The Federal Democratic Republic of Ethiopia Regional State of Tigray, Bureau of Water Resource Development

Ruba Chemiet Pump Irrigation Project Agronomy Final Feasibility Report and Agricultural development

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April 2018

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1. INTRODUCTION

1.1. Background

Agriculture in Tigray Region like in other parts of the country is the main sector on which 85 % of the population is dependent (MoA, 2011). This sector is largely rainfed and characterized by mixed farming in which animal husbandry is closely integrated with crop husbandry. The main actors of the agricultural sector are small-scale resource poor farmers who produce crops with yield far below their agronomic potential. Rainfed agriculture is very vulnerable system which is adversely affected by weather and climate change. Let alone climate change, even considering optimal scenario, rainfed agriculture would not be able to provide all the food needed by the fast growing population. Hence this system should be changed by introducing irrigation agriculture.

Irrigation development can stabilize agricultural production and hence stable economy; it intensifies agricultural production; it contributes to poverty alleviation by targeting resource poor farmers for irrigation development to enhance farm income; it increases agricultural production and enhance food security; it extends cropping opportunities and provide a wide variety of crops in wet and dry seasons; it provides greater opportunity to transfer from subsistence to commercial farming and hence improve family income and household food security; it provides greater opportunity to grow a wide range of crops, such as horticultural crops, which in turn can improve family diet and nutrition and increase income so that extra food can be bought; and it increases production from a piece of land many-folds with farmers extending their growing season beyond the wet season.

Hence, in the growth and transformation plan of the region, the development of irrigation through exhaustive use of the available water resources is outlined as key priority. Tigray Region has a vast water resource potential that can be used for different scale of irrigation projects. As part of the irrigation development expansion plan, the regional government is conducting several irrigation projects in different parts of the region. Accordingly, Chemiet pump irrigation is studied and designed by Tigray Water Works Study, Design and Supervision Enterprise and this agronomy feasibility report is an integral part of that study.

1.2. Objective

The main objectives of the study were

- To assess the main constraints and potentials of crop production in the area
- To assess the potentials and constraints of the area for irrigated agriculture.
- To assess and evaluate the existing cropping pattern and propose new interventions based on the resource base (climate, soil and water) of the project
- To propose suitable crops, efficient water management and improved practices to the area so as to increase crop production.

2. METHDOLOGY

To fulfill the stated objectives of the study, the following methods were used:

- Reviewing previous studies and relevant literatures
- Baseline data collection
    - Field visits
    - Discussion with group of farmers, DAs, woreda and other concerned bodies of the project area,
    - Secondary data collection from the tabias under consideration, woreda office of agriculture and rural development, Abergelle agricultural research center.
    - Stakeholder consultation
- ETo of the project area was calculated based on FAO Penman-Monteith method (FAO-56)
- Crop water requirement was computed through widely accepted method using CROPWAT version 8. Computer software.

3. THE STUDY AREA

3.1. Location

Chemiet pump irrigation scheme is found in central zone of Tigray, Werei leke woreda, the site is accessible by asphalt and all weathered roads. That is the longest road for accessibility to the site is via Mekelle - Abyi-Adi - Edaga-Arbi asphalt (150km) and all weathered (15km) main road. The distance from Edaga-Arbi to the project sites of Chemiet pump irrigation scheme is 33km, geographically the proposed area is located in the coordinate of 1548921 N latitude and 526737E longitudes at elevation of 1718.95 meter above sea level.

3.2. Climate

Climate is the most important dominating factor influencing the suitability of a crop to a particular area. The yield potential of the crop mainly depends on climate. The most important climatic factors that influence growth, development and yield of crops are rainfall temperature and solar radiation.

3.2.1 Rainfall

The rainfall data for Chemiet pump irrigation scheme is taken from National Meteorological Station Agency (NMSA) Edaga-Arbi town meteorological station was considered. As the data shows, the study area has unimodal rainfall pattern that extends from June to September and the peak occurs on August.

The mean annual rainfall of the study area is about 776.25 mm. This amount of rainfall is sufficient for most of the rainfed crops growing in the area. Hence, the main limitation associated with the rainfall of the study area is not the amount but the distribution. The rainfall of the area is not uniformly distributed within the growing seasons. 64.43 % of the rain falls during July up to August. Additionally, lately, there is unusual trend that the rainfall starts late and ceases early. So, the rainfed crops growing in the area requires supplementary irrigation especially at the end of the growing season.

Table 1: Monthly Rainfall of Edaga-Arbi (mm)

Station:-	Eda-Arbi			Region: Tigray			Element: Rainfall						
Year	**Date**	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**
2005	1	0	0	0	0	0	0	83.6	188.2	73.5	0	0	0
2006	2	0	0	26	60.7	63.4	90.3	162	301.6	78.4	7.6	0	4.5
2007	3	0	0	0	24.6	35.7	183.2	285	529.5	152.1	0	1.6	0
2008	4	12	0	0	5.5	20.9	79.7	188.9	177.1	33	7.5	0	0
2009	5	0	0	71.1	0	20.7	1.5	300	306.2	13.6	8.5	2.5	0
2010	6	9.5	0	72.9	37.2	15.9	102.2	67.2	298.6	42.9	3.5	0	8.4
2011	7	4.6	0	10.2	27.5	50	11	130.7	239.7	197.3	0	0	0
2012	8	0	0	10	11.5	26	95	180.9	239	82.2	15.5	0	0
2013	9	0	0	0	33.6	40.8	160	136.1	220.7	0	12	53.5	0
2014	10	0	0	22.8	6.8	46.4	71.9	255.9	257.5	115.1	37	23	0
2015	11	0	0	21.8	0	42.1	37.8	157.7	286.6	201.7	6.6	14	25.2
2016	12	0	0	25.4	61.6	72.8	91.5	336.5	317.8	127.6	23.5	0	0
2017	13	0	0	18.4	0	164.7	83.1	368.9	485.7	37.5	0	0	0
Average		2.01	0.00	21.43	20.69	46.11	77.48	204.11	296.02	88.84	9.36	7.28	2.93

Length of growing period is determined by agro-climatic parameters in comparison with precipitation distribution. **The effectiveness of early rains increases considerably once Precipitation is equal to, or exceeds, half ET**. The growing period continues beyond the rainy season, when crops often mature on moisture reserves stored in the soil profile. Soil moisture storage must therefore be considered in defining the length of the growing period. Calculation of the monthly Potential Evapo-transpiration of the area using Pen-Monteith method or it can be available from Class I Meteorology station; or New-LocClim V1-10 software. However it's advisable to calculate the ETo with site specific climate data (SSIP technical manual for irrigation agronomy and agricultural development MOA 2009).

Table 2 Length of growing period (LGP) the study area

No	Month	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec
1	ETo, mm	111.6	127.8	167.1	204.1	197.1	174.9	151.8	156.3	150.6	137.4	105.3	98.1
2	ETo*0.5	55.8	63.9	83.55	102.05	98.55	87.45	75.9	78.15	75.3	68.7	52.65	49.05
3	Rainfall, mm	2	0	21.4	20.7	46.1	77.5	204.1	296	88.8	9.4	7.3	2.9
4	(3-2)	-53.8	-63.9	-62.15	-81.35	-52.45	-9.95	128.2	217.85	13.5	-59.3	-45.35	-46.15
5	LGP, days							31	31	30			
6	LGP Period	92 Days											

3.2.2 Temperature

Unlike the rainfall, the temperature data for the study area is estimated using New LocClim: Local climate estimator (computer software). Accordingly, the mean minimum temperature and mean maximum temperature of the study area are about 15.3 o C and 31.5 ^{o} C respectively. The lowest mean minimum temperature of the study area is that of January (13.3 ^{o} C) and the highest mean maximum temperature of the area occurs on April (35. 3 ^{o} C). Hence, the temperature is optimum for most crops growing in the study area.

Table 3 Temperature data

Month	Min Temp °C	Max Temp °C	Mean Temp °C
January	13.3	30.3	21.67
February	14.1	31.3	22.67
March	14.3	33.9	23.6
April	15.1	35.3	24.6
May	15.8	35.0	25.18
June	15.5	33.1	23.99
July	16.0	28.9	22.03
August	16.3	27.6	21.56
September	15.6	28.6	22.26
October	15.9	31.1	23.57
November	16.6	31.4	24.21
December	15.5	31.3	23.24

3.3. Agro-ecology

The agro-ecology of the study area is identified based on the modern classification of major agro-ecological zone of Ethiopia. This approach is followed scientific classification method. These efforts have been made were used as building block for the development of the present AEZ. The agro-ecology zone of Ethiopia (AEZE) have been modified, finalized and mapped by the natural resource management and regulatory department of ministry of agriculture (MOA 2005) to delineate homogenous resource units in terms of biophysical conditions, including climate, terrain, soil, vegetation and fauna. As consequence the previous 18 major agro-ecological zones of the country have been increased to 32 MAEZ. This refined MAEZ is used as best development tool to delineate areas requiring resource development and conservation program for different propose, MOARD 2005 (Appendix 9, Table 5).

Based on the modified agro-ecological classification using thermal zone and moisture regime (length of growing days) on the other hand, the study area falls into SM_2 agro-ecological zone. The average annual temperature of the study area is about 23 ^{0} C, according to reclassified thermal zone it falls on Thermal zone II (warm). Whereas the length of growing days of the study area is about 92 days considered as sub-moist (Appendix 9, Table 1).

3.4. Topography

The topographic features of the study area vary from flatter to steeper slopes due to the presence of depressions and ridges. The dominant slope of this command area is gentle slope (0-5 %). It is aforementioned that the altitude of the command area is around 1718.95 m above sea level. For detail description of the topography of the command area refer to the independent soil study report of the scheme.

3.5. Soils

The command area of Chemiet irrigation project is situated to the right side of Chemiet River. According to survey of soil expert the dominant soil types of the irrigation scheme is Cambisols 50.5 %, Leptosols 23 %, and Regosols 26.5 %. For detail, refer to independent soil study report of the scheme.

Texture influences the movement and availability of soil moisture, aeration, nutrient availability, and the resistance of the soil to root penetration. Soil texture also influences how best the soils are managed. The surface soil horizons had the textural variation across the sites of each profile area.

Accordingly, the soil textured of Chemiet irrigation project in the depth of 1 cm - 35 cm varies from loam to sandy loam, from depth of 35cm-60 cm varies sandy loam – to clay loam and a soil with the depth of 60 cm-145cm varies from sandy loam to clay loam.

Figure 1 Command area of Chemiet irrigation scheme

3.4.1. Existing soil potentials and limitations

3.4.1.1. Fertility

- The levels of exchangeable sodium are generally low. These characteristics are Favorable for crop production.
- In general, soils are rated as neutral in their PH. Electrical conductivity of the soils at the surface as well as the subsoil horizons was below unity and in general, it cannot affect the growth of most agricultural crops and the soils were salt free.
- Among exchangeable bases (Ca, Mg, K and Na), the exchange complex of the soils of the present study was predominantly occupied by divalent basic cathion (exchangeable Ca followed by exchangeable Mg). By and large, the magnitudes of exchangeable Ca

and Mg were rated as medium to high. The exchangeable K showed insignificant variation between profiles and horizons within the profiles as well. However, the rate of exchangeable K was rated as medium. (See the detail in the independent soil report and laboratory result). According to this result, it can be concluded that the fertility status of the project area is low to medium. In fact, soil fertility problem can be corrected by applying integrated soil fertility management practices.

3.4.1.2.Erosion

The total rainfall amount around the study area is about 776.25 mm. More than 80.85 % of this rain falls on June to September. That is to say that the rain of the study area falls within a short period of time with high intensity. So, the rainfall of the study area is highly erosive. Therefore, proper soil and water conservation practices should be applied at Chemiet watershed and the command area.

3.4.1.3.Salinity

Saline soils are characterized by the presence of excess salts on the soil surface and in the root zone. These soils occur due to saline parent material or irrigation with saline water. The soils and river water of the study area are non-saline. According the report of environmental team the salinity content of the soil is 0.21 ds/m. Based on (FAO 1989) the salinity content which is less than 0.25 ds/m is excellent, 0.75 ds/m good, 0.76-2 ds/m permissible, 2-3 ds/m doubtful, greater than 3 ds/m unsuitable. Even so, proper management of the irrigation water and provision of drainage system is highly crucial so as to avoid gradual buildup of salts.

3.5. Existing Agriculture

3.6. Farming system

The existing farming system of the study area is rainfed crop production mixed with animal husbandry. Although crop production is the main component of the farming system and meets most of the subsistence requirements of the farmers, animal husbandry also plays a significant role in the livelihood of the farmers by serving as the source of draught power, additional protein source, and additional cash income.

3.7. Landholding

The landholding size in these tabias range between 0.75 and 1 ha per households. These figures show that the landholding size in the study area is relatively small. Unfortunately, there are also some farmers who possess no farmland.

3.8. Crop Production and yield

The dominant crops growing in the study area are annual crops and they are grown under rainfed condition. These are mainly teff, maize and sorghum. Other minor crops are also growing in the study area; includes wheat, barley, lentil and chickpea. However, these crops cover very limited area. The existing cropping pattern of the project area is mainly based on the feeding habits of the farmers.

In the study area, crops are also growing under irrigation. These crops include vegetables (pepper) and perennial crops (mango, papaya, citrus and banana). The data obtained from the study area Adi-hedem tabia indicate that in the year 2010 E.C about 36.24 ha in have developed under irrigation. This area is developing once a year. The irrigation season is December to April. The source of irrigation water could be pumping from Chemiet River and mini-dam.

Figure 2 Figure Irrigation practice of the study area

The yield of the crops growing in the study area is relatively low. This is attributed to the different production constraints prevalent in the area. One of major production limiting factors in the study area is uneven distribution of rainfall. This distribution problem is associated with late onset and early cessation of rainfall. This phenomenon is causing moisture deficiency problem in the area. Additionally, intensive rainfall within short period of time associated with the soil fertility problem in the area. The study area has been under cultivation for several years. Nevertheless, the soil fertility management practice of the farmers is not up to the required level. Hence, nutrients of the soil are being depleted every year.

Weeds, pests and diseases are also other major production constraints in the study area. These agents are also causing significant yield loss in the area. These major production constraints coupled with other production constraints like backward farming practice therefore have caused the yield of the area to be low.

Table 4 Existing Crops and their Yield in the study area

crops	2008 EC		2009 EC		2010 EC	
	Area (Ha)	Yield Qt/ha	Area (Ha)	Yield Qt/ha	Area (Ha)	Yield Qt/ha
Teff	112	6	125	6	125	5
wheat	10	5	8	18	8	18
maize	267	22	287	35	287	28
Barley	8	7	6	7	6	7
Sorghum	349	18	379	40	379	20
lentil	4	3	4	3	3	3
Chickpea	2	4	4	3	1.5	3.5
pepper	2.5	4	2	3	2	2
Bannana					1.6	69.437
papaya		-			4.14	69.4
citrus	8.34	34.6			12	34
Mango	7.69	39			16	9.75
coffee					0.5	69.437

Source: agriculture and rural development office of the respective tabias (2017)

3.8.1. Agricultural Practices

3.8.1.1. Land Preparation

In the study area, land preparation time for rainfed crops depends on the onset of rainfall. The farmers' of the study area carryout clearing works on the months of April and May. Few farmers have started plowing their farmlands after their previous crops are harvested using draft animal drawn local plow known as mahresha. This process is carried out starting from November up to December. For the irrigated crops growing in the study area on the other hand, land preparation is carried out between September and November.

Land preparation (plowing) frequency varies from crop to crop. Generally, the land preparation frequency for the major crops growing in the study area is 1-2 times. Unlike the rainfed crops, the plowing frequency for the irrigated crops is 3 times.

3.8.2. Seed selection and Sowing

For centuries, the study area farmers have used their own seed saved from the previous crop, or informally obtained it from neighboring farmers, usually in exchange for grain or any other commodity.

Farmers select the seeds based on their own criteria and preferences. Likewise, most of the farmers of the study area are using local seeds that are the result of this process. Though well adapted to the local agro-ecological situations, and therefore resistant to factors like disease, insect attack or even moisture stress, “land races” are generally low yielding when compared to modern high yielding varieties bred. Some farmers are also using improved seed of teff, wheat and maize. Moreover, the seeds of most of the vegetables growing in the study area are improved.

Broad casting is mainly practiced for most rain fed crops and row planting of maize is also introduced to the study area. However, the area covered by this method is negligible. Unlike the rainfed crops, most of the crops growing under irrigation (vegetables) are planted in rows.

The sowing time of the crops growing in the study area depends on the onset of rainfall. They starts on June however, the sowing time of these crops may be delayed up to

July. The sowing (planting) date of the crops growing under irrigation on the other hand, is December.

3.8.3. Harvesting and threshing

The crops are harvested when they are dry. Separate harvesting and threshing is the method most widely used by the small scale farmers. The crop harvesting equipment is sickle. Harvesting is carried out starting from the end of September to December.

3.8.4. Storage

Storage is practiced in a traditional storage structures such as material made from stone, mad and cow dung however some farmers in the study area also store the yield of their crops in sacks. Theses sacks are kept inside the living rooms of the farmers.

3.9. Soil Fertility Management

3.9.1. Fallowing

Fallowing is a traditional soil fertility management that is keeping the farm land uncultivated for a year or more to rejuvenate/ heal itself. By doing this farmers with large farm size let the farm to grow grasses and broad leaved plants in the rainy season and give time the leafs and stubbles of weeds decayed on the land by cultivating them at their juvenile stage in turn the land heals itself due to the grown organic matter added to the soil.

If the farmlands are cultivated repeatedly without any soil fertility management practice, the infestation of striga increases and hence causes serious yield loss. So, the farmers leave their farmland uncultivated for one year. By doing so they try to increase the fertility of their farmlands and simultaneously try to protect the infestation of striga. Nevertheless, this practice is decreasing from time to time and farmers are choosing to other soil fertility management practices. This is mainly due to decreasing size of farmlands attributed to population growth.

3.9.2. Farmyard Manure

Applying farmyard manure enriches the fertility of the soil. It adds into the soil perhaps all nutrients that are essential for plant growth. Additionally, it improves structure and water holding capacity of the soil. In the study area, farmers mainly apply farmyard manure on maize (for it is grown near their homesteads) and on irrigated crops. The reason why they do not apply farmyard manure for all major crops growing in the area is that huge amount of farmyard manure is needed to add the required amount of nutrients to the soil. Hence, such amount of farmyard manure is too bulky to transport to the farmlands.

In fact, the farmers are being persuaded to apply farmyard manure on the rainfed crops. So, last year significant numbers of farmers have applied farmyard manure on sorghum, teff and pepper. The problem, however, is that the farmers do not apply the recommended amount of farmyard manure. Moreover, the farmyard manure is not properly decomposed.

3.9.3. Crop residue management

Very few farmers used crop residue management practiced in order to maintain soil fertility to their farmlands. However, majority of the farmers of the study area released their cattle onto the farmlands to graze on the crop aftermath. So, the crop residues are not plowed under to enrich the fertility of the soil.

3.9.4. Crop Rotation

Crop rotation is one of the traditional soil fertility management practice use in the project area. The usual crop rotation use in the project area is (Teff – Sorghum/Maize - Teff). Legume crops (chickpea) are also included in the cropping pattern However; this method of soil fertility is management is not in use universally in all farm types. That is farms found near the house yard are cropped every year by maize only (no rotation is made) because the farmers in the project area believe that farms found close to their homes are fertile land so no need of rotating the crop grown on them. This is because the smaller amounts of manure collected in the house are applied to these farms only.

3.9.5. Compost

Compost is one of the soil nutrient management practices used in the study area; however the experience of using compost is low. Though, very low dose of compost application is used in the area, the trend of using this soil nutrient management practices are increasing from year to year. So, a lot of work will be needed to convince the farmers so as to prepare and apply compost.

3.9.6. Chemical Fertilizers

The most common practice that are using for soil nutrient management is application of inorganic fertilizer. These farmers have appreciated the benefit that can accrue from applying chemical fertilizers. Nevertheless, increasing price of the chemical fertilizers is becoming a challenge to many of the farmers. The rainfall variability is also another risk for the farmers to apply chemical fertilizers.

3.10. Crop Protection

3.10.1. Weeds

According to the interviewed farmers and development agents, several broad and grass family weeds are growing in the study area. Of these weeds the parasitic weeds striga is causing serious damage. Actually, the damage caused by the other weeds is also significant.

The main weed control practices in the study area are hand-weeding (for both the rainfed and irrigated crops) and using herbicide (2, 4-D) on sorghum, teff and wheat. The weeding frequency for the rainfed crops growing in the study area is mostly 1-2 times. Unlike the rainfed crops, the vegetables growing in the study area are weeded more frequently that is 3-4 times.

3.10.2. Insect pests

As to the farmers and DAS of the project area the prevailing insect pests are shoot fly, white fly, Aphid stalk borer, grass hopper, cut worm, Leaf miner**,** weevil and termites are common bio-problematic project area. However, American army worm had happened for the last time 2010 E.C. at damaging stage. The chemicals applied in the study area to control the insect pests are carate, diazinone, fentrotine and malathione**.**

Figure 3 White fly attack in in citrus trees

3.10.3. Diseases

Furthermore, the data obtained from the tabia revealed that, Crop diseases also a common problem of project area. Major diseases prevalent in the study area are smut (on sorghum), root rot (on pepper), early and late blight (on pepper) and anthracnose (on sorghum, mango).

To prevent smut farmers treat seeds of sorghum with cattle urine. They also rogue out diseased plants and drain excess water to prevent root rot. They also use chemicals like mancozeb and ridomil to prevent diseases on irrigated crops.

3.10.4. Vertebrate pests

Vertebrate pests are also very problematic in the study area. Those pests prevalent in the study area are rats (attacks all crops at field and store) and birds (attacks sorghum).

4. Agricultural Support Services

5.1. Extension Service

In the tabiya of the command area there are extension agents giving technical assistance in crop production, animal husbandry, soil and water conservation and others. So, the farmers of the study are receiving extension service from tabia extension center. Moreover, the extension agents are giving training and demonstration to the farmers in the farmers training center (FTC) on improved seeds, fertilizers, crop protection, soil fertility management, moisture harvesting and other improved technologies.

In spite of the presence of technical support, the extension service is low and ineffective with a gap in number of Development Agents. The number of well-trained grass-root level staff needs to be increased for guiding the farmers.

5.2. Credit Service

The delivery of microfinance has been considered as one of the policy instruments of the government and non-government organizations in the fight against rural and urban poverty. In this case microcredit is introduced in every rural and urban areas of the region. Moreover, saving and credit cooperatives also emerging as alternative for credit access for the rural areas. The access of credit within their cooperatives credit and saving institution and Dedebit microfinance are main sources. Credit and saving institution and Dedebit microfinance give credit to individual farmers directly on cash.

The maximum amount of loan provided by Credit and saving institution is 5000 birr with rate interest of 12% for off farm and farm activities (for agricultural inputs and for livestock rearing), moreover Dedebit microfinance provided maximum amount of credit is also limited, that is 15000 with rate interest of 15%. The main problems stated by the beneficiaries are high rate, limited amount of credit and not timely accessed

5.3. Cooperatives

Multipurpose cooperative is established in the tabia. This cooperative is supplying agricultural inputs to the beneficiary like fertilizer, improved seed and the like.

5.4. Market

It has been found that teff, maize and sorghum are the major crops grown by farmers. Teff, vegetables (pepper) and fruits (mango, orange and papaya) are the predominant produce primarily destined to the domestic market.

The findings of the study also indicate that lack of market infrastructure (The lack of all-weather road network within the tabiya and well developed transport system) is the major bottleneck for the movement of agricultural produces particularly in Edaga-Arbi area. The irrigation project area is isolated from Edaga-Arbi to Nebelet main road. The beneficiaries have to travel 5-11km from different corner of the tabiya to reach the road connection of Adi-hedem tabiya to Edaga-Arbi- Nebelet main road.

Most of the produce of farmers is marketed soon after harvest because of urgent cash needs for the repayment of input credit and also to fulfill social obligation and meet personal and household members cash needs.

Since many farmers do not have access to market information, the producers are usually the loser particularly in the event of price rise since the information will reach the farmer very late. Therefore, the project should identify agricultural produces in which it could have a comparative advantage to be more competitive in the zonal and regional market. Improve agricultural-market information system of collection and dissemination and undertaking the market assessment and network establishment with close technical supports of the woreda, zonal and regional agricultural offices or other relevant institution by establishing permanent institutional linkage through farmers' association or irrigation water users' association.

5.5. Agricultural research

Axum research center is under taking adaptation trial and seed multiplication of new varieties in the study area. These works are being carried on farmers' fields and FTC of the study area. To facilitate these works, this research center is organizing farmers' research groups (FRG) in the study area. Hence, the research works being carried in and around the study area will be great input for the envisaged irrigation agriculture.

6. Constraints to and potentials for irrigation development

6.1. Constraints

The crop production and livestock production technologies are still very traditional though mixed farming system is common in the area. In crop production there is very limited introduction of modern inputs like chemical, fertilizers, improved crop varieties, quality seed and agro-chemicals. Moreover, different natural hazards such as recurrent drought condition, land degradation due to erosion, flood problem etc. have resulted in poor yield in the project command area.

6.2. Potential

Chemiet project command, despite the number of agricultural production constraints, has fairly high potential that can be exploited through comprehensive integrated agricultural development program, sound and applicable rural credit system, well developed infrastructure etc. The existing farming systems being practiced in the project command are very traditional and lead to low level of output. Through proper utilization of resources, particularly the water resources and by solving the other major agricultural constraints mentioned above, the current low level of production can be enhanced. The following major potential areas requiring intervention are to be considered for exploiting the yield potential.

There is a good scope of development of agriculture under irrigated production system by exploiting the existing irrigation potential and utilizing the **water available from Chemiet River** in or around command area. There is already indication of enhanced productivity per unit area by using the small scale irrigation. However, the yields of crops are not as high as expected with irrigated farming at present. The reason for this is lack of knowledge how among the farmers is lack of staff from relevant supporting institutions, inadequate coverage by extension agents and lack of institutional support, absence or shortage of proper agricultural inputs (seeds, varieties, fertilizers, improved farm implements etc). Thus, to achieve good results and to utilize the potential of the sector the irrigated agriculture is to be fully supported and the respective and relevant back up services especially related to extension must be strengthened.

The Rainfed Agriculture in catchment of the project command can also produce more than one good crop in a year if proper soil and water conservation measures and genetically potential crop varieties are introduced. These may be supported with quality seed and need based fertilizer application. Supply constraints and financial limitations at farm level pose considerable hindrance to the simultaneous adoption of a comprehensive input package of fertilizers, improved varieties, quality seed and agrochemicals along with the adoption of improved package of production practices and soil moisture conservation. The increase in yield will solve the financial limitations and other constraints of small holders.

To improve the productivity of small holdings, and to exploit the potential of the latest technologies and other inputs, the research extension linkage has to be made very strong, and the need based capacity building at all levels including the farmers is essential.

Diversification of cropping pattern is important in the project command and catchment both under irrigated and rain fed production system. There is good potential in the area to include cash and commercial crops along with the high value cereals, pulses and oil seeds. This may include fruits and vegetable crops, important cereals like teff, oilseeds like flux, pulses like lentil and chickpea spices like fenugreek etc. The enhanced production of these may encourage the establishment of agro- industries in the area to benefit the people.

7. Proposed water management for the envisaged irrigation scheme

In the previous chapters of the report the existing situations at Chemiet irrigation scheme were discussed; whereas in the next chapters, the crops to be grown, their water requirement, and irrigation scheduling are discussed. In the next chapters, however, the improved agronomic practices and other interventions recommended to the envisaged irrigation scheme will be dealt with.

7.1. Proposed crops and cropping pattern

The study area is suited for the growth of several field crops, vegetables and fruit trees. The following crops are selected and proposed to be grown under the envisaged irrigation scheme. These crops are selected after thorough evaluation of:

- Agro climate and soil of the area; experience and preference of farmers; Economic consideration (marketability of the crop) and improved seed availability; and response of the crop toward irrigation (yield potential).

Table 5: Proposed cropping pattern

Crops	Area (%)	Planting date	Growing season
Chickpea	10	June 1	Rainy
Lentil	10	June 1	>>
Linseed	10	June 1	>>
Maize	20	June 1	>>
Sorghum	30	June 1	>>
Teff	10	June 20	>>
Fenugreek	15	Dec 1	Dry
Peppers	30	Dec 1	>>
Swiss chard	20	Dec 1	>>
Tomato	25	Dec 1	>>
Citrus	5	Dec 1	Perennials
Mango	5	Dec 1	>>

Actually, the farmers are not limited to grow only these crops. They can shift to other more profitable crops when conditions are convenient.

Months	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Crops												
1. Chickpea				Turn Around Period (TAP)		1st	10%	29th			Turn Around Period (TAP)	
2. Lentil						1st	10%		18th			
3. Linseed						1st	10%		28th			
4. Maize						1st	20%	29th				
5. Sorghum						1st	30%		8th			
6. Teff						20th	20%			10th		
7. Fenugreek	15%		10th									1st
8. Peppers	30%	28th										1st
9. Swiss chard	20%		10th									1st
10. Tomato	25%		5th									1st
11. Citrus						5%						
12. Mango						5%						

Figure 4 Proposed cropping pattern and cropping calendar

7.2. Crop water requirement

7.2.1. Reference Crop Evapotranspiration (ETo)

The reference crop evapotranspiration (ETo) of the study area is calculated using the FAO Penman-Monteith method using estimated meteorological data for the project area. These meteorological data are estimated using New LocClim: Local climate estimator.

According to this result, the ETo of the study area ranges between 3.78 mm/day (on December) and 6.03 mm/day (on May). The average ETo of the study area on the other hand is 4.77 mm/day.

Table 6: Monthly ETo Penman-Monteith Data

Country: Ethiopia Station: Edaga-Arbi Altitude: 1718.95 m. Latitude: 14.01 °N Longitude: 37.24°E

Month	Min Temp	Max Temp	Humidity	Wind	Sun	Rad	ETo
	°C	°C	%	km/day	hours	MJ/m?/day	mm/day
January	13.3	30.3	65	69	10.1	20.9	3.92
February	14.1	31.3	65	86	10.4	23	4.52
March	14.3	33.9	30	69	11.8	26.8	5.22
April	15.1	35.3	31	86	12.5	28.7	6
May	15.8	35	32	86	12.4	28.4	6.03
June	15.5	33.1	34	104	11.8	27.2	5.96
July	16	28.9	32	69	9.3	23.4	4.79
August	16.3	27.6	29	69	8.1	21.8	4.48
September	15.6	28.6	25	52	8.9	22.6	4.24
October	15.9	31.1	25	52	9.8	22.5	4.12
November	16.6	31.4	27	86	9.3	20.1	4.19
December	15.5	31.3	29	69	9.5	19.6	3.78
Average	**15.3**	**31.5**	**35**	**75**	**10.3**	**23.8**	**4.77**

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7.3. Effective Rainfall

The formula used to calculate the effective rainfall for Chemiet irrigation scheme is an empirical formula developed by FAO/AGLW to determine dependable effective rainfall, the combined effect of dependable rainfall (80% prob. exc.) and estimated losses due to run off and deep percolation. This formula was developed based on analysis carried out for different arid and sub-humid climates. Hence, this formula is more appropriate to our condition

Peff = 0.6 P – 10 for P ≤ 70 mm

Peff =0.8 P -24 for P > 70 mm;

Where, P is mean monthly total rainfall.

Based on this method, the mean total annual effective rainfall of the study area is about 460 mm (See figure 5). This is about 59.3 % of the mean total annual rainfall of the area.

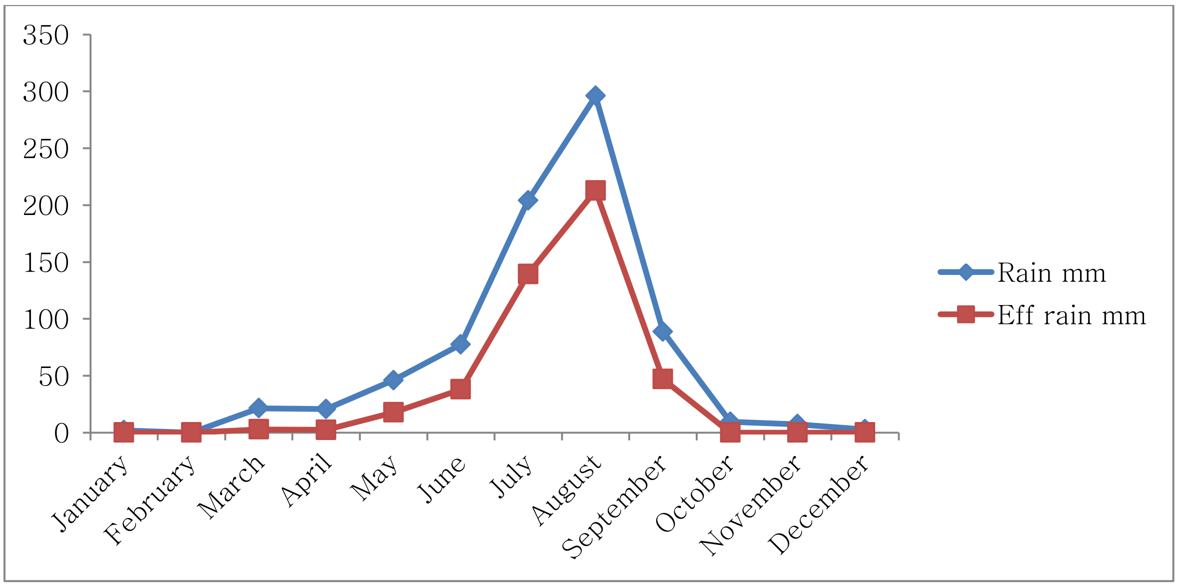

Figure 5 Rainfall pattern of the study area

7.4. Crop Water Requirement

The water requirement of the proposed crops is calculated using CROPWAT 8 computer software. As the calculation results shows, the water requirement of the dry season crops is more or less dependent on irrigation water. The water requirement of the wet season crops on the other hand is satisfied from rainfall and supplementary irrigation (especially at the beginning and end of the rainy season). Of the crops proposed to be grown during the wet season, teff has the highest irrigation demand followed by flux. Of the crops proposed to be grown during the dry season on the other hand Swiss chard and tomato have the highest water demand. In fact, the irrigation demand of these crops is much less compared with that of the perennial crops.

7.5. Crop water requirement of the proposed crops

Table 7 Crop water requirements of chickpea

Month	Decade	Stage	Kc	ETc	ETc	Eff rain	Irr. Req.
			coeff	mm/day	mm/dec	mm/dec	mm/dec
Jun	1	Init	0.4	2.08	20.8	7.9	12.9
Jun	2	Init	0.4	2	20	8.9	11.2
Jun	3	Deve	0.56	2.63	26.3	21.4	4.9
Jul	1	Deve	0.86	3.74	37.4	36	1.3
Jul	2	Mid	1.11	4.48	44.8	47.7	0
Jul	3	Mid	1.14	4.46	49	55.5	0
Aug	1	Mid	1.14	4.24	42.4	70.3	0
Aug	2	Late	1.03	3.67	36.7	82.3	0
Aug	3	Late	0.56	2.16	19.4	49.2	0
					296.9	**379.1**	**30.4**

Table 8 Crop water requirements of lentil

Month	Decade	Stage	Kc	ETc	ETc	Eff rain	Irr. Req.
			coeff	mm/day	mm/dec	mm/dec	mm/dec
Jun	1	Init	0.4	2.08	20.8	7.9	12.9
Jun	2	Init	0.4	2	20	8.9	11.2
Jun	3	Deve	0.56	2.63	26.3	21.4	4.9
Jul	1	Deve	0.86	3.73	37.3	36	1.3
Jul	2	Mid	1.1	4.47	44.7	47.7	0
Jul	3	Mid	1.13	4.45	49	55.5	0
Aug	1	Mid	1.13	4.24	42.4	70.3	0
Aug	2	Mid	1.13	4.06	40.6	82.3	0
Aug	3	Late	1.07	4.12	45.3	60.1	0
Sep	1	Late	0.81	3.38	33.8	30.4	3.4
Sep	2	Late	0.58	2.55	20.4	8.1	10.3
					380.7	**428.5**	**44.1**

Table 9: Crop water requirements of flux

Month	Decade	Stage	Kc	ETc	ETc	Eff rain	Irr. Req.
			coeff	mm/day	mm/dec	mm/dec	mm/dec
Jun	1	Init	0.35	1.82	18.2	7.9	10.3
Jun	2	Init	0.35	1.75	17.5	8.9	8.6
Jun	3	Deve	0.39	1.82	18.2	21.4	0
Jul	1	Deve	0.62	2.72	27.2	36	0
Jul	2	Deve	0.88	3.57	35.7	47.7	0
Jul	3	Mid	1.11	4.34	47.7	55.5	0
Aug	1	Mid	1.13	4.22	42.2	70.3	0
Aug	2	Mid	1.13	4.04	40.4	82.3	0
Aug	3	Mid	1.13	4.35	47.9	60.1	0
Sep	1	Late	1.04	4.34	43.4	30.4	13
Sep	2	Late	0.74	3.26	32.6	10.1	22.5
Sep	3	Late	0.46	2.1	16.8	5.4	10.1
					387.8	**435.9**	**64.5**

10: Crop water requirements of maize

Month	Decade	Stage	Kc	ETc	ETc	Eff rain	Irr. Req.
			coeff	mm/day	mm/dec	mm/dec	mm/dec
Jun	1	Init	0.3	1.56	15.6	7.9	7.7
Jun	2	Init	0.3	1.5	15	8.9	6.1
Jun	3	Deve	0.49	2.31	23.1	21.4	1.7
Jul	1	Deve	0.84	3.68	36.8	36	0.8
Jul	2	Mid	1.14	4.62	46.2	47.7	0
Jul	3	Mid	1.18	4.62	50.8	55.5	0
Aug	1	Mid	1.18	4.4	44	70.3	0
Aug	2	Late	1.06	3.8	38	82.3	0
Aug	3	Late	0.57	2.2	19.8	49.2	0
					289.3	**379.1**	**16.4**

Table 11: Crop water requirements of sorghum

Month	Decade	Stage	Kc	ETc	ETc	Eff rain	Irr. Req.
			coeff	mm/day	mm/dec	mm/dec	mm/dec
Jun	1	Init	0.3	1.56	15.6	7.9	7.7
Jun	2	Init	0.3	1.5	15	8.9	6.1
Jun	3	Deve	0.45	2.11	21.1	21.4	0
Jul	1	Deve	0.72	3.15	31.5	36	0
Jul	2	Mid	0.95	3.85	38.5	47.7	0
Jul	3	Mid	0.98	3.84	42.3	55.5	0
Aug	1	Mid	0.98	3.66	36.6	70.3	0
Aug	2	Late	0.98	3.5	35	82.3	0
Aug	3	Late	0.82	3.17	34.9	60.1	0
Sep	1	Late	0.61	2.55	20.4	24.3	0
					290.8	**414.3**	**13.9**

Table 12: Crop water requirements of teff

Month	Decade	Stage	Kc	ETc	ETc	Eff rain	Irr. Req.
			coeff	mm/day	mm/dec	mm/dec	mm/dec
Jun	2	Init	0.4	2	2	0.9	2
Jun	3	Init	0.4	1.87	18.7	21.4	0
Jul	1	Init	0.4	1.75	17.5	36	0
Jul	2	Deve	0.45	1.84	18.4	47.7	0
Jul	3	Deve	0.71	2.78	30.6	55.5	0
Aug	1	Mid	0.97	3.63	36.3	70.3	0
Aug	2	Mid	1.04	3.73	37.3	82.3	0
Aug	3	Mid	1.04	4.02	44.2	60.1	0
Sep	1	Mid	1.04	4.34	43.4	30.4	13
Sep	2	Mid	1.04	4.59	45.9	10.1	35.9
Sep	3	Late	0.77	3.52	35.2	6.7	28.5
Oct	1	Late	0.27	1.31	13.1	0.1	13
					342.7	**421.5**	**92.4**

Table 13: Crop water requirements of fenugreek

Month	Decade	Stage	Kc	ETc	ETc	Eff rain	Irr. Req.
			coeff	mm/day	mm/dec	mm/dec	mm/dec
Dec	1	Init	0.4	1.61	16.1	0	16.1
Dec	2	Deve	0.45	1.73	17.3	0	17.3
Dec	3	Deve	0.74	2.94	32.3	0	32.3
Jan	1	Mid	1.07	4.3	43	0	43
Jan	2	Mid	1.18	4.84	48.4	0	48.4
Jan	3	Mid	1.18	5.1	56.1	0	56.1
Feb	1	Mid	1.18	5.36	53.6	0	53.6
Feb	2	Late	1.17	5.56	55.6	0	55.6
Feb	3	Late	0.91	4.49	35.9	0.1	35.8
Mar	1	Late	0.54	2.74	27.4	0.7	26.7
					385.7	**0.8**	**384.9**

Table 14: Crop water requirements of pepper

Month	Decade	Stage	Kc	ETc	ETc	Eff rain	Irr. Req.
			coeff	mm/day	mm/dec	mm/dec	mm/dec
Dec	1	Init	0.6	2.41	24.1	0	24.1
Dec	2	Init	0.6	2.33	23.3	0	23.3
Dec	3	Deve	0.72	2.83	31.1	0	31.1
Jan	1	Deve	0.92	3.7	37	0	37
Jan	2	Mid	1.07	4.4	44	0	44
Jan	3	Mid	1.08	4.69	51.6	0	51.6
Feb	1	Mid	1.08	4.93	49.3	0	49.3
Feb	2	Late	1.06	5.04	50.4	0	50.4
Feb	3	Late	0.97	4.79	38.3	0.1	38.2
					349.2	**0.1**	**349.1**

Table 15: Crop water requirements of swish chard

Month	Decade	Stage	Kc	ETc	ETc	Eff rain	Irr. Req.
			coeff	mm/day	mm/dec	mm/dec	mm/dec
Dec	1	Init	0.7	2.81	28.1	0	28.1
Dec	2	Init	0.7	2.71	27.1	0	27.1
Dec	3	Deve	0.79	3.12	34.4	0	34.4
Jan	1	Deve	0.95	3.82	38.2	0	38.2
Jan	2	Mid	1.07	4.38	43.8	0	43.8
Jan	3	Mid	1.08	4.66	51.2	0	51.2
Feb	1	Mid	1.08	4.9	49	0	49
Feb	2	Late	1.07	5.08	50.8	0	50.8
Feb	3	Late	1.03	5.1	40.8	0.1	40.7
Mar	1	Late	1	5.09	50.9	0.7	50.2
					414.4	0.8	413.6

Table 16: Crop water requirements of tomato

Month	Decade	Stage	Kc	ETc	ETc	Eff rain	Irr. Req.
			coeff	mm/day	mm/dec	mm/dec	mm/dec
Dec	1	Init	0.6	2.41	24.1	0	24.1
Dec	2	Init	0.6	2.33	23.3	0	23.3
Dec	3	Deve	0.74	2.93	32.2	0	32.2
Jan	1	Deve	0.98	3.97	39.7	0	39.7
Jan	2	Mid	1.17	4.8	48	0	48
Jan	3	Mid	1.18	5.12	56.3	0	56.3
Feb	1	Mid	1.18	5.38	53.8	0	53.8
Feb	2	Late	1.18	5.61	56.1	0	56.1
Feb	3	Late	1.03	5.1	40.8	0.1	40.7
Mar	1	Late	0.88	4.51	22.5	0.3	22.2
					396.7	**0.5**	**396.2**

Table 17: Crop water requirements of citrus

Month	Decade	Stage	Kc coeff	ETc mm/day	ETc mm/dec	Eff rain mm/dec	Irr. Req. mm/dec
Dec	1	Init	0.7	2.81	28.1	0	28.1
Dec	2	Init	0.7	2.71	27.1	0	27.1
Dec	3	Init	0.7	2.77	30.4	0	30.4
Jan	1	Init	0.7	2.82	28.2	0	28.2
Jan	2	Init	0.7	2.87	28.7	0	28.7
Jan	3	Deve	0.7	3.03	33.3	0	33.3
Feb	1	Deve	0.7	3.16	31.6	0	31.6
Feb	2	Deve	0.69	3.29	32.9	0	32.9
Feb	3	Deve	0.68	3.37	27	0.1	26.9
Mar	1	Deve	0.68	3.46	34.6	0.7	33.9
Mar	2	Deve	0.67	3.54	35.4	1	34.3
Mar	3	Deve	0.66	3.59	39.5	1	38.6
Apr	1	Deve	0.66	3.65	36.5	0.4	36.1
Apr	2	Deve	0.65	3.7	37	0.1	36.9
Apr	3	Mid	0.65	3.65	36.5	2	34.4
May	1	Mid	0.64	3.61	36.1	4.1	32.1
May	2	Mid	0.64	3.6	36	5.7	30.3
May	3	Mid	0.64	3.47	38.2	8	30.1
Jun	1	Mid	0.64	3.34	33.4	7.9	25.6
Jun	2	Mid	0.64	3.22	32.2	8.9	23.3
Jun	3	Mid	0.64	3.01	30.1	21.4	8.7
Jul	1	Mid	0.64	2.81	28.1	36	0
Jul	2	Mid	0.64	2.6	26	47.7	0
Jul	3	Mid	0.64	2.52	27.8	55.5	0
Aug	1	Mid	0.64	2.4	24	70.3	0
Aug	2	Mid	0.64	2.3	23	82.3	0
Aug	3	Late	0.67	2.58	28.4	60.1	0
Sep	1	Late	0.72	2.98	29.8	30.4	0
Sep	2	Late	0.72	3.16	31.6	10.1	21.5
Sep	3	Late	0.72	3.28	32.8	6.7	26.1
Oct	1	Late	0.72	3.45	34.5	0.1	34.3
Oct	2	Late	0.72	3.59	35.9	0	35.9
Oct	3	Late	0.72	3.42	37.6	0	37.6
Nov	1	Late	0.72	3.22	32.2	0	32.2
Nov	2	Late	0.72	3.08	30.8	0	30.8

Table 18: Crop water requirements of mango

Month	Decade	Stage	Kc coeff	ETc mm/day	ETc mm/dec	Eff rain mm/dec	Irr. Req. mm/dec
Dec	1	Init	0.9	3.61	36.1	0	36.1
Dec	2	Init	0.9	3.49	34.9	0	34.9
Dec	3	Init	0.9	3.56	39.1	0	39.1
Jan	1	Init	0.9	3.63	36.3	0	36.3
Jan	2	Init	0.9	3.69	36.9	0	36.9
Jan	3	Init	0.9	3.89	42.8	0	42.8
Feb	1	Init	0.9	4.09	40.9	0	40.9
Feb	2	Init	0.9	4.29	42.9	0	42.9
Feb	3	Init	0.9	4.44	35.5	0.1	35.4
Mar	1	Deve	0.91	4.65	46.5	0.7	45.8
Mar	2	Deve	0.93	4.91	49.1	1	48
Mar	3	Deve	0.95	5.15	56.7	1	55.7
Apr	1	Deve	0.97	5.4	54	0.4	53.6
Apr	2	Deve	0.99	5.65	56.5	0.1	56.4
Apr	3	Deve	1.01	5.73	57.3	2	55.3
May	1	Deve	1.03	5.81	58.1	4.1	54.1
May	2	Deve	1.05	5.89	58.9	5.7	53.3
May	3	Mid	1.07	5.8	63.8	8	55.8
Jun	1	Mid	1.08	5.62	56.2	7.9	48.3
Jun	2	Mid	1.08	5.41	54.1	8.9	45.2
Jun	3	Mid	1.08	5.06	50.6	21.4	29.3
Jul	1	Mid	1.08	4.72	47.2	36	11.2
Jul	2	Mid	1.08	4.38	43.8	47.7	0
Jul	3	Mid	1.08	4.24	46.7	55.5	0
Aug	1	Mid	1.08	4.04	40.4	70.3	0
Aug	2	Mid	1.08	3.87	38.7	82.3	0
Aug	3	Late	1.08	4.16	45.8	60.1	0
Sep	1	Late	1.06	4.43	44.3	30.4	13.9
Sep	2	Late	1.05	4.61	46.1	10.1	36.1
Sep	3	Late	1.03	4.71	47.1	6.7	40.4
Oct	1	Late	1.01	4.87	48.7	0.1	48.6
Oct	2	Late	1	4.99	49.9	0	49.9
Oct	3	Late	0.98	4.67	51.3	0	51.3
Nov	1	Late	0.96	4.32	43.2	0	43.2
Nov	2	Late	0.94	4.05	40.5	0	40.5

7.6. Scheme Irrigation supply

The net irrigation need of the scheme during both dry and wet seasons is shown on table 19. So, this result depicts that the maximum net irrigation of the project, is 134.3 mm/month on Feb. The per hectare irrigation water budget of the scheme is about 8470.59 m^3/ha.

Additionally, considering 57 % over-all project efficiency and 14 scheme operation the maximum duty is 1.57 l/s/h.

Table 19 Net scheme supply

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Precipitation deficit												
1. Chickpea	0	0	0	0	0	29	1.4	0	0	0	0	0
2. Lentil	0	0	0	0	0	29	1.4	0	14.3	0	0	0
3. Maize	0	0	0	0	0	15.6	0.9	0	0	0	0	0
4. Linseed	0	0	0	0	0	19	0	0	45.8	0	0	0
5. Sorghum	0	0	0	0	0	13.9	0	0	0	0	0	0
6. Teff	0	0	0	0	0	2	0	0	77.4	13	0	0
7. Tomato	138.6	144.4	21	0	0	0	0	0	0	0	0	79.1
8. Swiss chard	128.9	135.4	48.3	0	0	0	0	0	0	0	0	89.2
9. Peppers	127	131.5	0	0	0	0	0	0	0	0	0	78
10 Mango	116	119.3	152	172.7	175.6	135.6	14.9	0	100	157.9	126.5	110.2
11. Citrus	90.2	92.9	111.9	116.3	103	66.7	0	0	49.8	111	95.5	85.7
12. Fenugreeck	142.4	140.2	26.2	0	0	0	0	0	0	0	0	64.8
Net scheme irr.req.												
in mm/day	4.2	4.8	1	0.5	0.4	0.8	0	0	0.7	0.5	0.4	2.6
in mm/month	130.2	134.3	32	14.4	13.9	25.3	1.2	0	21.2	14.7	11.1	80.5
in l/s/h	0.49	0.56	0.12	0.06	0.05	0.1	0	0	0.08	0.06	0.04	0.3
Irrigated area	100	100	70	10	10	100	45	0	40	20	10	100
(% of total area)												
Irr.req. for actual are	0.49	0.56	0.17	0.56	0.52	0.1	0.01	0	0.2	0.28	0.43	0.3
(l/s/h)												
Irri. Effiecency	0.57	0.57	0.57	0.57	0.57	0.57	0.57	0.57	0.57	0.57	0.57	0.57
Gross irr. Req	230.34	237.59	56.61	25.48	24.59	44.76	2.12	0.00	37.51	26.01	19.64	142.41
Duty for 14 hours	1.52	1.57	0.37	0.17	0.16	0.30	0.01	0.00	0.25	0.17	0.13	0.94

7.7. Irrigation Schedule

Irrigation scheduling is a planning, measuring and decision making process focused on the primary questions of how much water to apply and when and where to apply it. These determinations may be undertaken by observation of crop water stress, weather based crop water use estimate, soil water content determination or some combinations of these.

The irrigation schedule for Chemiet irrigation scheme is calculated using CROPWAT 8 computer software, considering timing irrigated at fixed interval per stage and 70 % irrigation efficiency. The separate assessments of conveyance, distribution, and field application efficiencies will indicate if and where remedial measures are required to improve the efficiency of water use in the project as a whole. The efficiency of water in agricultural production is generally low. Only 40 to 60% of the water is effectively used by the crop under surface irrigation systems, the rest of the water is lost in the system or in the farm either through evaporation, runoff, or by percolation into the groundwater. Irrigation scheduling, if properly managed can offer a good solution to improve water efficiency in the farm. Various methods and tools have been developed to determine when crops require water and how much irrigation water needs to be applied. These include the various soil and plant monitoring methods (MOA 2009). In summary, in order to save water, it may be feasible to irrigate, during the early stages of the crop development, with smaller irrigation applications than during the peak period. During the late season stage it may be feasible to irrigate less frequently, in particular if the crop is harvested dry.

The results are annexed at the back of the report. In fact, the calculation of irrigation schedule should be a routine activity during the project implementation period based on actual condition like rainfall distribution and sowing time.

8. Proposed Agronomic Practices

8.1. Land Preparation

Land preparation especially for the proposed perennial crops (fruit crops) is digging the planting holes. This operation is carried out several weeks prior to planting. The planting holes are first staked out and then large holes 0.6-1.0 m in both width and depth are dug. Topsoil and subsoil of the holes are placed separately. The hole should then be refilled with a mixture of 50 percent topsoil and 50 percent well-decomposed farmyard manure or compost. These holes should be allowed to settle for several weeks before planting begins.

For the proposed annual crops, the land is prepared by plowing. As it is known, plowing loosens the soil and results in seedbed suitable for seed germination and development of the young seedlings. Plowing is also practiced to allow infiltration of excess water and to control weeds. So, the land for the proposed crops should be plowed 2-3 times.

8.2. Seed/propagation material selection and sowing/Planting

The major crops growing in the study area are mainly Teff, maize and sorghum. The farmers are using mostly local seeds of these crops. The local varieties are adapted to the local agro climatic conditions and they fulfill the social preferences and local priorities. Most of the time however, the local varieties are low yielding. Thus, the local varieties should be replaced by high yielding improved varieties that meet the social preferences and local priorities.

The farmers in the study area are sowing the seeds by broadcasting. Broadcasting does not distribute the seeds uniformly. Moreover, more seed rate is required when sowing by broadcasting. Therefore, all the proposed crops should be planted in rows. Row planting distributes seeds uniformly and hence facilitates intercrop cultivation and other crop management activities.

The proposed fruit crops are already growing around the study area. The propagation material for these crops is obtained from other parts of the region. The propagation material should be grafted mango. In other words seedling mango is not recommended to be grown in the area for it takes longer time to bear fruits.

Table 20 List of varieties of the proposed crops

NO	Crops	Varieties
1	Maize	Melkasa-1, Melkasa-2, Melkasa-3,Gibe-2, Gibe-3, Hybrids
2	Sorghum	Gobiye, Abshir, Birhan
3	Teff	Quncho, Tsedey
4	Lentil	Alemaya 98, Alem tena
5	Chick pea	Mariye
6	Flux	Local
7	Fenugreek	Chala, hunda-01, local
8	Pepper	Marko fana, Melka Eshete, Melka Awaze, Melka dima Melka zala
9	Tomato	Roma V.F, Melka salsa, melkka shola
10	Swiss chard	Lukles, Jaint perpchwal, Lion rebreb chard
11	Citrus	Alendia Valencia, Campel Valencia, Washington naval
12	Mango	Apple mango, Kent, Keitt, Tomyatkins
Source: BOARD/TARI 2010,		

8.3. Irrigation

There are several methods that are used to supply irrigation water to crops. Of these methods, Chemiet irrigation scheme is designed for pump supported surface irrigation. This method applies irrigation water by lifting water to the main canal and to the field. Compared with other irrigation methods specifically with sprinkler and drip irrigation methods, surface irrigation method has low irrigation water application efficiency. So, to achieve at efficient water distribution and to reduce water wastage, furrow irrigation are recommended for the proposed annual crops and fruit crops respectively. Moreover, furrows which most of the farmers are destroying them during intercrop cultivation should be prepared on time. The canals should also be made ready for irrigation in time.

8.4. Crop Protection

8.5. Weed management

As it is discussed earlier, several weeds are growing in the study area. Due to the availability of enough moisture, these weeds are expected to be very problematic under the envisaged irrigated agriculture. Unless they are managed effectively, these weeds will cause severe yield loss on the proposed crops. Effective weed management practices include those that reduce the potential of weeds to adversely impact crop growth and yield. These practices often allow the crop to utilize all available resources necessary to achieve its yield potential.

The proposed weed control management practices for Chemiet irrigation scheme integrates **(IPM)** cultural, mechanical (physical) and chemical weed control strategies. The cultural weed management practices include selecting resistant variety (for instance to control striga), using clean seeds, adjusting planting date, proper spacing, crop rotation, improving soil fertility, intercropping and others. These cultural weed management practices improve the competitive ability of the crop. The mechanical weed management practices on the other hand involve the destruction of weeds by frequent plowing, hand weeding, hoeing, and mulching. The other weed management practice is using herbicides. Nevertheless, to promote sustainable agricultural land use system, the use of chemicals should be eliminated or reduced by integrating several of the other weed management practices.

8.6. Pest management

Insect pests are one of the major production limiting factors in the study area. These agents are also expected to be more problematic in the forthcoming irrigation agriculture. Especially if there is no crop rotation, insect pests will build up through time and will cause significant yield loss.

The best method to control insect pests is applying integrated pest management system **(IPM).** This system is designed around six components. These components are:

1. **Acceptable pest levels:** The emphasis of IPM is on control, not eradication. IPM holds that eliminating an entire pest population is often impossible, and the attempt can be more costly, environmentally unsafe, and all-round counterproductive than it is worth. Hence, it is better to decide on what constitutes acceptable pest levels, and apply controls if those levels are reached.
2. **Preventive cultural practices:** Selecting varieties best for local growing conditions, and maintaining healthy crops, is the first line of defense.

3. **Monitoring:** Regular observation is the cornerstone of IPM. Visual inspection, insect traps, and other monitoring methods are used to monitor pest levels. Record-keeping is essential, as is a thorough knowledge of the behavior and reproductive cycles of target pests.
4. **Mechanical controls:** When a pest reaches an economic-injury level, mechanical methods are the first options to consider. They include simple hand-picking, erecting insect barriers, using traps and tillage to disrupt breeding.
5. **Biological controls:** Natural biological processes and materials can provide control, with minimal environmental impact, and often at low cost. The main focus here is on promoting beneficial insects that eat target pests.
6. **Chemical controls:** Considered as an IPM last resort, synthetic pesticides may be used when other controls fail or are deemed unlikely to prove effective. Biological insecticides derived from plants or naturally occurring microorganisms are the safest options.

Hence, integrated pest management method **(IPM)** is proposed to manage insect pests in the study area. The main pest control practices to be integrated in the system include frequent plowing, timely sowing, timely harvesting, optimum plant population, intercropping, crop rotation, crop sanitation, trap cropping, observing off-seasons, resistant varieties, removing alternate hosts and chemicals. Nevertheless, priority should be given to non-chemical methods and chemicals should be used if there are no other control possibilities.

8.7. Disease management

Diseases are also other important production constraints in the study area. Crop diseases reduce the quantity and quality of plant produce, limit the kinds of crops to be grown in an area, may make plants poisonous to humans and animals and may cause financial losses.

For crop diseases to develop in an area there must be a susceptible host plant, a plant pathogen able to infect the host crop, and an environment that favors disease development. So, these components should be considered when designing disease control strategies. In other words, the diseases management practices should be designed to affect multiple components, an approach known as integrated disease management. Integrated disease management practices **(IPM)** usually results in better disease reaction and helps reduce selection pressures when certain individual management practices are used, which can result in new races of the pathogen or fungicide resistant strains of the pathogens being selected. Thus, the disease management practices proposed to be integrated includes sanitation, repeated plowing, timely planting and timely harvesting, using disease free planting material, crop rotation, resistant varieties, eradicating alternate hosts, proper weed management and using fungicides.

Another point that is worth noting is that proper diagnosis of the disease problem. Diagnosing a disease from symptoms alone is not always possible, and some pathogens can cause similar symptoms. Misidentification can lead to inappropriate control recommendations. So, to properly identify diseases, the field diagnosis should be assisted with plant diagnostic labs.

8.8. Soil Fertility Management

Plants require at least 16 elements for normal growth and for completion of their life cycle. Carbon, hydrogen and oxygen are supplied by air and water; whereas the remaining 13 elements are taken up by plants only in mineral form from the soil or must be added as fertilizers. If the nutrients taken up by plants are not replaced, soil fertility will be mined. Nutrients are added to the soil through mineral fertilizers, organic manures, atmospheric deposition, biological nitrogen fixation and sedimentation. Soil nutrients on the other hand are mined through harvested crop parts, crop residues, leaching losses, gaseous losses and soil erosion.

Soil fertility study made in almost all woreda of Tigray indicates that there is shortage of at least 7 nutrients namely, nitrogen, phosphorus, potassium, sulfur, zinc, boron and cupper. Similarly the soil fertility status of the study area is low and the organic matter content very poor. So, to solve this problem integrated soil fertility management is recommended to improve the soil fertility of the area. This method integrates all practices aimed at improving soil fertility and due consideration is given to cultural soil fertility management practices, the application of well decomposed farmyard manure, compost, crop residue and crop rotation. The cultural soil fertility management practices add most of the essential soil nutrients and improve the organic matter content of the soil and hence the structure and fertility of the soil.

Chemical fertilizers are also part of the integrated soil fertility management practice. The chemical fertilizers currently in use are NPSZn, NPSZnB, NPKSZnFeB and urea. These fertilizers add Nitrogen, Phosphorus, Sulfur, Zinc and Boron to the soil. Nevertheless, plants require more nutrients, so until blended fertilizers are introduced to the area, the available fertilizers should be used integrated with the other soil fertility management practices.

Table 21 Recommended inorganic and organic fertilizer application rate for the proposed crops

No	Crops	Fertilizer Rate
1	Maize		100 kg Compound, 50kg Urea, 2 Tomes of Farmyard manure or compost
2	Sorghum	100 kg Compound, 50kg Urea, 2 Tomes of Farmyard manure or compost
3	Teff	100 kg Compound, 50kg Urea, 2 Tomes of Farmyard manure or compost
4	Lentil	50 kg Compound, 2 Tomes of farmyard manure of compost
5	Chickpea	50 kg Compound, 2 Tomes of farmyard manure of compost
6	Flux	50 kg Compound, 5 Tomes of farmyard manure or compost
7	Pepper	200 kg Compound, 100kg Urea, 5 Tomes of farmyard manure or compost
8	Tomato	200 kg Compound, 100kg Urea, 5 Tomes of farmyard manure or compost
9	Swiss chard	50 kg Compound, 200kg Urea, 5 Tomes of farmyard manure or compost
10	Fenugreek	20 kg Compound, 2 Tomes of farmyard manure or compost

Fruits

Age year	1	2	3	4	5	6	7	8	9	10
DAP	50	100	150	200	250	300	350	400	450	500
UREA	50	100	150	200	250	300	350	400	450	500
Age year	**11**	**12**	**13**	**14**	**15**	**16**	**17**	**18**	**19**	**20**
DAP	0	0	0	0	0	0	0	0	0	0
UREA	600	700	800	900	1000	1100	1200	1300	1400	2000

Sources: BOARD/TARI 2010,

At this point one thing that needs more emphasis is crop rotation. Crop rotation is the growing of different crops one after the other on the same plot of land in sequential seasons. Crop rotation is practiced to maintain soil fertility and to control the buildup of pests, diseases, and weeds. When aiming at maintaining soil fertility, the main component of crop rotation is the inclusion of legume crops. Legume crops add nitrogen to the soil. Hence, lentil and chickpea are included in the proposed cropping pattern of

Chemiet irrigation project. There are also other legume crops that can grow in the study area. These crops include legume forage crops (alfalfa, pigeon pea, lablab and vetch). These legume crops can be included in the rotation pattern. They can also be intercropped with sorghum and the proposed fruit crops. By doing so the need for chemical fertilizer (urea) will decrease and hence the farmers can save their money. In fact, ever if nitrogen is not added to the soil, soil fertility can be sustained by alternating deep-feeder cereal crops with shallow-feeder cereal crops (for example sorghum followed by teff for rainy season and pepper followed by Swiss chard for dry season). In this way nutrient removal occurs uniformly from the various soil layers rather than occurring in one layer only.

8.9. Post-harvest management

Proper post-harvest management allows not only to minimize losses but also to increase the market value of the produce. The first phase of post-harvest management starts from the time of harvest of the produce. The time and method chosen for harvesting a produce influences its life span and the level of income. The life span of a produce that is harvested too early or too late, or which is damaged by bad harvesting techniques of tools, will obviously be shorter. Hence, the proposed crops should be harvested at proper time. In other words, harvesting should be done when the crops reach their full physiological maturity to avoid shriveling and shattering due to early and late harvesting respectively.

Harvesting operation of the proposed field crops, which is harvested by picking manually, can be done using sickle or machines like hand-held harvesters and reapers and self-propelled reaper. After harvesting, any delay in threshing should be avoided; and threshing should be done on level, clean and plastered threshing fields and mats (in the case of sesame).Threshing can also be made using machines.

Concerning the horticultural crops, Swiss chard should be lifted using hoe and be allowed to cure in the field. Moreover, tomato, peppers and the fruit crops should be picked manually.

After the crops are harvested and threshed; they should be sorted and graded. Traditionally, farmers sort the produce for consumption and for sale by establishing their own grading systems. This traditional grading system has to be technically supported and upgraded so as to increase the quality and hence the value of the produce. The sorting and grading criteria may be based on color, size, shape, presence of inert material, shrinkage and so on. Sorting and grading can be done by hand picking and sieving.

After sorting and grading, the produce should be stored properly if it is not supplied to market immediately. Hence, communal ventilated stores with slated shelves can be constructed using local material to store onion.

9. Yield Estimation

The average attainable yield of the crops proposed to be grown in the area is estimated considering the suitability of the crops to the area, assumed level of input use, availability of agricultural support services in the area, the experience of the farmers in irrigation, adoption rate of the farmers to modern agricultural inputs, improved agricultural practices and management, and the level at which the recommendations made are realized.

So, the attainable yield of the proposed crops is projected in such a way that the yield of these crops will increase year to year and reach maximum on the third (for mango and citrus) and fifth year for the remaining crops and stabilize then onwards.

Table 22 Yield build-up pattern

Crops	Existing Yield (Qt/ha)	Yield (quintal/ha)				
		1st year	2nd year	3rd year	4th year	5th year
Teff	10	10	12	14	18	22
Maize	25	28	30	35	38	40
Sorghum	26	28	29	32	35	35
Lentil	5	6	8	10	15	20
Chickpea	5	8	10	13	18	20
Fenugreek	-	6	8	10	12	13
Flux	-	4	6	10	12	15
Pepper	3	5	9	13	17	15
Tomato	-	90	100	150	180	200
Swiss chard	-	30	40	65	90	140
Citrus	30	-	-	120	200	300
Mango	25	-	-	80	160	200

10. Agricultural development Plan (ADP)

10.1. Objective of the agricultural development plan

This agricultural development plan is prepared aiming at improving crop production of the study area and hence securing food supply of the beneficiary farmers. Ultimately, it is aimed at improving the welfare of the farmers.

This plan is prepared by team of experts composed from Woreda office of Agriculture and Rural Development, Development Agent of the tabia, selected farmers from the irrigation users' association of the scheme in consultation with agricultural development office of the woreda and local officials (from the tabia and woreda). This plan is prepared by reviewing the agronomy feasibility reports of the scheme, in-depth discussion with the beneficiary farmers, and administration body of the tabia, and thorough assessment of the study area.

10.2. Location

Chemiet pump irrigation scheme is found in central zone of Tigray, Werei leke woreda, the site is accessible by asphalt and weathered main roads. That is the longest road for accessibility to the site is via Mekelle-Abi-Adi- Edaga-Arbiasphalt (150km) and weathered (15km) main road. The distance from Edaga-Arbi to the project sites of Chemiet pump irrigation scheme is about 33km respectively. Geographically the proposed area is located in the coordinate of 1,548,921 N latitude and 526,737E longitudes at elevation of 1718.95 meter above sea level.

10.3. Expected output of the ADP

The ultimate goal of any irrigation development is to increase yield so as to improve the living standard of the farmers. Similarly, the expected output of the agricultural development plan is increased production through efficient utilization of resources of the area, improved nutrition and health of the farming community and increased income of the beneficiary farmers. Moreover, the skill and confidence of the DAs and beneficiary farmers is expected to develop.

10.4 Improving the extension service

The extension service should be strengthening in man power, training and logistics. Unless effective extension system is developed, it will be less likely to achieve the required targets from the site. More over the extension system will have more acceptable extension approach and develop its linkage with other research and development institutions.

10.5 Farmers' capacity building

The ultimate goal of this irrigation scheme is increasing production and hence improving the living standards of the farmers. To achieve at this goal, the farmers need to practice the proposed improved agricultural technologies. These improved agricultural technologies include using improved seed, integrated soil fertility management, integrated pest management, and more importantly irrigation water management. Therefore, the beneficiary farmers should get training on the proposed improved agricultural technologies.

Currently the farmers are getting training in the farmers' training center of their tabia. Demonstrations on improved agricultural technologies, although not sufficient, are also made in the FTC of the tabias under consideration. Therefore, these endeavors should be strengthened and the FTCs should be equipped with necessary materials. It is also advisable to arrange field visits to other improved irrigation schemes locally or regionally (specifically in irrigation experiences). Such visits will help the farmers to learn about new innovations successfully tried in other areas and gives chance to adapt them to their conditions.

When thinking training and exposure visits, it should include the DAs and SMSs. The DAs and SMSs lack practical skills (qualification and communication skills). So, provision of continues and intensive training especially on irrigation agronomy will improve the extension service they provide.

Regular farm visit: it is a regular activity of the extension development agent expected to visit all irrigation users in each cropping season. In addition to the regular farm visits the development agents need to undertake demand or problem based visits as required to support the farmers. In order to carry out farm visit on time, the development agents should have transportation facilities and materials as appropriate.

On-farm technology demonstration: it should be suggested as a capacity building tool to improve the knowledge of the farmers for proper farm management and optimum crop yield achievement. It's the most appropriate technology dissemination mechanism using locally available technology and skilled farmers. Model farmers are expected to involve actively in technology demonstration activity where new crop technology promoted on farmers' plots.

Every 20 hectare of irrigable land would have at least one demonstration plot with the size of 0.15ha – 0.25 ha depends on the type of crops and technology being demonstrated.

Experience sharing visits: experience sharing tour in different parts of the country where the farmers can obtain good agronomic and on-farm water management skills. Group of farmers including model farmers, women and youth farmers should be member of the visitors' group.

- Number of visitors 5 farmer from each upper, medium and lower scheme totally 15 out of them 6 women should be involved.
- House experience sharing forum or sessions is required to disseminate their knowledge after experience sharing visits at least for 2 hours.

10.6 Improved seed production and establishing communal vegetable nursery.

Where reliable commercially produced improved seeds are available, the farmers are advised to use these seeds rather than using locally produced seeds. This is because commercial seeds, produced under controlled conditions, are likely to be high yielding and less likely to harbor pathogens than locally produced seed. Sometimes, however, commercially produced improved seeds may not be easily available or the source of the seeds may not be reliable. In such cases the farmers should produce their own seeds. So, the farmers should be provided training, starting seed and other necessary equipment to produce their own seeds. Therefore for onion seed multiplication the farmer should contribute 0.5 ha of land and free labor for preparation of pond or reservoir.

There are governmental and NGOS fruit nursery in the woreda center. Hence, the farmers can get seedlings of fruit crops from this nursery. However, they produce poor quality of vegetable seedlings on their own farm. Therefore it is recommended to establish communal vegetable nursery on the command area located as near as possible to the water source, not exposed to strong wind and/or protected from strong wind and sun, the area should have a flat or slightly with gentle slope; and should have light and medium texture and well-drained soils.

Major actors: irrigation water users' association, woreda and zone marketing department, business partners and others.

Expected output: The marketing wing of the irrigation water users' association will have clear plan for the management of the marketing system and to interact with identified potential business partners. Contractual agreement could be undertaken with identified traders, governmental institutions, NGOs and agro-processors.

10.7 Establishing market linkage

Objective of the intervention: to identify potential market outlets for each agricultural product and develop marketing network.

The crops growing in the study area are not well linked with market. Lack of market linkage will greatly reduce the income farmers could get. Especially for the perishable crops, traders offer prices that the farmers cannot negotiate on. So, to meet with the intended objectives of the project, it is highly crucial to link the producers, cooperatives, and the union with both national and international markets. By doing so, it is possible to transform the subsistence farming system into technology-supported and market-led household enterprise system capable of supplying produces on a sustainable basis.

Major actors: irrigation users' cooperatives, woreda and zone marketing department, business partners and others.

Expected output: The marketing wing of the irrigation users' cooperatives will have clear plan for the management of the marketing system and to interact with identified potential business partners. Contractual agreement could be undertaken with identified traders, governmental institutions, NGOs and agro-processors.

10.8 Establishing strong linkage with Research

Objective: Promote research based technologies to enhance crop productivity.

Axum agricultural research center is located at Axum town. This research center is established to generate appropriate technologies that enhance sustainable agriculture development and natural resources conservation, utilization and management; popularize improved technologies that have proven to be effective in innovative manner; to coordinate network research activities in its mandate areas (Chemiet irrigation project is under the mandate area of this research center). Axum research center is organized into different programs namely, cop research program, natural resources management research, livestock research and socio-economics and extension research.

This research center is undertaking adaptation trial and seed multiplication of improved varieties in the study area by organizing farmers' research groups. Moreover, the crops proposed for Chemiet irrigation project are major commodities of this research center. So, establishing strong linkage between Chemiet irrigation project and Axum agricultural research center will help to attain the intended objectives of the project.

Main actors: woreda/tabiya agriculturalists, potential and knowledgeable farmers, researchers, tabiya development committee

10.9 Establishing irrigation users' association

As it is stated above, the ultimate goal of any irrigation development is to increase production so as to improve the living standard of the farmers. To achieve at this goal, efficient utilization and management of the irrigation water is highly important. So, there must be strong irrigation users' association irrigation users' association in the area.

In view of this fact, the farmers of the study area should be organized under irrigation users' association. If there is strong irrigation users' association in the area, the farmers will develop strong sense of ownership and control over their scheme, the irrigation system will be well managed, improved water supply will be guaranteed, and any conflict that can occur in using the irrigation water will be resolved. Moreover, since the cooperative will facilitate communication and decision making, when to grow what type of crops will be planned ahead; inputs and other materials needed by the farmers will be available at the required amount and time and market problem to sell the produce will be solved for the produce will be supplied to potential markets by the cooperative.

10.10 Establishing Farmers' Research Group (FRG)

Poor Research – Extension-Farmers linkage is one of the main constraints of the project scheme. Hence, establishing farmers' research group is recommended as main approach to improve strong linkage between Axum research center and Ruba Chemiet irrigation scheme. The research works that are conducted on farmers' fields are done by organizing farmers' research groups (i.e. one team/scheme includes 40 farmers with two sub-groups). Organizing famers' research groups is very effective for demonstration, dissemination and adoption of new technologies. Hence, the research works being carried around the study area will be great input for the envisaged irrigation agriculture.

10.11 Land development plan

Considering the enthusiasm of the beneficiary farmers on the envisaged irrigation project and the commitment of the regional government to develop the area under irrigation, there is a possibility of developing the whole command area starting from the first year of the project implementation period; that is to say after completion of the infrastructures. Nevertheless, it is very important to plan ahead to avoid potential challenges to realize this assumption. These challenges could be unforeseen problems associated with technical, financial, social and environmental limitations.

10.12 Supports required from Governments and NGOs

According to the discussions made with the administrators and development agents of the tabia, the major support required from Governments and NGOs include:

- Supplying of high yielding verities of crops
- Purchase of pesticides and herbicides that are not locally available
- Adequate and timely supply of the above mentioned inputs
- Supplying of improved farm tools and post-harvest technologies
- Improvement of Research–Extension-farmers linkages
- Supplying of rural level agro-processing and value addition technologies
- Popularization of improved technologies

- Improvement of road connectivity
- Improve agri-market efficiency and information system of collection and dissemination
- Bring down the rate of interest on loans
- Training of the framers, development agents, woreda experts and the water users of the envisaged irrigation scheme; and
- Equipping the FTC with basic facilities such as audio-visual equipment's.

10.13 Implementation arrangements

After the construction of all the irrigation structures, the envisaged irrigation scheme will be handed over to the beneficiary farmers (IWUA). It will, then, be operated by the IWUA of the scheme with technical support from the Woreda Office of Agriculture and Rural Development and development agents of the tabiya. The Agricultural development plan shows all the interventions proposed for envisaged irrigation scheme over the next five years of the project implementation period. These interventions need to be implemented phase by phase based on the progresses scored.

10.14 Crops cost of cultivation and input requirement of the project area

Agricultural inputs estimation is part of the agricultural development planning that determine the rates of input applications, types of inputs and quantity considered to meet the proposed optimum crop yields. During this feasibility study the essential agricultural inputs such as fertilizer, improved seed, agro-chemicals, farm labor and oxen power was specified and quantified based on the proposed crops. Determination of the inputs will be a basis for input supply during implementation period and for financial analysis of the project.

Table 23 One year Seed r requirement of the study area

crops	CCA %	Area	Kg/ha	Total kg	Unit price	Total price
Wet season seed requirement						
Teff	10	10.2	12	122.4	22.1	2705.04
Maize	20	20.4	30	612	14.25	8721
Sorghum	30	30.6	10	306	5.47	1673.82
Flux	10	10.2	10	102	22	2244
Chickpea	10	10.2	10	102	18	1836
Lentil	10	10.2	80	816	28.3	23092.8
Total	**90**			**918**		**40272.66**
Dry season seed requirement						
Fenugreek	15	15.3	45	688.5	12	8262
Pepper	30	30.6	3	91.8	1500	137700
Swiss chard	20	20.4	10	204	698	142392
Tomato	25	25.5	0.25	6.375	2195	13993.13
Total	**90**			**990.675**		**302347.1**
Perrenial crops seed requirement						
Citrus	5	5.1	313 pieces	1596	15	8139
Mango	5	5.1	204 pieces	1040	20	5304

Note: Potential Source: Ethiopian improved seed agency, Regional seed agencies, Certified private commercial farms, Ethiopian agricultural research centers, Small holder farmers

Table 24 One year fertilizer requirement of the study area

crops	CCA %	Area	Kg/ha	Total kg	Unit price	Total price
Wet season seed requirement						
Teff	10	10.2	12	122.4	22.1	2705.04
Maize	20	20.4	30	612	14.25	8721
Sorghum	30	30.6	10	306	5.47	1673.82
Flux	10	10.2	10	102	22	2244
Chickpea	10	10.2	40	408	18	7344
Lentil	10	10.2	40	408	28.3	11546.4
Total	**90**			**816**		**34234.26**
Dry season seed requirement						
Fenugreek	15	15.3	45	688.5	12	8262
Pepper	30	30.6	3	91.8	1500	137700
Swiss chard	20	20.4	10	204	698	142392
Tomato	25	25.5	2.5	63.75	2195	139931.3
Total	**90**			**1048.05**		**428285.3**
Perrenial crops seed requirement						
Citrus	5	5.1	313 pieces	1596	15	8139
Mango	5	5.1	204 pieces	1040	20	5304

Potential Source: Multipurpose cooperatives and unions

Table 25 One year chemical requirement of the study area

crops	CCA %	Area	Compound				Urea			
			Kg/ha	Total kg	Unit price	Total price	Kg/ha	Total kg	Unit price	Total price
Wet season fertilizer requirement										
Teff	10	10.2	100	1020	13.932	14210.6	50	510	11.76	5997.6
Maize	20	20.4	100	2040	13.932	28421.3	50	1020	11.76	11995.2
Sorghum	30	30.6	100	3060	13.932	42631.9	50	1530	11.76	17992.8
Flux	10	10.2	50	510	13.932	7105.32	0	0	11.76	0
Chickpea	10	10.2	20	204	13.932	2842.13	0	0	11.76	0
Lentil	10	10.2	50	510	13.932	7105.32	0	0	11.76	0
Total				**7344**		**102317**		**3060**		**35985.6**
Dry season fertilizer requirement										
Fenugreek	15	15.3	50	765	13.932	10658	0	0	11.76	0
Pepper	30	30.6	200	6120	13.932	85263.8	100	3060	11.76	35985.6
Swiss chard	20	20.4	50	1020	13.932	14210.6	200	4080	11.76	47980.8
Tomato	25	25.5	200	5100	13.932	71053.2	100	2550	11.76	29988
Total				**13005**		**181186**		**9690**		**113954**
Perrenial crops fertilizer requirement										
Citrus	5	5.1	0.15/piece	239.4	13.932	3335.32	0.3/piece	478.8	11.76	8139
Mango	5	5.1	0.15/piece	156	13.932	2173.39	0.3/piece	312	11.76	5304

Potential Source: Multipurpose cooperatives and legal traders

Table 26 Labor and oxen requirement of the study area

crops	Oxen	Unit price	Total price	Labor	Unit price	Total price
Teff	36	250	9000	71	90	6390
Maize	12	250	3000	64	90	5760
Sorghum	12	250	3000	64	90	5760
Flux	16	250	4000	83	90	7470
Chickpea	16	250	4000	75	90	6750
Lentil	12	250	3000	72	90	6480
Fenugreek	12	250	3000	280	90	22500
Pepper	12	250	3000	280	90	25200
Swiss chard	12	250	3000	421	90	37890
Tomato	12	250	3000	375	90	33750
Citrus				480	90	43200
Mango				480	90	43200

Table 27 Summarized supportive intervention profile of Ruba-Tsedya irrigation project

1. Title	Strengthened Agricultural Extension Services
2. Rational	The extension service has been performing unsatisfactorily with respect to the needs of the farmers. The extension service staff requires continuous training to disseminate irrigated farming technologies and on-farm water management. The existing weak agricultural extension service has to be enhanced to address the expected production constraints to attain optimum outputs for small-scale irrigation project. The main constraints encounter the extension service which need to be addressed are: • Farmers', WUAs, DAS and experts knowledge on improved irrigated farming practices and water management • Poor facilities and budget for DAs to provide an improved and effective extension services; and • Inadequate technical skills and knowledge of extension staff with respect to irrigated crop production, production of high value crops, as well as crop storage and marketing. • Shortage of budget to undertake on farm demonstration activities • Weak linkages between agricultural research and extension services;
3. Objectives	• Strengthen agricultural extension service • Improve the linkage between relevant institutions • Improve the technical knowledge of technical staff
4. Description	The activities of the sub-project include: • Conduct on-farm farmer's training on improved and new agricultural technologies • Conduct training on crop, soil and water management practices • Provision of essential facilities and sufficient budget • Conduct workshops and experience sharing • Joint monitoring and Evaluation
5. Implementation	• Tabiya and woreda agricultural offices will conduct on-site demonstration periodical trainings for the farmers • NGOS will conduct experience sharing on best irrigation practices in/out of the region • NGOS will conduct workshops on overall achievement of the irrigation scheme in woreda and region • Provision of essential facilities and sufficient budget to the DAs execute farmers' trainings, trials and demonstrations; • Joint monitoring and Evaluation on overall achievement of the irrigation scheme
6. Main benefits	• Enhance effectiveness of the extension service • Up-grade the capacity of the extension provider institution • Increase the crop productivity due to efficient technical support
7. Implementing agency	• WUA, Tabiya administration, WOARD, RBARD and NGOS
8. Performance Monitoring	Seasonal monitoring on • Effectiveness of the extension service intervention • Number of demonstration site • Capacity building, experience sharing and workshops • Beneficiary satisfaction • Sustainability of the intervention

Table 28 Budget Requirement of the project area

Component two Capacity Building conducted to woreda responsible bodies					
TOT Training on irrigation agronomy for Woreda experts	No	5	300	1500	BOARD
TOT Training on integrated soil fertility management for woreda experts	No	8	300	2400	>>
TOT Training on integrated crop protection management fo woreda experts	No	5	300	1500	>>
Sub-total				5400	
Component three Demonstration material and Equipment for FTC					
Improved seed	Qt	1	1454.23	1454.23	NGOs/BOARD
Fertilizer	Qt	3	1320.89	3962.67	>>
Chemicals	Lt	3	137.86	413.58	>>
Sprayer	No	3	1200	3600	>>
Balance	No	1	800	800	>>
Water can	No	5	120	600	>>
Spade	No	10	80	800	>>
Rake	No	10	60	600	>>
Digging hoe	No	10	100	1000	>>
Pick axe	No	10	100	1000	>>
Sickle	No	10	80	800	>>
Wheel barrow	No	10	300	3000	>>
Tape meter(50m)	No	3	500	1500	>>
Plastic rope (200m)	No	3	120	360	>>
TV	No	1	10000	10000	>>
DVD player	No	1	3000	3000	>>
Overhead projector	No	1	20000	20000	>>
white board	No	1	3000	3000	>>
Desktop computer with accessary	No	2	14000	28000	>>
Printer	No	1	10000	10000	>>
Motor cycle	No	2	140000	280000	>>
GPS	No	2	12000	24000	>>
Sub-total				397890	
Component four material and equipment for vegetable Nursury 0.5 ha					
Improved seed	kg	1.75	22945.5	40154.6	NGOs/BOARD
Fertilizer	Qt	1	4028.16	4028.16	>>
Chemicals	Lt	1	140	140	>>
Sprayer	No	3	1200	3600	>>
Balance	No	1	800	800	>>
Water can	No	5	120	600	>>
Spade	No	10	80	800	>>
Rake	No	10	60	600	>>
Digging hoe	No	10	100	1000	>>
Pick axe	No	10	100	1000	>>
Sickle	No	10	80	800	>>
Wheel barrow	No	10	300	3000	>>
Tape meter(50m)	No	3	500	1500	>>
Plastic rope (200m)	No	3	120	360	>>
Fancing	Meter	300	85	25500	>>
Pond or Riservior Width (2mx2m) Depth 1m	M^3	4	375	1500	
Sub-total				85383	
Component five material and equipment for seed multi[plication 0.5 ha					
Improved seed	Kg	1.75	1500	2625	NGOs/BOARD
Fertilizer	Qt	2	1285	2570	>>
Chemicals	Lt	2	140	280	>>
Labor	Pd	100	70	7000	>>
Fancing	Meter	300	85	25500	>>
Pond or Riservior Width (2mx2m) Depth 1m	M3	4	375	1500	>>
Sub-total				39475	
Component Six Experience sharing					
Experience sharing visit on best irrigation practice out of region	No	30	500	15000	NGOs
Experience sharing visit on best irrigation practice in the region	No	30	400	12000	>>
Stakeholders workshop in woreda	No	30	200	6000	>>
Stakeholders workshop in region	No	30	500	15000	>>
Sub-total				48000	
Component srven					
Joint Monitoring and Evaluation for the scheme/every quarter	No	32	300	9600	
Sub-total				9600	NGOs/BOARD/WOARD
Total				620273.3	

11. CONCLUSION AND RECOMMENDATION

In this agronomy feasibility study report of Chemiet irrigation scheme, the base line agricultural information, input, yield, cropping system, meteorological and other related data's are collected. The existing crop production system, agricultural support services and constraints and potentials of the area for irrigation development are assessed. The crop water requirement of these crops is worked out using CROPWAT 8 software. Moreover, improved agricultural practices are recommended, yield of the proposed crops is estimated and possible interventions are proposed.

The main purpose of this irrigation scheme is increasing agricultural production and bringing food security. This in turn is believed to have significant contribution on poverty alleviation. To achieve at this objective, efficient utilization of the irrigation water is highly crucial. So, the farmers of the study area should be given training on how to manage the scheme and how to use the irrigation water properly and to be sustainable irrigation adoption of participatory approach, multidisciplinary approach, efficient watershed management, availability and accessibility of market, efficient and sufficient extension and involvement of social organization in water management are required.

Unreserved effort is also required from the farmers to implement all the recommendation made in this study report. Furthermore, strong commitment is required from the SMSs of the woreda and development agents of the tabias to give all necessary technical assistance to the farmers.

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13. Appendix

Annex 1: Irrigation Scheduling

Annex 1.1: Chickpea

Timing irrigate at fixed interval per stage

Initial: 14 days, Development: 13 days, Mid: 10 days, late: 14 days

Application fixed application depth of 40mm

Field Efficiency 70%

Date	Day	Stage	Rain	Ks	Eta	Depl	Net Irr	Deficit	Loss	Gr. Irr	Flow
			mm	fract.	%	%	mm	mm	mm	mm	l/s/ha
14-Jun	14	Init	0	1	100	4	40	0	34.3	57.1	0.47
27-Jun	27	Dev	18.4	1	100	1	40	0	37.4	57.1	0.51
10-Jul	40	Dev	0	1	100	6	40	0	25	57.1	0.51
20-Jul	50	Mid	0	1	100	6	40	0	22.1	57.1	0.66
30-Jul	60	Mid	0	1	100	6	40	0	22.2	57.1	0.66
9-Aug	70	Mid	0	1	100	4	40	0	27.3	57.1	0.66
23-Aug	84	End	42.6	1	100	1	40	0	37.8	57.1	0.47
29-Aug	End	End	0	1	100	1					

Annex 1.2: Lentil

Timing irrigate at fixed interval per stage

Initial: 10 days, Development: 8 days, Mid: 6 days, late: 10 days

Application fixed application depth of 40mm

Field Efficiency 70%

Date	Day	Stage	Rain	Ks	Eta	Depl	Net Irr	Deficit	Loss	Gr. Irr	Flow
			mm	fract.	%	%	mm	mm	mm	mm	l/s/ha
10-Jun	10	Init	0	1	100	6	40	0	31.7	57.1	0.66
20-Jun	20	Init	0	1	100	5	40	0	32	57.1	0.66
28-Jun	28	Dev	0	1	100	2	40	0	34.7	57.1	0.83
6-Jul	36	Dev	0	1	100	6	40	0	25.1	57.1	0.83
14-Jul	44	Dev	0	1	100	3	40	0	31.1	57.1	0.83
20-Jul	50	Mid	0	1	100	6	40	0	22.1	57.1	1.1
26-Jul	56	Mid	0	1	100	6	40	0	22.2	57.1	1.1
1-Aug	62	Mid	0	1	100	9	40	0	13.5	57.1	1.1
7-Aug	68	Mid	49	1	100	1	40	0	35.8	57.1	1.1
13-Aug	74	Mid	56.4	1	100	1	40	0	35.9	57.1	1.1
19-Aug	80	Mid	0	1	100	4	40	0	27.8	57.1	1.1
29-Aug	90	End	0	1	100	4	40	0	27.6	57.1	0.66
8-Sep	100	End	0	1	100	2	40	0	33.2	57.1	0.66
18-Sep	End	End	0	1	100	1					

Annex 1.3: Flux

Timing irrigate at fixed interval per stage

Initial: 14 days, Development: 12 days, Mid: 8 days, late: 14 days

Application fixed application depth of 40mm

Field Efficiency 70%

Date	Day	Stage	Rain	Ks	Eta	Depl	Net Irr	Deficit	Loss	Gr. Irr	Flow
			mm	fract.	%	%	mm	mm	mm	mm	l/s/ha
14-Jun	14	Init	0	1	100	2	40	0	36.4	57.1	0.47
26-Jun	26	Dev	0	1	100	3	40	0	32.7	57.1	0.55
8-Jul	38	Dev	0	1	100	2	40	0	34.6	57.1	0.55
20-Jul	50	Dev	0	1	100	4	40	0	25.7	57.1	0.55
28-Jul	58	Mid	0	1	100	2	40	0	31.3	57.1	0.83
5-Aug	66	Mid	0	1	100	3	40	0	27.3	57.1	0.83
13-Aug	74	Mid	56.4	1	100	1	40	0	36	57.1	0.83
21-Aug	82	Mid	0	1	100	5	40	0	19.5	57.1	0.83
29-Aug	90	Mid	0	1	100	3	40	0	26.9	57.1	0.83
12-Sep	104	End	0	1	100	6	40	0	16.1	57.1	0.47
26-Sep	118	End	0	1	100	5	40	0	21.5	57.1	0.47
28-Sep	End	End	0	1	100	1					

Annex 1.4: Maize

Timing irrigate at fixed interval per stage

Initial: 14 days, Development: 8 days, Mid: 7 days, late: 10 days

Application fixed application depth of 60mm

Field Efficiency 70%

Date	Day	Stage	Rain	Ks	Eta	Depl	Net Irr	Deficit	Loss	Gr. Irr	Flow
			mm	fract.	%	%	mm	mm	mm	mm	l/s/ha
14-Jun	14	Init	0	1	100	2	60	0	57	85.7	0.71
22-Jun	22	Dev	0	1	100	6	60	0	49.4	85.7	1.24
30-Jun	30	Dev	0	1	100	4	60	0	50.8	85.7	1.24
8-Jul	38	Dev	0	1	100	3	60	0	52.6	85.7	1.24
16-Jul	46	Mid	0	1	100	6	60	0	41.5	85.7	1.24
23-Jul	53	Mid	39.7	1	100	2	60	0	55.4	85.7	1.42
30-Jul	60	Mid	0	1	100	6	60	0	41.5	85.7	1.42
6-Aug	67	Mid	0	1	100	6	60	0	42.4	85.7	1.42
13-Aug	74	Mid	56.4	1	100	1	60	0	56.2	85.7	1.42
23-Aug	84	End	42.6	1	100	1	60	0	57.8	85.7	0.99
29-Aug	End	End	0	1	100	2					

Annex 1.5: Sorghum

Timing irrigate at fixed interval per stage

Initial: 14 days, Development: 10 days, Mid: 8 days, late: 14 days

Application fixed application depth of 60mm

Field Efficiency 70%

Date	Day	Stage	Rain	Ks	Eta	Depl	Net Irr	Deficit	Loss	Gr. Irr	Flow
			mm	fract.	%	%	mm	mm	mm	mm	l/s/ha
14-Jun	14	Init	0	1	100	2	60	0	57	85.7	0.71
24-Jun	24-Jan	Dev	0	1	100	2	60	0	55.8	85.7	0.99
4-Jul	3-Feb	Dev	0	1	100	2	60	0	53.7	85.7	0.99
14-Jul	13-Feb	Dev	0	1	100	2	60	0	52.3	85.7	0.99
22-Jul	21-Feb	Mid	0	1	100	6	60	0	36.9	85.7	1.24
30-Jul	29-Feb	Mid	0	1	100	4	60	0	44.6	85.7	1.24
7-Aug	8-Mar	Mid	49	1	100	1	60	0	56.3	85.7	1.24
15-Aug	16-Mar	Mid	0	1	100	3	60	0	49.5	85.7	1.24
29-Aug	30-Mar	End	0	1	100	2	60	0	50.5	85.7	0.71
8-Sep	End	End	0	1	100	1					

Annex 1.6: Teff

Timing irrigate at fixed interval per stage

Initial: 14 days, Development: 10 days, Mid: 8 days, late: 14 days

Application fixed application depth of 30mm

Field Efficiency 70%

Date	Day	Stage	Rain	Ks	Eta	Depl	Net Irr	Deficit	Loss	Gr. Irr	Flow
			mm	fract.	%	%	mm	mm	mm	mm	l/s/ha
3-Jul	14	Init	27.5	1	100	1	30	0	28.3	42.9	0.35
15-Jul	26	Dev	0	1	100	4	30	0	24.5	42.9	0.41
25-Jul	36	Dev	0	1	100	6	30	0	21.7	42.9	0.5
4-Aug	46	Dev	0	1	100	5	30	0	22.7	42.9	0.5
12-Aug	54	Mid	0	1	100	15	30	0	8	42.9	0.62
20-Aug	62	Mid	0	1	100	10	30	0	15.1	42.9	0.62
28-Aug	70	Mid	0	1	100	6	30	0	22	42.9	0.62
5-Sep	78	Mid	0	1	100	9	30	0	17	42.9	0.62
13-Sep	86	Mid	11.8	1	100	13	30	0	10.6	42.9	0.62
27-Sep	100	End	8.4	1	100	19	30	0	1.7	42.9	0.35
10-Oct	End	End	3.9	1	100	9					

Annex 1.7: Fenugreek

Timing irrigate at fixed interval per stage

Initial: 10 days, Development: 8 days, Mid: 6 days, late: 10 days

Application fixed application depth of 40mm

Field Efficiency 70%

Date	Day	Stage	Rain	Ks	Eta	Depl	Net Irr	Deficit	Loss	Gr. Irr	Flow
			mm	fract.	%	%	mm	mm	mm	mm	l/s/ha
10-Dec	10	Init	0	1	100	11	40	0	25.3	57.1	0.66
18-Dec	18	Dev	0	1	100	7	40	0	27	57.1	0.83
26-Dec	26	Dev	0	1	100	9	40	0	19.3	57.1	0.83
3-Jan	34	Dev	0.4	1	100	10	40	0	12.8	57.1	0.83
10-Jan	41	Mid	0	1	100	10	40	0	10.3	57.1	0.94
16-Jan	47	Mid	0	1	100	10	40	0	11.3	57.1	1.1
22-Jan	53	Mid	0	1	100	10	40	0	10.4	57.1	1.1
28-Jan	59	Mid	0	1	100	10	40	0	9.6	57.1	1.1
3-Feb	65	Mid	0	1	100	11	40	0	8.6	57.1	1.1
9-Feb	71	Mid	0	1	100	11	40	0	7.8	57.1	1.1
15-Feb	77	Mid	0	1	100	11	40	0	6.8	57.1	1.1
25-Feb	87	End	0	1	100	17	40	10.2	0	57.1	0.66
7-Mar	97	End	2.7	1	100	13	40	0	2.6	57.1	0.66
10-Mar	End	End	0	1	100	2					

Annex 1.8: Pepper

Timing irrigate at fixed interval per stage

Initial: 11 days, Development: 8 days, Mid: 6 days, late: 11 days

Application fixed application depth of 40mm

Field Efficiency 70%

Date	Day	Stage	Rain	Ks	Eta	Depl	Net Irr	Deficit	Loss	Gr. Irr	Flow
			mm	fract.	%	%	mm	mm	mm	mm	l/s/ha
11-Dec	11	Init	0	1	100	22	40	0	14.9	57.1	0.6
21-Dec	21	Dev	0	1	100	16	40	0	17	57.1	0.66
29-Dec	29	Dev	0	1	100	12	40	0	18.1	57.1	0.83
6-Jan	37	Dev	0	1	100	14	40	0	12.5	57.1	0.83
14-Jan	45	Dev	0	1	100	14	40	0	7.9	57.1	0.83
20-Jan	51	Mid	0	1	100	11	40	0	13.9	57.1	1.1
26-Jan	57	Mid	0	1	100	12	40	0	12.1	57.1	1.1
1-Feb	63	Mid	0	1	100	12	40	0	11.6	57.1	1.1
7-Feb	69	Mid	0	1	100	13	40	0	10.4	57.1	1.1
13-Feb	75	Mid	0	1	100	13	40	0	10.1	57.1	1.1
24-Feb	26-Mar	End	0	1	100	23	40	14.4	0	57.1	0.6
28-Feb	End	End	0	1	100	12					

Annex 1.9: Swiss chard

Timing irrigate at fixed interval per stage

Initial: 7 days, Development: 5 days, Mid: 3 days, late: 7 days

Application fixed application depth of 30 mm

Field Efficiency 70%

Date	Day	Stage	Rain	Ks	Eta	Depl	Net Irr	Deficit	Loss	Gr. Irr	Flow
			mm	fract.	%	%	mm	mm	mm	mm	l/s/ha
7-Dec	7	Init	0.7	1	100	21	30	0	11.7	42.9	0.71
14-Dec	14	Init	0	1	100	18	30	0	11.1	42.9	0.71
21-Dec	21	Dev	0	1	100	16	30	0	11	42.9	0.71
26-Dec	26	Dev	0	1	100	12	30	0	14.8	42.9	0.99
31-Dec	31	Dev	0	1	100	11	30	0	14.4	42.9	0.99
5-Jan	36	Dev	0	1	100	12	30	0	11.3	42.9	0.99
10-Jan	41	Dev	0	1	100	11	30	0	11.3	42.9	0.99
15-Jan	46	Mid	0	1	100	12	30	0	8.4	42.9	0.99
18-Jan	49	Mid	0	1	100	7	30	0	17.2	42.9	1.65
21-Jan	52	Mid	0	1	100	8	30	0	16.6	42.9	1.65
24-Jan	55	Mid	0	1	100	8	30	0	16.3	42.9	1.65
27-Jan	58	Mid	0.2	1	100	8	30	0	16.3	42.9	1.65
30-Jan	61	Mid	0	1	100	8	30	0	16	42.9	1.65
2-Feb	64	Mid	0	1	100	8	30	0	15.6	42.9	1.65
5-Feb	67	Mid	0	1	100	8	30	0	15.3	42.9	1.65
8-Feb	70	Mid	0	1	100	8	30	0	15.3	42.9	1.65
11-Feb	73	Mid	0	1	100	9	30	0	15.1	42.9	1.65
18-Feb	80	End	0	1	100	20	30	5.6	0	42.9	0.71
25-Feb	87	End	0	1	100	24	30	11.2	0	42.9	0.71
4-Mar	94	End	0	1	100	25	30	14.1	0	42.9	0.71
10-Mar	End	End	0	1	100	21					

Annex 1.10: Tomato

Timing irrigate at fixed interval per stage

Initial: 8 days, Development: 7 days, Mid: 6 days, late: 10 days

Application fixed application depth of 40mm

Field Efficiency 70%

Date	Day	Stage	Rain	Ks	Eta	Depl	Net Irr	Deficit	Loss	Gr. Irr	Flow
			mm	fract.	%	%	mm	mm	mm	mm	l/s/ha
8-Dec	8	Init	0	1	100	16	40	0	22.1	57.1	0.83
16-Dec	16	Init	0	1	100	12	40	0	21.6	57.1	0.83
23-Dec	23	Dev	0.4	1	100	10	40	0	22.3	57.1	0.94
30-Dec	30	Dev	0	1	100	9	40	0	19.9	57.1	0.94
6-Jan	37	Dev	0	1	100	10	40	0	13.7	57.1	0.94
13-Jan	44	Dev	0.3	1	100	10	40	0	10.1	57.1	0.94
19-Jan	50	Mid	0	1	100	10	40	0	11.6	57.1	1.1
25-Jan	56	Mid	0	1	100	10	40	0	9.8	57.1	1.1
31-Jan	62	Mid	0	1	100	11	40	0	9.5	57.1	1.1
6-Feb	68	Mid	0	1	100	11	40	0	7.7	57.1	1.1
12-Feb	74	Mid	0	1	100	11	40	0	7.3	57.1	1.1
18-Feb	80	Mid	0	1	100	12	40	0	6.3	57.1	1.1
28-Feb	90	End	0	1	100	18	40	11.9	0	57.1	0.66
5-Mar	End	End	0	1	100	9					

Annex 1.11: Citrus

Timing irrigate at fixed interval per stage

Initial: 15 days, Development: 12 days, Mid: 8 days, late: 8 days

Application fixed application depth of 60mm

Field Efficiency 70%

Date	Day	Stage	Rain	Ks	Eta	Depl	Net Irr	Deficit	Loss	Gr. Irr	Flow
			mm	fract.	%	%	mm	mm	mm	mm	l/s/ha
15-Dec	15	Init	0	1	100	10	60	0	20.1	85.7	0.66
30-Dec	30	Init	0	1	100	10	60	0	19.9	85.7	0.66
14-Jan	45	Init	0	1	100	10	60	0	18.6	85.7	0.66
29-Jan	60	Init	0	1	100	11	60	0	16.3	85.7	0.66
10-Feb	72	Dev	0	1	100	9	60	0	22.3	85.7	0.83
22-Feb	84	Dev	0	1	100	10	60	0	20.4	85.7	0.83
6-Mar	96	Dev	0	1	100	9	60	0	21.8	85.7	0.83
18-Mar	108	Dev	0	1	100	8	60	0	26	85.7	0.83
30-Mar	120	Dev	0	1	100	9	60	0	24.7	85.7	0.83
11-Apr	132	Dev	0	1	100	9	60	0	22.4	85.7	0.83
23-Apr	144	Dev	4.5	1	100	8	60	0	25.9	85.7	0.83
1-May	152	Mid	0	1	100	6	60	0	35.3	85.7	1.24
9-May	160	Mid	0	1	100	5	60	0	40.9	85.7	1.24
17-May	168	Mid	7.6	1	100	3	60	0	46.3	85.7	1.24
25-May	176	Mid	0	1	100	5	60	0	41.2	85.7	1.24
2-Jun	184	Mid	0	1	100	6	60	0	36	85.7	1.24
10-Jun	192	Mid	0	1	100	4	60	0	42.9	85.7	1.24
18-Jun	200	Mid	0	1	100	2	60	0	51.4	85.7	1.24
26-Jun	208	Mid	0	1	100	3	60	0	48	85.7	1.24
4-Jul	216	Mid	0	1	100	1	60	0	54.4	85.7	1.24
12-Jul	224	Mid	0	1	100	4	60	0	43.6	85.7	1.24
20-Jul	232	Mid	0	1	100	3	60	0	49.6	85.7	1.24
28-Jul	240	Mid	0	1	100	1	60	0	55	85.7	1.24
5-Aug	248	Mid	0	1	100	2	60	0	52.8	85.7	1.24
13-Aug	256	Mid	56.4	1	100	1	60	0	57.7	85.7	1.24
21-Aug	264	Mid	0	1	100	3	60	0	48.2	85.7	1.24
29-Aug	272	End	0	1	100	2	60	0	52.3	85.7	1.24
6-Sep	280	End	0	1	100	3	60	0	48.1	85.7	1.24
14-Sep	288	End	0	1	100	3	60	0	47.2	85.7	1.24
22-Sep	296	End	0	1	100	5	60	0	40.8	85.7	1.24
30-Sep	304	End	0	1	100	4	60	0	42.1	85.7	1.24
8-Oct	312	End	0	1	100	5	60	0	41.2	85.7	1.24
16-Oct	320	End	0	1	100	7	60	0	31.6	85.7	1.24
24-Oct	328	End	0	1	100	7	60	0	32.3	85.7	1.24
1-Nov	336	End	0	1	100	7	60	0	33.2	85.7	1.24
9-Nov	344	End	0	1	100	6	60	0	36.9	85.7	1.24
17-Nov	352	End	1.2	1	100	5	60	0	37.7	85.7	1.24
25-Nov	360	End	0	1	100	6	60	0	36.9	85.7	1.24
30-Nov	End	End	0	1	0	3					

Annex 1.12: Mango

Timing irrigate at fixed interval per stage

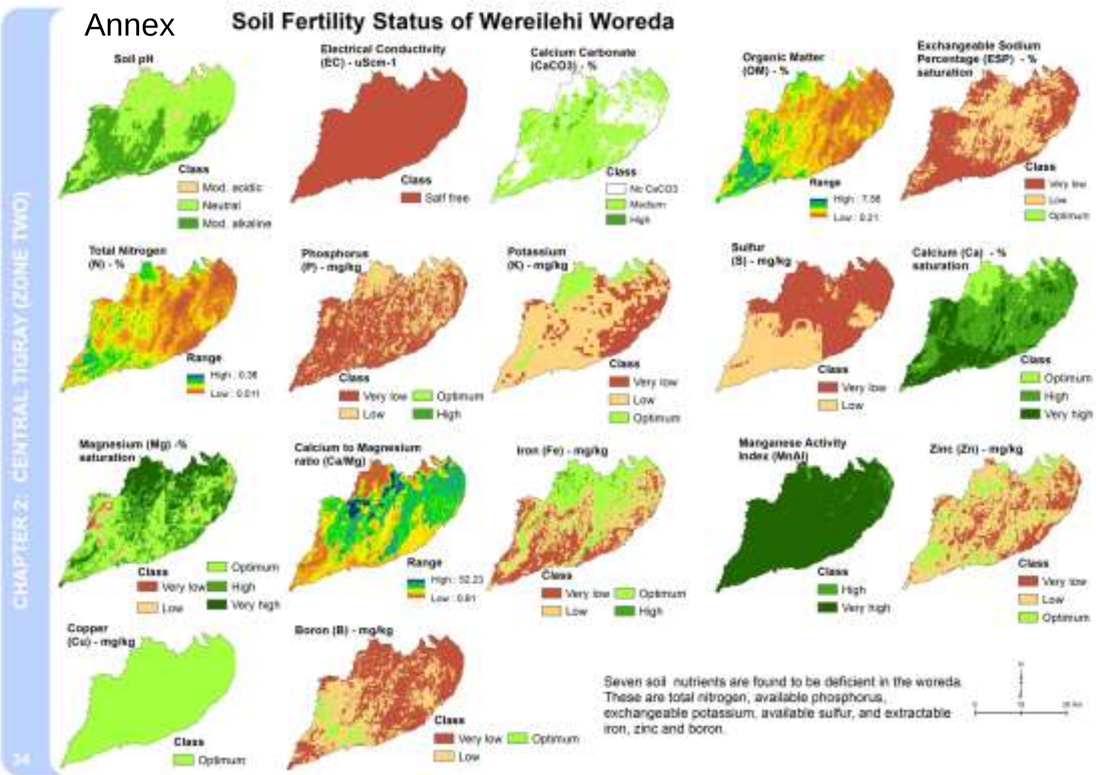
Initial: 15 days, Development: 12 days, Mid: 8 days, late: 8 days

Application fixed application depth of 60mm

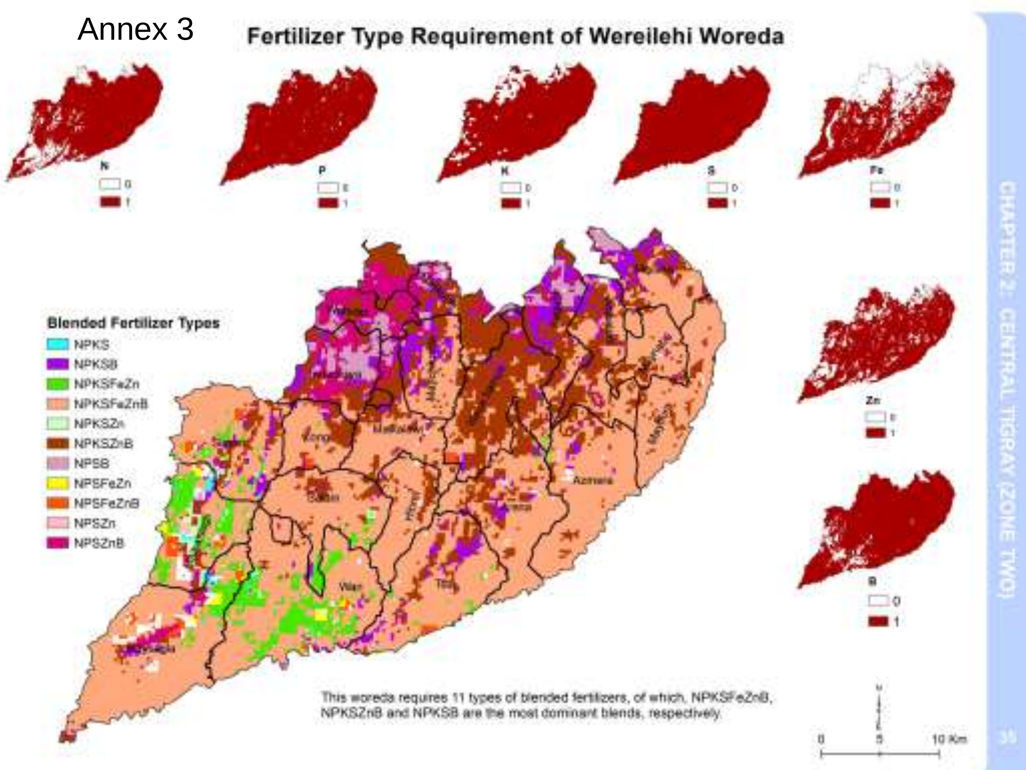
Field Efficiency 70%

Date	Day	Stage	Rain	Ks	Eta	Depl	Net Irr	Deficit	Loss	Gr. Irr	Flow
			mm	fract.	%	%	mm	mm	mm	mm	l/s/ha
15-Dec	15	Init	0	1	100	9	60	0	8.2	85.7	0.66
30-Dec	30	Init	0	1	100	9	60	0	8.1	85.7	0.66
14-Jan	45	Init	0	1	100	9	60	0	6.5	85.7	0.66
29-Jan	60	Init	0	1	100	10	60	0	3.6	85.7	0.66
13-Feb	75	Init	0	1	100	11	60	1.6	0	85.7	0.66
28-Feb	90	Init	0	1	100	12	60	7.1	0	85.7	0.66
12-Mar	102	Dev	0	1	100	10	60	0	2	85.7	0.83
24-Mar	114	Dev	0	1	100	9	60	0	8.1	85.7	0.83
5-Apr	126	Dev	0	1	100	10	60	0	3.9	85.7	0.83
17-Apr	138	Dev	2.9	1	100	10	60	0	2.3	85.7	0.83
29-Apr	150	Dev	0	1	100	10	60	0	0.4	85.7	0.83
11-May	162	Dev	0	1	100	10	60	0	2.6	85.7	0.83
23-May	174	Dev	9.3	1	100	8	60	0	12.4	85.7	0.83
31-May	182	Mid	0	1	100	6	60	0	23	85.7	1.24
8-Jun	190	Mid	0	1	100	4	60	0	34.4	85.7	1.24
16-Jun	198	Mid	0	1	100	6	60	0	27	85.7	1.24
24-Jun	206	Mid	0	1	100	4	60	0	36.6	85.7	1.24
2-Jul	214	Mid	0	1	100	5	60	0	30.3	85.7	1.24
10-Jul	222	Mid	0	1	100	3	60	0	41.1	85.7	1.24
18-Jul	230	Mid	0	1	100	2	60	0	51.2	85.7	1.24
26-Jul	238	Mid	0	1	100	3	60	0	43	85.7	1.24
3-Aug	246	Mid	49	1	100	1	60	0	56	85.7	1.24
11-Aug	254	Mid	0	1	100	3	60	0	40	85.7	1.24
19-Aug	262	Mid	0	1	100	2	60	0	48.4	85.7	1.24
27-Aug	270	Mid	42.6	1	100	1	60	0	55.8	85.7	1.24
4-Sep	278	End	0	1	100	2	60	0	49.9	85.7	1.24
12-Sep	286	End	0	1	100	5	60	0	33	85.7	1.24
20-Sep	294	End	0	1	100	4	60	0	34.9	85.7	1.24
28-Sep	302	End	0	1	100	4	60	0	39	85.7	1.24
6-Oct	310	End	0	1	100	6	60	0	25.7	85.7	1.24
14-Oct	318	End	0	1	100	7	60	0	20.5	85.7	1.24
22-Oct	326	End	0	1	100	7	60	0	20.7	85.7	1.24
30-Oct	334	End	0	1	100	6	60	0	23	85.7	1.24
7-Nov	342	End	1.3	1	100	6	60	0	27.8	85.7	1.24
15-Nov	350	End	0	1	100	6	60	0	28	85.7	1.24
23-Nov	358	End	1	1	100	5	60	0	30.4	85.7	1.24
30-Nov	End	End	0	1	0	4					

Annex



Annex 3



Annex 4 Typical values of surface irrigation efficiency

A. Conveyance efficiency (Ec) *(Losses in main and secondary canals)*

Canal length	Conveyance efficiency in %			
	Earthen canals by soil type			Lined canals
	Sand	Loam	Clay	
Long (> 2000 m)	60	70	80	95
Medium (200 – 2000 m)	70	75	85	95
Short (< 200 m)	80	85	90	95

B. Distribution efficiency (Ed) *(Losses in tertiary and quaternary canals)*

Blocks larger than 20 ha	Unlined canals	80%
	Lined or piped	90%
Blocks up to 20 ha	Unlined canals	70%
	Lined or piped	80%

C. Field Application Efficiency (Ea) *(Deep percolation and runoff losses)*

Light soils	55%
Medium soils	70%
Heavy soils	60%

Source: FAO Training manual 4 and Module on irrigation Agronomy, Mekele University

Appendix 5 Estimated irrigation schedules for the major field crops during peak water use periods at different climatic zones

Climate	Shallow and /or sandy soil				Loamy soil				Clayey soil			
	Interval (days)			Net Irr. Depth	Interval (days)			Net Irr. Depth	Interval (days)			Net Irr. Depth (mm)
	1	2	3		1	2	3		1	2	3	
Banana	5	3	2	25	7	5	4	40	10	7	5	55
Barley /oats	8	6	4	40	11	8	6	55	14	10	7	70
Beans	6	4	3	30	8	6	4	40	10	7	5	50
Carrot	6	4	3	25	7	5	4	35	11	8	6	50
Citrus	8	6	4	30	11	8	6	40	11	8	6	50
Coffee	9	6	5	40	13	9	7	60	16	11	8	70
Cotton	8	6	4	40	11	8	6	55	14	10	7	70
Cucumber	10	7	5	40	15	10	8	60	17	12	9	70
Cabbage / Cauliflower	3	2	2	15	6	3	2	20	7	5	4	30
Eggplant	6	4	3	30	8	6	4	40	10	7	5	50
Linseed	8	6	4	40	11	8	6	55	14	10	7	70
Fruit trees	9	6	5	40	13	9	7	60	16	11	8	70
Small grains	8	6	4	40	11	8	6	55	14	10	7	70
Grapes	11	8	6	40	15	11	8	55	19	13	10	70
Groundnuts	6	4	3	25	7	5	4	35	11	8	6	50
Lentils	6	4	3	30	8	6	4	40	10	7	5	50
Lettuce	3	2	2	15	6	3	2	20	7	5	4	30
Maize	8	6	4	40	11	8	6	55	14	10	7	70
Melons	9	6	5	40	13	9	7	60	16	11	8	70
Onions	3	2	2	15	6	3	2	20	7	5	4	30
Peas	6	4	3	30	8	6	4	40	10	7	5	50
Peppers	6	4	3	25	7	5	4	35	11	8	6	50
Potato	6	4	3	30	8	6	4	40	10	7	5	50
Safflower	8	6	4	40	11	8	6	55	14	10	7	70
Sorghum	8	6	4	40	11	8	6	55	14	10	7	70
Soybeans	8	6	4	40	11	8	6	55	14	10	7	70
Sugarcane	7	5	4	40	10	7	5	55	13	9	7	70
Sunflower	8	6	4	40	11	8	6	55	14	10	7	70
Tea	9	6	5	40	13	9	7	60	16	11	8	70
Tobacco	6	4	3	30	8	6	4	40	10	7	5	50
Wheat	8	6	4	40	11	8	6	55	14	10	7	70

Appendix 6 Sensitive growth periods to water deficit of major irrigated crops

Crop	Critical growth stages /periods to water deficit
Maize	Flowering > grain filling > vegetative period; flowering is very sensitive if no prior water deficit
Wheat	Flowering > yield formation > vegetative period
Groundnut	Flowering > yield formation, particularly during pod setting
Potato	Period of stolonization and tuber initiation > yield formation > early vegetative and ripening
Onion	Bulb enlargement, during rapid bulb growth > vegetative period /and for seed production at flower-ing/
Pepper	Throughout but particularly just prior and at start of flowering
Tomato	Flowering > yield formation > vegetative period, particularly during just and after transplanting
Banana	Throughout but particularly during first part of vegetative period, flowering and yield formation
Cabbage	During head enlargement and ripening
Alfalfa	Just after cutting (and for seed production at flowering)
Citrus	Grapefruit, lemon and orange flowering and fruit setting > fruit enlargement for lemon heavy flower-ing may be induced by withholding irrigation just before flowering
Cotton	Flowering and boll formation
Grape	Vegetative period, particularly during shoot elongation and flowering > fruit filling
Pineapple	During period of vegetative growth
Rice	During period of head development and flowering > vegetative period and ripening
Sugarcane	Vegetative period, particularly during period of tillering and stem elongation > yield formation
Watermelon	Flowering, fruit filling > vegetative period, particularly during vine development
Bean	Flowering & pod filling, vegetative period not sensitive when followed by ample water supply
Pea	Flowering and yield formation > vegetative, ripening for dry peas
Safflower	Flowering and pod filling > vegetative
Sorghum	Flowering > yield formation > vegetative period less sensitive when followed by ample water supply
Soybean	Flowering and yield formation, particularly during pod development
Sunflower	Flowering and yield formation, particularly during bud development
Tobacco	Period of rapid growth, yield formation and ripening

Source: Irrigation agronomy manual, former MoA- Agricultural Development Department, March 1990, Addis Ababa

Appendix 7 Approximate Rooting Depth of Major Field Crops

Shallow rooting crops (30-60 cm):	Crucifers (cabbage, cauliflower, etc.), celery, lettuce, onions, pineapple, potatoes, spinach, other vegetables except beets, carrots, cucumber.
Medium rooting crops (50-100 cm):	Bananas, beans, beets, carrots, clover, cacao, cucumber, groundnuts, palm trees, peas, pepper, sisal, soybeans, sugar beet, Sunflower, tobacco, tomatoes.
Deep rooting crops (90-150 cm):	Alfalfa, barley, citrus, cotton, dates, deciduous orchards, flax, grapes, maize, melons, oats, olives, safflower, sorghum, sugarcane, sweet potatoes, wheat.

Source: Irrigation agronomy manual, former MoA- Agricultural Development Department, March 1990, Addis Ababa

Appendix: 8 Soil laboratory result of Ruba-Cheniet and Ruba-Tsedya irrigation scheme

Tigray Agricultural Research (TARI)
Soil Research Center
Mekelle soil Laboratory
Wereda Semen, Mekelle, Ethiopia
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Testing Laboratory T0021

TEST REPORT

Client Name; Tigray water works study Design & Supervision enterprise
Address; Mekelle
Attention:Atsbha G/anenya
Tel.: 0914004028
e-mail; --

Report No.: RMSL-0304/18
Samples Received: 12/01/2018
Analysis Completed: 10/02/2018
Date of Report: 12/02/2018
Status of Report: Final
Nominated Representative
G/Giorgis Aregai, *QA/QC Head*
Technical Signatories:
Girmay Hajlu, Lab.Case team Head

Client Ref.: Your request for the lab. testing of samples
No. Samples:14 0f 167
Sample Type: Soil

For Administrative Case only
Name: G/medhine Berhe Responsibility: Centre Director Signature: Date:

Condition of samples:
This report relates specifically to the sample(s) tested in so far as that the sample(s) is truly representative of the sample delivered to our laboratory. All pages of this report have been checked and approved for release.

No.	Sample ID	Anayzed Parameters										
		PH	EC	MC	OC	CEC	AV.P	TN	Texture			
									% sand	% silt	% clay	class
45	MCTP03	7.320	0.029	2.145	1.164	13.687	7.252	0.055	36.0	34.0	30.0	Clay loam
46	ADH02	8.000	0.079	2.543	1.100	18.253	6.522	0.050	34.0	36.0	30.0	Clay loam
47	MCTP04	7.270	0.142	2.208	1.608	16.353	6.746	0.070	38.0	34.0	28.0	Clay loam
48	ADH06	6.390	0.049	1.958	1.114	13.458	6.301	0.055	32.0	36.0	32.0	Clay loam
49	ADH02	6.990	0.045	2.124	1.342	11.969	6.740	0.062	44.0	34.0	22.0	Loam
50	MCTP03	7.280	0.035	3.263	1.361	16.336	8.096	0.057	42.0	38.0	20.0	Loam
51	ADH04	6.920	0.027	4.690	1.249	14.028	7.601	0.056	30.0	40.0	30.0	Clay loam
52	ADH02	7.390	0.048	2.145	0.948	18.141	6.905	0.043	76.0	14.0	10.0	Sandy Loam
53	ADH08	7.160	0.056	2.501	1.985	24.047	6.089	0.099	38.0	32.0	30.0	Clay loam
54	ADH04	6.680	0.023	2.145	1.267	26.558	6.231	0.059	28.0	42.0	30.0	Clay loam
55	MCTP02	6.850	0.043	2.208	1.374	13.818	9.526	0.073	46.0	36.0	18.0	Loam
56	MCTP02	7.300	0.085	2.145	1.676	26.558	5.557	0.069	42.0	26.0	32.0	Clay loam
57	ADH04	6.900	0.083	1.235	0.807	13.687	6.256	0.043	72.0	8.0	20.0	Sandy Loam
58	ADH08	6.590	0.480	2.733	0.995	17.958	5.671	0.046	76.0	6.0	18.0	Sandy Loam
UNITS			Ms/cm	%	%	Meq / 100gm soil	ppm	%	%			Class
METHOD CODE		MSL-M5.05-1	MSL-M5.05-2	MSL-M5.05-3	MSL-M5.05-4	MSL-M5.05-5	MSL-M5.05-6	MSL-M5.05-7	MSL-M5.05-8			

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Special Notes:
The ISO 17025Accredited methods are OC (MSL-M5.04-4), TN (MSL-M5.04-7) & (CEC MSL-M5.04-5)!

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☎ (+251)344 41 61 22 , ✉ 1070

ENAO Testing Laboratory T0021

TEST REPORT

Client Name; Tigray water works study Design & Supervision enterprise
Address; Mekelle
Attention:Atsbha G/anenya
Tel.: 0914004028
e-mail; --

Report No.: RMSL-0304/18
Samples Received: 12/01/2018
Analysis Completed: 10/02/2018
Date of Report: 12/02/2018
Status of Report: Final

Nominated Representative
G/Giorgis Aregai, *QA/QC Head*

Technical Signatories:
Girmay Hailu, Lab.Case team Head

Client Ref.: Your request for the lab. testing of samples
No. Samples:14 0f 167
Sample Type: Soil

For Administrative Case only
Name: G/medhine Berhe Responsibility: Centre Director Signature: Date:

Condition of samples:
This report relates specifically to the sample(s) tested in so far as that the sample(s) is truly representative of the sample delivered to our laboratory. All pages of this report have been checked and approved for release.

No.	Sample ID	Anayzed Parameters				
		Exch.Ca	Exch. Mg	Exch.K	Exch.Na	OM
45	MCTP03	9.400	4.000	81.600	26.600	1.164
46	ADH02	12.200	3.600	63.200	30.400	1.100
47	MCTP04	7.200	1.600	45.900	29.100	1.608
48	ADH06	4.400	5.600	38.700	30.800	1.114
49	ADH02	5.600	3.800	44.700	28.000	1.342
50	MCTP03	7.400	5.000	37.300	30.500	1.361
51	ADH04	5.200	2.800	34.600	28.000	1.249
52	ADH02	11.000	2.600	43.200	20.000	0.948
53	ADH08	5.400	3.200	33.400	27.500	1.985
54	ADH04	6.000	3.800	36.700	28.900	1.267
55	MCTP02	6.800	5.400	61.700	27.800	1.374
56	MCTP02	9.400	3.600	7.500	30.900	1.676
57	ADH04	4.200	2.200	31.600	27.900	0.807
58	ADH08	6.600	3.600	34.900	29.500	0.995
UNITS		Meq/L	Meq/L	ppm	ppm	%
METHOD CODE		***	***		***	***

F5.10-2 Rev6 Feb 13, 2018
Special Notes:
The ISO 17025Accredited methods are OC (MSL-M5.04-4), TN (MSL-M5.04-7) & (CEC MSL-M5.04-5)!

Page 8 of 18

Tigray Agricultural Research
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TEST REPORT

Client Name; Tigray water works study Design & Supervision enterprise
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Client Ref.: Your request for the lab. testing of samples
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G/Giorgis Aregai,*QA/QC Head*
Technical Signatories:
Girmay Hailu, Lab.Case team Head

For Administrative Case only
Name: G/medhine Berhe Responsibility: Centre Director Signature: Date:

Condition of samples:
This report relates specifically to the sample(s) tested in so far as that the sample(s) is truly representative of the sample delivered to our laboratory. All pages of this report have been checked and approved for release.

TEST REPORT

No.	Sample ID	Analyzed Parameters (Bulk Density)								
		BD								
45	MCTP03	2.445								
46	ADH02	2.282								
47	MCTP04	2.059								
48	ADH06	2.048								
49	ADH02	2.223								
50	MCTP03	2.318								
51	ADH04	2.437								
52	ADH02	2.363								
53	ADH08	2.104								
54	ADH04	1.964								
55	MCTP02	2.206								
56	MCTP02	2.247								
57	ADH04	2.347								
58	ADH08	2.223								
UNITS		** gm/cm³								
METHOD CODE		**								

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Special Notes:
The ISO 17025Accredited methods are OC (MSL-M5.04-4), TN (MSL-M5.04-7) & (CEC MSL-M5.04-5)!

Appendix 9 Re-modified Agro-ecological zones of Ethiopia (MOA 2005)

Table 1. LGP classes (LUPRD, 1984)

LGP Days	Universal Terminology
A growing period of below 45 days	Arid
A growing period of 46-60 days	Semi-arid
A growing period of 61-120 days	Sub-moist
A growing period of 121-180 days	Moist
A growing period of 181-240 days	Sub-humid
A growing period of 241-300 days	Humid
A growing period of >300 days	Per-humid

Table 2. Thermal zones (LUPRD, 1984)

Temperature in ^{0}C	Universal terminology
>21	Hot to warm
11-21	Tepid to cool
<11	Cold to very cold.

Table 3. Reclassified thermal zones (2005)

Temperature in ^{0}C	Universal terminology	Elevation (m.a.s.l)
>27.5	Hot	<500
21-27.5	Warm	500-1600
16-20	Tepid	1600-2400
11-15	Cool	2400-3200
7.5-10	Cold	3200-3800
<7.5	Very cold	>3800

Table 4. Matrix, The combination of the thermal and moisture regime

Moisture regimes	Temperature regimes					
	1 Hot	2 warm	3 Tepid	4 cool	5 cold	6 very cold
Arid	A_1	A_2	A_3	-	-	-
Semi-arid	SA_1	SA_2	SA_3	-	-	-
Sub-moist	SM_1	SM_2	SM_3	SM_4	SM_5	SM_6
Moist	M_1	M_2	M_3	M_4	M_5	M_6
Sub-humid	SH_1	SH_2	SH_3	SH_4	SH_5	SH_6
Humid	No	H_2	H_3	H_4	H_5	H_6
Per-humid	PH_1	PH_2	PH_3	-	-	-

Table 5. Major Agro-ecological Zones

No	Major Agro-ecological zones	
1	A_1	Hot arid lowland plains
2	A_2	Warm arid lowland plains
3	A_3	Tepid arid mid highlands
4	SA_1	Hot semi-arid lowlands
5	SA_2	Warm semi-arid lowlands
6	SA_3	Tepid semi-arid mid highlands
7	SM_1	Hot sub-moist lowlands
8	SM_2	Warm sub-moist lowlands
9	SM_3	Tepid sub-moist mid highlands
10	SM_4	Cool sub-moist mid highlands
11	SM_5	Cold sub-moist mid highlands
12	SM_6	Very cold sub-moist mid highlands
13	M_1	Hot moist lowlands
14	M_2	Warm moist lowlands
15	M_3	Tepid moist mid highlands
16	M_4	Cool moist mid highlands
17	M_5	Cold moist sub-afro-alpine to afro-alpine
18	M_6	Very cold moist sub-afro-alpine to afro-alpine
19	SH_1	Hot sub-humid lowlands
20	SH_2	Warm sub-humid lowlands
21	SH_3	Tepid sub-humid mid highlands
22	SH_4	Cool sub-humid mid highlands
23	SH_5	Cold sub-humid sub-afro-alpine to afro-alpine
24	SH_6	Very cold sub-humid sub-afro alpine to afro-alpine
25	H_2	Warm humid lowlands
26	H_3	Tepid humid mid highlands
27	H_4	Cool humid mid highlands
28	H_5	Cold humid sub-afro-alpine to afro-alpine
29	H_6	Very cold humid sub-afro-alpine
30	PH_1	Hot per-humid lowlands
31	PH_2	Warm Per-humid lowlands
32	PH_3	Tepid Per-humid mid highland