 16.179272	1	No	7m	4m	Up to Jan	
5	Koro-I	9.085675 / 16.733715						Streams (7 km, 12 km)
6	Bewala	9.149319 / 16.683529	3 not working	3 not working	~30m		Up to Jan	Koro & Gama 4 & 5 km
7	Koundou	9.037945 / 16.777323	3; one defunct					10 km

8	Benguebe	8.948887 / 17.901695	2; one dry		72	52		River
9	Congosarh	8.949228 / 18.554497	Many		5m-10m	3-5m	Perennial/low	River Chari
10	Djoufouna-II	9.434598 / 15.133969	>50		12m (5-15m)	7-8m	Perennial	
11	Mahuin-II	9.50903 / 15.122653		1 defunct	12m (5-17m)	7-8m		3 rivers, 4 km
12	Mynda Midjiguil	9.344536 / 15.022291	Many	1 pump NW	40-50m	30-35m	<Mar-Apr	River Midjigil
13	Djodo Gassa	9.485729 / 15.162907	Many	1			<Apr	River Yassam
14	Tagal-II	9.573192 / 15.214768	1 dry	1 HP	32-36m		<Feb-Mar	2-3m to repair
15	Tagal-I	9.565258 / 15.283227	3	1 works sometimes	20m	8m	<Mar	Market well 2 km away
16	Golondou Bdu	9.750762 / 15.184265	1		>30m	4m	<Mar-Apr	Pond/ depression
17	Gonouka	9.720801 / 15.27965	6	3	12-15m		<Mar	V. Gaskala 2 km away
18	Gounou Jumbo	9.677206 / 15.359729						
19	NGuette-B	9.315393 / 15.217483	4	1	18-35m (GTZ100m)	30-35m		
20	NGuette-III	9.373856 / 5.286836	2	2	47&52m	44m		One pond
21	Mangsou Bougrou	9.203101 / 15.757557	2 dry	4 defunct	90 &100m			Rivers 2 & 3 km away
22	Boudo M'Bongue	9.183688 / 15.720136	1	1 defunct	100m	43m		HP mech failure

2.4 Agriculture and livelihoods

Agriculture : Sedentary agriculture is the main occupation in this region, with farmers growing millets, legumes and oilseeds mainly for self-consumption. Cotton is the main commercial crops grown of Chad, and sugarcane is grown in some regions, mainly Moyen-Chari province. Corn, rice and wheat are relatively recent arrivals. These are grown on a very small area in the flood plains of lake Chad and its receding waters, as well as around lake Fitri in Sahelian region. In the South, rice is cultivated in the lowlands around Bongor, Kelo and Lai in Chari-Baquirmi and Tandjile provinces.

Livestock : Almost all villagers own some livestock, goats and poultry being the most common. Nearly one-third (one-fourth in some villages) own large ruminants, mostly oxen for draught purpose. Rearing cattle for milk is not a common practice in Chad. However, it is getting popular in a limited large town areas, like, say, in and around N'Djamena, where urban consumers prefer to buy milk as a food. Therefore, this report does not recommend any dairy or milch cattle based livelihood.

In spite of vast grasslands present in the Sudanian area of Chad, the proportion of livestock is negligible. It is reported that the migratory pastoralists travel via the region, as reported in the villages covered in the study, and destroy their crops. This observation need to be studied in detail, as it could not be explored during the current study due to time constraints and translation limitations.

2.5 Recent climate trends

Different climatic zones of Chad, varying from arid in the north to tropical in the south, respond differently to climate change signals. There have been several studies in recent years on the changes observed and projections for future.

Temperatures : The changes in hydroclimatic fields such as rainfall and temperature were examined over the major cities in various regions for the period 1950 to 2014. A substantial rise in air temperature is observed after 1980−1985, reflecting the gradual rise of temperature in recent times. Mean annual temperature has increased by 0.7°C since 1960, an average rate of 0.16°C per decade. The rate of increase is most rapid in the wettest season (Jul-Sep) at 0.36°C per decade, but there is no evidence of a warming trend in the dry season (Jan-Mar).

Rainfall: Rainfall shows a significant decreasing trend especially over cities close to Lake Chad (Lere, Mondou, Mongo, and Sarh), whereas no significant trend is observed for cities farther from the lake. However, a consistently increasing trend in temperature is found across all cities. The cities in the north (Faya, Abeche, and Ati) receive far less rainfall than those located in southern Chad. All cities (except Faya and Lere) received higher rainfall during 1950−1965 (wet period), entering a dry regime between 1966 and 1990 (dry period) and subsequently recovering rainfall totals, toward previous levels, indicating a recovery phase from 1991 to 2014 (Pattnaik, et al, 2019). Mean annual rainfall over Chad has not changed with any discernible trend since 1960. Some unusually high rainfalls have occurred in the dry season in the very recent years (2000-2006), but this has not been a consistent trend.

According to the World Bank (undated), there have been no long-term trends in rainfall over the last century, although there have been distinct wetter and drier periods, with severe droughts between 1950 and 1980s and 2005, 2008, 2010 and 2012. Nonetheless, the early 2000s saw unusually high rainfall during the dry season.

Projections of Future Climate : The mean annual temperature is projected to increase by 1.0 to 3.4°C by the 2060s, and 1.6 to 5.4°C by the 2090s. The projected rate of warming is similar in all seasons and regions of Chad. A report by GIZ (2021) suggests that heavy rainfall events will become more frequent and the amount of rain falling during such events is projected to increase in southern Chad, but decrease in the north.

Projections of mean annual rainfall averaged over the country from different models in the ensemble project a wide range of changes in precipitation for Chad. Projected change range from -15 to +9 mm per month (-28 to +29%) by the 2090s, with ensemble means close to zero (McSweeny; 2012).

In view of the above, it appears that the water resources development and management strategies of the proposed project will not require incorporating any special considerations for climate change trends while planning. Nevertheless, is suggested to monitor the trends in rainfall patterns and variability in future.

2.6 Problem Analysis

From the foregoing discussions, it is clear that water resources in the Sudanian zone of Chad present interesting patterns of availability and seasonal variations. Because of its relatively flat lands and very gently rolling topography, this region is subjected to seasonal flooding in the rainy season and water scarcity in the dry season. The hydrogeology characterised by alluvium with occasional sandstone or basaltic outcrops presents potential for recharging large quantities of water in shallow to deep aquifers. Yet, ensuring year round availability of water for domestic uses sometimes poses a challenge because of the regional variations, mainly deep aquifers and high transmissivity.

Under such circumstances, drinking water security becomes the top priority in order to reduce the drudgery of women and children. While making water available for agriculture or other productive purposes may be considered of secondary importance, it is necessary in order to tackle to omnipresent problem of rural poverty and malnutrition. Thus, it is recommended to address the twin objectives of meeting the consumption and production needs of the community. The occurrence and behaviour of water varies widely across regions, thus calling for different strategies for diverse areas.

Development interventions in agriculture are the need of the hour in Chad because of its widespread poverty and malnutrition. Agriculture is the main occupation in southern Chad, with farmers growing millets, legumes and oilseeds mainly for self-consumption. Agronomic practices are traditional, with negligible use of chemical fertilisers and pesticides; which is partly because non-availability of agro-chemicals (all are imported) and partly because lack of incentive for production (low market prices of food grains). The traditional practice was cultivating a piece of land for 3-5 years and then leaving it fallow for 10-15 years to regenerate. However, this cycle of crop rotation has come down to 8-10 years due to increased population pressure. While low productivity is a matter of concern, the low use of agro-chemicals can be viewed as a boon from environmental (no pollution) and sustainability (resilience and low dependence of external inputs). Agriculture development interventions should focus on capitalising on these strengths.

These strategies are discussed in detail in the next chapter.

3. Proposed Strategy

Based on the situational analysis presented in the last chapter, it is proposed to address the water scarcity problem by aiming at drinking water security on one hand and for agriculture and livestock on the other. The latter calls for an integrated approach focussing on rainwater harvesting, *in situ* soil moisture conservation and appropriate water use practices for biomass production. This chapter presents the suggested strategy, separately for drinking water security and for overall water resources development and management.

3.1 Prioritisation of villages

While the need for integrated water resources management is important in all rural areas of Chad owing to all pervasive poverty and malnutrition, priorities can be assigned to those areas where drinking water scarcity is severe. The severity has been assessed on two criteria of availability and adequacy. Availability refers to proximity of source across the seasons, while adequacy refers to the number of reliable sources in proportion to the demand (say, population). The villages studied can be categorised as under:

Table 4 : Prioritisation of villages based on drinking water scarcity

Availability/ Adequacy	**Secure :** Perennial source within the village	**Scarcity :** Perennial source within 3 km of village	**Severe :** Perennial source beyond 3 km of the village
Adequate : More than one reliable source per 250 population	**Priority - Low** **Example :** Villages Pogru; Kongosara, Djoufouna-II; Tagal-I; Gounouka	**Priority - Moderate** **Example :** Villages Djoda Gassa; Mahuin-II; N'Guette-III, Gounou Jumbo;	**Priority - High** **Example :** Villages Tagal-II
Inadequate : More than 250 persons dependent on one reliable source	**Priority - Moderate** **Example :** Villages Benguebe, Koundou;	**Priority - High** **Example :** Villages Bameh, N'Guette-B; Boudo M'Bongue (Kelo)	**Priority - Very high** **Example :** Villages Golondou Bdu; Mongsou Bougrou (Kelo);

3.2 Drinking water solutions

According to the people from all villages covered in the study, an open well is the most preferred source of drinking water, followed by river (or river bed filtration pits). Tube wells and handpumps are not preferred mainly because of its maintenance and repairs requirement. Nevertheless, it is a technology of choice in a few villages where shallow groundwater, which can normally be tapped from open wells, is inadequate or does not last throughout the year.

Based upon the needs of the people and technical considerations, three interventions are recommended towards the drinking water security in the region:

3.2.1 New open wells : In villages with inadequate number of sources, it is recommended to take up new open wells, with a view to meet the provide one functional and perennial source per 250 population. Location of such a new open well should be determined by the convenience of the people (close to the habitation), in addition to the hydrologic (topographic) and geological considerations (based on geophysical surveys). New open wells are recommended in six villages Golondou Bdu, Mongsou Bougrou (Kelo), Benguebe, Bameh, N'Guette-B, and Boudo M'Bongue (Kelo).

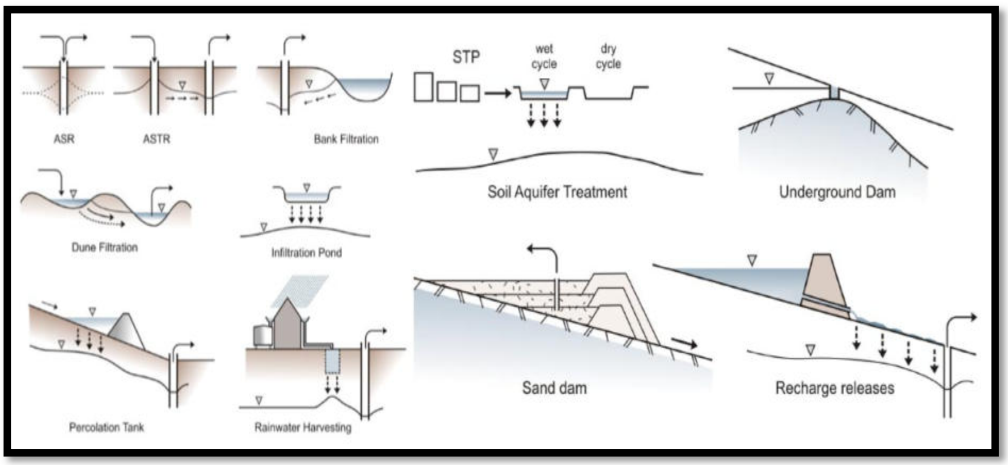
3.2.2 Source strengthening : Availability of water can be increased in volume and extended over a longer period by way of appropriate groundwater recharge measures. Source strengthening is recommended for the existing drinking water sources, whether open well or tube well, with a view to increase the period of water availability. Groundwater recharge measures are recommended in all villages except those falling in the low priority clusters. Groundwater recharge measures include (1) recharge trenches (and NOT recharge shafts) in the vicinity of the well, (2) small gabions or gully plugs on shallow gullies near the wells, and (3) small surface water ponds in the upstream of the wells. It is recommended that these measures should be implemented in combination so as to get maximum recharge benefits, and in turn, longer period of water availability. A broad combination of these measures for various villages is presented in the following table.

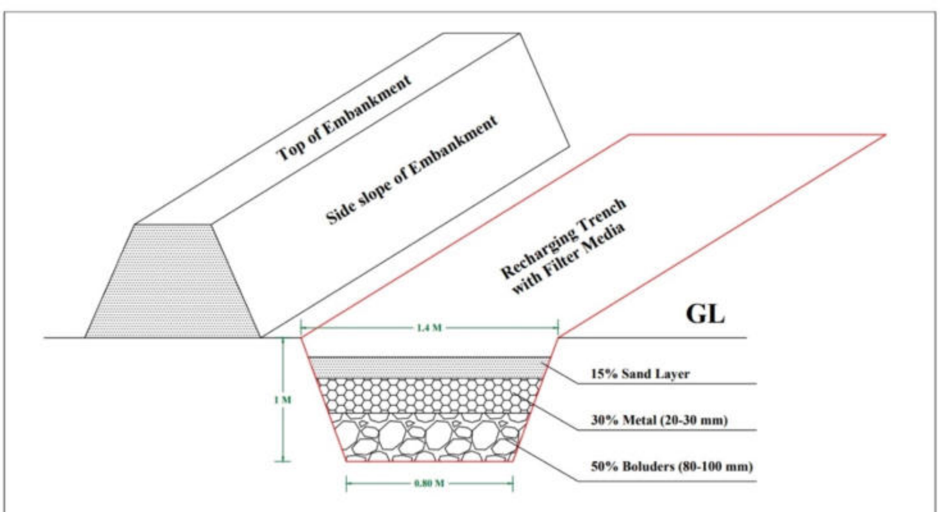
Table 5 : Suggested Source Strengthening Measures

S No	Village	Province	Recharge Trench	Gabion/ Gully Plug	Recharge Pond
1	Mouppon	Logone Occidental	Yes		
2	Koilele-I	Logone Occidental	Yes	Yes	
3	Doubotou	Logone Occidental	Yes	Yes	Yes
4	N Djinga/ Bameh	Logone Oriental	Yes		Yes
5	Koro-I	Mandoul	Yes	Yes	Yes
6	Bameh/ Gambia	Logone Oriental	Yes	Yes	Yes
7	Koundou	Logone Oriental	Yes		Yes
8	Benguebe	Moyen Chari			Yes
9	Mahuin-II	Mayo Kebbi (Pala)	Yes		Yes
10	Mynda Midjiguil	Mayo Kebbi (Pala)	Yes		
11	Djoda Gassa	Mayo Kebbi (Pala)	Yes	Yes	
12	Tagal-II	Mayo Kebbi (Pala)	Yes	Yes	Yes
13	Golondou Bdu	Mayo Kebbi (Kelo)	Yes		Yes
14	Gounou Jumbo	Mayo Kebbi (Kelo)	Yes		Yes
15	NGuette-B	Mayo Kebbi (Kelo)	Yes		Yes
16	NGuette-III	Mayo Kebbi (Kelo)	Yes	Yes	Yes
17	Mangsou Bougrou	Tandjile	Yes	Yes	Yes
18	Boudo M'Bongue	Tandjile	Yes	Yes	Yes

Typical treatments proposed in the above are described below:

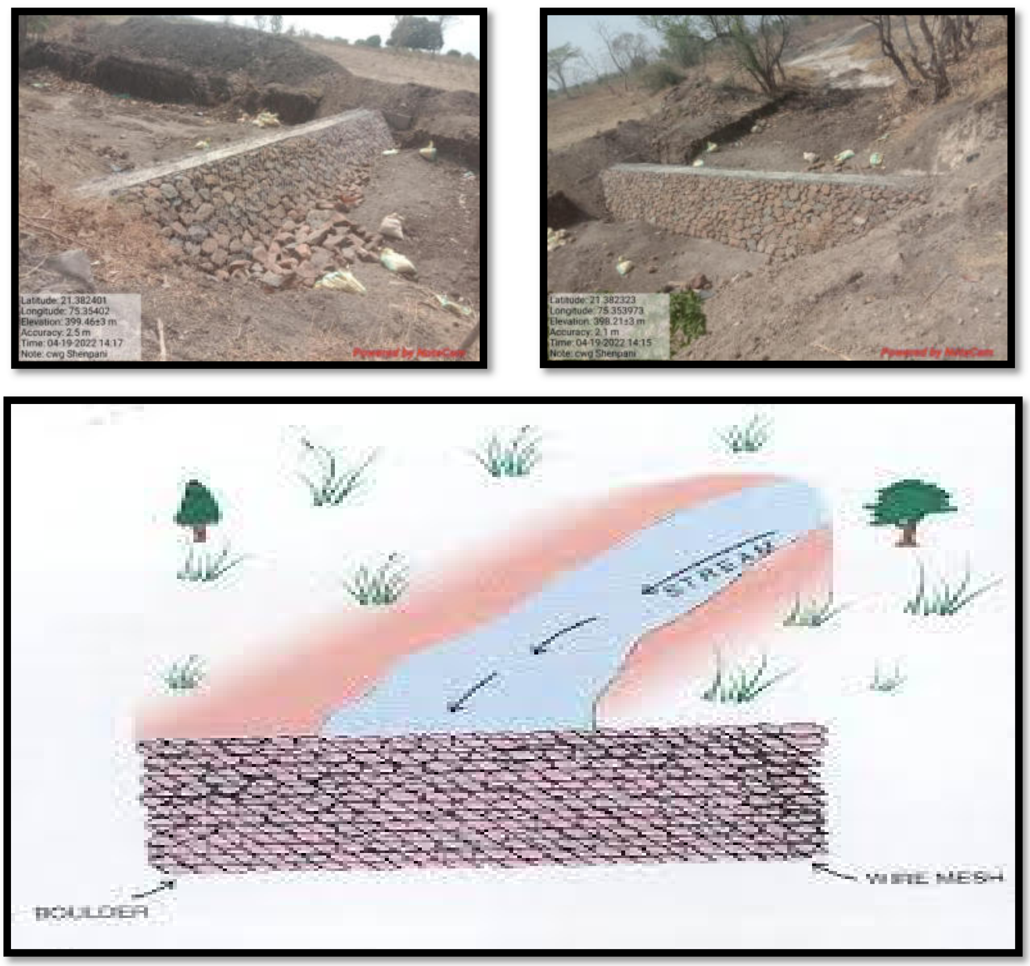
1) **Recharge Trench :** These are small trenches of about 1.0 m (bottom width) excavated across the flow of surface runoff to harvest the runoff water and guide it towards the well. Normally two trenches are excavated near a well in a shape of English alphabet V pointing towards the well. The length of the trench is in proportion to the depth of the well, normally 20m-100m depending upon the estimated runoff available. The depth of the trench can be between 2-5 m depending upon the geology (or presence of any clay layers), so that the harvested water is allowed to percolate past any such impervious layers.





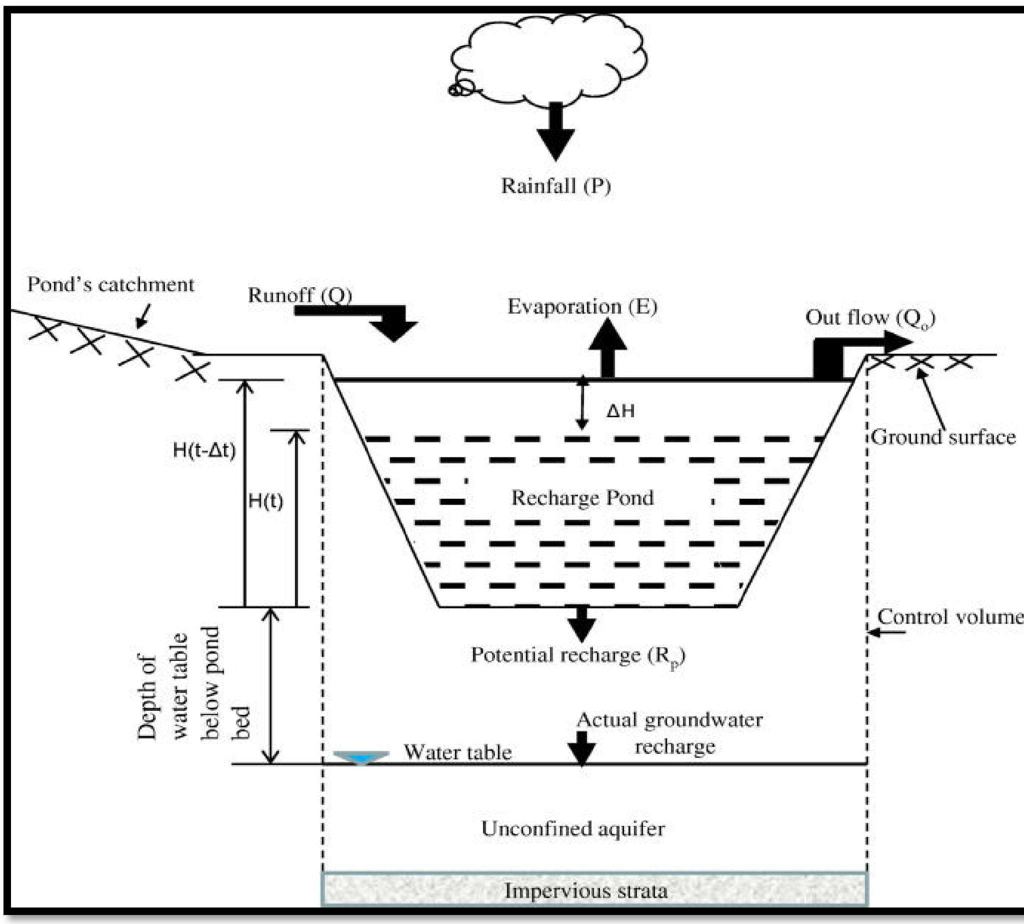
Proposed Sample Design of Recharge Trench with Filter Media

2) **Gabion or gully plugs :** are small structures constructed out of undressed stone across small gullies to retard the flow of water during the rainy season. By slowing down the flow of water, it gets a chance to percolate into the ground, thereby increasing the soil moisture in the region aiding groundwater recharge. Given the flood prone conditions and relatively flat topography in the project area, the gully plugs should be made strong with wide base width (3-5 m) and a maximum height of 0.75 m at crest, depending upon the catchment area at the site of construction. Gully plugs or gabions are generally constructed in compact stones (basalt, laterite, gneiss, etc) that is locally available.



Photographs and sketch of a gabion

3) **Recharge Ponds :** These are sunken ponds formed by excavation of soil up to a depth of the pervious layer which allows percolation. The lateral expanse and depth are determined according to the recharge potential of the well. Sunken ponds can also be excavated for storage, in which case the dimensions are determined as per the water demand (human and animal population).

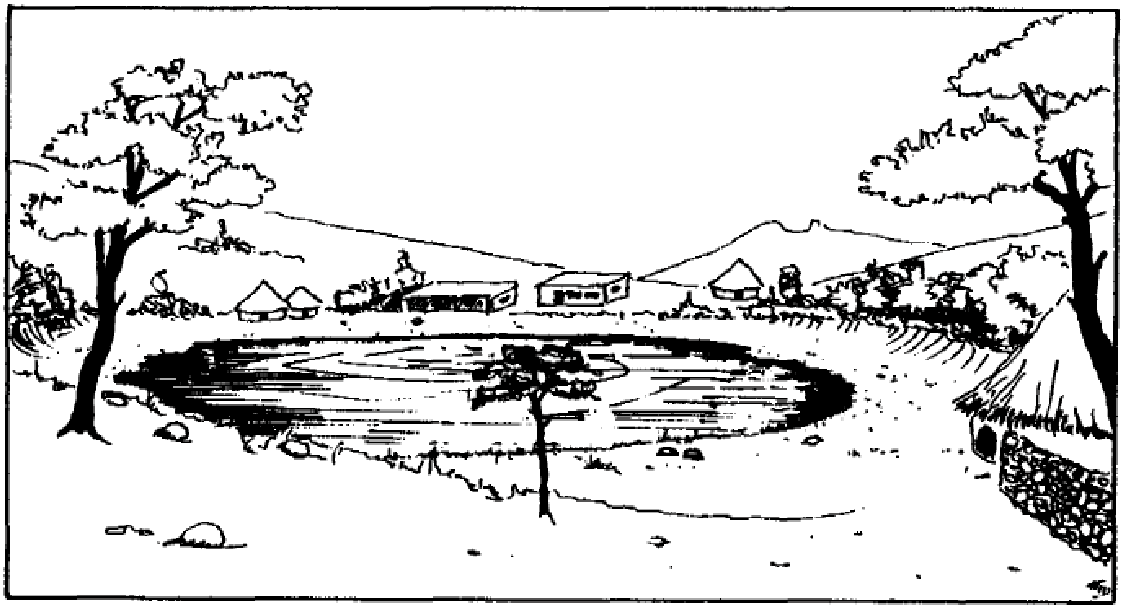


Photograph and sketch of a recharge pond

3.2.3 Sunken Ponds : Ponds may be excavated in villages where groundwater availability is low or potential of groundwater recharge is limited. Such ponds are also useful in villages with deep and large (continuous) aquifers with high transmissivity (in such cases large quantity of water is needed for recharge, but it may flow into the nearby villages). Sunken ponds are suggested in villages Koundou, Bameh, Benquebe, Djoda Gassa; Mahuin-II; N'Guette-III, Golondou Boudou, and Boudo M'Bongue. The sunken pond should be located close to the habitation so as to be accessible to the people. Given the flood prone nature of the entire region, the pond should be located a little away from the main water courses or gullies so as to prevent any flood damage. The pond should be provided with properly designed inlets and outlets with precise levels. It is recommended that the pond for drinking water should be separate from that for animals and that for washing and bathing, so as to maintain the water quality.

Photograph of a sunken pond

Open runoff basins : In addition to the sunken ponds, these traditional water harvesting structures are recommended in areas or villages where groundwater availability is low due to either deep aquifer or high transmissivity. Open runoff basin is a saucer shaped pit excavated and its bottom is sealed with impervious clay to prevent seepage. It collects runoff water during rainy season, which is used for drinking and domestic uses for several months. The size depends on the requirement of the family or the community. These open runoff basins are found in large parts of central and southern Chad. Household level basins are traditionally excavated by the people and used. Hence, additional investment will be minimum. Group or community level basins may be sponsored from the project.



Sketch of a large open runoff basin or Bonco Pit in Male

Photo showing open runoff basin in village Bameh (Logone Orientale)

3.3 Water and agriculture

Development interventions in agriculture are the need of the hour in Chad because of its widespread poverty and malnutrition. As suggested earlier, Chad presents a great scope of regenerative agriculture or sustainable farming because of low barriers and low chemical footprint. Further, large livestock population reared on semi-nomadic pastoral system can be leveraged as a strong support for regenerative agriculture as a source of organic manures[2].

It is strongly recommended to launch an agricultural development programme with a clear objective of food and nutrition security as an immediate priority, while not-so-simultaneously addressing the long-term macro-economic development concerns. Such a programme should focus on increasing and stabilising productivity of main food crops of millets, legumes and oilseeds mainly for self-consumption, the larger market linked economic returns being outside the purview and capacity of a micro-level development project. Such agricultural development intervention should be implemented in one or two small clusters of villages, more as a pilot-level demonstration of appropriate technology focussing on food and nutrition security.

3.3.1 Focus on soil health : The main problem of agriculture in Chad is the limitations of the farmer to be able to maintain the soil productivity (read, soil nutrient levels) for sustaining the crop production for more than 3-5 years. Our observation is that the loss of soil nutrition due to erosion of topsoil <u>is a bigger contributor</u> than depletion of soil nutrition due to crop cultivation over the years. Therefore, taking up soil and water conservation measures for erosion control on farmlands should be the primary objective of any intervention for the next several years. It should simultaneously be supplemented with improving soil nutrient levels by way of a combination of organic and mineral (or chemical) manures and fertilisers.

Soil and water conservation measures like farm bunding, with adequate arrangements of spillways for discharging the surplus runoff, is the key intervention proposed.

A word of caution : Heavy rainfall and flat topography in absence of a clearly defined drainage network are two main factors that should be taken into account while planning the soil water conservation measures in the large parts of southern Chad. Any over-enthusiastic or over-ambitious design is most likely to lead to total destruction of the structures due to floods.

3.3.2 Soil Moisture Conservation : Given the flat topography and very low drainage density in large parts of southern Chad, thus limiting the options for surface water augmentation, it is imperative to focus on *in situ* conservation of soil moisture. It is best possible with farm bunds on agricultural lands. Technically called compartment and peripheral bunds, these are soil conservation structures made by piling up soil across the major slopes of a farmland. recommended to prepare compartments of about half hectare each. The bund can be of 0.75m

2 The socio-economic relationship between the pastoralists and the sedentary farming community should be understood in detail, as this study could not capture the reality. It was mainly because of very limited time available, and partly due to inadequate communication because of language barriers. It must be noted that the sedentary crop cultivators and the nomadic (or semi-nomadic) pastoralists have very functional and pragmatic symbiotic relationship <u>in most parts of the world</u>. It was only in this part of Chad that the authors came across conflicting interests or relationship between these two groups. It also needs to be studied from the angle of exporting beef on the hoof and its economic implications. The two articles (in French) suggested by CTSN team confirm the prevalence of conflicts, with data and incidents. However, these remain popular articles without getting into systematic diagnosis of causal factors and mechanism.

settled height and a top width on 0.5 m. In view of the sandy and sandy loam soils available in the study area, the side slope of 1:1.5 is recommended. Each plot should be provided with a bund spillway, made of locally available rubble (or in brick masonry, where stone is not available). It is suggested to provide a stormwater drain (an open dug out channel) to carry the surplus runoff from such farms. Besides improving soil moisture, which is crucial for crop growth during dry spells, farms bunds control erosion of fertile top soil, thus contribution to plant nutrition and soil health.

Photographs of farm bunds and loose rubble bund spillway

3.3.3 Organic manuring : Two types of composting techniques are recommended, namely, composting of farm trash (agricultural residues and other biomass) using aerobic method and vermicompost. These will help the farmers maintain soil fertility for longer period, thereby reducing the frequency of the shifting cultivation cycle.

Photographs of aerobic composting pits

Photographs of vermi-compost beds

3.3.4 Bio-gas digester : This is one of the best methods of composting animal manure and farm waste. It may be promoted among the farmers with a few cattle and with availability of water throughout the year. The slurry coming out of this biogas plant can be used as a composting ingredient. AFPRO has a long standing experience of promoting biogas units and training local masons and youth on construction of biogas digesters.

3.3.5 Agronomic measures : Farmers in Chad are seriously lacking the technical guidance or support on farming practices. While the Department of Agriculture (through ANADER) provided some advice on crop husbandry the rainy season, it is very limited and infrequent. It is suggested to provide strong extension support on agronomy (scientific crop management practices) soil conservation, water management and efficient water use.

Schematic photograph of contour cultivation

Schematic photograph of bund plantation and mulching

3.4 Setting up a pilot

The aforementioned interventions and strategies are applicable to almost entire Soudanian region of Chad, and will prove useful in providing drinking water security and substantiating food and nutrition security to the rural communities. The interventions mentioned in the previous sections can be best implemented using a watershed approach over a small cluster (mini-watershed of around 3000-5000 ha) comprising of a few villages. Depending upon the resources available, the pilot may be implemented in one or more zones (See Fig 5).

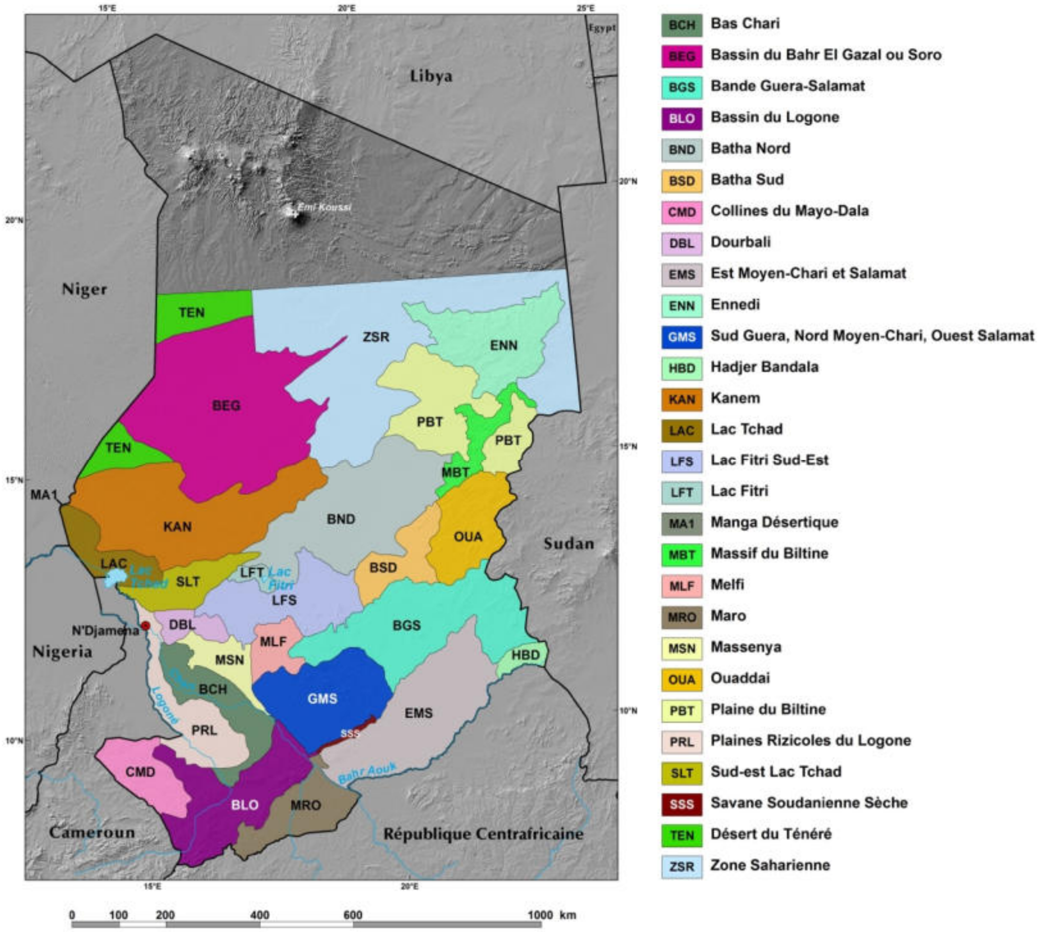


Fig 5 : Eco regions of Chad

The pilot will require intensive involvement of a dedicated team of local community mobilisers and experts in agronomy and engineering. Occasional services of hydro-geologist or geo-physicist may be required for siting of locations for open wells, recharge pits, farm ponds and for designing the strategies for well repairs or renovations.

Technical details and tentative costing of the interventions recommended in this chapter are presented in Appendix-C of this report.

4. Immediate Actions and Follow Up

The interventions proposed in the previous chapter to address multiple challenges of water resources development and livelihoods enhancement have to be implemented in a systematic and stage-wise manner. This chapter briefly describes some of the prominent implications, which should be considered while planning and implementing the proposed interventions, and more importantly, the performance metrics.

4.1 Conceptual foundation

4.1.1 Economic incentives : Markets of agricultural commodities in Chad are informal and the prices are often determined by the transport and collection costs incurred by the traders. As a result, the farmers do not get a fair price for their produce. Further, at the time of harvest, every family which is both a producer and a consumer has surplus produce. Thus, there is little incentive for farmers to produce food grains more than what is needed by his or her family. The classic example worth quoting is of mango. With abundant harvest every year and no access to market, it is said that each villager consumes about 2-3 tonnes of mangoes in the season. And even after feeding the animals, nearly half of the produce gets spoilt on the trees.

Therefore, any agriculture development initiative will have to include measures and support for accessing remunerative market.

4.1.2 Livestock : Rainfed farming is incomplete without a strong presence of livestock, which has an important role in improving soil fertility and maintaining soil health. Pastoral and sedentary livestock rearing is the most remunerative and sustainable farming system in such lush areas of southern Chad. However, the vast grasslands of this region seem have failed in bringing prosperity to the farmers. This team could not fully understand the access and usufructuary pattern of these grasslands, but learnt that external pastoralists graze their cattle in the lands for free, and often by coercion. This phenomenon needs to be understood while promoting cattle and livestock in the region.

Any development in this area should be promoted using farming systems approach.

4.1.3 Technology choices : Because of extremely low use of agro-chemicals and hybrid seeds, agriculturists in Chad are self-reliant in their production system. Such a system is also sustainable and resilient. Development organisations are often tempted to import such modern inputs with a view to increase production and productivity. This is a difficult choice that might jeopardise the stability of local farmers by increasing their dependence on such external supplies. In absence of a strong economic cushion against the risk of modern agriculture and a near absence of industrial and technology base in Chad, such interventions may prove disastrous in the long run.

It is therefore strongly recommended to promote agriculture development in Chad using sustainable farming methods (organic farming or regenerative agriculture) with stronger emphasis on resilience building rather than production increase alone.

4.1.4 General infrastructure : Promotion of any development interventions in water and agriculture will require technical back up to be effective. For example, the mechanics for handpump repairs, carpenters and masons to repair the wells and water bodies, artisans to repair agricultural tools, etc will be crucial for smooth operations and maintenance of the resources created. Communication infrastructure and facilities like engineering workshops in rural Chad are very poor.

Thus, investment in building the above skills among rural youth and providing them with basic tool kits will help overcome the general infrastructure deficit.

Water Quality has been identified as an issue in a limited area, the vicinity of Banda Canton in Moyen Chari province (Sahr), where the effluents from the sugar factory are dumped into river Chari. Further use of agrochemicals in sugarcane farms, which are mostly owned and operated by the government, have reportedly affected the quality of surface water (river Chari) and shallow groundwater which the villagers drink per force. The villagers have complained to the Governor and the factory authorities against this, but to no avail.

4.1.5 Soil and Water testing : Facilities of testing water quality and soil quality (nutrients) are highly limited. It was learnt that there is only one laboratory for testing of drinking water with the Public Health Department in N'Djamena. Similarly, the only soil testing facility exists in N'Djamena (with ITRAD HQ).

It is recommended to provide rapid field testing kits for both water quality and soils quality with the project team.

4.1.6 Hydrologic monitoring : Most of the water related data available in Chad is disparate and incongruent because of limited hydrologic monitoring facilities and infrastructure.

It is recommended to instal a weather monitoring station in the pilot area and maintain data on main parameters like precipitation, temperatures, humidity, wind velocity, etc.

While there are a limited options available to any private or corporate or a civil society development agencies to conclusively solve the above problems, the best way is to keep appraising the government on the need to address these issues. Within a limited sphere of influence, the development organisations should acknowledge the above challenges and formulate their strategies accordingly. Further, it is recommended to set up the deliverables and project outcomes on very pragmatic considerations.

4.2 Key Performance Indicators (KPIs)

The study recommended interventions aiming at (1) drinking water security and (2) water for agriculture and livestock.

4.2.1 Drinking water security : Three interventions are recommended towards the drinking water security in the region, *viz*., (1) new open wells, (2) source strengthening using either or a combination of recharge trenches, gully control structures and small surface water ponds, and (3) sunken ponds or runoff basins.

The performance on drinking water security can be measured at two levels, *viz*., Output and Outcome levels, borrowing the terminology from Logical Framework Approach. The output level indicators can be measured on annual basis, whereas the outcome level indicators can be measured at the end of the second or third year (as mid-term or end-of-the-project results).

Table 6 : Performance indicators of drinking water security

No	Intervention	Output indicator	Outcome indicator
1	New open wells	• Number of households and number of habitations covered • Number of new open wells commissioned	• Number of households and number of habitations got access to water • Number of months for which the source has water
2	Source strengthening	• Number of households and number of habitations covered • Number of old sources strengthened • Number of new sources covered	• Number of months for which the water availability increased
3	Sunken ponds	• Number of households and number of habitations covered • Number of new household level and community level ponds commissioned	• Number of households and number of habitations got access to water • Number of months for which the source has water

4.2.2 Water in agriculture sector : Three interventions are recommended towards conserving water for agriculture, viz., (1) farm bunds for *in situ* moisture conservation, (2) organic manures (including composting techniques), and (3) agronomic measures for conservation oriented agriculture.

Like before, the performance of these activities may be measured at output and outcome levels using the indicators given in the table below. It is strongly recommended that two higher level indicators, soil health and productivity, may be measured at the beginning (as baseline) and at the end of the project

Table 7 : Performance indicators of soil [water] health improvement

No	Intervention	Output indicators	Outcome indicators[3]
0	Specific Objective Level		• Improvement in soil health (measured in terms of increase in organic carbon content from xx% to yy% in 2-3 years) • Increase in productivity of principal crops from xx kg/ha to yy kg/ha
1	Farms bunds with spillways	• Number of households covered • Area covered in hectares	• Number of months for which the soil moisture availability increased • Estimated volume of water conserved *in situ*
2	Use of organic manure	• Number of households covered • Area covered in hectares • Volume of aerobic compost and vermicompost used	• Reduced incidence of insect pests and diseases[4] • Increase in production (yield) of the crops
3	Bio gas digesters	• Number of households covered • Number of units commissioned	• Volume of compost produced (and used in the farm) • Income from sale of manure, if any
4	Agronomic measures	• Number of households covered • Area covered in hectares	• Number of farmer groups formed • Number of new farmers adopted the techniques in the second and third year (as a result of demo effect)

4.3 Cost implications

Based on the local rates obtained from various markets in different cities of Chad during the study, the typical cost structure (very broad Bill of Quantities) of the main activities are presented below. It may be noted that scale economies operate in soil and water conservation works when implemented on watershed basis. Therefore, the following costing should be taken

[3] Many of the outcomes overlap, in the sense that those outcomes are result of a combination of activities, and not a direct result of any particular activity. Therefore, the outcome indicators are not repeated, but mentioned only once against that activity, which will contribute to the outcome to a relatively large extent.

[4] In the above table, two otherwise obvious outcome indicators were not added due to the specific context of Chad. First is the "savings due to reduction in use of chemical fertiliser" and another being "savings due to reduction in use of chemical pesticides", as both these inputs are not readily available and farmers are not in control of making a decision to purchase and use the same.

as indicative. Detailed and slightly more accurate cost estimation is expected after the detailed surveys of the specific villages once selected for the pilot.

4.3.1 Cost norms : At the programme level, the perspective planning and budgeting for such projects is done using the principles of watershed development, or loosely speaking, integrated soil and water conservation project. In drought-prone areas of India, the government has fixed a cost norm of INR 22,000 (or Euro 275) per hectare of treatable area in the watershed. Given the unpredictable pricing and higher overheads (logistic costs) in Chad, we should work with a guideline value of Euro 300 per hectare of treatable area.

The concept of treatable area in the context of southern Chad, where the watershed area extends beyond the boundaries of several villages, the interventions will be limited to a village or a cluster of villages. However, the allocations should not be made on the basis of the geographic area of the village/s. Large parts of Sudanian Chad have grasslands that do not need any immediate treatment. Under such circumstances, the so called treatable area should be limited to the total cultivated area in three years[5].

Example: *For pilot implementation in the next three years, a cluster 3-4 villages having 1000 ha of cultivated area every year (about 250-350 ha per village), we should be prepared for an investment (a ballpark figure) of Euro 750,000 for three years (considering shifting cultivation with rotation factor of 2.5 X 1,000 ha X Euro 300).*

4.3.2 Indicative Costing for Drinking water interventions

Given below are the indicative costing of the main interventions proposed.

New Open Well: The costing varied widely because of the geological formations prevailing in different areas. In case of clay (e.g. village Mouppon) or in rocky formations (e.g. village Gounouo Jumbo), the lining cost would be low, but it will be high in sandy formations (e.g. village N'Guette B). It is however, recommended to provide well lining in all open wells at least to the depth of reasonably firm formation, on which the lining wall could be seated. It is suggested to standardise the well diameter to 3.0 m, so that formwork for concrete casting can be fabricated accordingly. The platform cost can be reasonably standardised. In places (such as Tandjile or Moyen Chari) where Hume pipes (pre-cast concrete pipes) are available, well sinking using these rings (as lining and stabilising components) can be used. All these villages are from Mayo Kebbi East (Kelo) and Mayo Kebbi West (Pala) regions. Kindly note that the following table contains the list of villages where open wells are suggested. It should not be

[5] This time factor is important, as the common practice in Chad is to cultivate a plot of land for three years and then leave it fallow for regeneration for 7-12 years (a return cycle or rotation of 10-15 years). It is an expert judgement that a factor of two to three should be used for estimating the investment, that is to say, if a village has a cultivated area of 400 ha in a given year, the investment in soil water conservation may be calculated on the basis of 1000 ha of treatable area. It must be noted that the land treatment will have to be implemented over three successive years, and not in one year.

taken as a recommendation to implement in all villages listed therein. Final selection of villages should be done on considerations on selection of pilot clusters stated at the beginning.

Table 8 : Indicative size and cost (XAF) of new open wells for drinking water

S No	Cluster	Villages	Día, m	Depth, m	Lining, m	Digging cost	Lining & platform cost	Source strengthening	Total Cost
1	Banda (Moyen Chari)	Benguebe	3	30	20	3600,000	6,400,000	1,000,000	**11,000,000**
2	Bedjal (L Orientale)	Bameh, Gambiya	3	10	6	1,200,000	3,320,000	1,000,000	**5,520,000**
3	Pala (Mayo Kebbi West)	Golondou Bdu	3	30	10	3,600,000	4,200,000	1,000,000	**8,800,000**
4	Pala (Mayo Kebbi West)	Mongsou Bougrou	3	30	15	3,600,000	5,300,000	1,000,000	**9,900,000**
5	Kelo (Tandjile)	N'Guette-B	3	20	20	2,400,000	6,400,000	1,000,000	**9,800,000**
6	Kelo (Mayo Kebbi East)	Boudo M'Bongue	3	40	20	4,800,000	6,400,000	1,000,000	**12,200,000**
Total Amount						**19,200,000**	**32,020,000**	**6,000,000**	**57,220,000**

Recharge trenches: These are excavated trenches in the vicinity of a well. They are refilled in layers of boulders (lower 50% of depth), pebbles or metal (middle 30% of depth) and sand (top 15% of depth). Hardy bushes or grasses are planted in this sand as a protective layer that aids infiltration. The costing will vary according to the local availability of material. In places where boulders or stone is not available (such as villages Kongosara or Mouppon or Doubtu), brickbats (over-burnt bricks) are used. The indicative cost could be an average XAF 25000 per running metre.

Gully Plugs : can be taken up in small gullies that exist close to the existing or proposed open wells or tube wells. These are made of loose rubble. Where stone is not available (such as villages Mouppon or Doubtu or Kongosara, etc), brushwood dams can be taken up. Since the vegetation in the brushwood dams takes time to establish, some budgetary allocation. It is suggested to construct brushwood gully plugs in areas like Logon Occidental and part of Logon Orientale region, where stones are not readily available. The indicative cost is XAF 200,000.

Gabions (Core wall with Gabion): These are like gully plugs embedded in wire netting. These are recommended in small gullies where flows of high volume and velocity are expected. While innovations are possible in choice of material, it is recommended to construct it using rubble (compact stones, not fragile ones) in Chad, as the heavy flows my harm any structure made in a lighter material. The indicative cost will be around XAF 1,000,000 – 1,500,000.

Small recharge ponds: These are excavated runoff harvesting structures that should be located in the upstream of the water sources. The size and location should be determined according to the subsurface formations. Costing is difficult to indicate as the sizes of these recharge ponds would vary significantly depending upon the surface area and depth. It may vary from XAF 250,000 for a pond with a surface area of 500 sqm and 1 m deep (the shallowest depth required) in sandy-silty formations to XAF 5,000,000 for a pond of 4000 sqm and 1-3 m depth (the largest size recommended) in weathered laterite.

Farm bunds / Contour Bunds : It is a soil conservation measures, used for retaining soil and harvest water, thus controlling the soil erosion. Bunds are the tiny embankment constructed across the land slope. Contour bunding is an important measure to conserve the soil and water in arid and semi-arid areas with high infiltration rate and permeability. It is commonly used on agricultural land up to 6% slope. Tentative costing is XAF 650 per running metre for bund and about XAF 35,000 for a stone spillway.

The details of these and other interventions proposed are presented in Appendix-C.

4.4 Groundwork to implement the pilot

Cluster selection : For pilot implementation, it is recommended to take up two or three clusters of three villages each in three different typologies, so that replicable technologies can be tried and tested for scaling up in future. Ideal clusters, could be Baikoro cluster in Logone Occidental and Bedjal cluster in Logone Orientale, based on practical considerations, and Baskillim cluster in Mayo Kebbe East, due to severe water scarcity in that region. The following are the main suggestions under this section:

1) Initial survey and DPR can be done by AFPRO in consultation with local partners
2) A competent team of local people is essential to implement the project. It will not only help build local ownership, but also build capacities of local professionals, which will improve the replicability. It is suggested to engage one manager, one agronomist or an agricultural engineer, and one social worker for each cluster. In addition, two to four cluster level animators (like barefoot technologists, preferably one per village) may be promoted and engaged. Ideally, these staff may come under the programme related administrative line of control.
3) AFPRO can work as technical partner for the pilot project to provide technical and capacity building support to the field teams
4) Initial planning exercise should be treated as educative step for the local staff (and all concerned community organisations)

4.5 Livestock promotion

Here lies the big prospect for boosting Chad's economy. However, the micro-level strategies should be dependent upon the prevailing status of inter-relationship between the settled farmers and the migratory pastoralists. It is suggested to engage with the local authorities to support the livestock promotion in the socio-political domain.

On technology front, ranching or foraging systems are the most sustainable in the context of Chad. Hence, intensive livestock rearing methods are best avoided. Further, import of exotic breeds and cross-breeding of any kind should be discouraged.

4.6 Social acceptance and ownership

This is the concern raised by CTSN, who is supposed to anchor the social processes. AFPRO and its partners have several proven and long-standing examples of community leadership and ownership in natural resources management in India. An exposure visit, which is systematically planned and meticulously executed, is suggested.

4.7 Long term interventions and approach

Regenerative agriculture with farming systems approach is the future of Chad. From social perspective, community based organisations such as farmers' groups, SHGs and Village Water Management Committees should be the essential part of the development strategy. The concept of local contribution should be implemented through them. The senior team may consider the above recommendation for immediate application

Appendix A : Field visit schedule

S No	Village	Canton	Province	Visit date
1	Mouppon	N'Gandjibian	Logone Occidental	4/12/22
2	Porgu	N'Gandjibian	Logone Occidental	4/12/22
3	Koilele-I	Baikoro	Logone Occidental	5/12/22
4	Doubotou	Baikoro	Logone Occidental	5/12/22
5	Niou Djinga/ Bameh	Bedjal	Logone Oriental	6/12/22
7	Koro-I	Bedjal	Logone Oriental	6/12/22
8	Bameh/ Gambia	Bedjal	Logone Oriental	7/12/22
9	Koundou	Bedjal	Logone Oriental	7/12/22
10	Benguebe	Banda	Moyen Chari	9/12/22
11	Kongosara	Banda	Moyen Chari	9/12/22
12	Djoufouna-II	Pala	Mayo Kebbi (Pala)	12/12/22
13	Mahuin-II	Pala	Mayo Kebbi (Pala)	12/12/22
14	Mynda Midjiguil	Pala	Mayo Kebbi (Pala)	13/12/22
15	Djoda Gassa	Gounou Gaya	Mayo Kebbi (Pala)	14/12/22
16	Tagal-II	Gounou Gaya	Mayo Kebbi (Pala)	14/12/22
17	Tagal-I	Gounou Gaya	Mayo Kebbi (Pala)	14/12/22
18	Golondou Bdu	Basskilim	Mayo Kebbi (Kelo)	15/12/22
19	Gonouka	Basskilim	Mayo Kebbi (Kelo)	15/12/22
20	Gounou Jumbo	Gaskalla	Mayo Kebbi (Kelo)	15/12/22
22	NGuette-B	Dafra	Mayo Kebbi (Kelo)	16/12/22
23	NGuette-III	Dafra	Mayo Kebbi (Kelo)	16/12/22
24	Mangsou Bougrou	Djelassemgato	Tandjile	17/12/22
25	Boudo M'Bongue	Mandat	Tandjile	17/12/22

Appendix B : The Big Picture

The landlocked Sahelian country of Chad has a population of 13.5 million living on an area of 1.284 million square kilometres and is the largest country in Africa. Chad is made up of three major climatic zones, namely, Saharan, Sahelian and Sudanian. Southern part of Chad, the Sudanian region, is fertile land with good water resources availability and is the traditional food bowl of the country. It is having a favourable land to man ratio, with an average population density of 10.5. While the average cultivable land owned (or operated) by a farming family ranges between half a hectare to two hectares in different provinces, the availability of common land is substantial, say around 10 ha per family.

Chad's groundwater recharge, including for shallow aquifers accessible by pumping, are considered active. This means that extracting groundwater to smooth variability within seasonal rainfall patterns represents a high potential adaptation strategy for the country (DucPham, 2020).

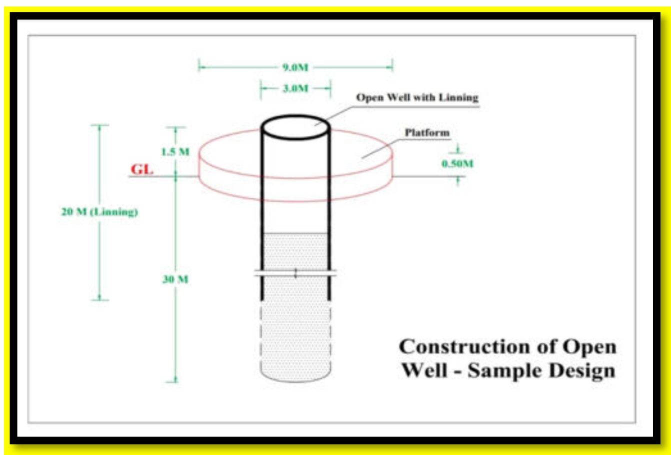
Conflict and the presence of non-state armed groups in Chad has had deep, long-lasting effects on economic security (Nagarajan). A major impact of climate change in Chad relates to food insecurity: 38.4 per cent of the population is below the international poverty line, and the country as a whole is categorized by the World Health Organization (WHO) as a "low-income food-deficit country" (WHO n.d.). It is one of the world's most food insecure countries: 40 per cent of children aged under five suffer stunting and low height connected to malnutrition (World Food Programme (WFP) n.d.); and, in 2020, an estimated 6.4 million people were in need of humanitarian assistance (OCHA 2020). Recently, metrics of food insecurity have increased, as severe insect and pest invasions as well as floods have destroyed agricultural production, leading to widespread and severe food insecurity with long-term health implications. Chad hosts more than 442,000 refugees and has over 170,000 Internally Displaced People (IDP).

Chad is plagued by situations of fragility, including: a difficult climatic environment; economic and financial vulnerability; a poor social inclusion system; and for several years, persistent hotspots of conflict along its borders. The country's one major abiding challenge is to resolve these various situations of fragility in order to efficiently combat poverty and preserve its social cohesion. In this regard, there is need to create conditions conducive to national economic transformation and natural resource development with a view to promoting the various production sectors (especially oil, mining, agroforestry and agro-industry). To attain this objective, it is crucial to: address infrastructural constraints, especially in the transport and energy sectors; ensure greater integration into the sub-regional economy; achieve significant progress in governance, especially at the sector and local level; and build an attractive environment for business development. (AfDB; 2015).

These multiple challenges will influence every development intervention operated by civil society organisations or by Corporates as a Corporate Social Responsibility. Some of the prominent implications, which should be considered while planning the development interventions, and more importantly, the performance metrics are summarised below.

Appendix C : Technical Details of the Interventions

New Open Well: The costing varied widely because of the geological formations prevailing in different areas. In case of clay (e.g. village Mouppon) or in rocky, the lining cost would be low, but it will be high in sandy formations (e.g. village N'Guette B). It is however, recommended to provide well lining in all open wells at least to the depth of reasonably firm formation, on which the lining wall could be seated. It is suggested to standardise the well diameter to 3.0 m, so that formwork for concrete casting can be fabricated accordingly. The platform cost can be reasonably standardised. In places (such as Tandjile or Moyen Chari) where Hume pipes (pre-cast concrete pipes) are available, well sinking using these rings (as lining and stabilising components) can be used. All these villages are from Mayo Kebbi East (Kelo) and Mayo Kebbi West (Pala) regions. Kindly note that the following table contains the list of villages where open wells are suggested. It should not be taken as a recommendation to implement in all villages listed therein. Final selection of villages should be done on considerations stated in Section 3 below on selection of pilot clusters.

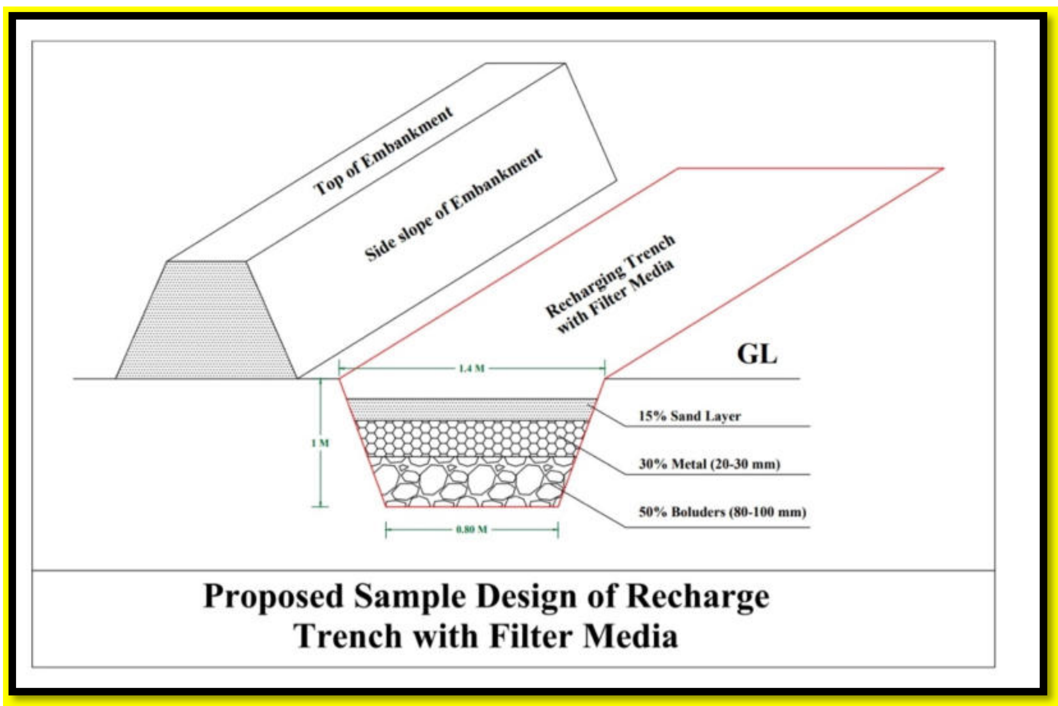


Open well with platform made of concrete lining

Open well without Platform and Stone Masonry Lining

Recharge trenches: These are excavated trenches in the vicinity of a well. They are refilled in layers of boulders (lower 50% of depth), pebbles or metal (middle 30% of depth) and sand (top 15% of depth). Hardy bushes or grasses are planted in this sand as a protective layer that aids infiltration. The costing will vary according to the local availability of material. In places where boulders or stone is not available (such as villages Kongosara or Mouppon or Doubtu), brickbats (over-burnt bricks) are used. The indicative cost could vary from Average XAF 25000 per running metre as shown in the following table.

S No	Item / Description	Rate in XAF
1	Excavation and Construction of Recharge Trench with filling of Filter media: 50% - Boulders (bottom) 30% - Metal / Pebbles (Middle) 15% - Sand (Top)	25,000 per metre



Recharge Trench with Filter Media

Gully Plugs : can be taken up in small gullies that exist close to the existing or proposed open wells or tube wells. These are made of loose rubble. Where stone is not available (such as villages Mouppon or Doubtu or Kongosara, etc), brushwood dams can be taken up. Since the vegetation in the brushwood dams takes time to establish, some budgetary allocation. It is suggested to construct brushwood gully plugs in areas like Logon Occidental and part of Logon Orientale region, where stones are not readily available.

S No	Item / Description	Rate, XAF
1	Construction of Gully Plugs (Loose Boulder Structures) in small gully	200,000
2	Planting of Brushwood in small gullies	

Gabions (Core wall with Gabion): These are like gully plugs embedded in wire netting. These are recommended in small gullies where flows of high volume and velocity are expected. While innovations are possible in choice of material, it is recommended to construct it using rubble (compact stones, not fragile ones) in Chad, as the heavy flows my harm any structure made in a lighter material. The indicative cost ranges from XAF 1,000,000 – 1,500,000.

Gabion are wire mesh containers, generally of rectangular shape, filled with stones. Gabion can be used for gully plugging in locations where failure of masonry structures due to settlement / subsidence could be a problem. The wire mesh holds the stone together and keeps them in place when the structure is subjected to pressure. A gabion is rigid bulky mass, not easily shifted by water, and yet, a row of linked gabions fairly rigid and responds well to terrain. The inherent flexibility of the gabions ability to bend without breaking – seems to be the primary reason for their success. The other advantages are:

1. These structures are flexible to soil moment.
2. They are permeable to water but retain soil.
3. The materials are reusable, if structure fails.
4. They are suitable when firm foundation is not available.
5. Height of the structure can be raised as and when required. Variable size stones can be used for constructions.

S No	Item / Description	Rate in XAF
1	Construction of Core wall with Gabion using Dry stones and GI Chain-link net with proper fixing around dry stones.	1,500,000

Gabion with Core Wall

Small recharge ponds: These are excavated runoff harvesting structures that should be located in the upstream of the water sources. The size and location should be determined according to the subsurface formations. Costing is difficult to indicate as the sizes of these recharge ponds would vary significantly depending upon the surface area and depth. It may vary as much as from XAF 250,000 for a pond with a surface area of 500 sqm and 1 m deep (the shallowest depth required) in sandy-silty formations to XAF 5,000,000 for a pond of 4,000 sq m and 1-3 m depth (the largest size recommended) in weathered laterite as shown in the following table.

S No	Item / Description	Pond Size, sqm	Depth, m	Amount, XAF
1	Excavation of Small recharge ponds on upstream side of the water shed Area	2,000	1	1,000,000
2		5,000	2	2,500,000
3		10,000	2.5	5,000,000
4		20,000	3	10,000,000
5		50,000	3	25,000,000

Farm bunds and Contour Bunds

The bunds passing through the points of equal elevation (i.e., on contour) of the land are known as contour bunding. It is an engineering soil conservation measures, used for retaining water, creating obstruction, and thus controlling the soil erosion/soil loss. Bunds are the embankment like structure, constructed across the land slope. Contour bunding is an important measure to conserve the soil and water in arid and semi-arid areas with high infiltration rate and permeability. It is commonly used on agricultural land up to 6% slope. Important objectives of Bunding area as following

1. To reduce the length of slope, which in turn to reduce the soil erosion.
2. Impound the water at upstream portion, and permits more water to get recharge into the soils that is utilized for crop cultivation.

<u>Step By Step Process for Bunding</u>

1. **Identification of Site**: If the slope is more than 6% do not go for contour bunds. This is because on steep slopes, the velocity of run-off may break the embankment.

If the slope is up to than 6% make contour/farm bunds. Avoid the big roots of trees, rocky area, and steep slope areas while selection of site. The Contour Bunding plot must be used for agriculture purposes.

2. **Calculating Slope**: The slope of land can be calculated using Abney level or Hydro-marker or Google maps very easily.
3. **Calculating Contour Intervals / Distance between two consecutive bunds using following formula**

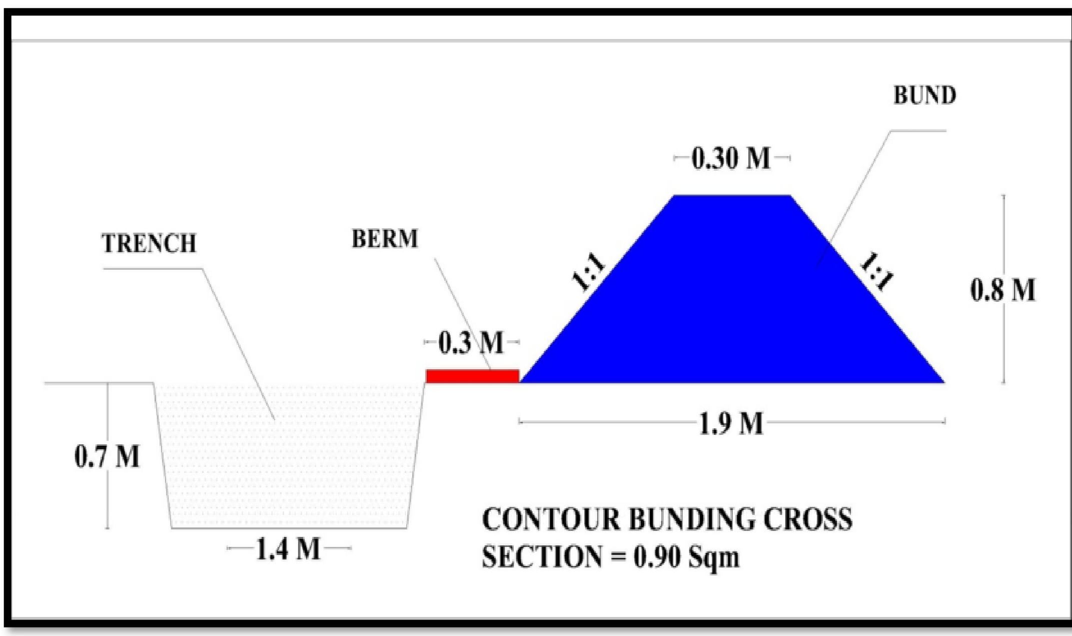
The phreatic zone of the upper bund should coincide the saturation zone of the immediate lower bund. The bund should be able to check the runoff at the point where flow attains an erosive velocity. The bund should satisfy all the requirements of agriculture operation.

Vertical distance between two consecutive bunds

VI = 0.3 x [S/3] + 2 where S = degree of slope in %

Horizontal distance between two consecutive bunds **(HI)**

HI = [VI/S] x 100



Design of Farm Bund

Stone Spillway Costings

S No	Item / Description	Unit	Amount
1	Excavation of Farm / Contour Bund by Manually	Cum	800
2	Construction of Stone Spillway / Outlet. Size- Length – 5.0m, Width – 2.0m, Height – 0.30 M	Nos	35,000

Farm Bund / Contour Bund

Gully Control Structures

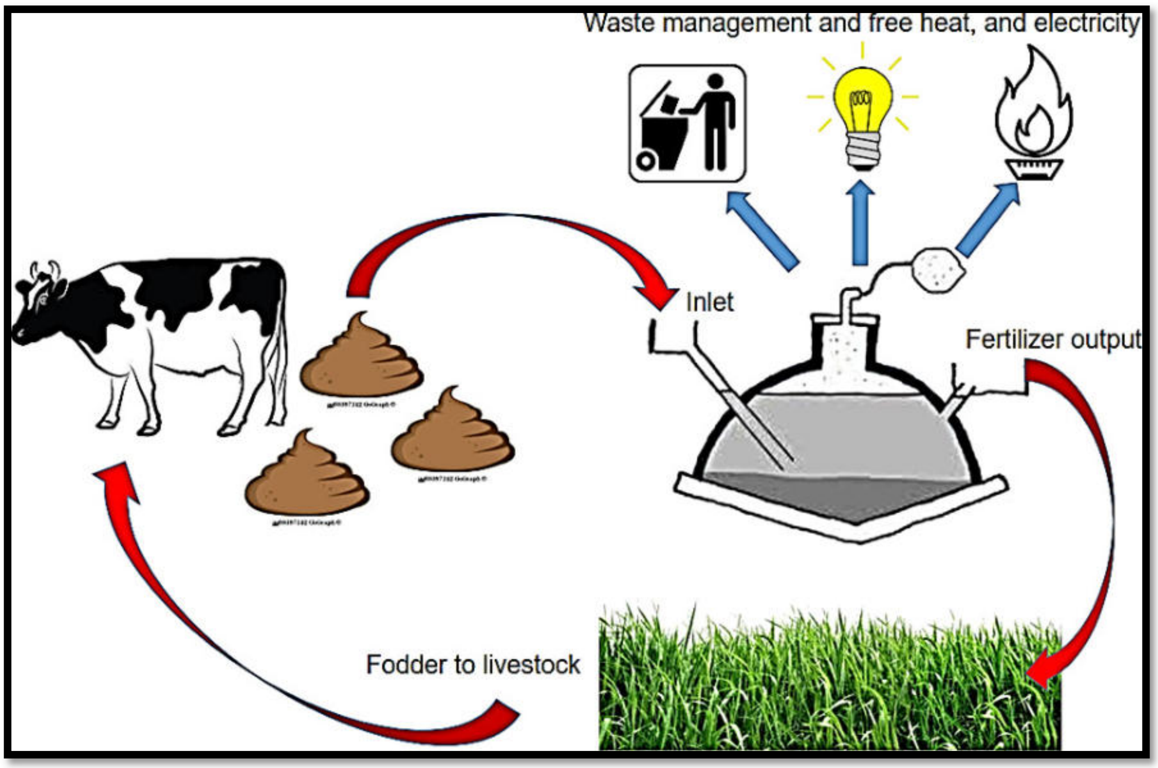
Loose Boulder Structure

S No	Item / Description	Qty	Unit	Amount, XAF
1	Construction with using dry Stone Length 10m, Bottom width 2.5m, top width 0.6 m, Height 1.2 m, Foundation depth 0.45m	1	Nos	450000

Biogas Plant

A biogas plant as an investment is in competition with a bicycle or moped, a radio set or diesel pump, a buffalo or an extension to the farmhouse. The economic benefit of a biogas plant is greater than that of most competing investments. However, the plant must also be worthwhile as a topic for the "chat in the market place".

A good biogas plant is appropriate. Appropriate to the needs of its owner and his abilities and capacity. It is appropriate to the necessities of the future.



The diagram above shows a floating-drum plant with internal gas outlet. The gas pipe is securely mounted on the wall and leads directly to the kitchen. Ideally, as in this example, the digester should be located directly beside the animal shelter, which should have a paved floor. Urine and dung can be swept into the inlet pipe with little effort. The plant has a sunny location, and the vegetable garden is situated directly adjacent to the digested slurry store. The well is an adequate distance away from the biogas plant.

Appendix- D Bibliography

AfDB (2015); Republic of Chad - Country Strategy Paper 2015-2020; Abidjan, Ivory Coast, African Development Bank, REGIONAL DEPARTMENT CENTRE (ORCE); September 2015; p. 18

Collelo, Thomas (1990); Chad: A Country Study - Area handbook of Chad; Washington DC. Federal Research Division. Library of Congress; 1990 (Second Edition); p. 254

Dedzo, Merlin Gountié, Désiré Tsozué, Mumbfu Ernestine Mimba, Fulbert Teddy, Romio Mofor Nembungwe and Sylvie Linida (2017); Importance of Rocks and Their Weathering Products on Groundwater Quality in Central-East Cameroon; J. *Hydrology 2017, 4, 23; doi:10.3390/ hydrology 4020023*; p. 18

Enriquez, Bryanna Lanai (undated); Chad: Environmental Issues; An article; https://www.ics.uci.edu/~wmt/courses/ICS5_W13/Chad.html (Accessed December 2022)

GIZ, 2016; Climate risk profile – Chad; A technical note on was commissioned and is conducted on behalf of the German Federal Ministry for Economic Cooperation and Development (BMZ) in close cooperation with the Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) as the implementing partner.

GIZ, 2021; *Climate Risk Profile: Chad,* 2021. Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ). https://agrica.de/wp-content/uploads/2021/01/GIZ_Climate-risk-profile-Chad_EN_final.pdf

ICRC (2021); Country Level Climate Fact Sheet – Chad; Geneva, Switzerland, International Committee of Red Cross – Climate Centre; 2021; p.9

IDH (2021); Cotontchad SN – Service Delivery Models Case Report; Utrecht, The Netherlands, IDH Trade; 20021; p. 60

IMF (2007); Chad: Selected Issues and Statistical Appendix; IMF Country Report No. 07/28; Washington DC, International Monetary Fund; January 2007; p. 146

IMF (2007); Chad: Poverty Reduction Strategy Paper - 2005; IMF Country Report No. 07/282; Washington DC, International Monetary Fund; August 2007; p. 82

Mahamat, Malik (2022); Tchad : un cheptel de plus de 137 millions de têtes de bétail en 2021; An article on https://www.alwihdainfo.com; Online, 5 January 2022. Available at https://www.alwihdainfo.com/Tchad-un-cheptel-de-plus-de-137-millions-de-tetes-de-betail-en-2021_a110227.html?print=1; Accessed on Feb 8, 2023

McSweeney C, M. New and G. Lizcano (Undated); UNDP Climate Change Country Profile Chad; Oxford, Oxford University
Downloaded from http://country-profiles.geog.ox.ac.uk in Nov 2022

Nkiaka, E, N R Nawaz and J C Lovett (2017); Analysis of rainfall variability in the Logone catchment, Lake Chad basin. *J. International Journal of Climatology, 37 (9)*; pp. 3553-3564. ISSN 0899-8418. Available at https://doi.org/10.1002/joc.4936

Pattnayak, Kanhu Charan, Ahmat Younous Abdel-Lathif, K. V. Rathakrishnan, Muskan Singh, Renuka Dash, and Pyarimohan Maharana (2019); Changing Climate Over Chad: Is the Rainfall Over the Major Cities Recovering? ; RESEARCH ARTICLE; j. Earth and Space Science 10.1029/ 2019EA000619; 2019; pp. 1149-1160

Pham-Duc, Binh Florence Sylvestre, Fabrice Papa, Frédéric Frappart, Camille Bouchez and Jean-francois Crétaux (2020); The Lake Chad Hydrology Under Current Climate Change; *J. Scientific Reports (2020) 10:5498*

Ramadane, Abakar (Undated); Water and sanitation issues Sanitation in Chad; a Powerpoint presentation; N'Djamena, Ministry of Water and Sanitation, Government of Tchad; undated; p. 26

SAGIR Consultancy (2021); Agri Job Booster Project - Realization of a Water Resources Study in the provinces of Logone Occidental and Tandjilé, Chad; N'Djamena, SAGIR Consultancy; May 2021; p. 80

UNEP (2004); Fortnam, M.P. and Oguntola, J.A. (eds), Lake Chad Basin, GIWA Regional assessment 43, University of Kalmar, Kalmar, Sweden; 2004; p.129

Unicef (2022); Tchad : des affrontements intercommunautaires ont fait plus de 500 morts depuis le début de l'année; An online article; 16 November 2022. Available at https://news.un.org/fr/story/2022/11/1129902; Accessed Feb 8, 2023

The World Bank (2020); A Groundwater Model for the Lake Chad Basin - Integrating data and understanding of water resources at the basin scale; Washington DC, The World Bank; January 2020; p. 184