An Appraisal of the Current Status and Potential of Surface Water in the Upper Anseba Catchment

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Abbreviations and Acronyms

AW	Available Water
CDE	Centre for Development and Environment
CWR	Crop Water Requirement
DEM	Digital Elevation Model
DFID	Department for International Development
ECS	Eritrean Catholic Secretariat
ERRA	Eritrean Relief and Rehabilitation Agency
ESAPP	Eastern and Southern Africa Partnership Programme
ET	Evapotranspiration
ETc	Crop Evapotranspiration
ETo	Potential Evapotranspiration
FC	Field Capacity
GIS	Geographic Information Systems
GMA	Groppo Mission Asmara
GoE	Government of Eritrea
GPS	Global Positioning System
Kc	Crop Coefficient
MAD	Management Allowable Depletion
MAP	Mean annual precipitation (mm)
MoA	Ministry of Agriculture
MoLWE	Ministry of land, Water, and Environment
MoND	Ministry of National Development
NFIS	National Food Information System of Eritrea
NGO	Non Governmental Organization
PRA	Participatory Rural Appraisal
RS	Remote sensing
SASE	Signs of active erosion
SLM	Sustainable Land Management Programme
SPOT	Systeme Probatoire d'Observation de la Terre
SSY	Specific Sediment Yield
UoA	University of Asmara
UTM	Universal Transverse Mercator
VC	Vegetation condition
WRD	Water Resource Department
Lt	Litre
t/ha/yr	Tonnes per hectare per year
km^2 or sq.km.	Square kilometer
m.a.s.l	Meters above sea level
Sy	Sediment yield ($t/km^2/year$)

Foreword

Surface water has been the main water source for irrigation, livestock watering, domestic water supply, and other uses in Zoba Maekel and specifically in the Upper Anseba Catchment. The main sources of surface water are the dams and ponds built over the entire region.

Dams were first constructed in this region during the Italian colonial era mainly for Asmara water supply. Most of the dams existing in the Upper Anseba Catchment were built in the last 25 years led by ministry of agriculture in cooperation with community and Non Governmental Organizations (NGOs). After independence the Government of Eritrea (GoE) gave more emphasis to water harvesting and surface water development, as to mitigate the ill effects of drought and secure the availability of reserved water for house hold, agricultural and other uses.

These days recurrent drought is observed where rain fed crop production is being unreliable and agriculture is depending on supplementary irrigation. In addition, reserved water is used for other purposes like domestic and industrial use, recreation, etc. Thus, in general terms the demand for water is increasing every year tremendously. On the other hand as most of the reservoirs were built at least two decades ago significant part of their useful life has decreased due to siltation. The siltation rate is relatively severe in some dams as compared to others due to several human activities in the watershed mainly land use and management. In addition to siltation inefficient use and management of reserved water is another constraint for development and sustainable use of reserved water.

Therefore, to accommodate the increasing demand of water for various uses and the problems and mismanagement on the other hand inventory of the current status is very crucial to all the stakeholders, community, water users, policy makers and the country at large. The researchers tried to focus on this issue, which is timely and very much helpful for further development.

Acknowledgements

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Above all, we would like to thank all the farmers who were very cooperative during the field work and through out the study in providing us with all the valuable information about their environment and their farming experiences.

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Executive summary

As the trend towards increasing industrialization continues water resources scarcity increases and hence the need to increase the importance of water resources management in meeting the demands for drinking water of a larger population, sanitation, agriculture and industry in the Sub-saharan Africa and this applies to the Eritrean situation.

Eritrea, as an arid and semi-arid Sahelian country, is not endowed with appreciable amount of water resources and is threatened by recurrent drought. Thus the overall picture is that water is in essence a finite resource. Water stored in reservoirs allows for all-year-round irrigated agriculture for some farmers and ensures that there are little or no domestic and drinking water shortages for the local population during dry periods. But the current knowledge on the development and management of surface water and specifically reservoirs is sketchy in Eritrea. Sustainable land management and water resources development are threatened by soil erosion and sediment- related problems. On top of that they are constrained by insufficient knowledge of the resources, in terms of quantity and quality. Thus, the current interest in the appraisal of current status and potential of surface water in the Upper Anseba catchment stems mainly from the utilization of reservoirs for irrigation, livestock watering and domestic use enhancement on a sustainable basis.

The Upper Anseba Catchment is one of the densely populated areas in Eritrea with a number of water sectors and stakeholders. There are 49 reservoirs within the catchment out of which 11 are used for town water supply of Asmara. The remaining are used for irrigation, livestock watering, rural water supply and domestic purposes. Thus, this area has been selected because there is a conflicting demand for water in the catchment and there is urgency for sustainable management of surface water resources.

The Upper Anseba Catchment has a total surface area of 633 km^2. The climatological data available for Zoba Maekel shows that rainfall is generally inadequate and unreliable. Annual rainfall records from MoA Maekel Zone from 1997-2007 shows that mean annual rainfall of the catchment is 450 mm. According to the general soils map of Eritrea, the dominant soil type in the catchment is vertic luvisol covering 66% of the area.

The Catchment is covered by the low-grade metamorphic rock of chloride and basic metavolcanics. The rock covers the southern part of the catchment and narrows its extent towards the central part of the catchment to die out itself. The moist highland agro ecological zone covers 99% of the catchment while the remaining 1% falls under the sub humid agro ecological zone. A land cover map of the catchment compiled from Africover land cover data and a recent SPOT satellite image reveals that about 70% of the area is rainfed agriculture, 13% open and sparse shrubs, 7 % urban area, 5 % tree plantations, 4.5 % irrigated agriculture and the remaining 1% is covered by bare soil and artificial water bodies.

The aim of this study is to create a basis for informed decision-making processes in the use of surface waters for community members, planners, implementers and policy makers. It addresses the shortcomings in stakeholder participation and the information required for more efficient management of surface waters. It will allow for better planning, implementation, and management of surface water, with a focus on reservoirs.

In this study, review of previous work related to reservoirs, their history, previous preliminary inventory, livestock and irrigation activities and other related literatures was done. This was followed by a field survey in two phases: Phase one, general survey of all reservoirs existing in Zoba Maekel and Phase two detailed quantitative and qualitative data collection on 9 selected case study reservoirs. Both Remote sensing (RS) and Geographic Information systems (GIS) techniques are extensively utilized. Estimated design capacity of all the reservoirs was documented from secondary data. In addition, current reservoir capacity of selected reservoirs has been estimated by reservoir resurvey. Bathymetric survey has been used to estimate the sediment deposition because the reservoirs were full of water. Reservoir resurvey and catchment characterization were also used in this study to estimate the level of silt accumulated in the selected reservoirs.

The study found out that there are 74 reservoirs in total within the administrative boundaries of Zoba Maekel with an aggregate water holding capacity of 67 million cubic meter. Analysis of the time distribution of reservoir building indicates that reservoirs were first constructed in Eritrea during the Italian regime mainly for the purpose of Asmara water supply.

The catchments of each and every surveyed reservoir delineated from Digital Elevation Model (DEM) range from 0.15 to 141 km^2. Seven of the 49 reservoirs in the upper Anseba Catchment were found to have catchment less than 1 km^2. In Zoba Maekel, there are two reservoirs with catchments less than 1 km^2 in addition to the 7 reservoirs situated in Upper Anseba. Additional 23 reservoirs also have catchments ranging between 1 and 40 km^2. Generally, the relationship observed between catchment size and reservoirs capacity is weak.

The biggest reservoirs are used for town water supply and the smaller ones mainly for livestock watering. The average capacity of the reservoirs is 850,000 m^3. The aggregate design capacity of all the surveyed reservoirs reaches 67 million cubic meter out of which 32 million cubic meter is reserved in the Upper Anseba Catchment.

The actual storage capacity of selected reservoirs obtained from the reservoir resurvey shows that 11- 45% of the original capacity of the reservoirs is filled up with sediment on average with in two decades. Results from the catchment characterization showed that sediment yield varies spatially between catchments, i.e., from 262 t/km^2/year in Hayelo-Geshnashm to 1769 t/km^2/year in AdiAsfeda with an average of 856 t/km^2/year. On the other hand, the sediment deposition data obtained from bathymetric survey shows that SSY ranges between 132 m3/km^2/yr and 1846 m3/km^2/yr with a mean SSY of 703 m3/km^2/yr.

Many of the parameters crucial for water balance calculation are absent. The depth of water in the catchment was calculated using the rainfall records from the five rain gauge stations taken. Using the isohyetal map the average yearly rainfall or input in this catchment is about 289 million cubic meter of water.

In total, roughly around 41 million cubic meter of water runs off through the channels every year in this catchment. The surface reservoirs in this catchment have a potential reserve capacity of 32 million cubic meter of water. This means the reserve capacity of the surface reservoir in this catchment is almost 70% of the annual yield calculated for the whole catchment.

Out of the 31 reservoirs used for irrigation, three reservoirs (Adisheka, AdiNifas_D01 and AdiNifas_D02) are mainly used for town water supply and irrigation is practiced from seepage water downstream of the reservoirs. In the Upper Anseba Catchment, 19 out of the 49 reservoirs are used for active irrigation.

In addition to the 487 ha of irrigation practiced on the class one active reservoirs for irrigation around 40 ha is irrigated in some of the class two reservoirs. The main constraint for the expansion of irrigation is availability of water, though land scarcities as well as inefficient design for water controlling and distribution system have a lesser effect.

The water conveyance system in the area is mainly open channel alone or open channel with lined or pipe channel. Water is lifted or delivered to the channels using diesel or petrol operated water pumps. In places where the irrigated plots are close to the reserved water mainly on the upstream side no special water conveyance system is needed. Farmers use buckets to fetch water and irrigate their fields.

Most farmers irrigate their fields' ones a week unless the crops are at flowering stage when they need more water but the amount of water used is not known. Using the soil-water budget method can assist users in their decisions about when to irrigate and how much water to apply.

Participatory Rural Appraisal (PRA) and group discussions were practiced in order to have an insight on the perception and ambition of the communities towards reservoirs. Prioritization of activity and its contribution to the household income in the villages indicate the commitment of the villages to that activity. The higher the source of income from an activity, the higher is the commitment of the villagers to that source or activity.

In addition to the irrigation water requirements for crop production, the estimated need for water for other purposes, domestic use and livestock watering should be considered in the allocation of water for irrigation development to avoid possible conflicts between different water users. Almost all villages access the reserved water directly for livestock. Water is used for drinking, cooking and washing. Reserved waters are also used for domestic purposes specially for washing clothes. Most of the beneficiaries or villagers access water from reservoirs in two ways: directly from the reservoir or from hand dug wells downstream of reservoirs.

At the village level, water management is still at traditional level despite the bylaw developed. For example for the majority of the villages there is no water association. The rest of the villages who use their own motor pump to water their field see no point of having a water committee.

Based on the wealth of information collected it is recommended that water efficient irrigation systems should be introduced and promoted in the catchment and there is an urgent need of less water demanding and high yielding crops. It is also advisable to explore other sources of water like fog harvesting roof catchment to supplement the reservoir water in the catchment. On the other hand establishing and strengthening water user association and prepare comprehensive water use byelaw is required. Above all it is also crucial to prepare a coordinated water use and development master plan at catchment level.

1 BACKGROUND

Water is one of the most crucial resources for human existence which nature has to offer. Especially in developing countries like Eritrea, where a majority of the population directly relies on the productivity of the land; it is a fundamental prerequisite to development and food security.

Eritrea, as an arid and semi-arid Sahelian country, is not endowed with appreciable amount of water resources and is threatened by recurrent drought. Average precipitation in the country is about 384 mm/yr (FAO, 2004) with only 1% of the total area receiving more than 650 mm of annual rainfall (FAO, 2005). Worsening the situation, rainfall in Eritrea is torrential, has high intensity, short duration, and varies greatly from year to year (FAO, 2005). Except the Setit River, which is perennial, all rivers in the country are seasonal, and flow for short period of time after rainfall and are dry for the rest of the year. There are no natural fresh water lakes in the country. Groundwater can be tapped in all parts of the country but not in the quantities and qualities desired (FAO, 2005; NEMPE, 1995). The overall picture for Eritrea is that water is in essence a very limited resource.

The importance of small reservoirs during dry period for local population in most arid and semi-arid environments cannot be under estimated. Water stored in these reservoirs allows for the practice of irrigated agriculture for some farmers and ensures a constant supply of domestic and drinking water for the local population during dry periods. Among the various uses water for the purpose of growing agricultural products has become a major issue in Eritrea today as rainfall being inadequate and uncertain over large parts of the country.

Since the Italian colonial regime many reservoirs have been constructed in Eritrea and especially in the central highlands. The Upper Anseba Catchment has a total surface area of 633 sq.km. and is located on the central highlands of Eritrea. Since 1930s a total of 49 reservoirs have been constructed in this catchment. It has a range of sectors and stakeholders. In the rural areas rain fed and irrigation agriculture are the main economic activities of the population whereas in the urban areas particularly in Asmara civilization is primarily dependent on the availability of water, which is increasingly becoming a scarce resource.

Cleaver and Schreiber (1994) indicated that as the trend towards increasing industrialization continues water resources scarcity increases. Hence there is a need to increase the importance of water resources management in meeting the demands for drinking water of a larger population, sanitation, agriculture and industry in the Sub-saharan Africa. This also applies to the Eritrea situation. The current research in the Upper Anseba Catchment stems mainly from competitive utilization of reservoir water for irrigation, livestock watering and domestic use (rural and urban water supply) and aims to create a basis for the enhancement of the uses on a sustainable basis.

Thus, if the use of reservoirs for irrigation and domestic purposes is to become efficient and more productive, there should be precise and up to date information on the existing situation of reservoirs and the size of the irrigable land downstream. Therefore a careful study and understanding of the existing situation and proper analyses of the existing problems are essential. These could be the basis for decision and policymaking.

1.1 Maekel Zone

Maekel zone is one of the six administrative regions of Eritrea. It is the smallest region in the country with a total land area of 1,040 sq.km. It borders Zoba Debub to the south, Zoba Anseba and Zoba Semenawi Keih Bahri to the north, Zoba Semenawi Keih Bahri to the east, and Zoba Gash Barka to the west. Maekel zone lies at a latitude range of 15°10' – 15°35'N and longitude range of 38°41'- 39°30'E. Its altitude ranges from 1276- 2625 m with an average of 2200 m.a.s.l.

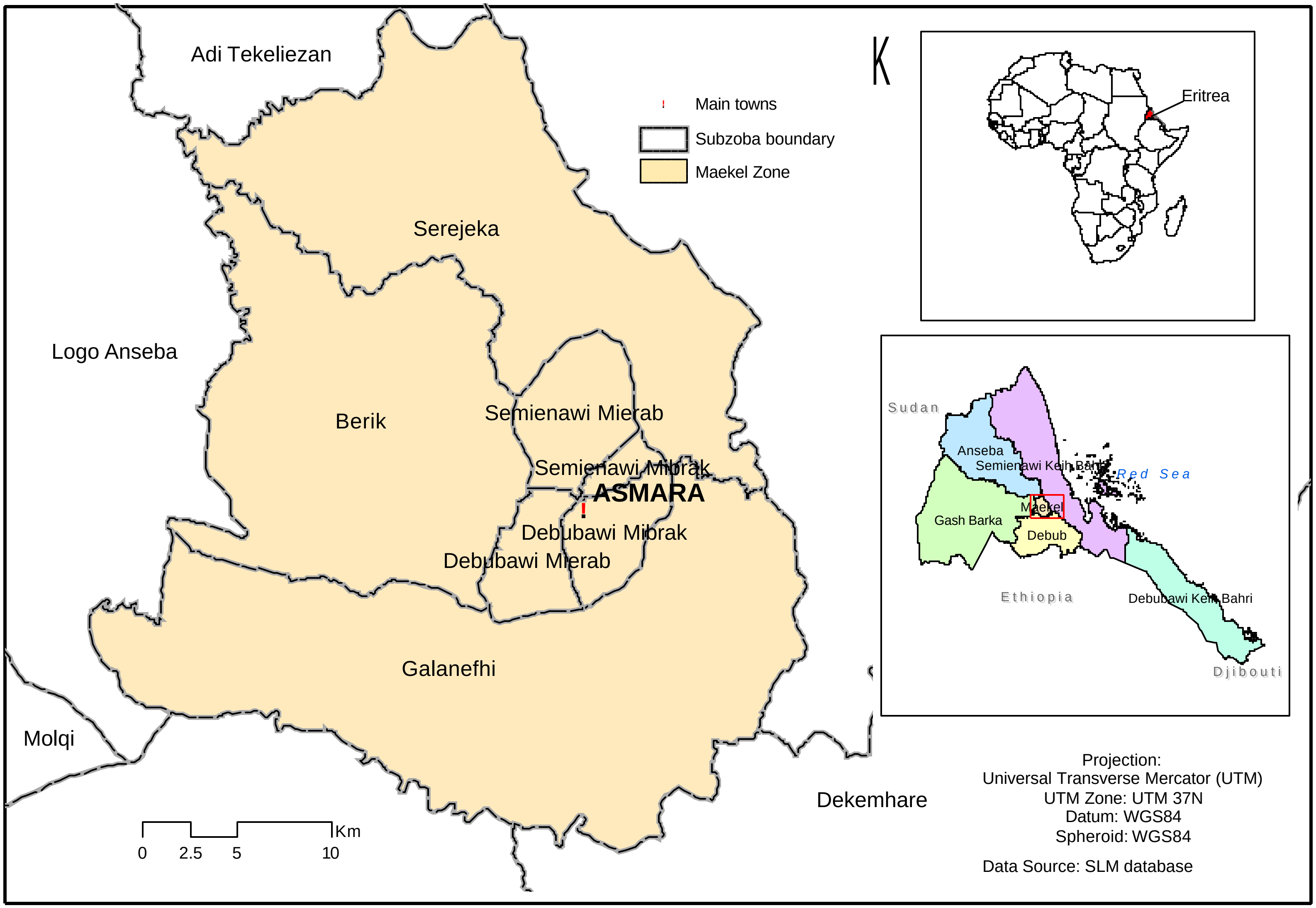
The region has 7 subzobas and 85 villages with an estimated population of 518,400 in about 114, 600 households (Administration office of Maekel Region). The four smaller subzobas comprise the area of the city of Asmara, the three larger ones include the rural areas (Map 1.1). According to the Ministry of Agriculture branch office of Maekel Zone, 27% of the total population is engaged in agriculture, 23.5 % in trade and services, 18% in manufacturing and handicrafts, while 7.5 % in civil service and 24% in casual labor.

According to the Ministry of Agriculture branch office, about 47,000 ha (or 45%) of the total land is rain-fed area, 24,000 ha (23%) grazing land, 7,300 (7%) forest area, 1,000 (1%) irrigated area and the remaining 24,600 ha (24%) is area used for residential houses and other buildings, and land not suitable for agriculture.

The region can be divided into two major agro ecological zones namely moist highland (92%) and sub humid (8%) on the basis of the broad similarities of moisture and temperature regime, natural vegetation cover, soils, and land use (Kifle and Randcliffe, 1997). These agro ecological zones are further divided into 7 agro ecological units based on more specific differences of landform, soil type, land cover or land use. The moist highland has five agro-ecological units, while the sub-humid escarpment has two.

The climatological data available for Zoba Maekel shows that the zoba's rainfall is generally inadequate and unreliable. The main rainy season is between June and August with too little rains between March and May. Annual rainfall records from MoA Maekel Zone from 1997-2007 show a maximum of 574 mm in 2001 and a minimum of 297 mm in 2002. The mean annual rainfall during this 11 years period is 418 mm (Appendix 1).

The mean maximum and mean minimum annual temperatures of the region are 25.5 ºC and lowest 4.3 ºC respectively. All subzobas experience the same climatic condition except subzoba Serejeka which experience warmer temperatures. The sunshine hours range between 10 –14 hours per day.



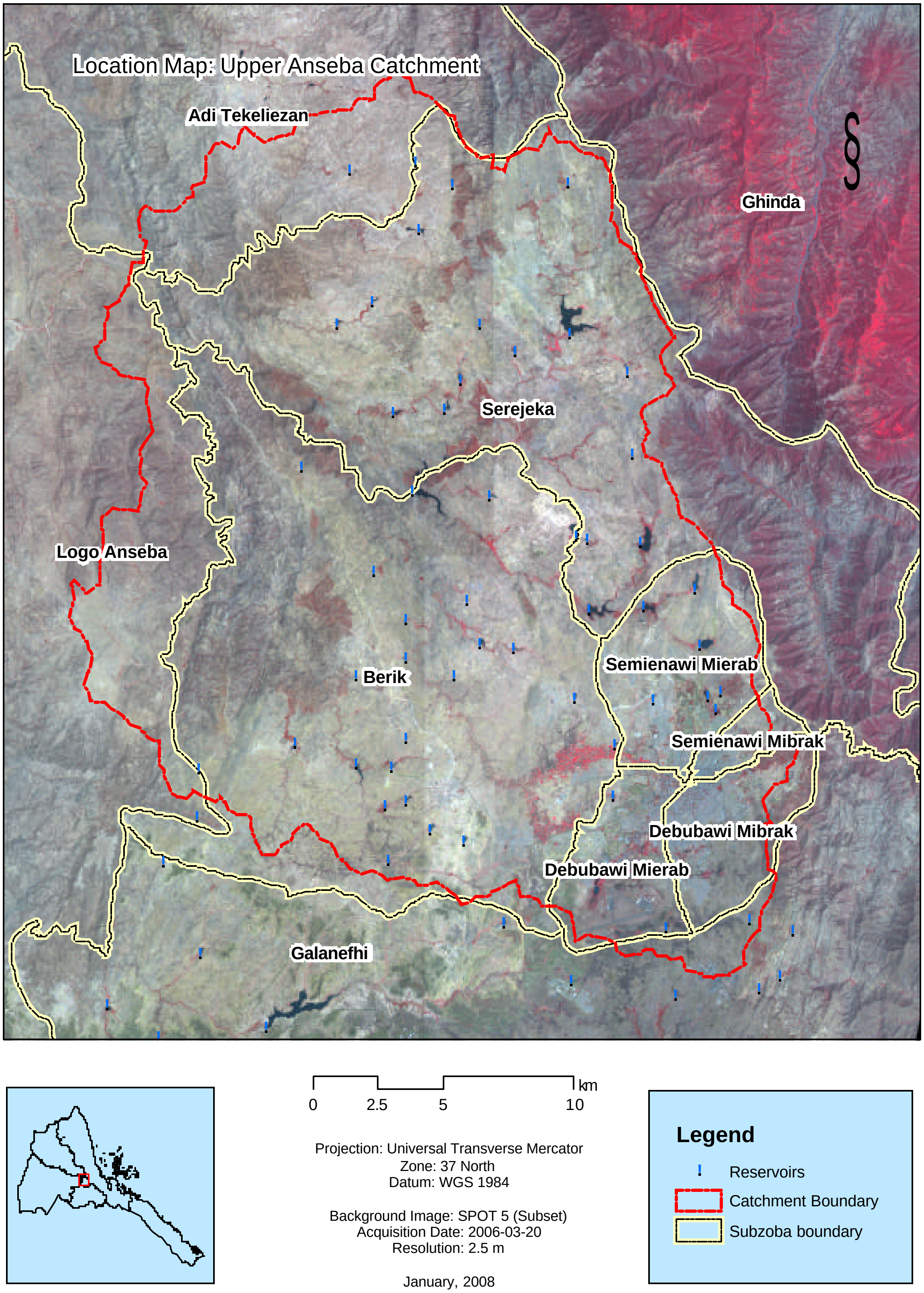
Map 1.1 An Administrative Map of Maekel Zone

1.2 Description of the Study Area

River catchments provide a natural unit for water management. Thus a watershed boundary has been used to delineate the extent of the study area. A catchment approach to the study is important, as it will involve all the stakeholders; upstream to downstream, as well as appraise the physical and natural environment that influences surface runoff.

The study area forms the upper part of the Anseba river basin. Anseba is one of the five main river basins in Eritrea with a total catchment area of 12,198 km^2. It rises from the vicinity of Asmara and flows northwest through a rough terrain towards Keren. The river then flows northeasterly only to change its course towards the north. It then joins the Barka river and finally drains into the Red Sea. The runoff reaches the sea only during good rainy season. Even though the Anseba river basin drains a small watershed, on average, the unit runoff is relatively high (Woldetzion, 1991).

The Upper Anseba catchment has a total area of 633 km^2 and 85% of it falls with in the administrative boundaries of Zoba Maekel, 8 % with in Subzoba of Logo Anseba, Zoba GashBarka and 7% with in Subzoba of AdiTekelezan, Zoba Anseba (Map 1.2).



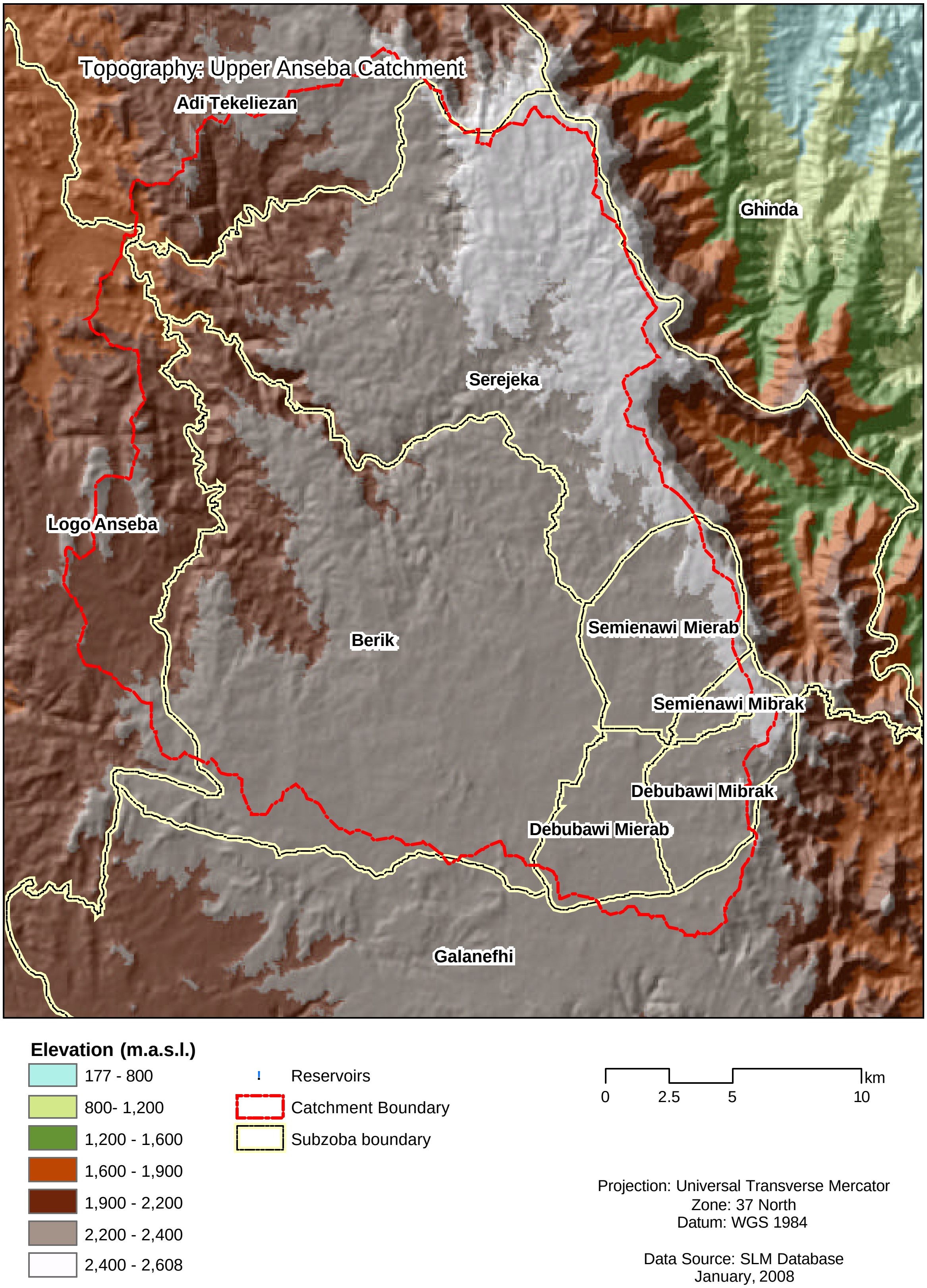
Map 1.2 Location Map of the Study Area

1.2.1 Topography

A large part of the catchment is dominated by a gentle to almost flat landform with some hills and undulating areas (Map 1.3). The plain and undulating areas are 78%, 21% slightly or moderately steep slopes with a slope of 8-30 degrees. In this area, there are also few mountains and river gorges covering 1% (Table 1.1).

Table.1.1 Slope (in degrees) of the Upper Anseba Catchment

Slope in degrees	Landform	Area in Hectares	Percent from total
0-2	Plain	14,817	23 %
2-8	Undulating	34,727	55 %
8-15	Slightly steep	9,742	15 %
15-30	Moderately steep	3,801	6 %
>30	Steep	188	1 %
Total		**63,275**	**100%**



Map *1.3 Topography of the Upper Anseba Catchment*

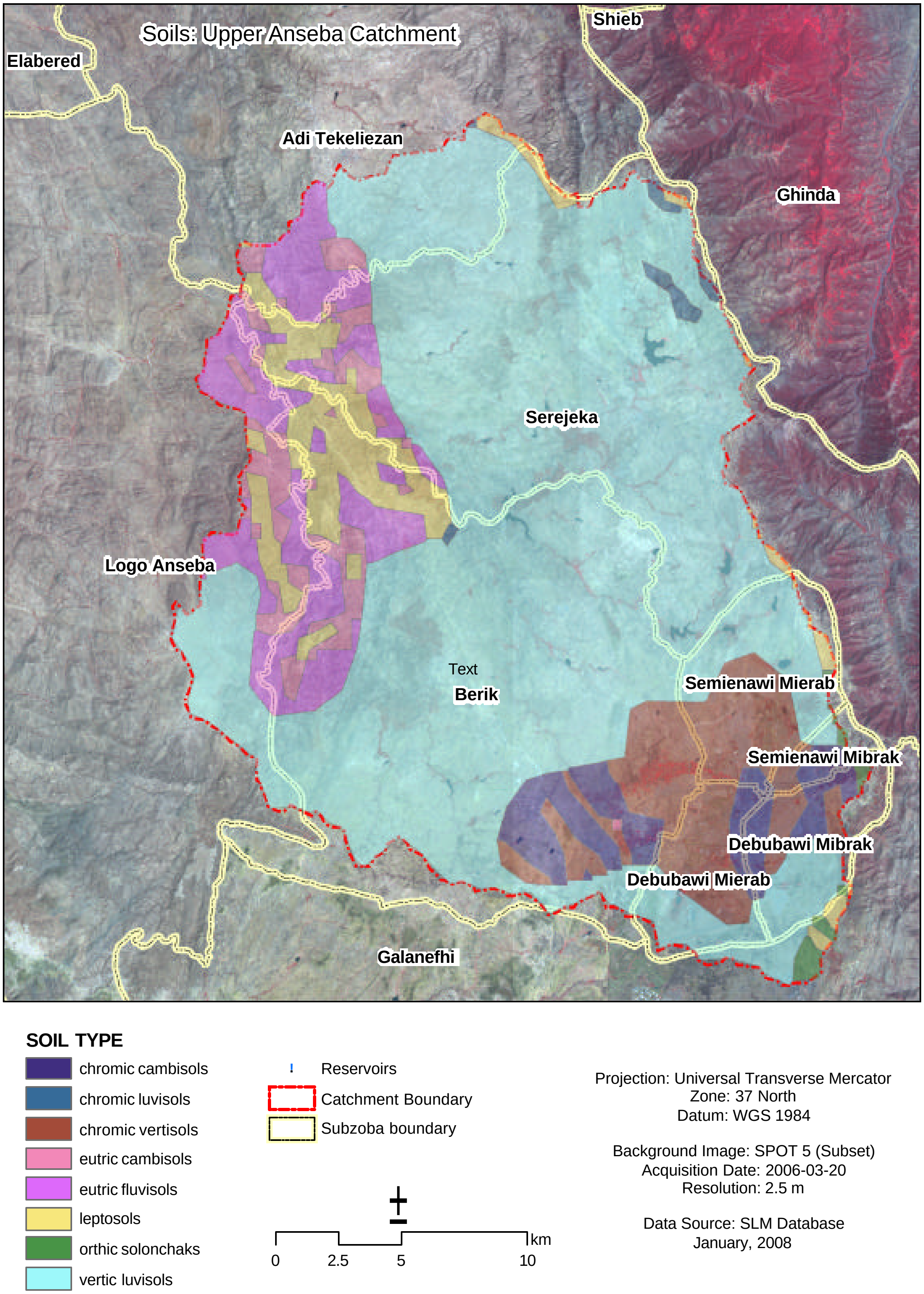
1.2.2 Vegetation

Except the community plantations of eucalyptus trees and some pockets of natural forests with small bushes and shrubs the catchment is not endowed with natural vegetation. Most of the area is deforested and degraded by water and wind erosion. In the small pockets of vegetated areas located mainly in Subzoba Berik and Galanefhi the dominant trees and shrubs include *Acacia-tortilis (a'lla), Acacia etbaica (seraw), Dodnaea-angustifolia (tahses), Euclea-schimperi (kilaw), Becium-grandiflorm (tahbeb), and Rumex usambarensis (hehot)*. Most of the community plantation especially in subzoba Serejeka is dominated by Eucalyptus and Acacia species.

1.2.3 Soils

According to the general soils map of Eritrea (FAO, 1988) the dominant soil type in the catchment is vertic luvisol covering 66% of the area. The next dominant soil types are eutric fluvisols and chromic vertisols each covering 9% of the area. Leptosols and cambisols are also found to a smaller extent (Map 1.4). Leptosols are found on steep slopes and rolling hills and are mostly used for grazing because of their poor potential for crop production.

In general land degradation is worst in the study area. A long history of cultivation, grazing as well as fuel wood and timber harvesting without recycling of nutrients or management of organic matter has resulted in poor soils and depleted vegetation.



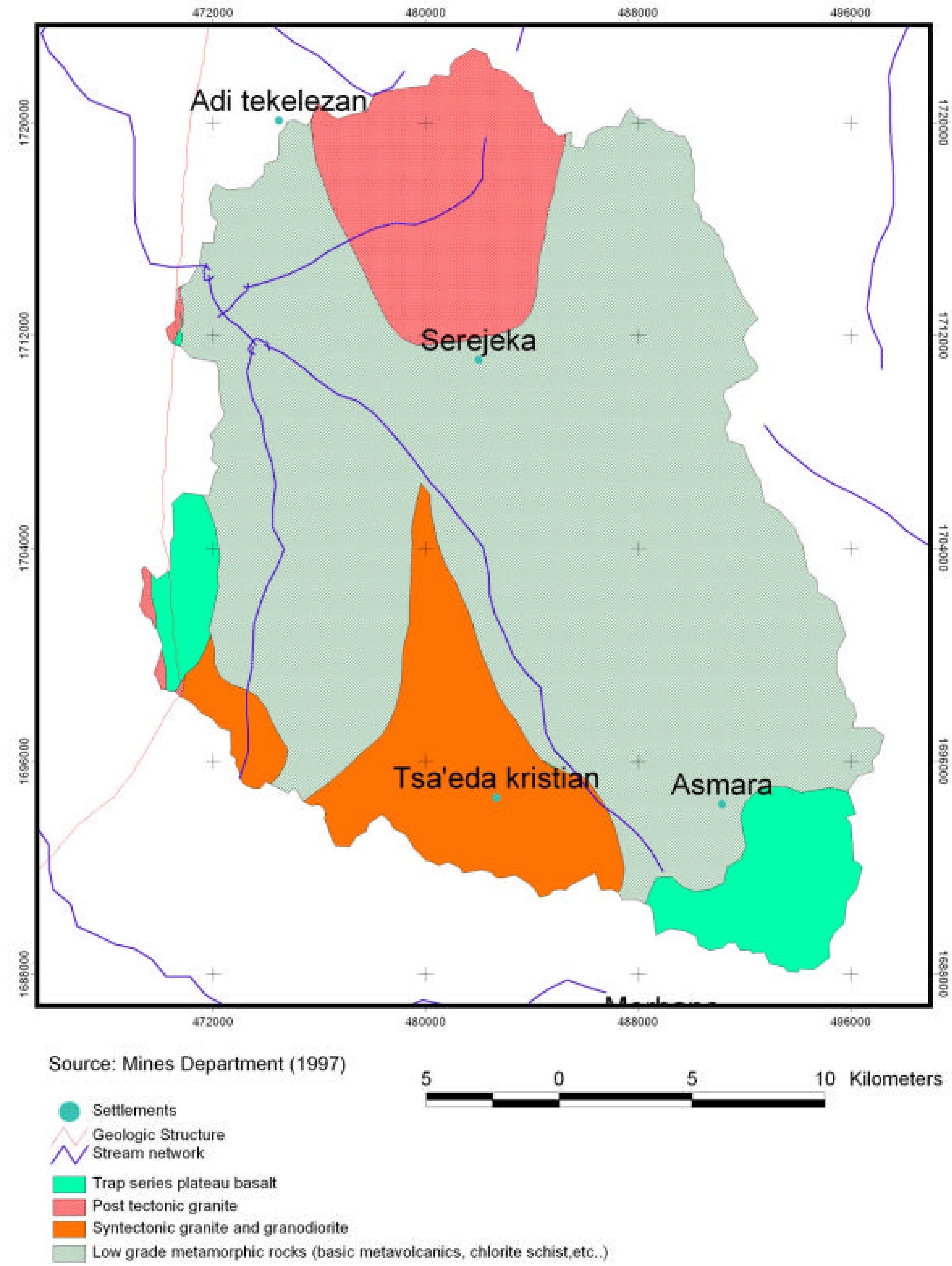
Map 1.4 Soils of the Upper Anseba Catchment

1.2.4 Geology

Geologically the Upper Anseba catchment is covered by a low-grade metamorphic rock of chloride and basic metavolcanics. This rock is of Precambrian era exposed to several tectonics of various degrees. Due to these tectonic incidences the geology is comparably complex and so as the faults and fractures in these rocks. The dominant structural (faults or fracture) orientation is N-S and NW-SE direction. These tectonic occurrences have also caused different degree of alteration, which has endowed this area with gold and other base metals deposits. Relatively these metavolcanics are soft rock type and highly weathered and also fractured to some tens of meters of depth.

The Southern part of the catchment is covered by younger granite and granodiorite to the Precambrian rock. These rocks are formed during the major tectonic era and are therefore relatively less fractured and affected. The rock covers the southern part of the catchment and narrows its extent towards the central part of the catchment to die out itself. On the opposite of this rock, which is northern side of the catchment, post tectonic granite is dominant. The post tectonic granite has coarse-grained minerals indicating the plutonic nature of the rock. This granite has been exposed less to pressure and temperature and therefore are massive and less weathered.

The late geologic formation in this catchment is the trap basalt series, which covers the southern part of Asmara. The basal trap series floods towards southern part of the country up to the Northern part of Ethiopia. These basalt lava series are characterized by massive part at the lower part of each series and softer at the top due to the vesicular openings.



Map 1.5 Geological Features of the Study Area

1.2.5 Climate

For the past 11 years, mean annual rainfall of the catchment is 450 mm, with the highest of 628 mm registered in 1997 and the lowest of 295 mm in 2002. As can be seen in Table 1.2, rainfall in the area is low. It is also torrential and unevenly distributed and as a result rainfed agriculture has become very risky livelihood. Thus, it would be essential for the farmers to increasingly engage in irrigation activities in order to supplement the low income obtained from rain-fed agriculture.

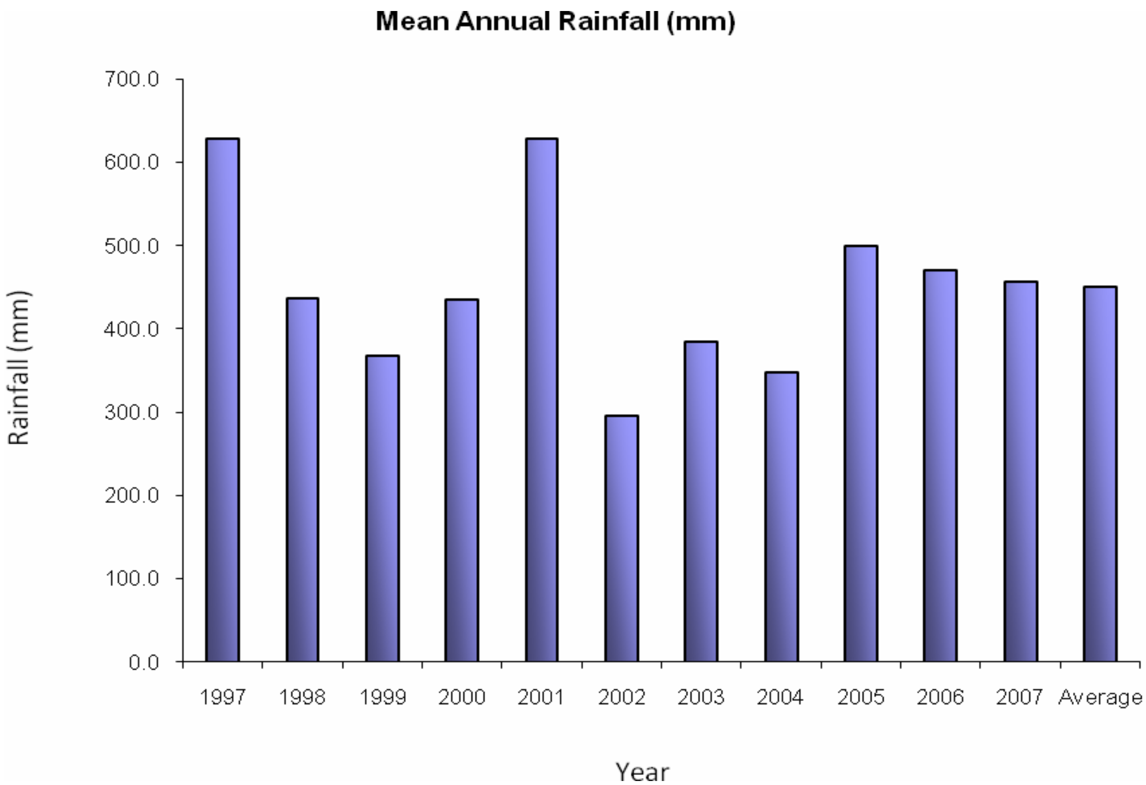


Figure 1.1 Mean Annual Rainfall (mm) in the Upper Anseba Catchment (1997-2007)

The main rainy season is between June and September and is known as 'Kremti'. There is a short rainy season in March and April locally known as '*asmera'*. The duration of the rainfall during the long rainy season (June-September) is getting shorter from time to time.

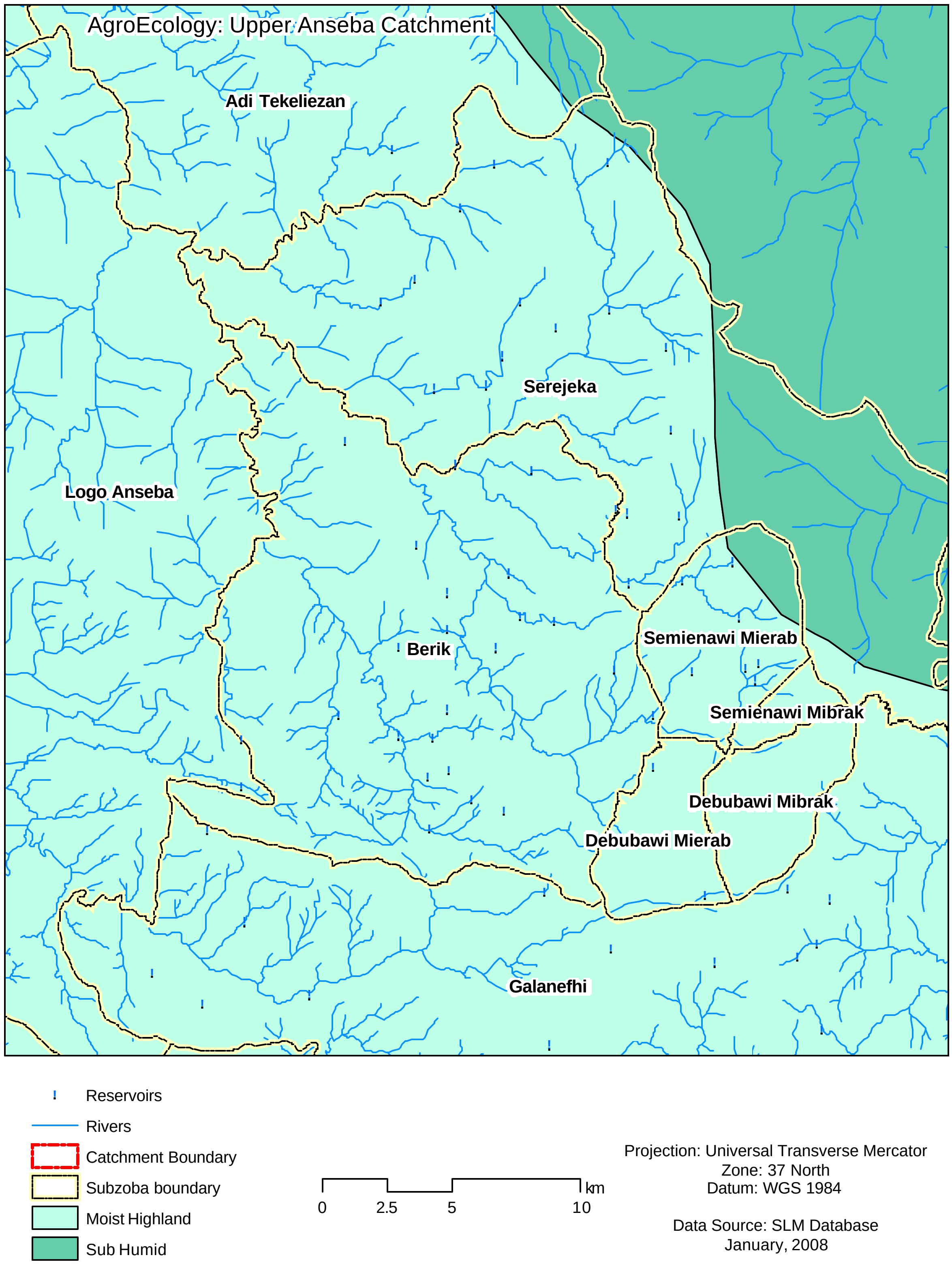
Table 1.2 Mean Annual Rainfall (mm) for Selected Stations (1997-2007)

Stations	**1997**	**1998**	**1999**	**2000**	**2001**	**2002**	**2003**	**2004**	**2005**	**2006**	**2007**	**Average**
Bet Giorgis				365.5	603.9	372.4	394.7	288.1	485	642.1	575.2	465.9
AdiNefas							393.7	294.4	590.1			426.1
Tsaedachristian	717.3	439.8	332.4	499.6	530.6	383.8	366.9	301.1	498.6	391.9	409.2	442.8
Tseazega	556.5	343.3	243.1	351.2	506.0	221.8	278.6	292.4	378.1	368.5	401.3	358.3
Hazega	591.0	344.0	295.5	531.7	819.3	380.3	422.1	296.1	541.2	398.5	473.6	463.0
Afdeyu	648.0	618.8	601.9	407.1	625.9	179.5	405.6	430.8	324.0			471.3
Hayelo				388.0	564.4			351.4				434.6
Geremi				568.2	607.9	220.7	415.5	421.1	630.0			477.2
Embaderho				372.6	814.0	327.8	383.2	391.8	463.9	405.9	533.1	461.5
Serejeka				436.0	576.0	273.1	397.1	413.7	587.5	617.4	349.0	456.2
Mean Annual Rainfall (mm)	**628.2**	**436.5**	**368.2**	**435.5**	**627.6**	**294.9**	**384.2**	**348.1**	**499.8**	**470.7**	**456.9**	**450.1**

Source: MoA-Zoba Maekel

The mean annual temperature of the study area is 18.4 °C. The average monthly maximum and minimum temperatures are 26.5 °C and 14.1 °C respectively. The warmest months are March through May with a mean monthly maximum of 23.8 °C and. the coldest month lasts from November through February with a mean monthly minimum of 9.2 °C.

The moist highland agro ecological zone covers 99% of the Upper Anseba catchment while the remaining 1% falls under the sub humid agro ecological zone. The moist highland agro ecological zone is further sub-divided into three and the sub-humid escarpment into two agro-ecological units based on more specific differences of landform, soil type, land cover or land use.



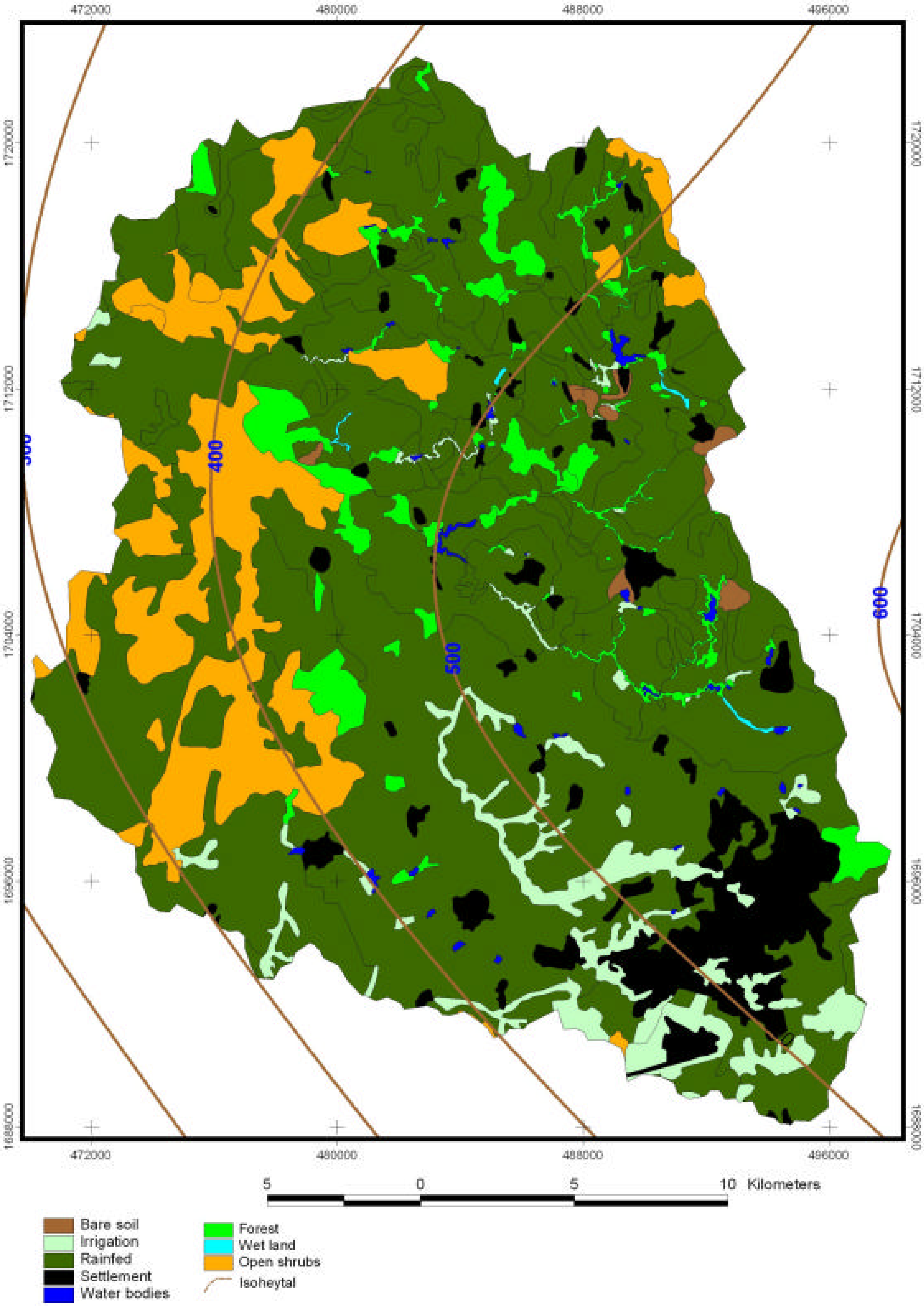
Map 1.6 Agro ecology of the Upper Anseba Catchment

1.2.6 Land Use Land Cover and Land Tenure

A land cover map of the catchment (Map 1.7) compiled from Africover land cover data and a land cover map that covers part of the area prepared by Burtcher (2003) generally reveals that about 70% of the area is under rainfed agriculture (large to small scale, scattered and isolated), 4.5 irrigated agriculture, 5 % tree plantations, 13% Open and sparse shrubs, 7 % Urban area and the remaining 1% is covered by bare soil and artificial water bodies.

In Eritrea in general the government owns land and farmers have the right of use. The land tenure system, which is dominant in the central highlands, is the '*diessa* system'. Under the 'diessa system' farm areas are redistributed among eligible farmers every 5-7 years. This has led to fragmentation of land, and has discouraged farmers from long-term investment in their land.

Photo 1 and 2: AdiAsfeda, Rainfed agriculture: the dominant land use type of the catchment



Map 1.7 Land cover of the Upper Anseba Catchment

1.2.7 Water Resources

There are no major/ big rivers in the study area that can be used for large-scale irrigation activities. Dams, wells and Maibela River the main sources of water in the study area and are mostly used for small-scale irrigation and for domestic water supply. It is important to note that the quality of water from *Maibela* is very poor as a result of sewage and industrial effluents. The effluent is used for irrigation to produce vegetables and forage crops. This is posing a significant health hazard to human and livestock population in the area.

1.2.8 Farmers' Association and Extension Services

Agricultural extension services are provided to farmers at subzoba branch offices. There are currently five different associations in Zoba Maekel with a total membership of 1,126 farmers engaged in horticultural production, cattle fattening, beekeeping, poultry and dairy production. These associations have their own management committees comprising a chairperson, secretary and treasurer. Toker Project is providing these associations with technical and financial support. The project has so far assist the associations in the establishment of 10 village shops in Zoba Maekel aimed at providing members with easy access to agricultural inputs such as fertilizers, chemicals, veterinary drugs, chicks, selected seeds, and hand tools. These village shops have their own management committees comprising of three persons composed of representatives of farmers, village administration and the project (NFIS, 2005).

1.3 Problem Statement

Since the Italian colonial regime many community reservoirs have been constructed in Eritrea. These reservoirs represent an important component of agricultural development in providing food security for the beneficiary communities, as a source of drinking water, for livestock, for recharging of groundwater, and for irrigation.

In Eritrea where rainfall is both insufficient and erratic, the reservoirs provide an effective coping mechanism for dry years. They are secure sources that are more reliable than ground water especially in the central highland where the geologic formations are tighter. The government is continuously trying to identify more efficient use of reservoirs water from so as to get higher and sustained yields, and hence improve household as well as national food security.

Mugabe *et al.* (2004) explained that generally the sustainable use of the limited water resources is constrained by insufficient knowledge of the resources, in terms of quantity and quality, and by lack of proper water resource management. Unfortunately the current knowledge on the development and management of surface water and specifically reservoirs is sketchy in Eritrea. The exact number of existing reservoirs, the quantity and quality of their water is not exactly known. Little recorded information is available regarding extent and condition of areas draining to the reservoirs.

Sustainable land management and water resources development have been threatened by soil erosion and sediment- related problems. Though sediment deposition in reservoirs is a serious off-site consequence of soil erosion in the catchment, there are no sufficient and reliable sediment-yield data, which are important for designing new reservoirs and for implementing soil conservation practices.

Even though the extent of irrigated area from reserved water is increasing in recent years it is still insignificant compared to the number of reservoirs and the aggregate volume of reserved water. Thus efforts have to be made to improve the irrigation systems and to increase their efficiencies.

Therefore, it is very crucial to assess the water resources, create a basis for informed decision making and assist the societies by proposing and implementing systems that enhance better use of water resources and management for competing uses in the river basin to ensure long-term sustainability.

1.4 Objectives of the Study

The general objective of this study is to create a basis for informed decision-making processes in the use of surface waters for community members, planners, implementers and policy makers. It addresses the shortcomings in stakeholder participation and the information required for more efficient management of surface waters.

It encompassed assessment of surface water capacity and management, awareness raising and capacity building for the major stakeholders. These will allow better planning, implementation, and management of surface water, with a focus on reservoirs. This will result in more sustainable economic and social benefits for end users.

1.4.1 Specific Objectives

- To create a spatial database, high-resolution satellite image maps to address the shortcomings in the information required by planners, implementers and policy makers as a basis for informed decisions for more efficient management of surface waters, i.e., to fair allocation of resources according to the needs of the population and balanced with the capacity of the catchment to generate the required water resource.
- To evaluate the general characteristics and problems of reservoirs in Zoba Maekel with more emphasis in the Upper Anseba Catchment
- To assess the extent and efficiency of water use with a focus on the existing irrigation system and estimate the extent of the potential irrigable areas
- To estimate the extent of sediment deposition of selected reservoirs
- To assess community perceptions and ambitions regarding the exiting reservoirs and their use.
- To identify promising practices, methodologies and approaches that can be a basis for replication in other catchments as pilot for similar studies and implementation of small projects.

2 METHODOLOGY

The methodology followed to collect the data required in this study was a holistic assessment, comprised one or both quantitative and qualitative components designed to capture as many information as possible on the area that falls within Upper Anseba catchment.

2.1 Site Selection

According to Ogbagabriel (2001) more than 30% of the Eritrean population live in the moist highland zone, which makes up 7.4 % of the total area of the whole country. The Upper Anseba Catchment is one of the densely populated areas in Eritrea with a number of sectors and stakeholders. There are 49 reservoirs within the catchment out of which 11 are used for town water supply of Asmara. The remaining are used for irrigation, livestock watering, rural water supply and domestic purposes. Thus this area has been selected because there is a conflicting demand for water in the catchment and there is urgency for sustainable management of surface water resources.

2.2 Literature Review and Field Survey

First of all, review of previous work related to reservoirs, their history, previous preliminary inventory, livestock and irrigation activities and other related literatures was done. This was followed by a field survey. The survey had two phases: Phase one, general survey of all reservoirs existing in Zoba Maekel and Phase two detailed quantitative and qualitative data collection on 9 selected case study reservoirs.

In the first phase a survey of all villages with reservoir and within the administrative boundary of Zoba Maekel was carried out using a semi structure questionnaire (Appendix 2) with the assistance of 10 enumerators. A total of 75 reservoirs were studied. Out of the total 10 reservoirs are found in the four Subzobas of Asmara and one reservoir in Zoba Anseba Subzoba of AdiTekelezan. At the first phase general field observations were also carried out to log the physical data related to catchment characteristics, reservoir condition, irrigation activities and infrastructure. This data was processed and encoded into a database and spatial GIS dataset.

The enumerators who undertook the work were extension workers of the Ministry of Agriculture of Zoba Maekel. The extension workers were chosen because they are experienced in administering questionnaires and interacted on daily basis with the respondents at all levels. The enumeration was preceded by a two-day orientation and pre-test of the questionnaire.

In the second phase detailed study was made on selected case study reservoirs. The reservoir size or capacity, spatial distribution or location, current water use and management, and irrigation activities are factors that were used in determining the selection of the 9 reservoirs. In addition the age of reservoirs and ease of accessibility were also secondary factors in the selection. The selected 9 reservoirs were surveyed in detail. Here the bigger component was assessment of the natural resources at a Catchment level; reservoirs water capacity and downstream irrigation areas. Quantitative and physical measurements were made to figure out the resources one by one. For instance, sampling and laboratory analyses were also carried out to assess the physical soil properties of some representative areas on the irrigated field of the case study reservoirs.

2.3 Remote Sensing and GIS data Analyses

Both Remote sensing and GIS techniques were extensively utilized in this study. Recent SPOT 5 georeferenced satellite image with 5m spatial resolution captured on the 20th of March 2006 was used to locate all the reservoirs, to prepare satellite image maps for field data collection and to modify the land use land cover map of the study area. In addition the catchment area of each reservoir was calculated from DEM with 50 m grid size derived from Russian map prior to fieldwork. Both the satellite image and DEM data processing and mapping were done in GIS using ArcGIS 9.1 GIS software.

During field visits to the selected reservoirs the maps prepared from the SPOT5 satellite image and secondary feature dataset were verified and locations of all reservoirs were taken using hand held Global Positioning System (GPS) in Universal Transverse Mercator (UTM) coordinate system. In addition, GPS was used to accurately measure the crest length of reservoirs and delineate the current irrigated fields upstream and downstream of the reservoirs.

Photo 3: An extension worker collecting GPS data to calculate Dam crest length, AdiKeshi

2.4 Estimating Actual Reservoir Capacity and Sediment Deposition

In order to have a water resources assessment it is crucial to know the capacities of reservoirs in question. To calculate the volume of water contained in the reservoir requires a more accurate method of estimating capacity i.e., to consider area enclosed by contours at appropriate intervals. The volumes between two successive contours were calculated and these volumes were then summed up to get the total capacity of the reservoir. The equipment used in the study to estimate current volume or actual water level of reservoirs includes boat, GPS, Theodolite, height measuring rod and rope, 1: 50,000 maps, Level, tape measure (50m), vehicle, and notebooks.

Bathymetric survey has been used to determine the present capacity of the reservoirs. The original reservoir survey was compared with the current capacity.and the sediment deposition was estimated. Information on the original capacities of the reservoirs was acquired from the Ministry of Agriculture Maekel Zone. To derive existing storage capacity, the depths from the water surface to the top of the sediment were measured at more than 20 locations for each reservoir using a small boat with a depth counter and a GPS. These data were used to create bathymetric maps and derive existing storage capacity of reservoirs. The original and current storage capacities of each reservoir were then compared and their differences gave an estimation of the volume of sediment deposition in cubic meters (m^3).

Photos 4 & 5: Bathymetric survey at Embaderho reservoir

There are three ways of estimating sediment yield from catchments:

- Sediment yield from stream flow sampling,
- Reservoir resurvey data, and
- Catchment characterization method together with mean annual rainfall.

In the current study reservoir resurvey and catchment characterization were used to estimate the silt accumulated in the selected reservoirs. Because the reservoirs had reserved water the technique bathymetric survey was utilized to as outlined above to determine the present capacity of the reservoirs and at the same time to estimate silt deposition.

In the case of catchment characterization, which is very subjective and that requires only mean annual precipitation data, the knowledge of key informants, secondary raster and feature datasets, and field observation were used to give scores representing the characteristics of the catchments (Appendix 3). Based on the scores given to vegetation condition, soil type and drainage and signs of active erosion the sediment yield was calculated for the selected reservoirs using the equation below as outlined in DFID (2004).

$$\mathbf{Sy = 0.0194 * Area^{-0.2} * MAP^{0.7} * Slope^{0.3} * SASE^{1.2} * STD^{0.7} * VC^{0.5}}$$

Where:

Sy - sediment yield (t/km^2/year)

Area- Catchment area (km^2)

MAP- Mean annual precipitation (mm)

Slope- River slope from the catchment boundary to the dam

SASE- Signs of active erosion (Score from catchment characterization)

STD- Soil type and drainage (Score from catchment characterization)

VC- Vegetation condition (Score from catchment characterization)

2.5 Qualitative Data Collection

The qualitative component of the survey on selected reservoirs provided contextual information essential to understand the natural resources and the existing water use and management activities of the area. It included the following main instruments: focus group discussions with selected farmers and water committees if exiting, key informant interviews with administrators and representative farmers, and participatory rural appraisal (PRA). PRA was conducted in selected villages to assess the ccommunity perceptions on how to use a dam (the need for a dam), ambitions (potential of the dam as perceived by the community) and identify and prioritise constraints of production.

In addition to the discussions with the zonal officials and other relevant officials, the field visit enabled the collection of primary and secondary data and information related to common cropping systems and calendars, time of production and marketing opportunities, irrigation system and infrastructure, current water management and the impact of the implemented bye-law.

Photos 6 & 7: Group discussion with farmers

2.6 Awareness Creation

A participatory workshop involving all the relevant stakeholders including planners, implementers and policy makers was conducted on the 18th of September 2007. The workshop provided the opportunity for all to make comments on the work and methodologies proposed. At the end of the study the stakeholders were engaged in a half-day participatory workshop with a representative cross-section of the community. The aim of the workshop was to communicate the outcomes of the research with the stakeholders and receive constructive comments and suggestions.

3 RESULTS AND DISCUSSION

3.1 Catchment Reservoir Capacity and Current Reserved Water

3.1.1 Reservoirs

3.1.1.1 Distribution

In the administrative boundaries of Zoba Maekel there are a total of 74 reservoirs with an aggregate water holding capacity of 67 million cubic meter (Appendix 4). Out of these reservoirs a total of 49 reservoirs, with an aggregate capacity of 34 million cubic meter, are located in the Upper Anseba Catchment including Deki Zeru from Subzoba of AdiTekelezan, Zoba Anseba. In addition to these, 3 reservoirs (AdenGoda, Quazien and Afdeyu) were built in the catchment but are no more functional because Afdeyu was damaged shortly after construction and the remaining two are completely silted.

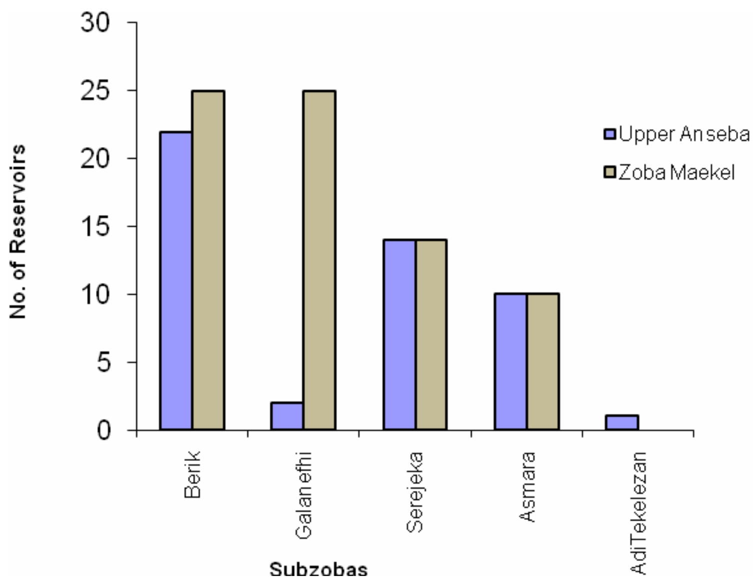


Figure 3.1 Frequency Distribution of Reservoirs by Subzoba

3.1.1.2 Reservoirs Age and Implementing Agencies

Analysis of the time distribution of reservoir building (Table 3.1 and Figure 3.2) indicates that reservoirs were first constructed in Eritrea during the Italian colonial period mainly for the purpose of Asmara (town) water supply. These reservoirs are bigger in size and mainly situated in the vicinity of Asmara. About two-third of all the reservoirs in both the Upper Anseba Catchment and Zoba Maekel were built before independence and the remaining one-third after independence of the country. Many reservoirs were constructed during 1950 - 1991 especially during 1988 and 1989 and were mainly constructed by human labor. Most of these reservoirs were small in size, used for livestock watering. They have been upgraded and rehabilitated in recent years. The reservoirs constructed after 1992 were mainly for irrigation development.

Table 3.1 Frequency Distribution of Reservoirs by Year of Construction

Year of Construction	Number of Reservoirs	
	Upper Anseba	Maekel
Before 1950	8	8
1950-1991	25	41
1992-2007	16	25
Total	**49**	**74**

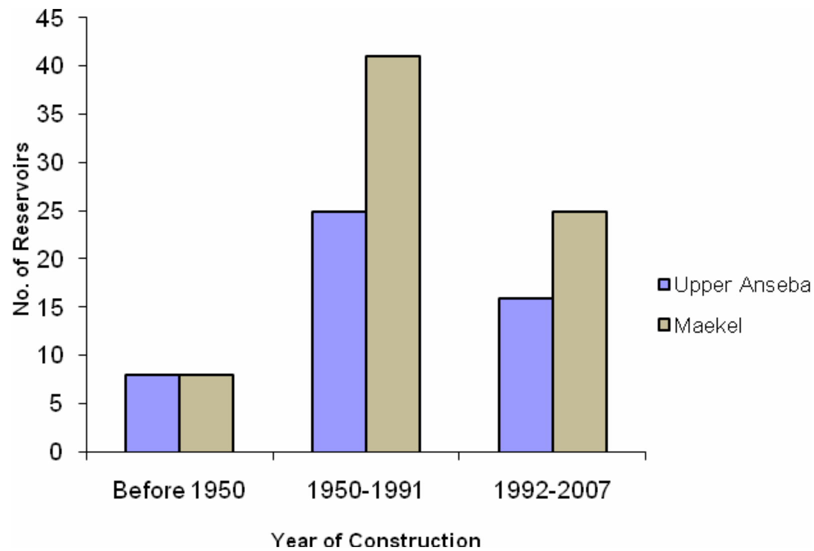


Figure 3.2 Frequency Distribution of Reservoirs by Year of Construction

The survey confirmed that MoA built most of the reservoirs in Zoba Maekel and particularly in the Upper Anseba Catchment (Table 4). From the total 74 reservoirs MOA alone constructed 36 out of which 20 are situated in Upper Anseba. Seven reservoirs were constructed by MOA in partnership with Red Cross, ERRA, KR2, GMA and other projects as well as with different NGOs. Three of such dams are found in the Upper Anseba Catchment. There are also 5 reservoirs in Subzoba Berik built by village communities.

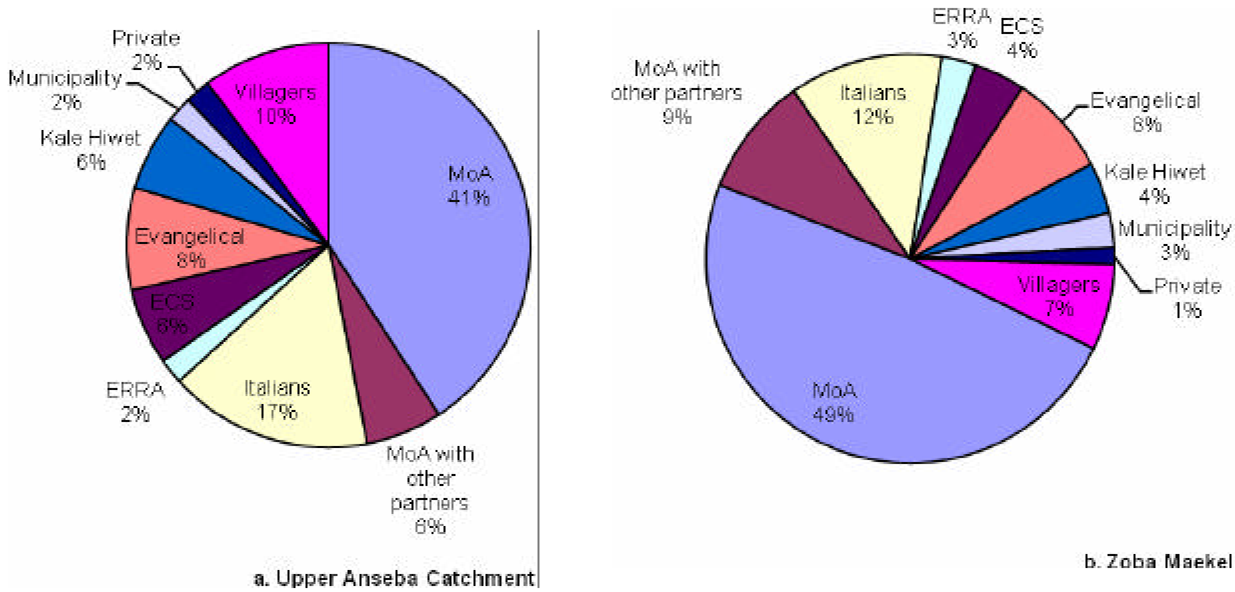


Figure 3.3 Pie-charts showing the Percentage of Reservoirs by Implementing Agencies

Table 3.2 Frequency Distribution of Reservoirs by Constructing Agencies

Constructed by	No. of reservoirs	
	Upper Anseba	Zoba Maekel
MoA	20	36
MoA with other partners	3	7
Italians	8	9
ERRA	1	2
ECS	3	3
Evangelical	4	6
Kale Hiwet	3	3
Asmara Municipality	1	2
Private	1	1
Villagers	5	5
Total	49	74

3.1.1.3 Characteristics of Dam Bodies

As indicated in Table 5 all the surveyed reservoirs are found in the highlands with an elevation range of 2000-2500m.a.s.l. The dam crest length ranges from minimum of 45 meters (Hazega-D02) to a maximum of 403 meters (AdiSheka) with an average of 145 meters. The dam height ranges from a minimum of 4 meters in AdiKontsi (D-02) to a maximum of 73 meters in Tokor with an average of 11 meters.

Table 3.3 General Characteristics of Surveyed Reservoirs in Zoba Maekel and Upper Anseba Catchment

	Capacity (Million m^3)		**Dam crest length (m)**		**Dam height (m)**		**Elevation (m.a.s.l)**		**Catchment area (ha)**	
	Maekel	UAC	Maekel	UAC	Maekel	UAC	Maekel	UAC	Maekel	UAC
Average	0.87	0.7	145	144	11	10	2247	2281	806	850
Minimum	0.04	0.04	45	45	4	4	2040	2125	15	15
Maximum	26	14	403	403	73	73	2474	2474	14,136	14,136

UCA: Upper Anseba Catchment

The dams are earth fill, rock fill, masonry or concrete (Table 3.4). Most of the dams are earth fill because it is cheaper and relatively easy to construct. Out of the total only two dams (Hayelo Gheshnashm and Laugen AdiHamushte) are rock fill and excessive seepage is observed in these reservoirs. Downstream of these reservoirs small embankments have been built to collect the seepage water and make it available for irrigation and other purposes.

Table 3.4 Types of Dams in Zoba Maekel and Upper Anseba Catchment

Dam type	Zoba Maekel	Upper Anseba
Earth fill	67	43
Rock fill	2	1
Masonry or concrete	5	5
Total	**74**	**49**

Photo 9: AdiBidel Concrete Dam

3.1.1.4 Catchment Areas

The catchments of each and every surveyed reservoir delineated from DEM in ArcView 3.3 GIS software range from 0.15 to 141 km^2. Seven (14%) of the 49 reservoirs in the upper Anseba Catchment have catchment less than 1 km^2. These reservoirs are Tselot, AdiMerawi, TsaedaEmba, AdiAbeyto, AdiKontsi (D-03), AdiBidel and Mesfnto. 34 (70%) of the reservoirs have catchment areas between 1 and 10 km^2. In Zoba Maekel, there are two reservoirs with catchments less than 1 km^2 in addition to the 7 reservoirs situated in Upper Anseba. Additional 23 reservoirs also have catchments ranging between 1 and 40 km^2.

Table 3.5 Frequency Distribution of Reservoirs by Size of Catchment Area

Catchment area (km^2)	Number of reservoirs	
	Upper Anseba Catchment	Maekel
< 1 km^2	7	9
1-10 km^2	35	54
> 10 – 40 km^2	6	10
>100 km^2	1	1
Total	**49**	**74**

Generally, the relationship observed between catchment size and reservoirs capacity is weak. Even in the medium and small sized reservoirs the relationship was much weaker. The biggest town water supply reservoir in terms of capacity is MaiNefhi with 26 million cubic meter but it has the second largest catchment (8.7 km^2). The reservoir with the biggest catchment is Toler having 14 million cubic meter capacity however, there are a number of small reservoirs on the Toker catchment reserving considerable amount of the runoff draining from the catchment.

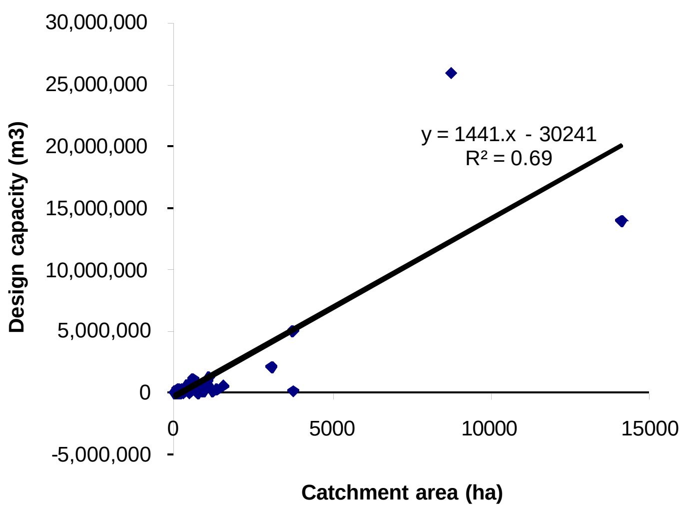


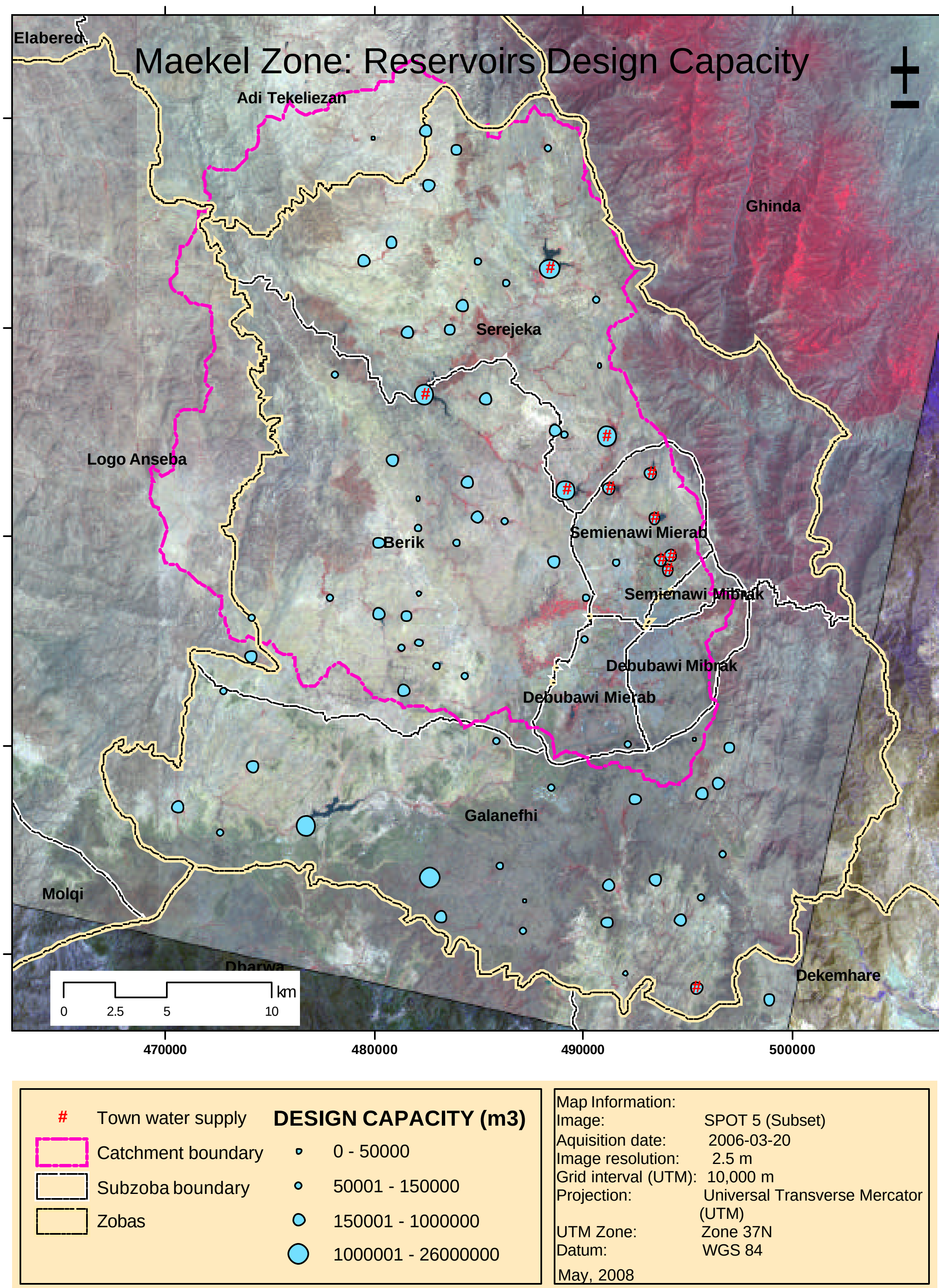
Figure 3.4 Relationship between Catchment Area and Reservoir Design Capacity

3.1.2 Reservoir Capacity

Efficient water management, and sound reservoir planning and management are hindered by inadequate knowledge of storage volumes. The absence of adequate knowledge on reservoir storage capacities and catchment yield are constraints in decision-making process regarding planning and management of existing water resources. Thus in this study design capacities of all the reservoirs were documented from secondary data. In addition current reservoir capacity of selected reservoirs has been estimated by surveying the reservoirs using a total station, depth-measuring road and a boat.

3.1.2.1 Design Capacity

The design capacities of the surveyed reservoirs are presented in Appendix 4. The survey revealed that the design capacity of the reservoirs range from 40,000 cubic meters (AdiKeih and Hazega dams) to 26 million cubic meter (Abardae-MaiNefhi dam). The biggest reservoirs are used for town water supply and the smaller ones are used mainly for livestock watering. The average design capacity of the reservoirs is 850,000 m^3 (Map 3.1). The aggregate design capacity of all the surveyed reservoirs reaches 67 million cubic meter out of which 32 million cubic meter is reserved in the Upper Anseba Catchment. Most of the reservoirs are more than a decade old that their capacities have been significantly decreased due to sediment deposition. In order to assess the percentage decrease of storage volume a more detailed survey of selected reservoirs was carried out. The current reservoir capacity was determined by a bathymetric survey and the results are presented in Table 3.6.



Map 3.1 Estimated Design Capacities of Surveyed Reservoirs

Table 3.6 Actual Storage Capacity and Current Water Volume of Selected Reservoirs

Reservoirs	CWLA (m^2)	CWLV (m^3)	SLA (m^2)	SLV (m^3)	DSC (m^3)	UC (m^3)
Hayelo	26,049	69,551	138,573	650,043	1,000,000	
Zagr	18,943	41,963	42,684	81,926	150,000	
Embaderho	86,033	166,306	136,000	314,833	330,000	
Tseazega	111,936	214,272	200,239	353,803	230,000	453,420
Ametsi	25,522	99,303.8	44,909	118,720	180,000	
Adesfeda	74,710	153,912	116,905	294,749	200,000	365,755
Laguen	43,633	114,202	232,217	1,031,791	1,200,000	
Lamza	15,870	25,612	93,674	442,780	500,000	
Himbrty	39,034	66,208	118,076	337,829	330,000	450,000

CWLA-Current water level area, CWLV-Current water level volume, SLA- Spillway level area (m2), SLV- Spillway level volume or actual reservoir capacity (m3), DSC- Design (original) storage capacity, UC- upgraded capacity

(Upgraded capacity means a capacity gained after the height of the dam is increased)

The bathymetric survey was done for two purposes, one to estimate the sediment deposition in the reservoirs and second to estimate the current or actual amount of water available in the reservoirs. The results are presented in detail below.

3.1.2.2 Siltation

Reservoirs normally have limited life because they eventually lose their storage capacity due to uncontrolled sedimentation. In Eritrea 15% of the original reservoir capacity is usually provided for sediment accumulation. Under ideal conditions, the useful lifespan of the medium and small dams is in the range of 15-20 years and this could be reduced to five years or less if siltation is severe (Negassi, *et al.,* 2002). High levels of siltation rates of up to 30% of reservoir capacity (over a period of about 40 years) have been recorded in some reservoirs found in Masvingo Province in southern Zimbabwe (Zirebwa and Twomlow, 1999).

From the general survey it is clear that many reservoirs have siltation or sedimentation problems though it is very difficult to have a quantitative figure. Reservoirs with observable siltation problems are AdiHabteslus, Himbrti Chea, AdiHawsha, Laugen, AdiGombolo and Mesfnto. For instance Mesfnto is a small reservoir with 60,000 cubic meters capacity situated in Subzoba Serejeka. Its catchment, which is 1 sq. km. is dominated by slightly steep slopes, prone to erosion and partially treated with soil conservation structures. During the field survey it was observed that the reserved water was polluted with sediment. In addition, the villagers reported that the reservoir capacity is decreasing with time and they are not any more irrigating twice a year. They do have a good experience in irrigation and their system and management seems efficient. They grow potatoes during summer when they irrigate from the reservoir and maize and garlic during the rainy season.

Photo 10: A reservoir with sediment-polluted water (offsite effect of erosion), Mesfnto

Though there is no evidence on how much silt has been accumulated it is obvious that the original storage capacity of all the reservoirs is decreasing with time. In this study an attempt was made to estimate the volume of the sediment deposited in the reservoirs using two different approaches. As outlined in the methodology sediment deposition, was estimated by reservoir resurvey and catchment characterization.

Reservoir Resurvey

The sediment deposition data (Table 3.7) shows that Specific sediment yield (SSY) ranges between 132 and 1846 $m^3/km^2/yr$ with a mean SSY of 703 $m^3/km^2/yr$ excluding that of Hayelo Gheshnashm dam. It is suspected that the design or original capacity of Hayelo Gheshnashm was incorrect, as the amount of storage capacity lost in two decades is considerably high and is not within the range of values obtained from the other reservoirs. The mean sediment yield varied from 948 to 12,939 m^3/year with a mean annual deposition rate of 4600 m^3/year. These figures are not far from the findings of a research done on reservoir siltation in Northern Ethiopia by Tamene *et al* (2006).

The volume of sediment deposited in Embaderho is very small as compared to the other reservoirs and this is attributed to desilting practiced in 2002 in the reservoir. The actual storage capacity was found to be 357,000 cubic meters from a survey data after the desilting. Therefore the silt has accumulated in five years time and the data should be analyzed accordingly.

Table 3.7 Reservoir Sediment Deposition Derived from Bathymetric Survey Data Analysis

Reservoirs	Design capacity (m^3)	Current capacity (m^3)	Catchment area (km^2)	Age (yr)	SV (m^3)	SY (m^3/yr)	SSY (m3/km^2/yr)
Hayelo	1,000,000	650,043	10.32	11	349,957	31814	3074
Zagr	150,000	81,926	2.84	24	68,074	2836	999
Embaderho	330,000	314,833	2.40	16*	15,167	948	397
Tseazega	453,420	353,803	37.62	20	99,617	4981	132
Ametsi	180,000	118,720	1.66	20	61,280	3064	1846
Adesfeda	365,755	294,749	7.86	20	71,006	3550	452
Laguen-AdiHamushte	1,300,000	1,031,791	10.94	13	168,209	12939	1184
Lamza	500,000	442,780	8.52	22	57,220	2601	305
Himbrti	450,000	337,829	11.29	19	112,171	5904	523

SV- sediment volume, SY- sediment yield, SSY- specific sediment yield

*Though Embaderho dam was built 16 years ago it was desilted before 5 years.

Catchment Characterization

The sediment yield of the selected catchments calculated using the equation from DFID (2004) is shown in Table 2.8. There is high variation in the sediment yield between catchments: 262 in Hayelo Gheshnashm dam to 1769 in AdiAsfeda dam with an average of 856 t/km^2/year. The magnitude and range of values of SSY in this study area are high as compared to global and regional datasets. DFID (2004) shows that African and world median SSY values are 299 and 252 t/km^2/year respectively. These values seem to agree with the figures obtained in Tigray (Nothern Ethiopia) by Haregeweyn *et al* (2006) where the specific sediment yield obtained by reservoir resurvey ranged from 237 to 1817 t/km^2/yr with an average of 909 t/km^2/yr. It was also documented that the average annual sediment yield from the Anseba basin as 598 t/km^2/year and with an average of 782 t/km^2/year for the all the major river basin of Eritrea (MoLWE, 1998).

Photo11 and 12: Major catchment characteristics of the selected reservoirs: Terraced farmlands or Eucalyptus plantations

Table 3.8 Parameters used to Calculate Sediment Yield

Reservoirs	Parameters used						Sediment Yield (t/km^2/year)
	Area (km^2)	MAP (mm)	Slope	SASE (score)	STD (score)	VC (score)	
Hayelo Gheshnashm	10.35	434	0.063	10	10	15	262
Zagr	2.84	434	0.083	20	10	40	1275
Embaderho	2.4	461	0.097	20	10	40	1376
Ametsi	1.66	452	0.058	10	10	40	636
AdiAsfeda	7.86	463	0.016	20	20	40	1769
Lamza	8.52	328	0.047	10	20	10	298
Laugen AdiHamushte	10.94	348	0.022	20	20	15	830
Himbrti Gomini	11.29	348	0.037	10	20	15	359

Sy - sediment yield, Area- Catchment area, MAP- Mean annual precipitation, Slope- River slope from the catchment boundary to the dam, SASE- Signs of active erosion, STD- Soil type and drainage VC- Vegetation condition

As shown in Table 3.8 no data is presented regarding Tseazega dam catchment because it was difficulty to characterize it. The catchment has several small reservoirs built in it and a greater proportion of the runoff retains there. From the eight reservoirs presented Himbrti Gomini has the larget catchment while Ametsi is a reservoir with the smallest catchment. The MAP is higher in subzobas Serejeka and Berik as compared to Galanefhi. The score of SASE is higher in catchment with less vegetation cover and mainly in places with more human interference like settlements.

Photo 13: Former gold mining site and possible source of silt for downstream reservoir, AdiAsfeda

High magnitude and contrasts of SSY in the study area could be attributed to variations in land use and land cover, drainage density, and other physiographic characteristics of the catchments. In addition the prevailing management systems of surface water practiced by the community can also make a great deal of difference in the degree of land degradation and amount of sediment that can be accumulated in the reservoirs. For instance, the two photos below show that farming practiced up to the edge of the reservoir in AdiAsfeda. Signs of serious erosion have been observed on the upstream area of many reservoirs, the former gold mine area of AdiAsfeda, as shown in Photo No. 13 is a typical example of neglect by the responsible community.

The results obtained from bathymetric survey were in $m^3/km^2/yr$ because it is the actual volume of water estimated deducted from the design capacity of the reservoirs. Specific sediment yield was also obtained from catchment characterization in $t/km^2/year$. However, lacking in this study is the assessment of sediment yield, because of its complexity due to temporal and spatial variability of the bulk densities in the reservoir storage. Thus the volume in $m^3/km^2/yr$ could not be converted to $t/km^2/year$ and couldn't be compared with the SSY values.

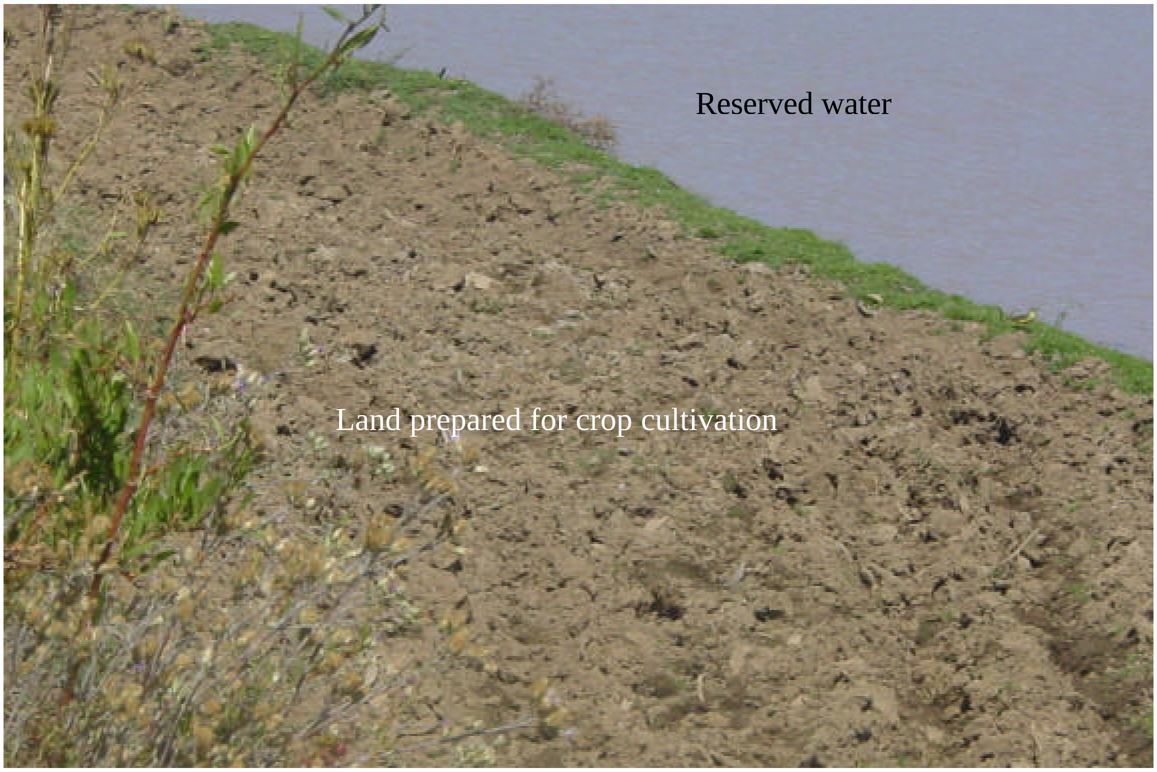


Photo 14 & 15: Cultivated plots next to the reserved water, AdiAsfeda

3.1.2.3 Actual Reserved Capacity

It was difficult to have a very precise figure representing the actual capacities of all the reservoirs under this study, as there are many factors that need to be studied in detail. However, in order to give a general picture or figure on the actual capacities and loss of storage volume with time the actual reserved capacity of the selected reservoirs was calculated using the bathymetric survey and the results are presented in Table 3.6.

The table shows that 11- 45% of the original capacity of the reservoirs is filled up with sediment on average with in two decades. This can also be explained as 0.5 - 2 % storage capacity of the reservoirs is lost every year and it coincide with estimates of Pimentel *et al* (2004) where 1% of the storage capacity of the world's dams was reported to be lost due to silt each year (cited from Economist, 1992).

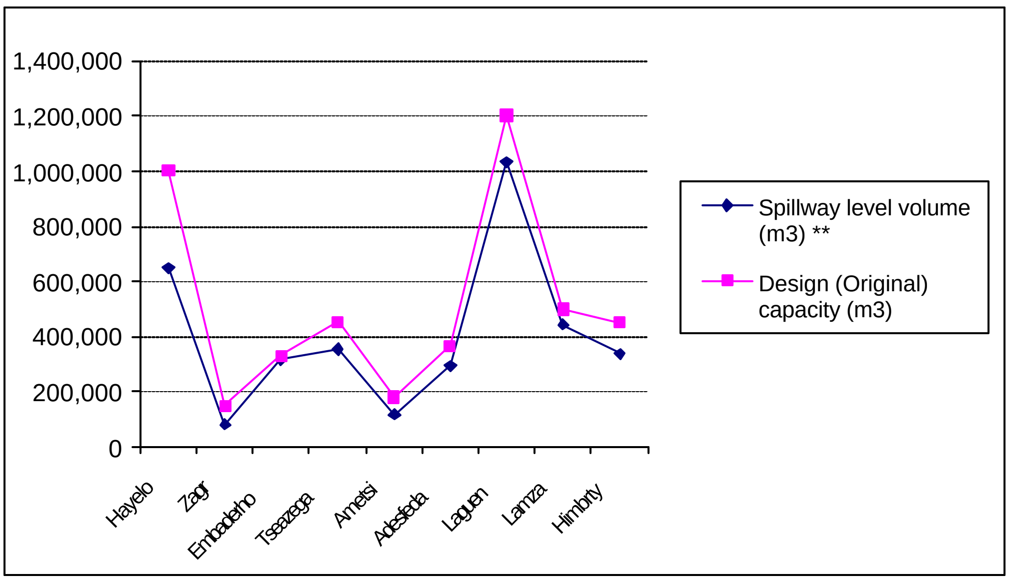


Figure 3.5 Comparison between Design (Original) and Actual Capacities of Selected Reservoirs.

3.1.3 Catchment Water Balance

The factors that influence the different status of water are many and the assumption to be taken is also complicated. These factors and their coefficients can be obtained using several models developed in catchment where long time record of meteorological data and remote sensing information is available.

Unfortunately the reality for most catchment in Eritrea and also to the catchment of Upper Anseba is different. Many of the parameters crucial for water balance calculation are absent. Available meteorological data are inconsistent, intermittent, have scarce distribution spatially and unreliable at best. Some of the reason for the poor data records is financial problem but poor institutional capacity is also apparent.

Even though with effort the data collection and data collection capacity can be improved at a catchment level, it is however not easy and is less practical in countries like Eritrea where shoestring financial and human capacity is engaged in solving primary problems. Moreover, it is not always logical given the economic situation and importance of catchment to have network of meteorological monitoring facility on every catchment.

Thus this water budget exercise is carried out in uncontrolled catchments to represent the majority of the catchment of the country. This water budget exercise is not meant to give a scientific coefficient or analysis of the several factors that influence the water budget. It is merely to give decision makers and planners with some ideas or figures of the water resources potential in the catchment. The input water, and the runoff, evaporated, infiltrated, and reserved water that would give a chance of informed decision for future water developments.

Through this water budget exercise figures that indicate the potential water resources of catchment were obtained. These figures are then used by planners, developers or stakeholders or decision makers to plan, manage and develop the resources according to the needs of the users thereby avoids possible environmental degradation, upstream and downstream conflict and helps to maximize benefits by allocating available water resources to the primary needs and economically profitable development works. This task is not however easy. The attempt made here below is a preliminary one and need to be refined through time.

The equation of a water budget approach is input minus output is equal to change in storage. In the case where the catchment storage capacity is minimum or is insignificant, the equation is input = output. The different reserve of water in the catchment after the precipitation is evapo-transpiration; infiltration, which is either evapotranspirated or is joined to the groundwater reserve; stored in reservoirs.

$P = R + ET + F$

Where P = precipitation

R = runoff

ET = Evapo-transpiration

F = Infiltration

The input parameter in the upper Anseba is only precipitation. There is no ice-melting source nor is water flowing from other catchment. The output is sum of water that flow out of the catchment, evapo-transpiration and water that flow to groundwater. To avoid complication the amount of water retained on the soil are considered to evaporate or to join groundwater reserve.

3.1.3.1 Precipitation

The common form of precipitation in Upper Anseba catchment as in most part of the country is rainfall. Rainfall data are obtained from five rain gauge stations respectively located at Adinfas, Embaderho, Hazega, Serejeka, Tseazega and Asmara. These stations were selected because of their relatively longer period (years) of rainfall records and their spatial distribution. Each rain gauge represents an area of around 120 km^2. The data set used in this analysis is from 1997 to 2007. Out of this period, there are two years with missing records: 2002 and 2006. An exception to this is Asmara, which has longer years of record.

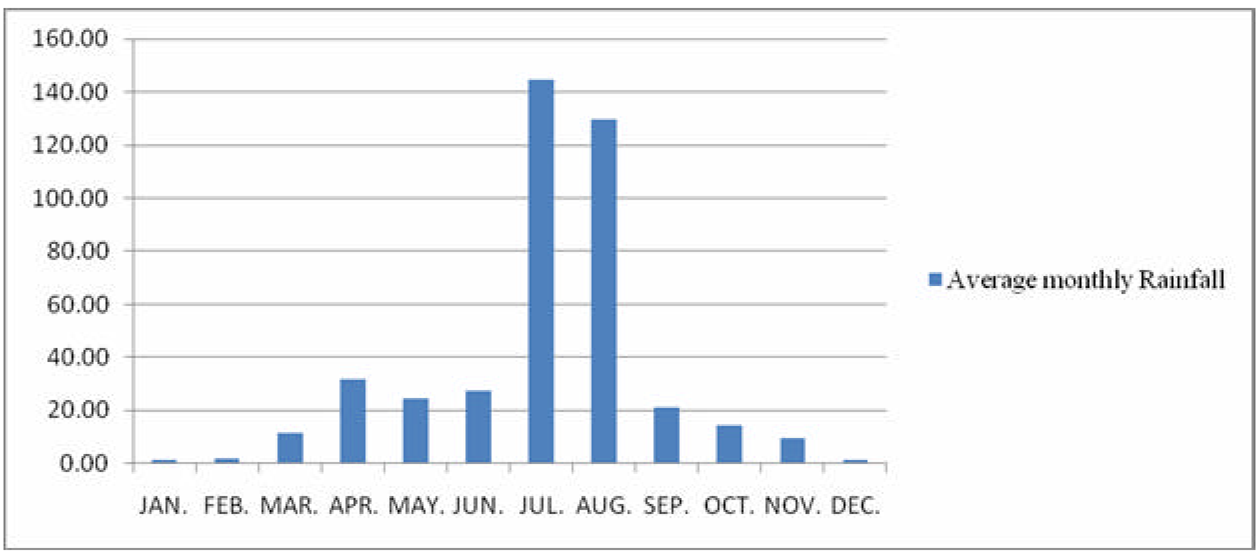


Figure 3.6 Mean Monthly Rainfall of Asmara.

According to the histogram of rainfall data from Asmara for the duration of 1988 – 2007 (Fig 1), the major proportion of the precipitation in this catchment falls in the months of April to September. From the total amount of rainfall, around 65% is received in the months of July and

August alone. This has an important implication both in terms of the amount of water which can yield or runoff and which can be stored and the catchment.

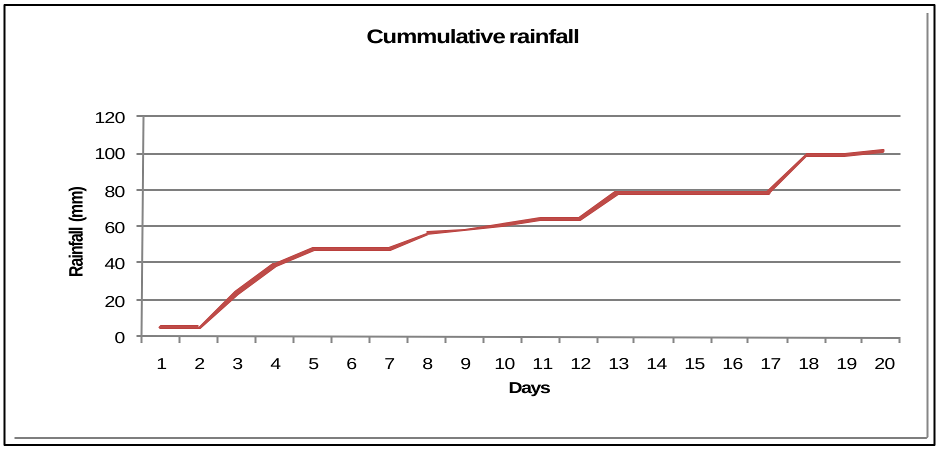


Figure 3.7 Commulative Diagram of Daily Rainfall in Serejeka for the Month of July

Figure 2 presents a daily cummulative graph of rainfall from Serejeka rain gauge station for the month of July. This figure shows some steep sections indicating high downpour of rainfall. The horizontal section results from series of subsequent days without rainfall.

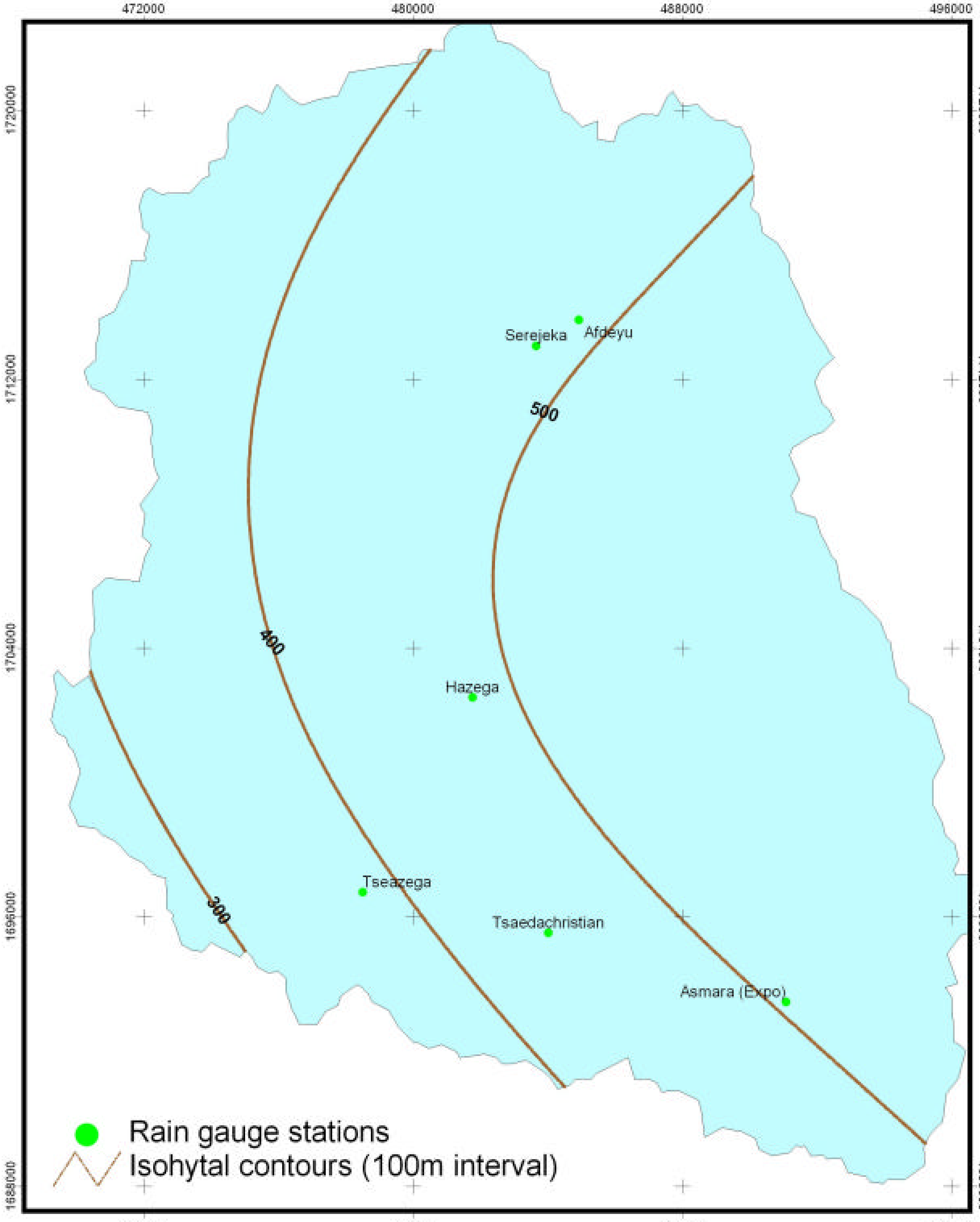
Input

The depth of rainfall in the catchment was calculated using the records from the five rain gauge stations. Rainfall depths from around ten years were used to calculate the average annual rainfall. The average rainfall at the respective five locations was subsequently used to produce an isohyetal map. Using the isohyetal map the average yearly rainfall or input in this catchment is about 289 million cubic meter of water.

Table 3.9 Average Yearly Rainfall Data from 1997 - 2007

Year	Station					
	Tsaedachrstian	Tseazega	Hazega	Serejeka	Afdeyu	Asmara
1997	608.8	555.6	604.0	580.5	643.0	688.5
1998	412.0	332.8	329.0	494.4	598.7	562.4
1999	359.9	258.6	327.8	505.8	649.7	494.3
2000	499.6	351.2	531.7	487.0	500.6	572.9
2001	587.6	568.0	823.8	557.2	517.2	616.4
2002	NA	NA	NA	NA	NA	374.9
2003	366.9	278.6	422.1	397.1	405.6	399.1
2004	301.1	292.4	296.1	413.7	430.8	345.5
2005	498.6	378.1	541.2	587.5	324.0	509.9
2006	NA	NA	NA	NA	NA	544.4
2007	409.2	401.3	473.6	349.0	348.5	443.9
Average	**449.3**	**379.6**	**483.3**	**485.8**	**490.9**	**504.7**

NA- Data not available



Map 3.2 Isohyetal Map of the Upper Anseba Catchment

3.1.3.2 Evaporation

Where energy source i.e. sun is available, water changes its status from liquid to vapor. This process is called evaporation, while evapo-transpiration is a term combining both evaporation and transpiration from plants. Evapo-traspiration is influenced mainly by climatic condition, land cover and availability of water. The climatic nature includes the sun energy which is the source of energy for the evaporation, wind, humidity, air pressure and others. The extent of forest or plant coverage and water bodies also form an important contribution to the amount of water that can evapo-transpire. Simply because it the land use nature of a catchment that determines the availability of water for evapo-traspiration.

Pan evaporation, a commonly instrument used in meteorological stations is mainly employed to obtain the potential evaporation rate in open water bodies. However, this instrument limits itself to measure evaporation from water bodies only. The amount of evaporation from different types of land use and transpiration from plants is not possible to quantify using this instrument. Nevertheless the data from the pan evaporation instrument can be used in the calculation of evapo-traspiration.

Several scientists have derived different equations to calculate the evaporation and evapo-transpiration from different climatic data. Equations such as those of Thornthwaite (1931), Thornthwaite (1949), Turc (1954) and Blaney and Criddle (1950) are temperature-based evaporation estimation methods. The simplest equation of Thornthwaite (1931) equates the ratio of annual precipitation to evaporation with ratio of precipitation to mean annual temperature. Blaney and Criddle's (1950) equation incorporates an additional variable k (empirical crop factor) alongside temperature. Generally, temperature-based evaporation estimation equations are still widely used and have been found to be relatively successful (Jones, 1997). Nevertheless, as temperature is not the dominant and the only factor that affects evaporation and moreover as the relation between temperature and evaporation is not fixed (Jones, 1997) it cannot be taken as the final say on evaporation.

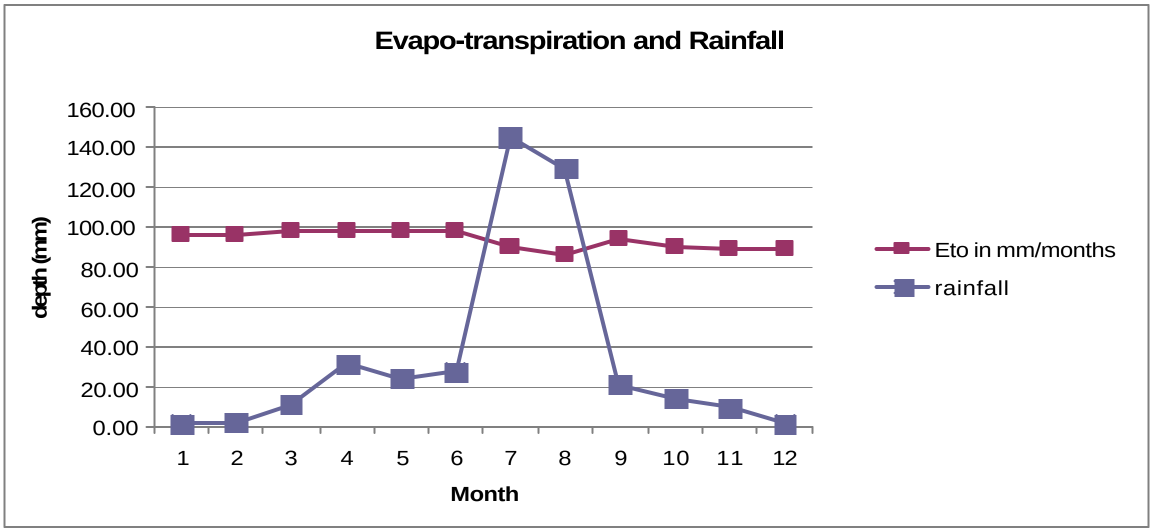


Figure 3.8 Potential evapo-traspiration and rainfall – According to Blaney-Criddle equation (ETo = p(0.47Tmean +8)

Due to the shortcomings of temperature-based equations, several complicated mass transfer equation, energy balance and combined formulae by Penman were later introduced. As the equations requires numerous input parameters owing to the complexity of evapo-transpiration (ETo). A monthly evapo-transpiration value calculated in section 3.2.1 and as indicated in table 17 and table 18 shows that Asmara has a high of 6.6 mm day of evapo-traspiration during March and April and a low of 3.8mm/day in the month of August. Annual Average ETo for Asmara station is 5.3mm/day. The same calculation made for Afedyu station shows slightly lower value. The annual average ETo in Afedyu station as indicated in table 3.17 is 4.3.

The monthly precipitation in the months of July, August and September is higher than the potential evaporation and thus overflow of water and saturation of soil is possible due to the surplus. The surplus of water lasts until the month of September.

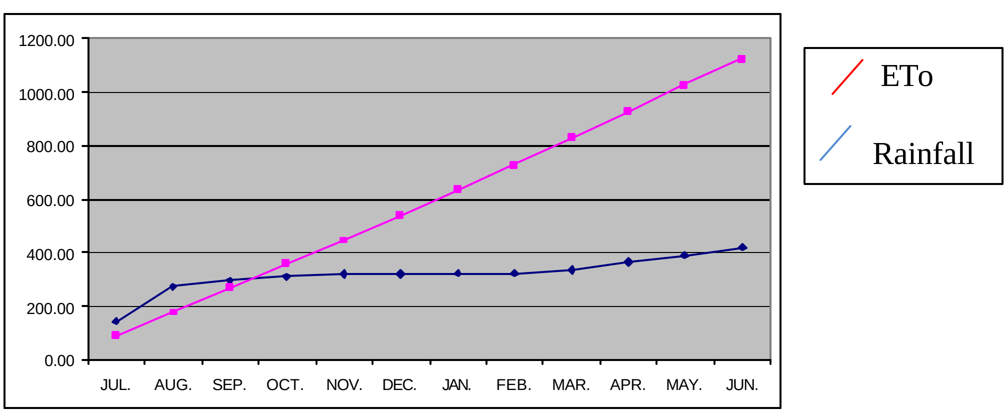


Figure 3.9 *Cumulative Rainfall and Potential Evapo-traspiration from the Asmara Meteorological Station*

3.1.3.3 Runoff

Runoff is concentrated flow of water in a catchment. It is the amount of water that flows to the river channels on the surface and/or through base flow. This amount of water is the surplus of rainwater to evaporation and infiltration. The amount of runoff, sometimes called the surface yield of catchment, depends on many factors. These are land cover or land use, soil, topography and rainfall characteristics.

In the upper Anseba catchment, owing to the geomorphology and soil or geology of the Central Highland, runoff starts immediately after the rain. Though the short time lag also depends on the previous rain records, shallow soil depth, steep and mountainous morphology and high intensity (and short-lived?) rainfall causes high runoff and soil erosion. For these reasons runoff in this catchment is expected to be high when compared with lowland catchments. This stems from the fact that soil eroded in the central highland is deposited in the western lowlands, creating deep soils with a high water retention capacity, and thus less rush, high infiltration, high evaporation and ultimately less runoff. Land cover and land use constitute also factors that significantly affect the behavior of the runoff in a catchment. For example urban settlements, untreated land or uncultivated land or barren land would yield more runoff than forest or vegetated areas.

The exercise to estimate runoff of the upper Anseba catchment was made by employing the data collected at the Toker domestic water supply dam. As daily water level in the Toker dam reservoir which corresponds with its volume of water storage is recorded, it indicates the amount of water retained by the dam for a specific day. Since the catchment of the Toker dam is not big and the rainfall-runoff lag time is short, it is relatively easy to outline the volume of water retained in Toker after a certain amount of rainfall on that day.

The problem however with this calculation is that there are several small and medium size dams upstream of the Toker dam which may hold some of the water. These dams can completely hold the water or slow down river channels resulting in more infiltration. Groundwater recharge downstream of dams is a common phenomenon understood or observed by locals. To eliminate this problem, the calculation was started from the rainy season, which to some extent ensures that the yield from the whole Toker catchments makes its way to the dam. The equation for the calculation is:

$$I – O = ?S,$$

$$I = ?S + O$$

Where: - I is Input water

O is Output which is discharged water and evaporation & leakage

?S is change in storage in the dam

I = Rv + Pw,

Rv = I – Pw

Where Rv is volume of water from runoff of the catchment

Pw is rainfall on the dam's reservoir water surface

C = Rv/Pd

Where C = runoff coefficient

Pd = isohytal average precipitation

Pd = ? (Wi * Pi)

Where Pd is isohyetal average precipitation

Pi average precipitation between the two consecutive contour values

Wi = Ai / A

Where Ai is area between two adjacent isohyets

A is total area of the catchment

i is the number of isohyetal polygons

Overall, this exercise is prone to different types of errors. One of the significant ones may be due to the overrepresentation of one rain gauge or because of the scarcity of rain gauge stations in the catchment. The rain gauge network is especially sparse in the north eastern part of the catchment which makes it vulnerable for a wild extrapolation. Thus the calculation has assumed a 20% margin of error in the rainfall.

Table 3.10 Change in Storage and Run off Coefficient for the Toker Catchment

Date	Pd	Pw	E	Q	?S	C
1 - 5 of July	9,451,200	7060.4	1861.4	50000	656,000	0.07
6 - 12 of July	8,248,800	9061.7	2425.7	60000	576,000	0.08
13 - 26 July	15457406	19270.8	6054.2	130000	1,172,902	0.08
1 - 9 August	10397612	5833.8	6475.5	90000	1,573,000	0.16
10 -17 August	3231469	10888.9	5127.7	80000	513,090	0.18
17 - 25 August	6943548	9223.6	6825.7	80000	1,912,360	0.29

The result from the table above shows that the runoff coefficient ranges from 0.07 to 0.29. The result agrees with the logic that in the early days of the rainy season the runoff coefficient or the catchment yield is small. This is basically because some of the water is retained in the upstream small dams and also because there is high infiltration until saturation is attained in the soil. However as the upstream ponds gradually fill up and there is high base flow from the groundwater and soil of the catchment, the runoff coefficient is observed to increase. On average thus the runoff coefficient in this catchment can be taken as 0.14. This result should be taken only for the rainy season. Catchment yield during the dry season of April to June could be taken of less than 0.07 as a runoff coefficient. In this case the average yearly runoff coefficient could be taken as 0.12.

The result from this calculation is on the maximum range of what other research has come up with. A figure obtained in Afdeyu by Burtscher (2003), in a controlled catchment, for the runoff coefficient ranges from 5.4 (%) at minimum to 12.9 maximum. Burtscher (2003) has attributed the low runoff coefficient in this catchment to the extensive soil and water conservation infrastructure in place. The Toker catchment (catchment used for the exercise in this research) has sporadic soil and water conservation measures. The figure from this exercise is on the maximum end of the range given by Burtscher (2003).

To calculate the amount of runoff for the whole catchment, an isohyetal map is used to divide the area into several rainfall areas. In addition to this, the runoff coefficient for the precipitation in the rainy season and dry season are taken separate. For the dry season a RC of 0.08 was taken and for the precipitation during rainy season a runoff coefficient of 0.17 was taken. According to the rain gauge station from Asmara plotted in this document, 70% of precipitation falls during the rainy season.

Table 3.11 Table showing Runoff Volume for the Upper Anseba Catchment

Rainfall (m)	Area (m^2)	Runoff Coefficient		Runoff volume (m^3)
0.30	13413975	0.14 X 70%	0.07 X 30%	478878.9
0.42	138259221	0.14 X 70%	0.07 X 30%	6910195.9
0.54	265086926	0.14 X 70%	0.07 X 30%	17034485.9
0.66	215996681	0.14 X 70%	0.07 X 30%	16964379.3

In total roughly around 41 Mm^3 of water is drained through the channels every year in this catchment. Considering a 10% margin of error, the estimate would be 41 Mm^3 ±4 Mm^3.

Another supplementary exercise undertaken was using the assumption that land use has significant hydrologic influence. It is safe to assume that land use classification of a catchment represents the different characterization that significantly affects hydrological responses. These are factors such as soil cover, topography, soil saturation, land cover and others. In this exercise forests are for example assumed to be on steep topography and shallow soil. Another example is irrigation, which is mainly present in valleys with saturated and deep soil; rain fed agricultural areas are in relatively flat areas with deep and less saturated soil.

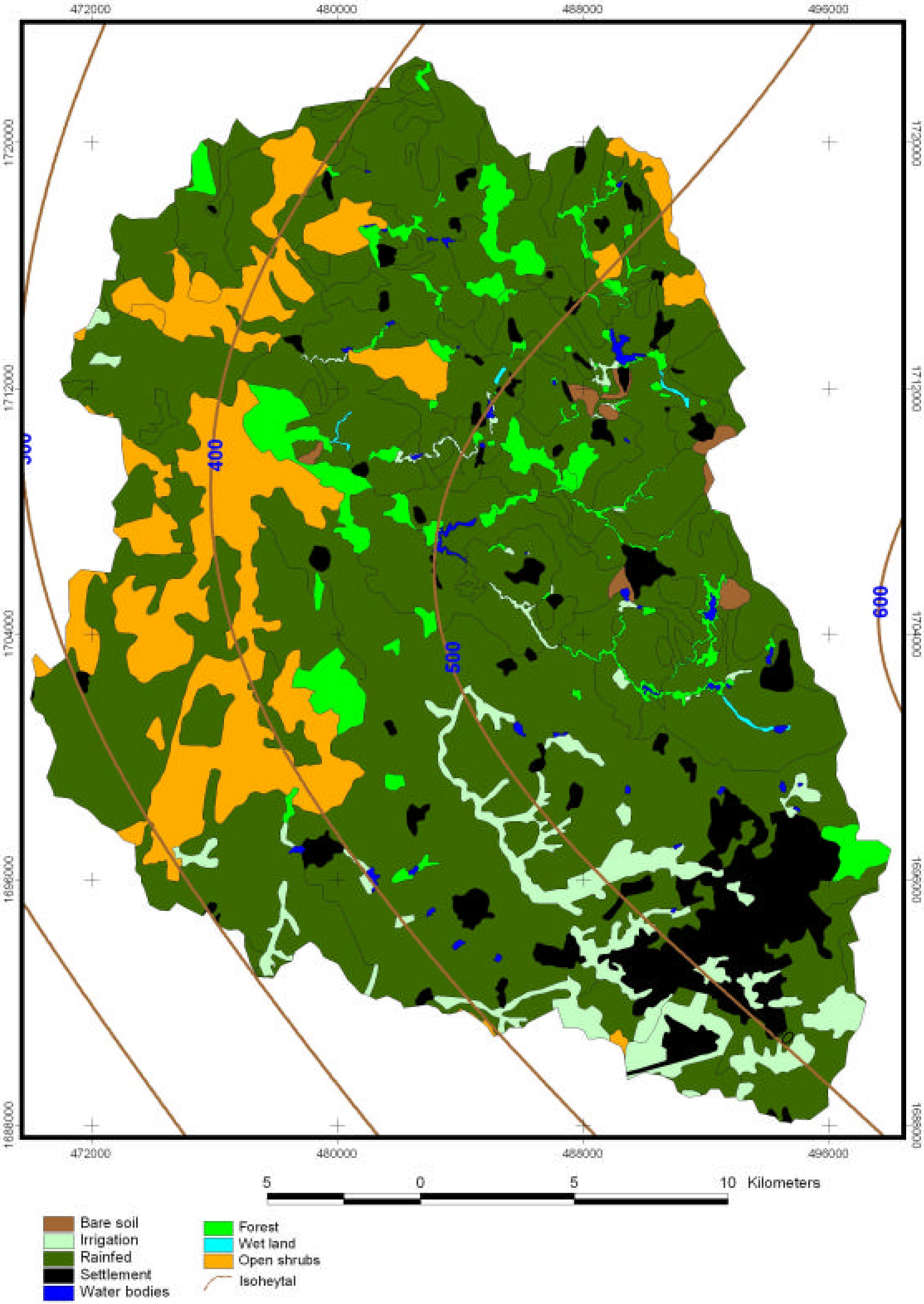
Having stated the above assumptions, a land use map was simplified and summarized into major eight land use categories. Each category was then assigned a runoff coefficient based on professional estimation. For example, settlements give a high runoff coefficient because the infiltration is significantly reduced due to the asphalt roads and smooth and tight tops of the houses. The same like settlements, wetlands have also a relatively high runoff coefficient due to the high saturation and topography. Bare soil and forest area, due to their shallow soil and steep topography have also higher runoff coefficients when compared with rain fed and irrigation areas which are situated in flat areas and with deep soil profile.

Table 3.12 Expert Estimation of Different Land Use Coefficient

NO.	Land use	Estimated Coefficient
1	Forest	0.12
2	Rain fed (Agriculture)	0.07
3	Settlement	0.15
4	Water bodies	1.00
5	Wet land	0.20
6	Open shrubs	0.10
7	Irrigated land	0.08
8.	Bare soil	0.13

Source: Questionnaire filled by experts

After the professional estimation of run-off coefficient was given to the different land use map, an isohyetal map with polygon classifying the different rainfall region was intersected with the land use map. Using the area calculated from the intersection of the two themes, yield from each land use category is calculated.



Map 3.3 Intersection of Land Use Map and Isohyetal Map.

The overall run off coefficient of the catchment using this calculation is equal to 11.5%, which is in line with the earlier exercise. This indicates the professional guess made is close to the calculation made earlier and thus is safe to use for sub catchment runoff calculation using the land use coefficient.

3.1.3.4 Groundwater Reservoir

Water infiltrated into the soil is either evaporated, joins a surface river as base flow, or trickles down to join the ground water reservoir. Depending on the geology or lithology the water that joins the reservoir acts differently. In most cases the flow in groundwater is slow, so that the water is almost literally stored in the underground. In some cases however, the water uses major fractures with wide aperture to swiftly move from the place of recharge. These cases occur in crystalline rocks where major fractures control the groundwater flow.

The geology in Upper Anseba catchment is dominated by meta-volcanic rock type, which has gone through successive tectonic incidence. It is not easy to completely understand the groundwater occurrence and movement in this area due to its complex geology. In addition to this reason, not many researches have been carried. Bed rock aquifers behave considerably different from the sedimentary deposits.

Among the few researches carried out in the crystalline rock of the Central Highland are the estimations made on groundwater recharge by Hail (2005) and Solomon (2003). Both of the researches used the mass balance method to estimate recharge. Both came with similar figures on the rate of recharge. According to the research by Hail (2005), the rate of recharge in metavolcanic geology is 8%, greater than the basalts, where it is 6%, and the granites, where it is 3%. This result is in agreement with the simple calculation one can make to get the balance of water. For the rainy season, evapo-traspiration was calculated to be around 75% of the rainfall, runoff is around 14% and groundwater recharge is greater than 8% (as the vast majority of the catchment is covered by metavolcanic rock). Evapo-traspiration in the dry season is expected to be greater than 90%, runoff to be as low as 7% and groundwater recharge to be insignificantly small.

The groundwater recharge has a vague meaning in the case, the nature of groundwater which comprises geometry, storage capacity, movement and occurrence of groundwater is not revealed.. Both of the researches were not able to explain how planners can use this information to plan and manage the groundwater.

The apparently obvious morphological factor is expected to significantly influence the movement of groundwater in the upper Anseba region. Water recharged in the relatively uplifted areas has higher potential energy due to gravity to create a gradient towards the steepest slope's direction. In the case of this basin the groundwater flows to the North West. This may not be always true as the fractures created by the tectonic effects also control much of the flow direction. Nevertheless it is important to note that the water recharged could be easily moving out of the catchment due to the high flushing rate marked bytopographic difference (Haile, 2005).

Besides what has been said, the groundwater flow rate, which could indicate the residence time, is vague to the date. Not much study has been carried out to quantify the extent of groundwater residence time in a basin or in this kind of geology. It requires future meticulous efforts to understand the potential of the groundwater and the potential groundwater reservoir in this area. Nonetheless, the recharge rate indicates the amount of water that is lost from the surface water to the groundwater reserve. Assuming that the rate of recharge is uniform in all the catchment the yearly groundwater recharge is roughly around 23 Mm^3 of water per annum.
For the time being, assuming the amount of water recharged as a potential groundwater reservoir is a safe assumption. If reserve potential of the geology is higher and groundwater moves slow, the assumption is safe for future use and planning.

3.1.3.5 Surface Water Reservoir

There are 49 ponds and dams in the Upper Anseba Catchment. More or less concentrated near Asmara, these dams are fairly well distributed in the whole catchment leaving a stretch of gaps in the central west part of the catchment. The central west stretch is the Maibela River laden by the sewerage waste from Asmara. Though a potential water source, due to contamination from untreated sewage, the surface runoff flows without being reserved.

In total, the surface reservoirs in this catchment have a potential reserve capacity of 32 Mm^3 of water. Given that the majority (88%) of the dams and ponds are constructed before a decade, the dams and ponds are considerable silted. Based on the survey carried out in this study depicted in section 3,1,2, 23% of the potential reserve capacity is silted. Thus the reserve capacity in this catchment would be roughly around 24.5 Mm^3. This means that the reserve capacity of the surface reservoir in this catchment is almost 70% of the annual yield calculated for the whole catchment.

3.2 Reserved Water Use

3.2.1 Agricultural Use

3.2.1.1 Irrigation

In Zoba Maekel out of the total 74 reservoirs, 31 are used for irrigation, domestic purposes and livestock watering and are considered as class one reservoirs for irrigation in this study. The remaining 43 reservoirs are used for human and livestock consumption only. But some interested farmers practice irrigation in very small areas not more than 4 hectares in some of the reservoirs, which are not active for irrigation. These reservoirs are categorized as class two reservoirs for irrigation in this study. Out of the 31 reservoirs used for irrigation (Appendix 6) three reservoirs (Adisheka, AdiNifas_D01 and AdiNifas_D02) are mainly used for Asmara town water supply and irrigation is practiced from seepage water downstream of the reservoirs.

In the Upper Anseba Catchment 19 out of the 49 reservoirs are active for irrigation. The extent and intensity of irrigation is not the same or equal in almost all the reservoirs. They can be rated as good, medium and low depending on their experience and the availability of land and water. For instance Lamza and Ametsi can be taken as role models in irrigation in Zoba Maekel. These farmers are not only good in producing but also in marketing their produce that is in delivering directly to the consumers.

Photo 16: Irrigation from seepage water downstream of Adisheka town water supply dam

Some reservoirs are shared between two neighboring villages because the dam and reservoir site is constructed in areas jointly owned by two villages. Villages like Laguen and AdiHamushte, AdiGhebru and AdiTeklay, and Hayelo and Gheshnasm share common reservoirs and irrigate or utilize the resources together with harmony.

Photo 17 & 18: Irrigation practices at Laguen and AdiHamushte

In some villages where no irrigation is practiced from reservoirs the main constraint is shortage of reserved water that they use it for livestock watering and domestic uses only. However, in some places lack of awareness and previous experience as well as mismanagement of resources could be the main reasons for the absence of irrigation. The case of Tseazega and Zagr can be mentioned as relevant examples. In Tseazega there are two reservoirs and were being used for irrigation until 1996. But currently there is no irrigation practiced in the second dam because the irrigable area has been planted with eucalyptus. There is severe water shortage in Zagr and the reserved water is used only for livestock watering for a limited period of time annually. The downstream area has been planted with eucalyptus 80 years back by few farmers and all the seepage water is consumed by these trees.

Photo 19 & 20: Eucalyptus trees planted downstream of reservoirs at Tseazega (left) and Zagr (right) to consume the scarce resource, i.e., water.

3.2.1.1.1 Current and Potential Irrigable Areas

In almost all the villages surveyed the average land holding for each household is less than half of a hectare. The areas allocated for irrigation are shared among all the villagers based on the land fertility status and topography and are fragmented into small plots. The survey revealed that the total currently irrigated land in Zoba Maekel reaches 487 ha out of which 322 ha is situated in the Upper Anseba Catchment (Table 3.14). The total number of beneficiaries from these reservoirs was estimated to be 11,720 households in Zoba Maekel which is equivalent to the number of households in the villages with reservoirs because every farmer has a right to have a piece of irrigable plot. In addition to the 487 ha of irrigation practiced on the class one active reservoir for irrigation around 40 ha is irrigated in some of the class two reservoirs (Table 3.15).

Table 3.13 Irrigation in Class One Active Reservoirs in Upper Anseba and Zoba Maekel

S.No	RESERVOIR	YEAR OF CONSTRUCTION	DESIGN CAPACITY (M^3)	CURRENT IRRIGATION (HA)	POTENTIAL IRRIGABLE (HA)*
1	Hazega	1982	40,000	7	4
2	Tseazega	1988	230,000	33.5	23
3	Shinjibluk	2007	350,000	10	35
4	Adi Kontsi-D01	1970	250,000	2	25
5	Ametsi	1988	180,000	30	18
6	Adi Asfeda	1988	200,000	32	20
7	Adi Habteslus	1941	80,000	4	8
8	Adisheka	Before 1930	5,100,000	12	20
9	Adikolom	1989	270,000	5	27
10	Embaderho-D01	1992	330,000	24	33
11	Guritat-D01	2006	300,000	6	30
12	Hayelo	1995	1,000,000	40	100
13	Mekerka	2003	270,000	16	27
14	Mesfinto	1995	60,000	9	6
15	Shmangus laelai	1985	400,000	15	40
16	Shmangus Tahtai	1992	230,000	15	23
17	Teareshi	1989	280,000	11	28
18	Adi Nefas_D01	Before 1930	600,000	30	-
19	Adi Nefas_D02	1941	200,000	20	-
20	Daero Paulos	1987	60,000	2	6
21	AdiGhebru-AdiTeklay	1985	160,000	6	16
22	Tselot_D03	1989	250,000	2	-
23	Tselot_D02	2005	300,000	3	30
24	Adi-Ahderom	2007	250,000	12	25
25	Laguen-AdiHamushte	1995	1,300,000	29	130
26	Himbrti Shaka	1985	400,000	11	40
27	Himbrti Gomini	1989	450,000	15	45
28	Laguen	1987	200,000	15	20
29	Adi Gombolo	1982	150,000	7	15
30	Adi Hawesha	1988	150,000	5	15
31	Lamza	1986	500,000	18	50
	Total			446.5	859

- Reservoirs assigned Serial No 1-19 are situated within the Upper Anseba Catchment while the rest are outside of the catchment but located within the Administrative boundaries of Zoba Maekel.
- AdiSheka, AdiNefas_D01 and AdiNefas_D02 are town supply reservoirs where irrigation is practiced from seepage water.

- * The potential irrigable area is based on the design capacity of the reservoirs and has already be decreased due to siltation.

The main constraint for the expansion of irrigation is availability of water. Inefficient design for water controlling and distribution systems has also constrained the development of irrigation. If water is made available it is possible to expand irrigable areas by leveling undulating landscapes and applying proper design and implementation of irrigation infrastructure and water conveyance system. Thus based on the design capacity of the reservoirs the potential irrigable area in Zoba Maekel was supposed to be 1082 ha. The bathymetric survey on selected reservoirs in this study revealed that 11 – 45 % (average of 23 %) of their actual storage capacity has been lost on average in two decades. Thus if it is taken as 23 % of the design capacity is lost the potential irrigable area in the zoba has to be decreased by 23 %. Therefore the potential irrigable area can be estimated to be 833 ha. This indicated that it is only 58 % of this potential that is used or utilized currently. In other words, considering the potential for expansion in irrigated area and the assessments made it is estimated that additional 300 ha can be irrigated using reservoir water in Zoba Maekel. Here the main resource used as criteria for irrigation is water because if water is available hilly areas can be reclaimed by indigenous soil conservation structures like bench terraces and excavation drainages.

In the upper Anseba Catchment similar analysis revealed that the potential irrigable area reaches 475 ha out of which almost 73 % (346 ha) is currently under irrigation (Table 3.14).

Table 3.14 Irrigation in Class Two Reservoirs in Upper Anseba and Zoba Maekel

S.No	RESERVOIR	YEAR OF CONST.	DESIGN CAPACITY (M^3)	CURRENT IRRIGATION (HA)	POTENTIAL IRRIGABLE (HA)
1	Adi Merawi	1992	110,000	3	11
2	TsaedaChristian	1944	80,000	4	8
3	Adi Musa	1992	250,000	2.5	25
4	Adi Kontsi_D01	1970	250,000	2	25
5	Adi Yacob	1993	80,000	3	8
6	Adi Musa	1992	250,000	2.5	25
7	Tsaeda Emba	1980	55,000	2.5	6
8	Adi Bidel	2007	90,000	-	9
9	Guritat	1997	180,000	3	18
10	Zagr	1984	150,000	2	15
11	Adi Arada	2007	200,000	3	20
12	Himbrti	1986	150,000	2	15
13	Selaadaero	1981	80,000	6	8
14	Adi Keshi	1988	250,000	2	25
15	Adi Teklay	1988	53,000	3	5
	Total			40.5	223

- Reservoirs assigned Serial No 1-19 are situated within the Upper Anseba Catchment while the rest are outside of the catchment but located within the Administrative boundaries of Zoba Maekel.

The figures presented in Table 3.14 and 3.15 are summarized in Table 3.16 below.

Table 3.15 Extent of Current and Potential Irrigable Area in Upper Anseba and Zoba Maekel

	Upper Anseba	Zoba Maekel
Currently irrigated area (ha)	346	487
Potential Irrigable area (ha) calculated on the basis of design capacity	617	1082
Potential irrigable area (ha) estimated from actual capacities (actual capacity decreased due to siltation)	475	833

In the second phase of the survey accurate measurement of the irrigated land was done on the 9 selected reservoirs using GPS. Results showed that the estimated areas obtained from key informants were lower than the GPS measured areas.

3.2.1.1.2 Agricultural Inputs and Production

Crops Grown:

A variety of horticultural crops are grown in the irrigated areas. The main crop grown widely and considered as the most valuable cash crop is potato. Tomato, cabbage, carrot and salad are also grown widely. Maize, garlic, spinach and alfalfa are grown at a lesser scale on specific places. It is not common to grow onions in the highlands but Hayelo, Guritat and Adikolom and Shmangus laelay are trying to introduce it in recent years and it is being grown in these places widely specially in Hayelo Geshnashm.

Agricultural Inputs:

The Ministry of Agriculture branch offices at subzobas level supply and sell farm inputs such as fertilizers, seeds, pesticides and other necessary materials to the farmers with fair prices though they are not supplied on time. Farmers complain that the supplies are not sustainable/ reliable and try to get the inputs from other source like private sellers at a very high price.

In addition in places where they use pumps, the farmers face price and availability problems to get fuel.

Market Accessibility, Transport and Storage:

Farmers do not have proper storage facilities for their produce. Thus they are forced to sell their produce specially the perishables like tomato at low price. After they harvest they sell their products directly at farm gate prices or off farm gate markets. Farmers sell their products directly to consumers or wholesalers. Asmara, the main and important market for agricultural products is located in the center of Zoba Maekel. Asmara market is easily accessible to the majority of the farmers in the study area. Generally speaking there are convenient roads and transportation of farm products is easy.

Most of the farmers sell their produce in the nearby markets like Serejeka or transport their produce on foot, by animals or vehicles to Asmara. Only few farmers, which are out of the easy reach of the main road like Teareshi, sell their produce at farm gates to wholesalers who buy and bring the products using their own transport from the production fields.

The study showed that most of the farmers sell above 90% of their products and leave the low quality ones for household consumption.

Photo 21: A farmer harvesting one of the major horticultural crops, Carrot at Lamza.

3.2.1.1.3 Irrigation System and Infrastructure

Furrow and basin irrigation are the most common practices in the region. Furrow irrigation is mainly practiced in subzobas Serejeka and Berik, while basin and furrow irrigation are common in Subzoba Galanefhi.

Photo 22 & 23:

Top: Basin Irrigation at Himbrti, Galanefhi

Left: Furrow irrigation at AdiAsfeda, Berik

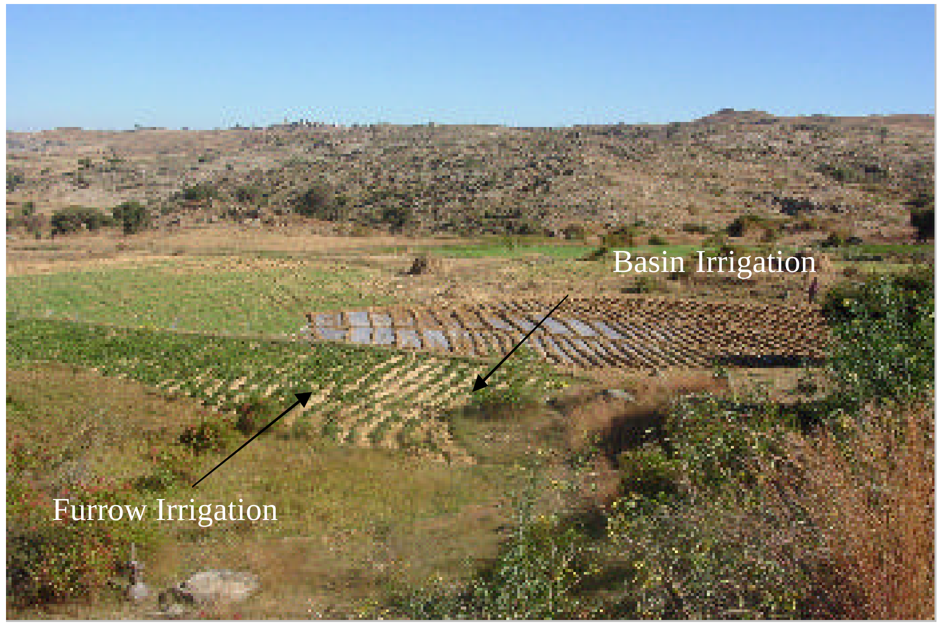


Photo 24: Both basin and furrow irrigation at Subzoba Galanefhi.

The water conveyance system in the area is mainly open channel alone or open channel with lined or pipe channel. Water is lifted or delivered to the channels using diesel or petrol operated water pumps. In Himbrti shaka, Himbrti Gomini, Laugen-AdiHamushte, Ametsi, AdiAsfeda, Merkerka, Embaderho, Adikolom, Hayelo-Geshnashm, and Tseazega impoved pipe is used as the main irrigation distribution system. In Lamza lined concrete canal is use. More over in Geshnashm pilot pressurized, sprinkler irrigation has been installed and electrified. In places where the irrigated plots are close to the reserved water mainly on the upstream side farmers use buckets to fetch water and irrigate their fields.

In general the irrigation system is characterized as inefficient and labor intensive. The construction method of earthen canals, the use of closed pipes for water distribution and further the introduction of sprinkler and drip irrigation should be great consideration.

Photo 25, 26 & 27: Different water conveyance system for irrigating crops

3.2.1.1.4 Irrigation Scheduling

The study showed that most of the villagers grow crops twice a year. However, there are few farmers or villagers who grow three irrigated crops a year. Mixed cropping is practiced by few villages in order to use the time and resources efficiently. Most of the farmers irrigate their field ones a week unless the crops are at flowering stage during which the crops need more water. The amount of water used in each irrigation is not known and is not uniform even in one field. They tend to apply water until the fields are oversaturated. They are mainly limited by availability of fuel for the water pumps and sometimes by the availability of irrigation water when it in short supply. This indicates that the irrigation system in the area is still traditional and it is clear that such a system or management practice doesn't allow efficient and sustainable use of the available water. Thus good irrigation management is required for efficient and profitable use of water for irrigating agricultural crops. A major part of any irrigation management program is the decision-making process for determining irrigation dates and/or how much water should be applied to the field during each irrigation. This decision-making process is referred to as irrigation scheduling and there is urgent need for its implementation in the study area.

As a model or pilot the water budget of four main crops potato, tomato, carrot and cabbage have been calculated and presented in the following sections.

Soil-Water Budget

The use of a soil-water budget method can assist users in their decisions about when to irrigate and how much water to apply. The method consists of assessing the incoming and outgoing water flux into the crop root zone over some time period (Figure 3.10).

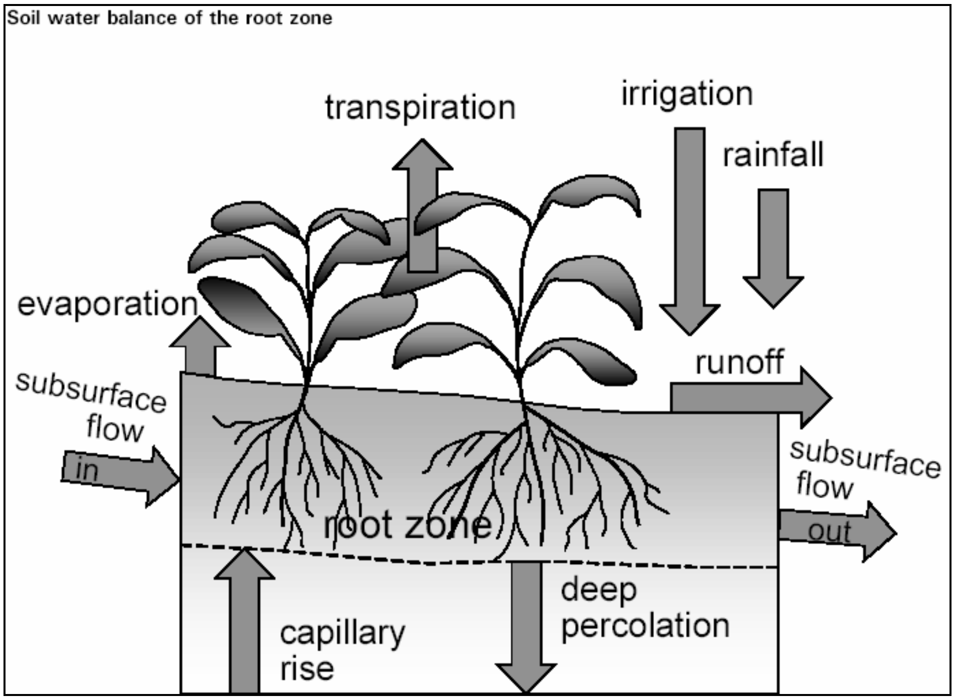


Figure 3.10 Soil Water Balance of the Root Zone

If the initial available soil water can be determined the required amount of water can be estimated by the following equation:

$\pm$SW = I + P - RO - DP –ET + CR ± SF

Where Irrigation (I) and rainfall (P) are water added up to the root zone. Part of I and P might be lost by surface runoff (RO) and by deep percolation (DP) that will eventually recharge the water table. Water might also be transported upward by capillary rise (CR) from a shallow water table towards the root zone or even transferred horizontally by subsurface flow in to (SFin) or out of (SFout) the root zone. In many situations, however, except under conditions with large slopes, SFin and SFout are minor and can be ignored. Soil evaporation and crop transpiration deplete water from the root zone. If all fluxes other than evapotranspiration (ET) can be assessed, the evapotranspiration can also be estimated from meteorological data using the standardized Penman-Monteith equation. Finally the required soil water content (SW) or in other words the crop water requirement can be calculated. Some fluxes such as subsurface flow, deep percolation and capillary rise from a water table are difficult to assess and short time periods cannot be considered.

Potential Evapotranspiration (ETo)

In this study an attempt was made to estimate the potential evapotranspiration (ETo) from Afdeyu and Asmara meteorological data (Table 3.17 and Table 3.18). Owing to the difficulty of obtaining accurate field measurements, evapotranspiration (ET) is commonly computed from weather data. A large number of empirical or semi-empirical equations have been developed for assessing crop or reference crop evapotranspiration from meteorological data. The FAO Penman-Monteith method is now recommended as the standard method for the definition and computation of the reference evapotranspiration, ETo. The meteorological data used are mean monthly maximum and minimum temperature (°C), relative humidity (%), sunshine, wind speed (km/d) and Solar radiation ($MJ/M^2/d$).

Afdeyu data of relative humidity, wind speed and global solar radiation is only one-year data collected after the installation of the automated meteorological station. Thus the ETo value estimated based on one year data can not be as reliable as the ETo calculated using Asmara meteorological data of two decades.

Table 3.16 Monthly ETo Values Computed from Meteorological Data of Afdeyu (2007) using CROPWAT

Month	**Max. Tem (°C)**	**Min. Tem (°C)**	**Humid. (%)**	**Wind-speed (Km/d)**	**Sun-Shine (Hours/ day)**	**Solar radiation ($MJ/M^2/d$)**	**ETo (mm/d)**
January	23.5	7.2	53	185.4	9.8	20.1	4.0
February	25.3	9.4	46	176.5	9.6	21.6	4.6
March	25.9	10.4	44	233.3	9.4	23.1	5.5
April	26.0	12.2	52	245.4	9.1	23.5	5.5
May	26.0	9.4	47	271.3	9.5	24.1	5.9
June	25.5	13.4	49	250.6	8.5	22.3	5.5
July	22.2	12.9	78	184.9	5.7	18.1	3.6
August	21.6	12.8	81	190.1	6.0	18.6	3.5
September	23.4	11.4	60	198.7	8.4	21.8	4.5
October	21.7	10.7	59	176.3	9.2	21.5	4.1
November	22.4	9.2	63	250.6	9.6	20.2	4.0
December	22.9	8	63	172.8	9.6	19.2	3.5
Average	23.9	10.8	57.9	211.3	8.7	21.2	4.5

Table 3.17 Monthly ETo Values Computed from Meteorological data of Asmara (1998-2007) using CROPWAT

Month	Max.Tem (°C)	Min.Tem (°C)	Humid. (%)	Wind-speed (Km/d)	Sun-Shine (Hours/ day)	Solar radiation ($MJ/M^2/d$)	ETO (mm/d)
January	23.0	4.2	53.0	371.2	9.4	19.7	5.0
February	24.5	5.5	46.0	406.1	10.1	22.4	5.9
March	25.5	7.5	44.0	414.7	9.2	22.8	6.5
April	24.5	9.3	52.0	423.4	9.3	23.9	6.3
May	25.5	10.9	47.0	414.7	9.2	23.6	6.6
June	25.3	11.4	49.0	406.1	8.5	22.2	6.2
July	22.2	12.2	78.0	388.8	5.5	17.8	3.9
August	22.0	12.2	81.0	371.5	4.8	16.8	3.8
September	23.5	9.6	60.0	345.6	8.6	22.1	5.1
October	22.2	9.0	59.0	423.4	9.9	22.6	5.1
November	22.1	7.3	63.0	345.6	10.4	21.4	4.4
December	22.5	5.4	61.0	354.2	10.5	20.5	4.4
Average	23.6	8.7	57.8	388.8	8.8	21.3	5.3

The ETo values of Afdeyu ranged from 2.3 mm/day in December to 5.5 mm/day in March, April and June and are relatively lower than that of Asmara meteorological data. Where as for Asmara the lowest ETo value was found to be in August (3.8 mm/day) and the highest in May (6.6 mm/day).

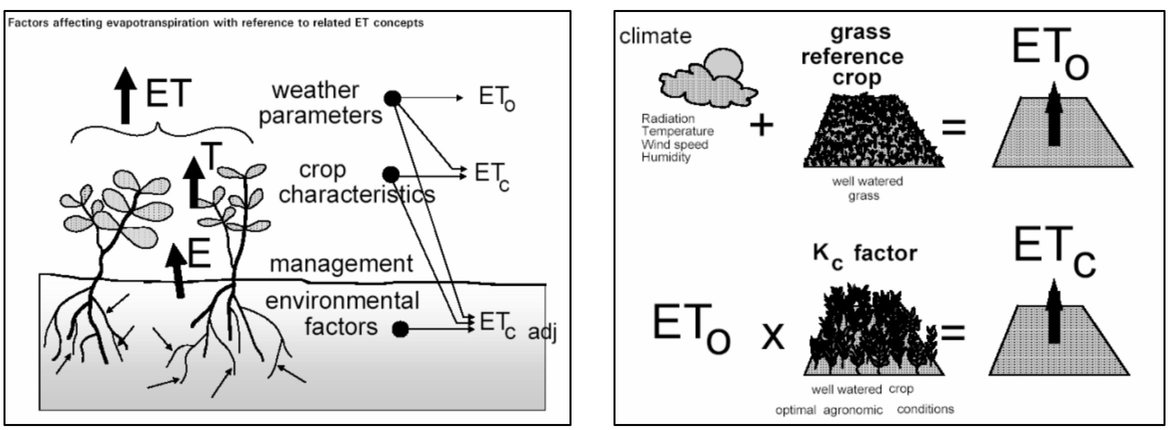


Figure 3.11 Parameters for estimating ETc (Source: FAO Report No. 56)

Potential Crop Evapotranspiration (ETc)

ETc is the amount of water lost through an evapotranspiration process from a disease free and well-fertilized crop. This value differs according to the canopy cover, development stage, and aerodynamic resistance of crops. In this study ETc was calculated from the reference evapotranspiration (ETo) estimated above and a crop coefficient (Kc) as ETc = ETo x Kc as indicated in Figure 3.11.

Crop Data

Since the ETc values differ with canopy cover and development stages of the crop it is necessary to look at the length of crop development stages and their related crop coefficient (Kc) values in detail. Thus referenced values were obtained from FAO Report No 56 and selected values are presented in the tables below.

As the crop develops, the ground cover, crop height and the leaf area change. Due to differences in evapotranspiration during the various growth stages, the Kc for a given crop will vary over the growing period. The growing period can be divided into four distinct growth stages: initial, crop development, mid-season and late season.

Table 3.18 Length of Crop Development Stages (Days)

CROP	INI.(L INV)	DEV.(L. DEV)	MID(L. MID)	LATE(L.LATE)	TOTAL
Potato	25	30	30/45	30	115/130
Tomato	30	40	40	25	135
Carrot	20	30	50/30	20	100/120
Cabbage	40	60	50	15	165
Onion	30	55	55	40	180
Lettuce	30	40	25	10	100
Zuccini	20	30	25	15	90
Cauli flower	35	50	40	15	140
Spinach	20	30	40	10	100
Broccoli	35	45	40	15	135

Primary source: FAO Irrigation and Drainage Paper 24 (Doorenbos and Pruitt, 1977), Table 22.

Crop growth stages

INI.(L INV) - Initial stage which runs from planting date to approximately 10% ground cover.

DEV.(L. DEV) - Crop development stage which runs from 10% ground cover to effective full cover.

MID(L. MID) - Mid season stage which runs from effective full cover to the start of maturity.

LATE(L.LATE)- Late season stage which runs from the start of maturity to harvest or full senescence.

Table 3.19 Crop Coefficient (Kc) at Different Stages of Crop Development

CROP	Kc INITIAL	Kc MID	Kc END
Potato	0.5	1.15	0.74
Tomato	0.6	1.15	0.7-0.9
Carrot	0.7	1.05	0.95
Cabbage	0.7	1.05	0.95
Onion	0.7	1.05	0.75
Lettuce	0.7	1.00	0.95
Cauli flower	0.7	1.05	0.95
Spinach	0.7	1.00	0.95
Garlic	0.7	1.00	0.70
Broccoli	0.7	1.05	0.95

This shows that crops require different amount of water throughout their development stages. The higher Kc values at middle stage as compared to Kc initial or establishment stage and Kc at late stage indicate that plants require more water at middle flowering and yield formation stage when they have more vegetative parts.

Both the length of crop development stages and the Kc values presented in Table 2.19 and 2.20 enable to calculate crop specific ETc values. It is used to determine daily ETc estimates that is day by day soil water depletions from field capacity and thus can be used to schedule irrigations. Thus it is necessary to find out what field capacity is and how it can be attained first.

Soil Data

Soil is storehouse for plant nutrients, reservoir for water, environment for biological activity and anchorage for plants. The root system of crops differs according to their genetic set up. Some of them have long roots that penetrate deep into the soil while others are shallow rooted. The plant rooting system, soil characteristics, and water management determines the depth of soil reservoir that holds water available to plant. In most plants, the concentration of moisture absorbing roots is greater in the upper part of the root zone, where it is most favorable for aeration, biological activity, temperature and nutrient availability.

Field capacity (FC) is the quantity of water stored in a soil volume after drainage of gravitational water. Only a portion of the water content can be potentially removed from a volume of soil by a crop and this quantity is called "available water" (AW). The amount of available water within the crop root zone at any given time is often called "soil moisture reservoir". Unfortunately, only a fraction of the reservoir is readily available to the crop without water stress. The amount of the available water depends greatly on the soil texture and structure. A range of values for different types of soil is given in Appendix 6.

In addition, when you irrigate specific crop you need to select the Management Allowable Depletion (MAD) of the available soil moisture. MAD is defined as the percentage of the available soil water that can be depleted between irrigations without serious plant stress. MAD should be evaluated according to type of crop, stage of growth and growing seasons.
Recommended value of MAD which depends on depth of root zone is presented below:

25 – 40% for high value shallow rooted crops

50% for deep-rooted crops

60-65% for low value deep crops.

Root depths of the common crops in the study area are presented in Appendix 6.
Recommended value of MAD which depends on soil type is presented below:

- Fine texture soils (clayey) 40%
- Medium texture (loamy) soils 50%
- Coarse textured soils (sandy) 60%

Here the 50 % MAD was used because most of the soils sampled and analyzed in the downstream irrigated fields of the selected dams are medium textured soils ranging from silt-loam to sandy-loam and loam.

Table 3.20 Some recommended MAD for crops at different growth stages growing in loamy soil.

CROP	Crop growing stages			
	Establishment	Vegetative	Flowering yield formation	Maturity Ripening
Potato	35	35	35	50
Onion	40	30	30	30
Lettuce	40	50	40	20
Spinach	25	25	25	25
Garlic	30	30	30	30
Vegetables 30-60 cm root depth	35	30	30	35
Vegetables 90-120 cm root depth	35	40	40	40

SOURCE: Irrigation guide, USDA National Engineering Hand Book

It is also known that generally the total available moisture for loam soils is 140mm/m with a maximum infiltration rate 10-20mm/day (Appendix 6).

Rainfall data

The amount of effective rainfall (P_{eff}) must be determined in order to estimate the crop water requirement. Rainfall data for the last 24 years was used to get the entire precipitation of the year or season. Then effective rainfall for the growing season was obtained or computed using the USDA, soil conservation service in the Crop water soft ware.

Once the potential evapotranspiration, Kc values and effective rainfall are estimated or calculated the final step would be calculating the crop water requirement of specifc crops if there is some information on the soil type and crop characteristics. The amount of water required to compensate the evapotranspiration loss from the cropped field is defined as crop water requirement. A sample table is presented below showing the crop water requirement of potato in the Upper Anseba Catchment. Similar tables for three more common crops: tomato, carrot and cabbage are presented in Appendix 6.

Table 3.21 Crop water Requirement Table for Potato in Zoba Maekel

Crop Potato Time step (days) 7 Irrigation Efficiency (%) 50

Date	ETO (mm/ Period)	Crop area (%)	Crop KC	CWR (ETc) (mm/period)	Total rain (mm/period)	Effect rain (mm/period)	Irrigation Req. (mm/period)	FWS (L/S/ha)
1\1	24.27	100.00	0.50	12.14	0.00	0.00	12.14	0.40
8\1	25.96	100.00	0.50	12.98	0.00	0.00	12.98	0.43
15\1	27.56	100.00	0.50	13.78	0.00	0.00	13.78	0.46
22\1	29.04	100.00	0.52	15.07	0.00	0.00	15.07	0.50
29\1	30.39	100.00	0.65	19.82	0.00	0.00	19.82	0.66
5\2	31.60	100.00	0.80	25.40	0.00	0.00	25.40	0.84
12\2	32.64	100.00	0.95	31.18	0.00	0.00	31.18	1.03
19\2	33.52	100.00	1.10	37.00	0.00	0.00	37.00	1.22
26\2	34.23	100.00	1.15	39.37	0.00	0.00	39.37	1.30
5/3	34.78	100.00	1.15	40.00	0.00	0.00	40.00	1.32
12/3	35.17	100.00	1.15	40.45	0.00	0.00	40.45	1.34
19/3	35.41	100.00	1.15	40.72	0.00	0.00	40.72	1.35
26/3	35.51	100.00	1.15	40.83	2.15	0.00	40.83	1.35
2/4	35.47	100.00	1.15	40.79	2.59	0.00	40.79	1.35
9/4	35.31	100.00	1.12	39.60	3.22	0.00	39.60	1.31
16/4	35.05	100.00	1.03	36.11	3.95	0.00	36.11	1.19
23/4	30.70	100.00	0.94	32.51	4.66	2.68	29.82	0.99
30/4	34.27	100.00	0.84	28.91	5.20	4.57	24.34	0.80
7/5	19.37	100.00	0.77	14.91	3.10	2.88	12.04	0.70
Total	604.26			561.56	24.86	10.12	551.44	[0.98]

CWR:Crop water requirement for a specific crop calculated as ETo x Kc also called consumptive use (cu).

IR: Irrigation requirement for a given crop in (mm) for a given time set up. IR can be calculated as:

$$IR = CWR - P_{eff}$$ i.e crop water requirement minus effective rain fall.

FWS = Field water supply in l/s/ha assuming continuous supply.

In table 3.22 the crop area is 100 % and this means that the whole field is planted with a single crop of potato and this simplifies the calculation of consumptive use. Irrigation efficiency for surface irrigation is taken as 50 % as water loss is high before it reaches the irrigated fields. As can be seen from the photographs below the water conveyance system is one of the main factors for the decreased efficiency of surface irrigation.

The time step taken was 7 days because farmers in the study area usually irrigate their fields once a week. The total crop water requirement of potato in the Upper Anseba catchment was estimated to be 562 mm, which is higher than the requirement of carrot (372 mm) and cabbage (337 mm) but lower than that of tomato (643 mm). If it is planted on the 1st of January there is a possibility that it can get some "Asmera" rain on its late stage that the required water from irrigation has to be reduced by an the amount equal to effective rainfall.

Table 3.22 Irrigation Water Supply (m3/ha/growing season) for Major Crops in Upper Anseba

Crop	Tomato	Potato	Cabbage	Carrot
CWR (mm/period)	561	643	337	372
CWR (m3/ha/growing period)	5610	6430	3370	3720

Photo 28 & 29: Inefficient water delivery or conveyance system

Therefore if the irrigation scheduling was done and implemented properly it should result in improving the performance of any irrigation system and may have the following benefits:

- Increased application efficiency by decreasing the amount of water applied
- Increased yields and thus profit
- Decreased energy usage
- Decreased nutrient leaching
- Decreased tail water runoff

3.2.1.1.5 Community Perception and Ambition

The study aimed to understand the perception and ambition of the community, carried a set of activities. Four villages were selected with an idea to obtain a diversity of perception and ambition that represent different villages. Based on the observation of the preliminary assessment, villages with high and low irrigation performance were selected. Two villages actively involved in irrigation and two with low performance in irrigation were considered in the study. Zager and Tseazega considered as villages with low or no irrigation performance and Ametsi and Lamza villages with exemplary irrigation activity.

3.2.1.1.5.1 ***Livelihood***

The table below shows the livelihood as an order of importance to the villages according to the group discussion from each village. The groups were asked to mention all source of income and then were later used to prioritize according to the importance in their life.

Table 3.23 Table showing Source of Income in their Order of Importance to the Community

Livelihood in priority	Zagr	Ametsi	Tseazega	Lamza
1st	Rain-fed (Bahir)	Irrigation	Rain-fed	Irrigation
2nd	Herding	Rain-fed	Irrigation	Rain-fed
3rd	Trade	Herding	Herding	--
4th	Daily laborers	Daily laborers	Daily laborers	--
5th	Public office	Trade	Trade	--
6th	Remittance	--		--

As indicated in the table 23, Zagr and Tseazega, unlike Ametsi and Lamza, who mentioned irrigation, stated rain-fed agriculture as the first important source of income in the village. The second choice, quit uniformly on all village prioritized rain-fed in Lamza and Ametsi. Animal herding, daily laboring and remittance were listed in low priority in the livelihood of the farmers. In Zagr, irrigation is absent; the village is more effective in the Bahri rain-fed agricultural area. Bahri (a greenbelt zone) is a concession area with double rain season and fertile land & warm climate. In Lamza, the farmers have no alternative except irrigation and rain-fed agriculture, indicating high dedication to irrigation. The people from this village think the only way to succeed in farming in their village is by developing irrigation activity.

Table 3.24 The Contribution of the Different Income Source in Each Village

Livelihood	Zagr	Ametsi	Tseazega	Lamza
Rain-fed	50%	25%	75%	13%
Irrigation	--	50%	13%	87%
Herding	25%	13%	4%	--
Daily laboring	13%	6%	4%	--
Trade	4%	6%	4%	--
Public office	4%	--	--	--
Remittance	4%	--	--	--

As shown in the table 3.24 communities from both Ametsi and Lamza, irrigation contributes the highest to the total income. Around 50% and 87% of the total income in the Ametsi and lamza is obtained from irrigation respectively. Second source of income in these two villages are rain-fed agriculture. This covers the rest majority of the income. In Lamza this is insignificant, only covering 13%. Supplementary activity like herding, daily labor works and petty trade are also mentioned to have small contribution to the total income in Ametsi. These sources of income have contribution in the ranges from 4 – 6% of the total income.

Zagr and Tseazega in other side have the rain-fed agriculture as the main source of income. The percentage in contribution is 50% in Zagr and 75% in Tseazega. In Zagr, the agriculture activity in Bahri, which is rain-fed, has major contribution. Most farmers from Zagr have access to wide agricultural area in the Bahri area. One of the common characters in both Tseazega and Zagr is the fact that both of the villages have relatively wider area for rain-fed agriculture. The rest supplementary small proportion mentioned in these villages are irrigation, herding, trade, remittance and daily laboring.

The Prioritization and contribution to the household income in the villages indicate the commitment of the villages to a certain type of activity. The higher the source of income from one activity, the higher is the commitment of the villagers to that source or activity. As indicate in the table, Lamza with 87% of their income coming from irrigation are highly committed to this activity. This is followed by Ametsi who have 50% their income generated through irrigation activity. Tseazega has 12.5% and Zagr with no contribution from irrigation activity.

3.2.1.1.5.2 Community Ambition

To understand the community ambition or goal a set of exercise were practiced. In the exercise the groups were asked to list resources and belongings that make a village and someone identified as rich village or person. Assuming the community would list the resources they want to have in their village and the belonging they want to acquire, these question will able to display the ambition or goal of the communities.

The first exercise was to list resources that make one village identified as rich village. The lists from all members of the group were listed in flip chart according to their order mentioned. Later the groups prioritized the resources according to their importance in their life. The table below show the prioritize resources listed by the groups.

Table 3.25 Resources in Priority that make a Village Rich

Priorities	Zagr	Ametsi	Tseazega	Lamza
1st	Clean water	Fertile land	Abundant water	Sufficient water
2nd	Irrigation potential	Dam	Human power	Fertile land
3rd	Wide irrigation land	Man power	Wide farm land	Irrigation potential
4th	Land for animal	Terraced land	Road	
5th	Access road	Forest cover	Domestic animals	
6th	Forest cover	Large farm land	Forest cover	
7th	Mineral resources		Market place	
9th	Closure		Mineral resources	

The responses in all the villages were almost similar giving less difference between the two groups. All groups in the villages agree that presence of natural or reserved water and fertile land is what makes a village rich. Abundant manpower, terraced land, forest cover, closure, access road, market place and mineral resources were mentioned by the some of the groups.

Reserved or natural water which can be used for the irrigation purpose and domestic use were prioritized as important resource in all villages. Only one village, Zagr, with less practice on irrigation, prioritized water for domestic purposes as first important resources. Tseazega and lamza prioritized water for irrigation as first priority.

Ametsi argued fertile land as the first important resources of a rich village. This was also prioritized as second and third in the other villages. Lamza again look much focused and didn't mention other resources other than what is required for irrigation. This confirms to the previous discussion of their livelihood, where they only depend heavily on irrigation.

Zagr on the other hand is the only village that prioritized a resource, which is not related to irrigation, though number 2 and 3 priorities were for irrigation activity. Their dependency on animal herding is showed significantly higher than the other village for prioritizing land for animal herding as important resources.

Following water resources and fertile land these villages prioritized manpower. Forest covers; access road and closures were also prioritized in sequence. Forest cover was prioritized higher in the two villages where irrigation performance is low.

The second exercise was to list belongings that make someone to be identified as rich or wealthy person in his or her community. The list was then prioritized by the group.

Table 3.26 Belongings in Priority that make Some one Identified as Rich in the Respective Villages

Priorities	Zagr	Ametsi	Tseazega	Lamza
1st	Health and not lazy	Healthy	Healthy	Healthy
2nd	Educated person	Educated person	Children	Children
3rd	owns large area	positive attitude	Educated	positive attitude
4th	Children	Have kids (children)	positive attitude	Wide farm
5th	Owns cattle	Owns a House to accommodate animals	Modern farming	Animal
6th	Source of remittance	who owns many animals	has wise wife	
7th			owns many animals	

The entire groups in all the villages agree health to be the first priority that makes a person rich. This result is quite unique but sound as people suffer from several health problem which makes them alert for the importance of health. In addition to this the fact that the work involved in farming is to high degree a physical work, healthy body is a number one criterion. A person with poor health cannot do much success in farming.

The second priority mentioned more or less by all the communities was a person with several offspring. This also explains the physically hard job in the rural areas of Eritrea. Children from their early age shoulder responsibilities and share the physical burden of the breadwinner or the mother. In addition to this, having children to keep the name for the next generation is considered as important in social life of the rural community.

Education was also mentioned as third important wealth of a person. Education was not only for a higher achievement in academy but also in irrigation knowledge. The groups from Ametsi defined educated person as a person who knows the seasons and the crops timing. While, in Zagr the group was referring to academic achievement, were someone will get a better job and knows better how to lead his life.

The villages separated in their fourth prioritization depending on their resources and problems at home. In Zagr for example the community mentioned concession land at Bahri. In the other villages where land is equally distributed to every household positive attitude and cooperation were mentioned as important characters of rich person.
It was found unique that the community mentioned financial and material resources at the end of the priority. This indicates relatively low economic disparity among the rich and the poor of the village in terms of financial or material measurements.

3.2.1.1.5.3 Community Priority
Following the exercise to understand the community ambition and perception, an exercise was carried out to understand the community priority. Again in this exercise the groups were asked to list their priority in their village.

Table 3.27 Community Needs in Priority

Priorities	Zagr	Ametsi	Tseazega	Lamza
1st	New dam	New dam	Proper management of farm lands	New wells
2nd	Bore a well	Water supply	Land for houses	Unsilt the existing dam
3rd	Support on fertilizer	Electricity	High school education	New dam
4th	Kindergarten	Health facility	Upgrade Health facility	Enlarge irrigation areas
5th	Secondary school	Road	Unsilt the existing Dam	Electricity
6th	Connect to national electric grid	School	Road (asphalt) – transportation	
7th			Kindergarten	
8th			Market place	
9th			New dam	

All of the groups from the villages prioritized water as their first need except Tseazega. In Tseazega the groups prioritized proper management of farmland. This is because this village has a serious problem related with sharing of farmlands among the villagers and mention existing tenure system as the main reason for the low performance of the irrigation activity.

Despite the small difference in their prioritization, villages from both groups prioritized their needs to increase their irrigation activity except Zagr. In Zagr, domestic animals are considered as important part of the farming activity, which suffers from shortage of water resources.

The second choice of the village differ according to their need but can be generalized as looking for better social life in education and health facility. The response of Lamza is quite an exceptional at this as the choice sticks to improving irrigation needs. The people from this village believe the only way to survive is to upgrade and enlarge their irrigation activity. The response from the village with better irrigation performance show high determination to successes in having better life by upgrading their irrigation.

3.2.1.1.5.4 Main Constraints

The fourth exercise was zoomed to irrigation and was asked to obtain the main constraints of irrigation in their daily activities. The responses of the question are organized as follows.

Table 3.28 Farmers' Constraints in their Irrigation Activity in Priority

Priorities	Zagr	Ametsi	Tseazega	Lamza
1st	Water	Water	Land tenure problem	Shortage of water
2nd		Shortage of improved Seed	Shortage of water	Shortage of land
3rd		Diesel shortage and expenses	Shortage of Improved seed	Shortage of improved seed
4th		Shortage of Fertilizer	Shortage of Fertilizer	Shortage of Fertilizer
5th		Shortage of Medicine	Shortage of Medicine	Shortage of medicine
6th		Transportation problems	Lack of transportation	Shortage of irrigation tools
7th		Lack of market place (poor trade)	Market place (poor trade)	

The main constraints in the practice of irrigation or extension of irrigation activity stated in all the villages are water and land. Unreliable water source, which dries up before the consecutive rainy season appeared, was mentioned as main reason for not practicing irrigation activity in

Zagr. In Zagr water can only last to provide water to animals and domestic purpose and thus discourages irrigation activity. Even with this rate the reserved water doesn't last before the next rainy season. This problem is also apparent in the other villages though to a lower degree.

Second major constraint was mainly shortage of land and land tenure system. In some village where there is good appetite for irrigation work, shortage of land cripples the advantage they could have harvested from the activity. The advantage from a small plot of land is small and thus fails to have significant contribution in changing the economic status of the families. Though villagers have accepted the small land, as they don't expect for change in land tenure system, they however look for support to level rugged land for use as irrigation land.

The land tenure system currently in practice also plays a negative role in the irrigation. Farmers are discouraged to invest in a land, which they know will be given to another person. This is especially if the period of land exchange is close. Land are exchanged and allocated every seven years in the rural highlands of Eritrea.

The third commonly mentioned irrigation related constraints are limited supply of improved seed, fertilizer and pesticide. Though these problems seem to be temporary and easy to rectify, the damage rending is tremendous. Most of these materials used to be provided by the government but since last year the necessary amount of stock was not delivered in time. Prices from private dealers are exceptionally high and are not affordable for the majority. In some case, even with high prices these materials were not available.

Lack of market place, transportation, and shortage of irrigation materials or tools were also mentioned as some of the main problems mentioned in the irrigation problem. The problems have added up to substantially constraint irrigation activity and thus the benefits from the activity.

3.2.1.2 Livestock Watering

In addition to the irrigation water requirements for crop production, the estimated need for water for other purposes, domestic use and livestock watering should be considered in the allocation of water for irrigation development to avoid possible conflicts between different water users.

3.2.1.2.1 Livestock Population

General livestock census data from the MoA Zoba Maekel branch office (2008) shows that the total livestock population reaches nearly 152,000 (Table 3.29). Subzobas Serejeka, Berik and the four subzobas of Asmara are located in the Upper Anseba Catchment that the livestock population in the catchment reaches around 100,000.

Table 3.29 Livestock Population of Zoba Maekel in 2008

SubZoba	Cattle	Sheep	Goat	Donkey	Horse	Mule	Camel	Total
Asmara	6,779	4,588	627	-	1,632	-	-	
Serejeka	15,624	21,027	5,050	8,722	10	63	7	
Berik	14,315	17,058	3,839	-	3,915	-	-	
Galanefhi	10,525	20,836	11,988	4,732	27	15	372	
Total	**47,243**	**63,509**	**21,504**	**13,454**	**5,584**	**78**	**379**	**151,751**

Source: MoA Zoba Maekel

For detailed analysis during the field survey the kind and number of livestock of the nine selected reservoirs and or villages was estimated based on the information collected from the key informants (Chapter 4). In addition, farmers were asked to estimate the average water requirement per livestock head (Table 3.30). As shown in the table the average water demand for cattle, shoats, and donkey, mules and horses was estimated to be 27, 5, and 16 litres per day per livestock head (MoLWE, 1998). In this study the values are lower as compared to these figures and were estimated to be 18 litres per day for cattle, 2.5 litres per day for shoats and 10 litres per day for donkey, mule and horses. These lower values could be attributed to the environmental condition like climatic condition of the area, type of animal breed and feed type.

3.2.1.2.2 Livestock Water Requirement

Table 3.30 Livestock Drinking Water Requirements (From farmers' etimate)

Type of livestock	Water demand (L/day)*	Water demand (m3/ year)	Average water use (L/day) **	Water demand (m3/ year)**	Drinking water demand (m3)***
Cattle	27.0	9.9	18.0	6.7	316,500
Goats and sheep	5.0	1.8	2.5	0.9	76,500
Donkey, mules and horses	16.0	5.8	10.0	3.7	71,000
Total					**464,000**

Source: *Modified from MoLWE (1998)

** Current survey

***Based on numbers of livestock as presented in Table2.29 and actual livestock drinking water requirement obtained from the researchers survey.

These figures obtained from farmers in this study can be used to estimate the drinking water demand for livestock based on the daily requirements of the major types of livestock and livestock population data. Thus the annual livestock water requirement for Zoba Maekel was estimated to be around 464,000 m3 and around 340,000 m3 for the Upper Anseba Catchment.

In most of the villages, the livestock have free access to the reservoirs as is shown in the photo below. It is not common to use separate watering troughs for livestock in this area except in AdiMerawi, AdiBidel and Lamza. It is also rare to dig wells on the downstream of the reservoirs for livestock consumption but few villages like Himbrti, Lamza and AdiNefas use wells in addition to the direct extraction of water from the reservoirs.

Photo 30: Reservoir water for livestock watering

3.2.2 Domestic Use

It is not easy to estimate accurately the domestic water consumption especially in the rural areas. The average countrywide domestic water consumption was estimated to be 17 and 22L/capita/day for 2002 and 2010 respectively based on projected population data (MoA, 2002). This per capita amount is less than the requirement considered necessary for health. Such low average consumption results from the lack of an adequate water-supply infrastructure, long walking distances to watering points, and in some places from insufficient supply from rivers, streams and boreholes.

The main source of water for household consumption in the study areas of Zoba Maekel is from hand dug wells. Reserved waters are also used for domestic purposes specially for washing clothes. Most of the beneficiaries or villagers access water from reservoirs in two ways: directly from the reservoir or from hand dug wells downstream of reservoirs.

Photo 31: Villagers fetching water directly from reservoir using human labor or using donkeys

Photo 32: Adiadfeda ladies washing clothes using reserved water

Rapid urbanization and industrialization in many areas are creating stress to Eritrea's water bodies. The stress is higher or more in the Upper Anseba Catchment as more than 50% of the population are urban dwellers. Considerable amount of water is delivered to Asmara from reservoirs of Toker, AdiSheka, MaiSirwa and MaiNefhi. Urban areas are also main sources of water pollutants. Asmara city is a main threat to the discharge of Maibela River because untreated water from industries and tanneries, textile mills, and chemical industries is derived and domestic sewage is discharged untreated. The solid waste deposited around cities is another source of pollutant to surface-water and groundwater pollution especially when they are leached out during the rainy seasons.

3.2.3 Other Uses

The main use of reservoirs is for irrigation, domestic use and animal watering. In addition reservoir water can be used for fishing, recreation, mining and other purposes. Fish have been introduced in many of the reservoirs in the Upper Anseba Catchment. However, the majority of the farmers are not familiar with fish eating. No attempt has so far been made to familiarize fish eating among the farmers. The fish just reproduce in the reservoirs and die out when the reserved water is finished during the dry season. In 2007 in Embaderho when the whole reserved water was used for mining with out any permission from the community all the fish died and the crops under irrigation completely failed.

Except for MaiSirwa, the other reservoirs in the catchment are not usually used for recreations. MaiSirwa reservoir is used for town water supply and at the same time as a recreation center. But there is a foreseeable future in the development of the sector because most of the reservoirs are close to Asmara, the biggest town of Eritrea.

Photo 33: Reserved water can be used for recreation, and is a habitat for many plant and animal species.

3.3 Catchment Surface Water Management

3.3.1 At Local Level

3.3.1.1 The By-law

A bylaw drafted by the Ministry of Agriculture Maekel branch is the only currently available bylaw related to water management in this catchment. The bylaw with five articles and total page of five was effective since the mid of June of the year 2004. The objective of the bylaw was mainly to ensure the efficient use of dams and their downstream irrigable areas.

The bylaw gives a brief description on legal ownership of the dams, establishment of governmental and community institution to promote efficient and sustainable use of dams and increase productivity and also contains coercion article to pressure farmers to use water in dams. A brief summary and comments of the main components of the bylaws are given below.

In its first article the bylaw states that all dams or surface water reservoirs are declared to have ownership to the government. Farmers from the village where the dam is located have the right of use. The article however does not separate dams, which are built by the government or by an NGO or a community. If this bylaw invariably applies to all dams, in the future a clear discussion is needed on why the government has to be the owner of all dam despite financing or implementing body is other than the government.

Even though, this article may have some significance on the legal term but may have less implication to farmers. The right of use and ownership may have close meaning and may not be able to be differentiated. However, care need to be put that overemphasizing ownership of dam by the government may result in debilitating the effort to nurture sense of ownership.

Article No. 4 of the bylaw shoulder the responsibility of dam management, maintenance and proper use to the users of the dams. This article is logical and crucial as it contributes in ensuring sustainability of the infrastructure and puts aside the government from shouldering the responsibility of maintaining the dams, which most of the time is not practical. However, it is also impractical to leave all the operation and maintenance duties to farmers who have seriously limited financial and technical capacity.

Despite the stress of this article, the communities visited during the fieldwork were found to noticeably expect the government intervention to maintain the dams. None of the villages have ever made their initiation to maintain their dam. Though it could be argued that the maintenance of dams is way beyond the capacity of the communities, none of the communities collect money that can be contributed for maintenance of dams. There is hardly any setup or awareness that the community has to take over maintenance of the dam they have right of use. Common maintenance problem were un-silting and sealing leaking dams. The government also inconsistent with this Article seems to have assumed the responsibility.

Article No.5 gave the institutional set up to follow the guideline or the bylaw. This is crucial component of the bylaw as it guarantees the implementation of the bylaw and consequently it’s follow-up. The bylaw proposes the establishment of four level of committee. These are, starting from bottom to top, Water users Association, Kebabi/village Committee, Desk Committee and Zonal Committee.

The Water association, a closest committee to the farmers, have a set of responsibilities, in which maintenance of the dam infrastructure, distribution of water to irrigation field, operating and maintaining conveyance system, implement technical advises from the Ministry of Agriculture are some of them. For duties beyond the capacity, the Water Association can seek help from the desk committee. The committees have the responsibility to support farmers through training, provision of fertilizers, improved seed and others, and other technical support.

Establishing a committee is always easier to the effort one can make to make these committees effective. Lack of interest, lack of budget and motivation are the main problems associated with failure of committees. Out of the eight villages surveyed during the field visit only four happen to have water committee who look after the infrastructure and distribution of water. Even these committees have limited themselves to operation of the conveyance rather than the reservoir and its overall aspect as indicated in the bylaw.

The bylaw also includes coercion in article 3 for farmers who have not used their irrigable land and reserved water. With this article efficient use of reservoir water is intended. A Farmer who failed to irrigate downstream irrigable land for six months will have his or her land confiscated after given a three-month grace period. The land reclaimed by the administration would be allocated to other farmer or investor. This article was made to pressure farmers to irrigate their downstream land and make investment on dam worth.

This article might have somehow made a slight contribution in increasing the investment on downstream of dam. Nonetheless it contribution should not be exaggerated If it has made any contribution, it might be because of the awareness created through the process of implementation of the bylaw. When asked what the farmers think about this law, most of the communities were unaware about it. When asked, after the article was discussed to them, if it would have a contribution, farmers said ‘no farmer want to leave the land undeveloped without reason because land can be rented to some farmers who can develop it. It is not necessary that every farmer have to irrigate his or her land. In case he or she is sick or unable to irrigate, he can rent the land get significant income from it. In one case the community said that lack of awareness was the main reason for their low activity in the past. They have now witnessed a significant contribution of irrigation in their livelihood.

3.3.1.2 Existing Water Management

At the village level water management is still at traditional level despite the bylaw developed. For example for the majority of the villages there is no water association. As has been described in the previous section out of the eight villages surveyed only four happen to have water committee who look after the infrastructure and distribution of water. These committees look after the distribution of water and charge the farmers according to their use of water for diesel. The money charged only covers the operation and maintenance cost of the motor pump. In some cases like Geshnashm, the money collected only covers diesel expenses.

The rest of the villages who use their own motor pump to water their field see no point of having a water committee. In case there is any need of decision the community assembly headed by the administrator of the village settles the matter. A typical example is the cases of Zagr where the village has decided to use the reserved water only to water their animals. This is because the water from the reservoir can only satisfy animal watering. The dam is sited in area where rainfall is low. The village also avoids washing clothes near the reservoir to avoid contamination of water. These kinds of regulations are practical and are most of the time are holdfast.

Water in the reservoir as other resources in the village is also managed in a traditional way. People with concern to the situation of the dam will communicate to the village in their assembly. This assembly lead by the administrator will release a bill to protect their reserved water. The process is the same for land, closure, and others. There is no as such a technical and institutionally developed water committee to look after the reserved system. As this kind of management is more participatory than all the decision made by the government, is effective. However, lack of knowledge, awareness and lack of concerned group make management of water reservoir quite an undermined issue.

The fact that the farmers over look support from the government for maintenance of water reservoir and the fact that government carry out this task without charge made farmers less enthusiasm for proper management. For example, in Adi-Asefeda, the farmers irrigate the land close to the water body that contributes to high siltation. In the same village a small erosion hot spot identified by the farmers as the main source of silt in the dam could not be terraced by the farmers. All expectations are extended from the government, which is overwhelming difficult to be carried by the government.

Another case noticed in the study villages was the scene that the farmers irrigate their land without any water budget calculation. This often resulted in severe financial crises to farmers who would saw without enough water. Second it results the death of many habitats such as fishes, birds in the reserved water. The 2007 scene in Embaderho dam was one of the typical examples. Ministry of Agriculture in an informal way has to advice the village administration to stop pumping water from the close to dry dam.

This scene could have been improved with proper management of water with well-organized and aware community committee. Committee with enough training could alert and advice farmers on the budget of water and also distribute water with fair share.

4 CASE STUDY RESERVOIRS

The study was conducted in two phases. During the first phase general survey of all the reservoirs situated in Zoba Maekel was conducted. During the second phase a detailed study was conducted on 9 selected reservoirs. The data collected on the selected reservoirs were analyzed and presented in chapter 3 as part of the results of the study. The detail information collected will be presented in this chapter. The selected reservoirs were Hayelo-Geshnashm, Zagr, Embaderho, Ametsi, AdiAsfeda, Tseazega, Lamza, Laugen-AdiHamushte and Himbrti Gomini. The reservoir size or capacity, spatial distribution or location, current water use and management, and irrigation activities are characteristics that were used in selecting these 9 reservoirs, besides the age of reservoirs and issue of easy accessibility of reservoirs.

Photo 34: A well treated catchment, a reservoir and downstream irrigation at AdiGhebru-AdiTeklay

4.1 Hayelo Geshnashm Dam

Hayelo-Geshnashm is a rock fill dam built in 1998 in between the villages of Hayelo and Geshnashm. It is owned by two villages and the reserved water is used for irrigation and livestock watering by the two villages. Seepage problem is evident in the area and a second embankment has been constructed to reserve the water leaked and prevent it from loss.

Photo 35. *Hayelo Gheshnashm reservoir*

General Information

Location: 37 482621 E,
1716791 N

Date of Construction: 1998

Constructed by: MoA

Design capacity: 1,000,000 m^3

Actual capacity : 650,043 m^3

Actual water volume at the time of survey: 69,551 m^3

Crest length: 80 m

Dam height: 18 m

Type of dam: Rock fill

Condition of Catchment:

Catchment area: 1035 ha (10 km^2)

Slope: Mainly undulating and slightly steep slope areas with small areas of moderate to steep slope

Catchment land cover types: See Table 4.1)

Table 4.1 Catchment Land Cover Types, Hayelo-Geshnasm

Land Cover Type	Area (ha)	% Catchment Cover
Artificial Waterbodies	6.4	0.62
Isolated (in natural vegetation or other) Rainfed Small Herbaceous Fields (field frequency 10-20% polygon area)	357.9	34.57
Rainfed Small Herbaceous Fields	285.1	27.54
Rainfed Small Herbaceous Fields (mixed unit with natural vegetation or other) (field area approx. 60% polygon area)	110.2	10.64
Tree Plantation – Eucalyptus	17.4	1.68
Tree Plantation - Eucalyptus (mixed unit with natural vegetation or other) (field area approx. 60% polygon area)	244.5	23.62
Urban and Associated Areas	13.7	1.33
Total	**1035.4**	**100.00**

Irrigation

Number of beneficiaries: Hayelo- 240 households and Gheshnashm- 198 households

Surface area of currently irrigated fields: 40.5 ha

Potential of irrigable area: 90 ha

Main horticultural crops: (see Table 4.2)

Table 4.2 Horticultural Crops Grown in Hayelo-Geshnashm

Common Horticultural crops grown	Coverage in %	Planting time	Harvesting time	Yield Quintal/ha	Average price NKF/kg
Onion	40	February	May	234	15
Tomato	40	February	May	139	11
Potato	15	15 May	July	278	8
Cabbage	5	July	Nov	334	3

Irrigation Intensity: Twice/year

Irrigation Interval: Once a week, twice a week at flowering

Irrigation system: Furrow and basin

Water conveyance system: Pipe system

Physical properties of the soil of the irrigable areas: Sandy loam

Frost occurrence: December – Mid February

Market: Serejeka

Percent of marketable produce: Over 90%

Production constraints: Lack of inputs mainly seed, seedlings, fertilizer, pesticides, sprayer (no supply or very expensive), post harvest storage problem, shortage of water (dam seepage)

Domestic Water use:

Two drilled wells, located downstream of the dam, are used for domestic water supply. An estimated 40 liters/family/day for drinking, and 200liters/week for washing is consumed. Annually domestic consumption amount to 3200m^3 and 4200 m^3 for drinking and washing respectively.

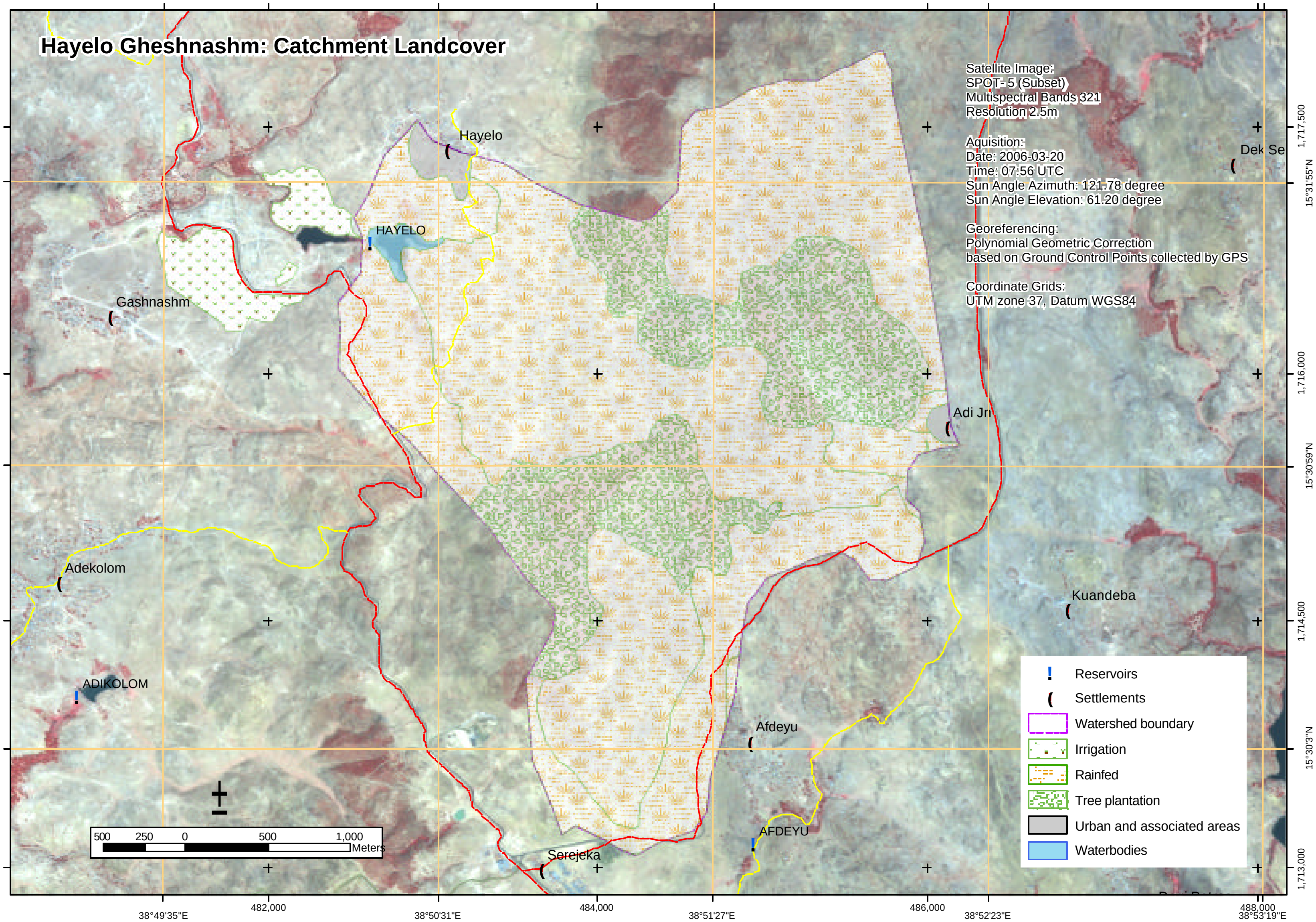
Livestock Watering

Type and number of livestock and daily and yearly consumption of water in Hayelo-Gheshnashm are presented in Table 4.3.

Table 4.3 Type and Number of Livestock in Hayelo-Gheshnashm

Type of Livestock	Daily water Consumption (litres/head)	Total number of animals	Water consumption per year (m^3)
Cattle	20	500	3660
Sheep and Goats	3	100	110
Donkey	10	400	1464
Total		-	**5234**

Other uses: There are fish in the dam but it is not common to eat fish.



Map 4.1 Catchment land cover map of Hayelo-Gheshnashm dam

4.2 Zagr Dam

Zagr is a village located on subzoba Serejeka with a small reservoir constructed in 1984 by human labor under food for work program. The reservoir is partially filled with silt and needs to be upgraded.

General information

Location: 37 488333 E,
1718554 N
Date of Construction: 1984
Constructed by: MoA
Design capacity: 150,000 m^3
Actual capacity: 81,926 m^3

Actual water volume at the time of survey: 41,963 m^3
Dam crest length: 101 m
Dam height: 7.5 m
Type of dam: Earth fill

Photo 36 & 37*: Zagr reservoir and downstream*

Condition of Catchment:

Catchment area: 284 ha (2.84 km^2)

Slope: Mainly undulating with small patches of flat and slightly steep slope

Catchment land cover types: (see Table 4.4)

Table 4.4 Catchment Land Cover Types, Zagr

Land Cover Type	**Area (ha)**	**% Catchment Cover**
Artificial Waterbodies	2.0	0.7
Open Shrubs	127.3	44.8
Rainfed Herbaceous Fields	83.1	29.2
Rainfed Small Herbaceous Fields	1.1	0.4
Rainfed Small Herbaceous Fields (mixed unit with natural vegetation or other) (field area approx. 60% polygon area)	38.3	13.5
Riverside Plantation – Eucalyptus	0.7	0.2
Tree Plantation – Eucalyptus	10.8	3.8
Urban and Associated Areas	20.9	7.4
Total	**284.3**	**100.0**

Irrigation

Number of beneficiaries: 814 households

Size of currently irrigated fields: 1 ha No irrigation due to water shortage

Physical properties of the soil of the irrigable areas: Loam soil

Production Constraints: Shortage of water

Domestic Water Use:

Each household fetches on average 20 liter/day for domestic purposes totaling to 5,958 m^3 per year.

Livestock Watering

Type and number of livestock and daily and yearly water consumption in Zagr is presented in Table 4.5.

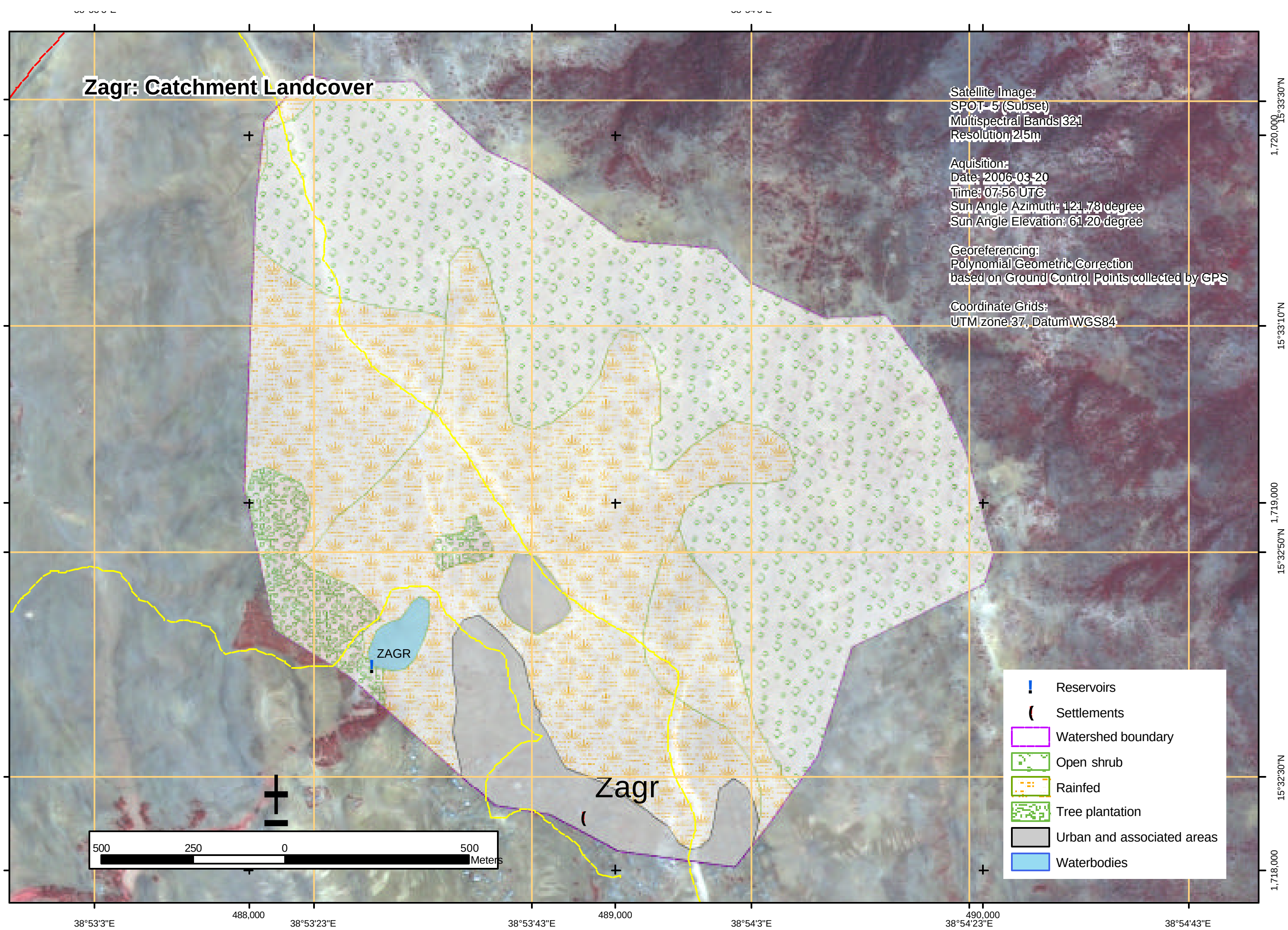
Photo 38. *Eucalyptus trees planted on the downstream side of zagr dam, 80 years ago*

Table 4.5 Type and Number of Livestock, Zagr

Type of Livestock	Daily water Consumption (litres/head)	Total number of animals	Water consumption per year (m^3)
Cattle	20	1000	7320
Sheep and Goats	2.5	5000	4575
Equines	10	1200	4392
Total			**16,287**

Other Uses:

No other uses.



Map 4.2 Catchment land cover map of Zagr dam

4.3 Embaderho Dam

Embaderho is a large village found on the border between Asmara and Subzoba Serejeka and it is under the administration of Subzoba Serejeka. The dam in Embaderho was constructed in 1992 by Evangelical church.

General Information

Location: 37 488655 E,
1705052 N
Date of Construction: 1992
Constructed by: Evangelical Church
Design capacity: 330,000 m^3

Actual capacity: 314,833 m^3
Actual water volume at the time of survey: 166,306 m^3
Dam crest length: 180 m
Dam height: 8 m
Type of dam: Earth fill

Photo 39. *Embaderho dam and its environs*

Condition of Catchment:

Catchment area: 240 ha (2.40 km^2)

Slope: Mainly undulating, with small percentage of flat or slightly steep slopes

Catchment land cover types: (See Table 4.6)

Table 4.6 Catchment Land Cover Types, Embaderho

Land Cover Type	Area (ha)	% Catchment Cover
Artificial Waterbodies	10.0	4.1
Irrigated Herbaceous Fields	1.0	0.4
Isolated (in natural vegetation or other) Rainfed Small Herbaceous Fields (field frequency 10-20% polygon area)	21.5	8.9
Rainfed Small Herbaceous Fields	0.8	0.4
Rainfed Small Herbaceous Fields (mixed unit with natural vegetation or other) (field area approx. 60% polygon area)	38.3	15.9
Scattered (in natural vegetation or other) Rainfed Small Herbaceous Fields (field frequency 20-40% p	7.3	3.0
Tree Plantation – Eucalyptus	0.9	0.4
Urban and Associated Areas	160.6	66.8
Total	240.4	100.0

Irrigation

Number of beneficiaries: 1800 households (The irrigated fields are rented to 18 farmers for a total of 340,000 Nakfa per year).

Size of currently irrigated fields: 23.9 ha
Potential irrigable area: 35 ha
Main horticultural crops: (See Table 4.7)

Table 4.7 Horticultural Crops Grown in Embaderho

Common Horticultural crops grown	Coverage in %	Planting	Harvesting	Yield Quintal/ha	Average price NKF/kg
Tomato	50	Feb	April	205	4
Potato	40	Feb	May	273	10
Carrot	4	Any time	After 3 months	320	5
Cabbage	2	Oct	Feb	330	4
Lettuce	1	Sep	November	386	3
Zuccini	2	May	July	164	4
Garlic	1	Sep	Feb	70	60

Irrigation Intensity: Two to three times per year (200 - 300%)

Irrigation Interval: Once a week, twice a week at flowering

Irrigation system: Furrow and basin

Water conveyance system: Open earthen channel

Soil Physical properties of irrigable areas: Loam to silt loam

Frost occurrence: November – February

Market: Asmara and Serejeka

Percent of marketable produce: Over 90%

Production Constraints: Lack of inputs mainly fertilizer, pesticides, and fuel for water pumps

Domestic Water Use:

For domestic supply two wells are used, one is downstream of the dam and about 30% of the population uses it. If each household fetch 40 liters per day the total consumption would be 880 m^3 per year.

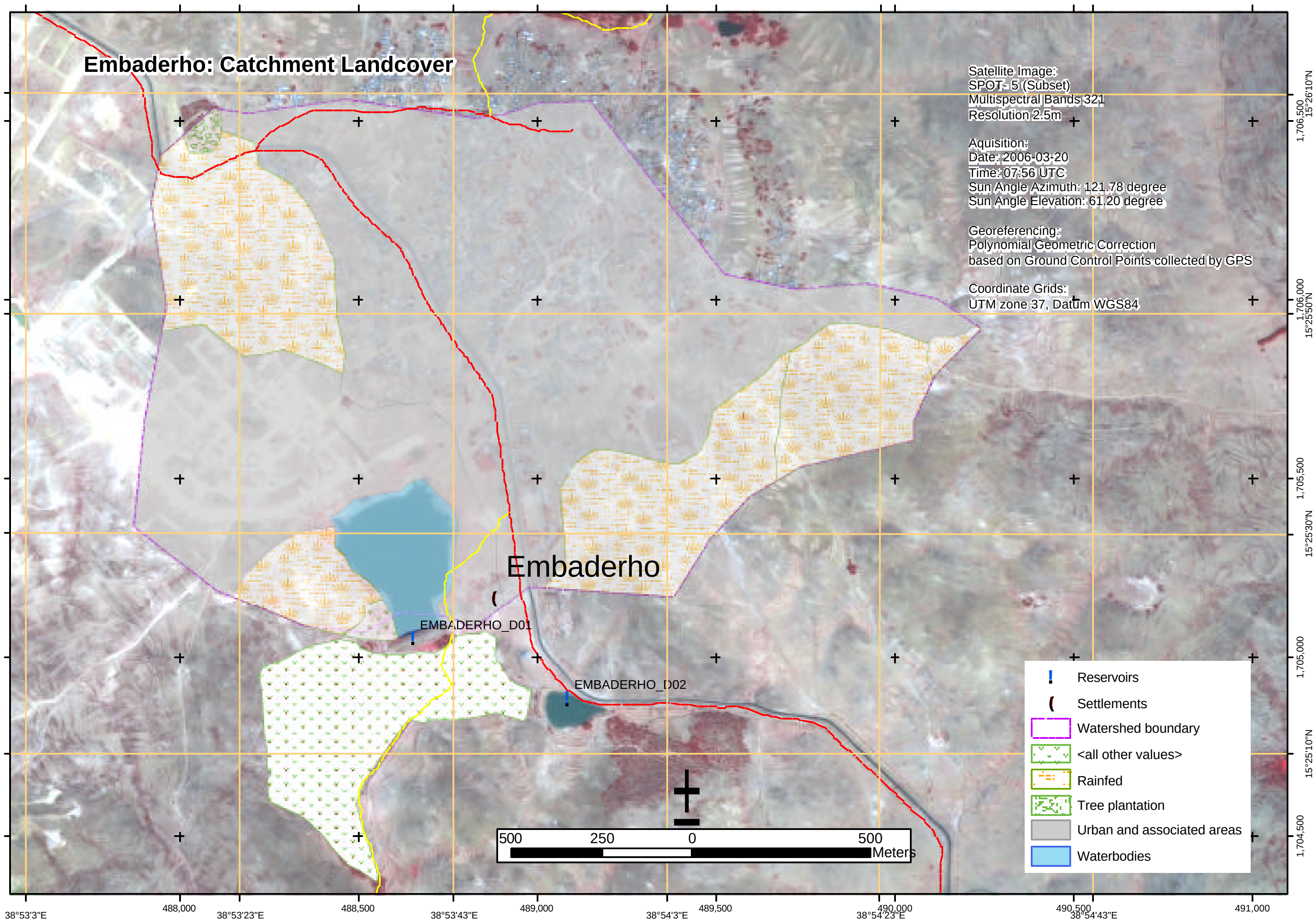
Livestock Watering

Type and number of livestock and daily and yearly consumption of water in Embaderho is presented in Table 38.

Table 4.8 Type and Number of Livestock, Embaderho

Type of Livestock	Daily water Consumption (litres/head)	Total number of animals	Water consumption per year (m^3)
Cattle	20	1500	10,980
Sheep and Goats	2	10000	7,320
Equines	10	1000	3660
Total			**21,960**

Other uses: The reserved water is also used for house construction at a rate of approximately 6000 liters/day (farmers' estimation) and this can be totaled to 2,200 m^3 per year.



Map 4.3 Catchment land cover map of Embaderho dam

4.4 Ametsi Dam

Ametsi dam was built in 1988 by ECS and rehabilitated in 2004 by MoA. Its height increased by 2 m. The catchment area is mostly agricultural land with old terrace grassed on the top.

General Information

Location: 37 485355 E,
1706555 N
Date of Construction: 1988
Constructed by: Eritrean Catholic Secretariat
Design Capacity: 180,000 m^3

Actual capacity: 118,720 m^3
Actual water volume at the time of survey: 99,304 m^3
Dam crest length: 116 m
Dam height: 10 m
Type of dam: Earth fill

Photo 40. Irrigated fields in the Gedena area of Ametsi

Condition of Catchment:
Catchment area: 166 ha (1.66 km^2)
Slope: Mainly undulating and flat in some places
Catchment land cover types: (See Table 4.9)

Table 4.9 Catchment Land Cover Types, Ametsi

Land Cover Type	Area (ha)	% Catchment Cover
Artificial Waterbodies	3.5	2.1
Irrigated Herbaceous Fields	1.2	0.7
Isolated (in natural vegetation or other) Rainfed Small Herbaceous Fields (field frequency 10-20% polygon area)	5.9	3.6
Rainfed Small Herbaceous Fields	74.7	45.1
Rainfed Small Herbaceous Fields (mixed unit with natural vegetation or other) (field area approx. 60% polygon area)	70.5	42.5
Urban and Associated Areas	9.9	6.0
Total	**165.8**	**100.00**

Irrigation

Number of beneficiaries: 330 households

Size of currently irrigated fields: 30.3 ha

Potential irrigable land: 12 ha

Main horticultural crops: (See Table 4.10)

Table 4.10 Horticultural Crops Grown in Ametsi

Common Horticultural crops	Coverage in %	Planting time	Harvesting time	Yield Quintal/ha	Average price NKF/kg
Potato	60	Feb/May	May/August	120	10
Carrot	20	March	June	240	4
Tomato	10	March	July	200	8
Spinach	5	March	June	257	8
Cabbage	5	May	August	320	3

Irrigation Intensity: Twice per year

Irrigation Interval: Once a week, twice during hot months (May)

Irrigation system: Furrow and basin

Water conveyance system: Pipe system and open channel

Physical properties of the soil of the irrigable areas: Loam to sandy loam

Frost occurrence: December –January

Market: Asmara

Percent of marketable produce: Over 90%

Production Constraints: Lack of inputs mainly seed and seedlings, tools, fertilizer, pesticides, and shortage of water.

Domestic Water use:

The villagers use 200 liters/week/family for washing from the dam while and 60liter/day/family for drinking water from a well downstream. downstream. The water being deducted from the reservoir totals to 3160 m^3.

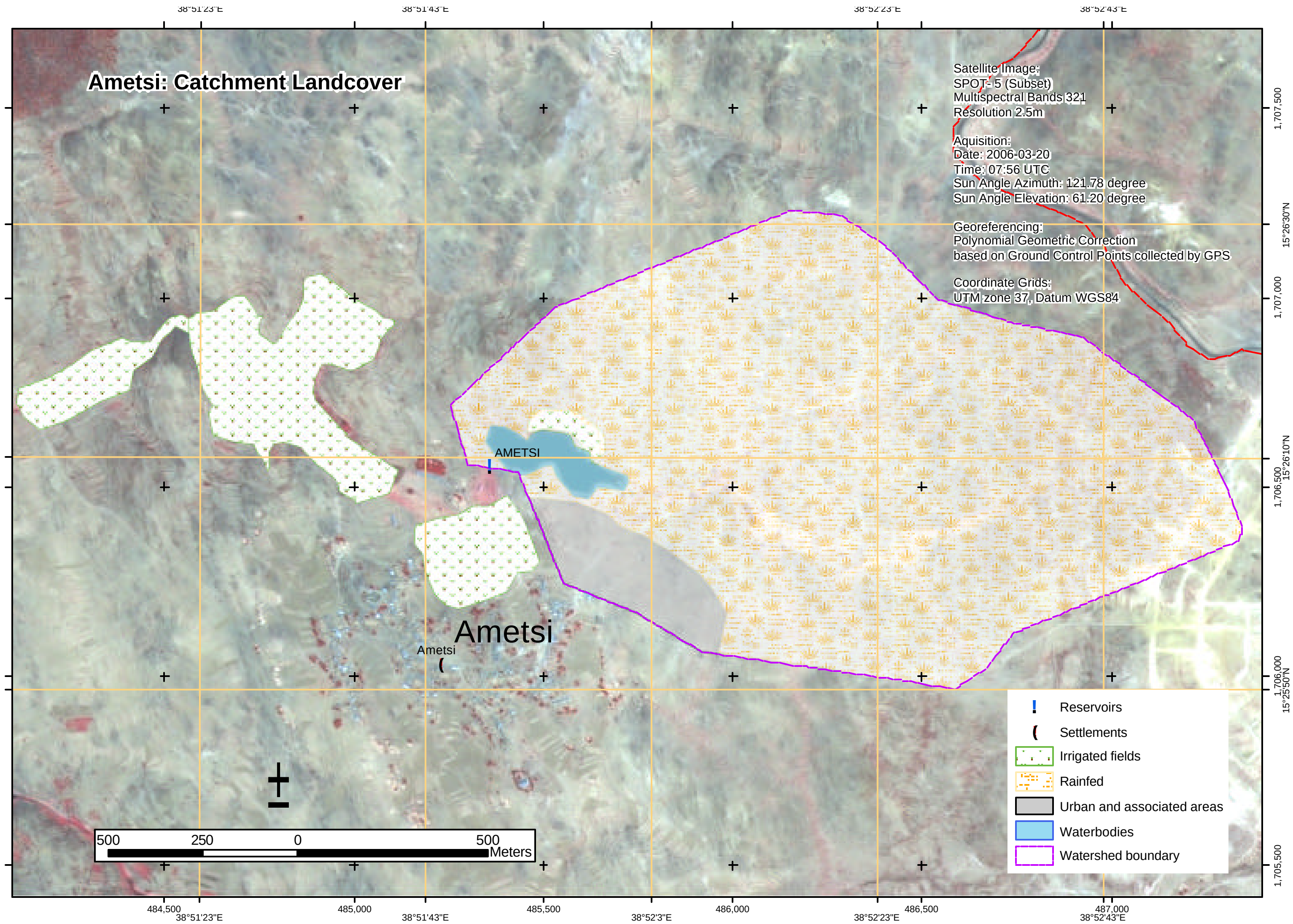
Livestock Watering

Type and number of livestock and daily and yearly consumption of Ametsi is presented in Table 4.11.

Table 4.11 Type and Number of Livestock, Ametsi

Type of Livestock	Daily water Consumption (litres/head)	Total number of animals	Water consumption per year (m^3)
Cattle	10	300	1,098
Sheep and Goats	1	1800	659
Equines	5	300	549
Total			**2,306**

Other uses: No other use.



Map 4.4 Catchment land cover map of Ametsi dam

4.5 Adi Asfeda Dam

Adi Asfedsa is a village located in Subzoba Berik. Adi Asfeda dam was built in 1988 and rehabilitated and increased in height by 2m in 2002 as a result its design capacity increased from 200,000m3 to 365,755 and reservoir area increased from 6.4 ha to 10ha.

General Information

Location: 37 484950 E,
1700905 N
Date of Construction: 1988
Constructed by: MoA
Design capacity: 200,000 m^3
Actual capacity: 294,749 m^3

Actual water volume at the time of survey: 153,192 m^3
Dam crest length: 120 m
Dam height: 11 m
Type of dam: Earth fill

Photo 41. AdiAsfeda reservoir

Condition of Catchment:

Catchment area: 786 ha (7.86 km^2)

Slope: Mainly flat to undulating

Catchment land cover types: (See Table 4.12)

Table 4.12 Catchment Land Cover Types, AdiAsfeda

LC_TYPE	Area (ha)	% Catchment Cover
Artificial Waterbodies	13.4	1.7
Rainfed Small Herbaceous Fields	644.0	81.9
Riverside Forest	13.1	1.7
Urban and Associated Areas	115.7	14.7
Total	**165.8**	**100.00**

Irrigation

Number of beneficiaries: 180 households

Size of currently irrigated fields: 32.2 ha

Potential irrigable area: 30 ha

Main horticultural crops: (See Table 4.13)

Table 4.13 Horticultural Crops Grown in AdiAsfeda

Common Horticultural crops grown	Coverage in %	Planting time	Harvesting time	Yield Quintal/ ha	Average price NKF/kg
Potato	45	Sep-Feb	Dec-May	225	8
Cabbage	30	May-Oct	Aug- Feb	355	3
Carrot	10	May	Aug	300	4
Zuccini	5	Aug- Feb	Oct-April	375	6
Lettuce	5	May	August	150	5
Tomato	5	March	June	237	10

Irrigation Intensity: Three times per year

Irrigation Interval: Once a week

Irrigation system: Furrow and basin

Water conveyance system: Earth channel and pipe system

Physical properties of the soil of the irrigable areas: Loam to sandy loam

Frost occurrence: December –January

Market: Asmara

Percent of marketable produce: Over 90%

Production Constraints: Shortage of supplies in fertilizer, pesticide, and seed

Domestic Water Use: No

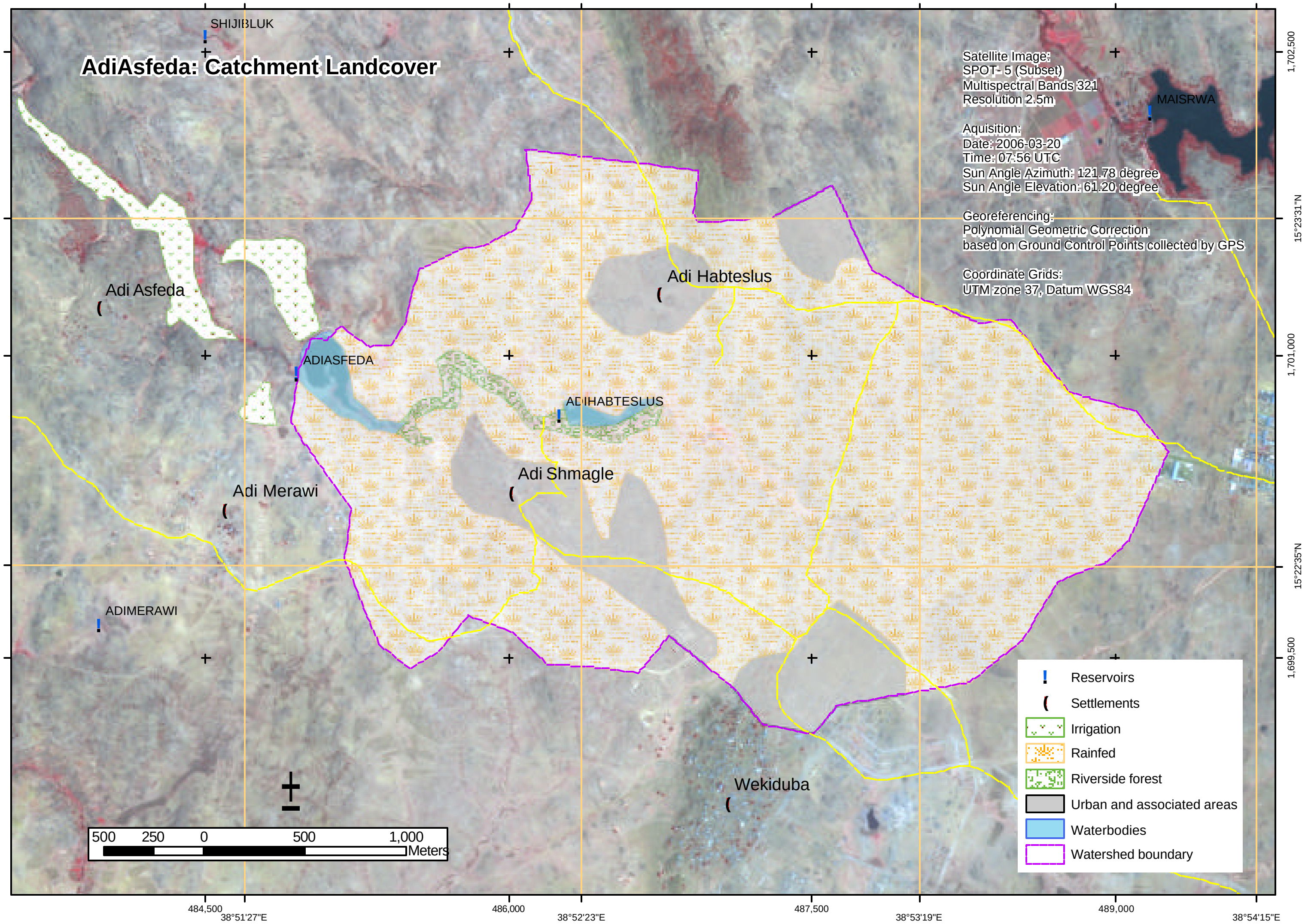
Livestock Watering

Type and number of livestock and daily and yearly consumption of water in Adi Asfeda is presented in Table 4.14.

Table 4.14 Type and Number of Livestock, AdiAsfeda

Type of Livestock	Daily water Consumption (litres/head)	Total number of animals	Water consumption per year (m^3)
Cattle	15	150	824
Sheep and Goats	3	400	439
Equines	10	60	220
Total			**1,483**

Other uses: No other use.



Map 4.5 Catchment land cover map of AdiAsfesda dam

4.6 Tseazega Dam

Tseazega is a large village located in Subzoba Berik. Tseazega dam was constructed in 1988 by Evangelical church and was rehabilitated and increased in height by 2.3m in 2000. As a result its capacity increased from 230,000 m^3 to 453,421 m^3 and reservoir area increased from 7.1ha to 15 ha.

General Information

Location: 37 480226 E, 1696267N
Date of Construction: 1988
Constructed by: Evangelical church
Design capacity: 230,000 m^3
Actual capacity: 353,803 m^3
Actual water volume at the time of survey: 214,272 m^3
Dam crest length: 230 m
Dam height: 10.5 m
Type of dam: Earth fill

Photo 42. MoA staff members at the time of bathymetric survey in Tseazega

Condition of Catchment:
Catchment area: 3,762 ha (37.62 km^2)
Slope: Flat to undulating
Catchment land cover types: (See Table 4.15)

Table 4.15 Catchment Land Cover Types, Tseazega

Land Cover Type	Area (ha)	% Catchment Cover
Artificial Waterbodies	38.9	1.7
Open shrub	209.7	9.1
Tree Plantation	6.5	0.3
Rainfed Small Herbaceous Fields	2019.2	87.6
Riverside Vegetation	8.4	0.4
Concession	21.7	0.9
Urban and Associated Areas	232.1	10.1
Total	2304.5	**100.00**

Irrigation

Number of beneficiaries: 1080 households

Area of currently irrigated fields: 33.5 ha

Potential irrigable area: 36 ha

Main horticultural crops: (See Table 4.16)

Table 4.16 Horticultural Crops Grown in Tseazega

Common Horticultural crops grown	Coverage in %	Planting time	Harvesting time	Yield Quintal/ha	Average price NKF/kg
Tomato	40	Feb/August	May/Dec	250	8
Potato	40	Feb/May	May/ August	120	10
Cabbage	10	Sep	Dec	300	3
Zuccini	5	Feb	May	150	6
Carrot	5	July	Oct	150	4

Irrigation Intensity: Twice per year

Irrigation Interval: Once a week, twice during hot months (on May) and at flowering

Irrigation system: Furrow and basin

Water conveyance system: Earth channel

Physical properties of the soil of the irrigable areas: Loam to clay loam

Frost occurrence: December – February

Market: Asmara

Percent of marketable produce: Over 90%

Production Constraints: Land tenure system, land reallocation (every 7 years), lack of farmers association, agricultural inputs like fertilizer, pesticides, seed, and fuel.

Domestic Water Use:

The villagers don not use reserved water directly from the dam for domestic purposes rather they take 100 liters/day/household from a well downstream. This amounts to 39,530 m^3 per year.

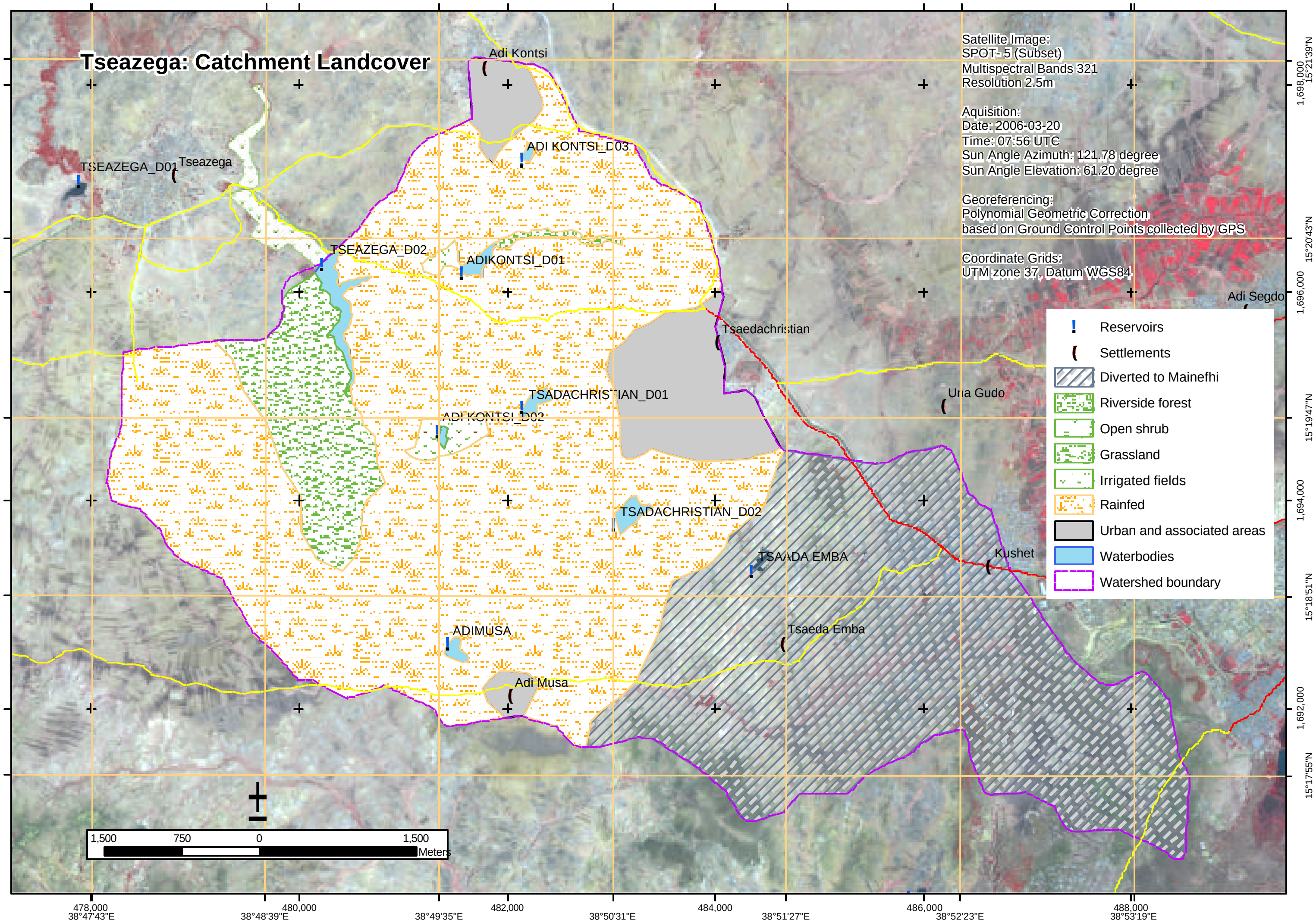
Livestock Watering

Type and number of livestock and daily and yearly consumption of water in Tseazega is presented in Table 4.17.

Table 4.17 Type and Number of Livestock, Tseazega

Type of Livestock	Daily water Consumption (litres/head)	Total number of animals	Water consumption per year (m^3)
Cattle	20	1500	10,980
Sheep and Goats	2	4800	3,514
Equines	10	850	3,111
Total			**17,605**

Other uses: For house construction, brick factory and in flour mills



Map 4.6 Catchment land cover map of Tseazega dam

4.7 Lamza Dam

Lamza is a small village in Subzoba Galanefhi. Lamza dam was built in 1986 by MoA and has been rehabilitated in 1995 as a result its height increased by 2 meters.

General Information

Location: 37 491234 E, 1683301 N
Date of Construction: 1986
Constructed by: MoA
Design capacity: 500,000 m^3
Actual capacity: 442,780 m^3
Actual water volume at the time of survey: 25,612 m^3
Dam crest length: 201 m
Dam height: 12.5 m
Type of dam: Earth fill

Photo 43. Lamza dam and its surrounding catchment

Condition of Catchment:

Catchment area: 852 ha (8.5 km^2)

Slope: Mainly undulating to slightly steep with small patches of flat and moderately steep slopes

Catchment land cover types: (See Table 4.18)

Table 4.18 Catchment Land Cover Types, Lamza

Land Cover Type	Area (ha)	% Catchment Cover
Artificial Waterbodies	4.3	0.5
Rainfed Small Herbaceous Fields	303.8	35.6
Open shrubs	491.7	57.6
Urban and Associated Areas	53.8	6.3
Total	**853.6**	**100.0**

Irrigation

Number of beneficiaries: 120 households
Area of currently irrigated fields: 17.7 ha
Potential irrigable area: 43 ha
Main horticultural crops: (See Table 4.19)

Table 4.19 Horticultural Crops Grown in Lamza

Common Horticultural crops grown	Coverage in %	Planting time	Harvesting time	Yield Quintal/ha	Average price NKF/kg
Carrot	50	June	Oct	360	5
Potato	15	June	Sep	180	10
Cauliflower	10	Any time	4 months	220	10
Tomato	5	June/Feb	Sep/May	285	5
Zuccini	5	Feb	April	198	7
Luttuce	3	Any time	3 months	200	8
Cabbage	5	Any time	4 months	414	2
Spice /sedeno	2	Any time	-	36	7
Spinache	5	June	Oct	145	10

Irrigation Intensity: Three times per year
Irrigation Interval: Once a week
Irrigation system: Furrow and basin
Water conveyance system: Open earth and lined channel
Physical properties of the soil of the irrigable areas: Loam to sandy loam
Frost occurrence: December – February
Market: Asmara
Percent of marketable produce: Over 90%
Production Constraints: Lack of inputs mainly fertilizer, pesticides, and fuel for water pumps.

Domestic Water use:

Domestic water is pumped from a well at the downstream of the dam to the village at a rate of 40 liters/family. The villagers fetch around 1,440 liters (24 jrba) of water per day from the dam for washing purpose. In total an estimated 2,284 m^3 of water is consumed for domestic purposes.

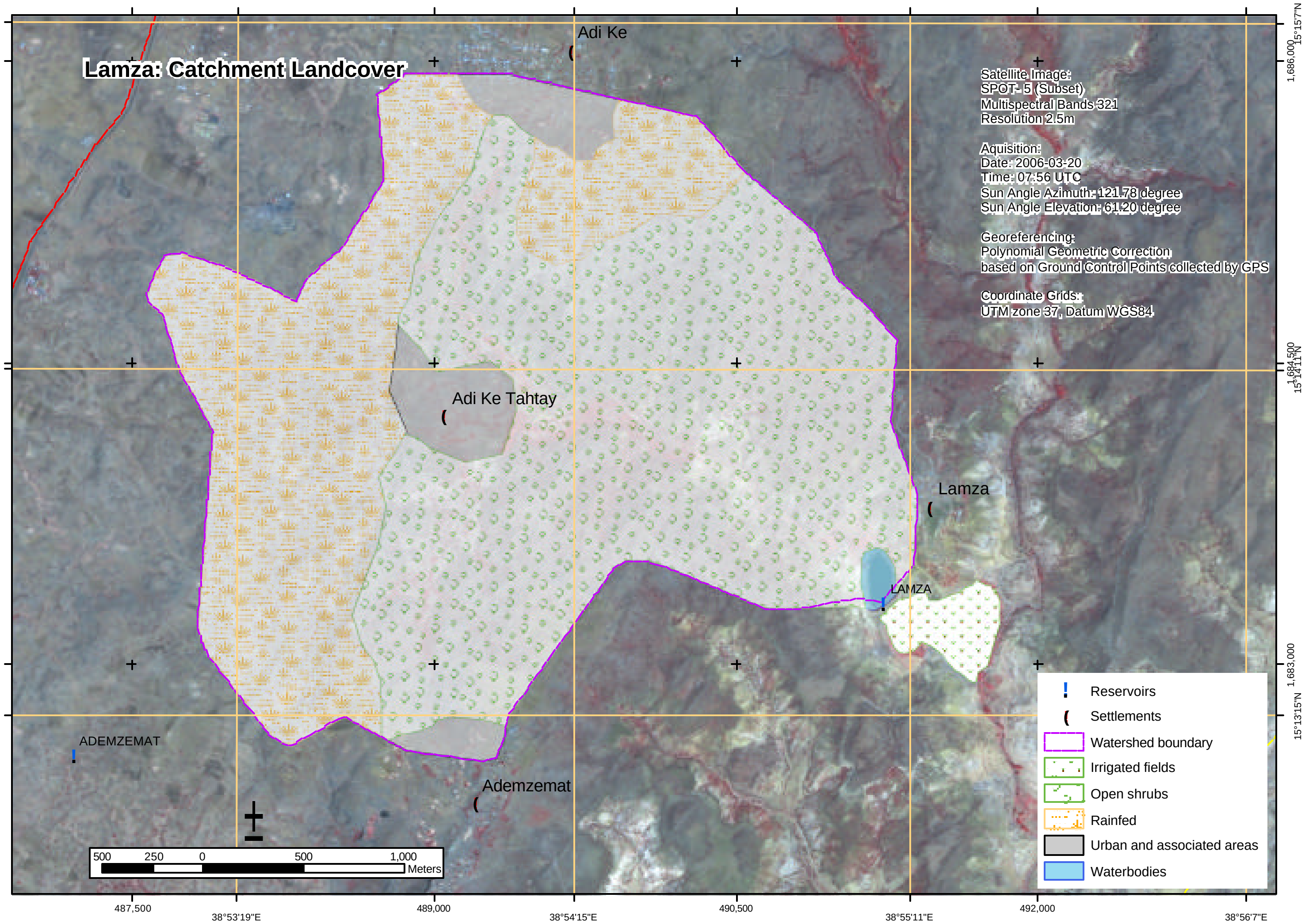
Livestock Watering

Type and number of livestock and daily and yearly consumption of water in Lamza is presented in Table 4.20.

Table 4.20 Type and Number of Livestock, Lamza

Type of Livestock	Daily water Consumption	Total number	Water consumption per year (m^3)
Cattle	20	180	1318
Sheep and Goats	2	150	110
Equines	10	80	293
Total			**1721**

Other uses: No other use.



Map 4.7 Catchment land cover map of Lamza dam

4.8 Laugen AdiHamushte Dam

Laugen AdiHamushte dam is located in Subzoba Galanefhi. It is a rock fill dam. The dam is situated between the villages of Laufen and AdiHamushte and thus it is shared between the two villagers.

General Information

Location: 37 482664 E, 1683651 N
Date of Construction: 1995
Constructed by: MoA
Design capacity: 1,300,000 m^3
Actual capacity: 1,031,791 m^3

Actual water volume at the time of survey: 114,202 m^3
Dam crest length: 190 m
Dam height: 22 m
Type of dam: Rock fill

Photo 44. Partial view of the Laugen AdiHamushte dam during a bathymetric survey

Condition of Catchment:

Catchment area: 1,094 ha (10.94 km^2)
Slope: Flat to undulating
Catchment land cover types: (See Table *4.21*)

Table 4.21 Catchment Land Cover Types, Laugen-AdiHamushte

Land Cover Type	Area (ha)	% Catchment Cover
Artificial Waterbodies	9.1	0.8
Irrigated Herbaceous Fields	18.4	1.7
Isolated (in natural vegetation or other) Rainfed Small Herbaceous Fields (Field frequency 10-20%)	144.1	13.2
Rainfed Small Herbaceous Fields	647.1	59.2
Open shrubs	177.6	16.2
Tree plantation	2.7	0.3
Riverside Forest	12.2	1.1
Urban and Associated Areas	81.8	7.5
Total	**1128.9**	**100.00**

Irrigation

Number of beneficiaries: 470 households

Area of currently irrigated fields: 28.6 ha

Potential irrigable area: 120 ha

Main horticultural crops: (See Table 4.22)

Table 4.22 Horticultural Crops Grown in Laugen-AdiHamushte

Common Horticultural crops grown	Coverage in %	Planting time	Harvesting time	Yield Quintal/ha	Average price NKF/kg
Potato	30	Feb/ Sep	May/Nov	220	8
Tomato	30	Sep/ Feb	Nov/May	315	5
Cabbage	30	Any time	4 months	235	3
Luttuce	5	Any time	3 months	210	5
Alfa alfa	3	Any time	3 months	80/every month	-
Zuccini	2	Feb/ Sep	May/Nov	310	7

Irrigation Intensity: Twice or three times per year

Irrigation Interval: Once a week

Irrigation system: Furrow and basin

Water conveyance system: Earth canals and pipe system

Physical properties of the soil of the irrigable areas: Loam to sandy loam

Frost occurrence: December – February

Market: Asmara

Percent of marketable produce: Over 90%

Production Constraints: shortage of Agricultural inputs like fertilizer, pesticide, sprayer, and irrigation infrastructure; weak water management system

Domestic Water Use: No

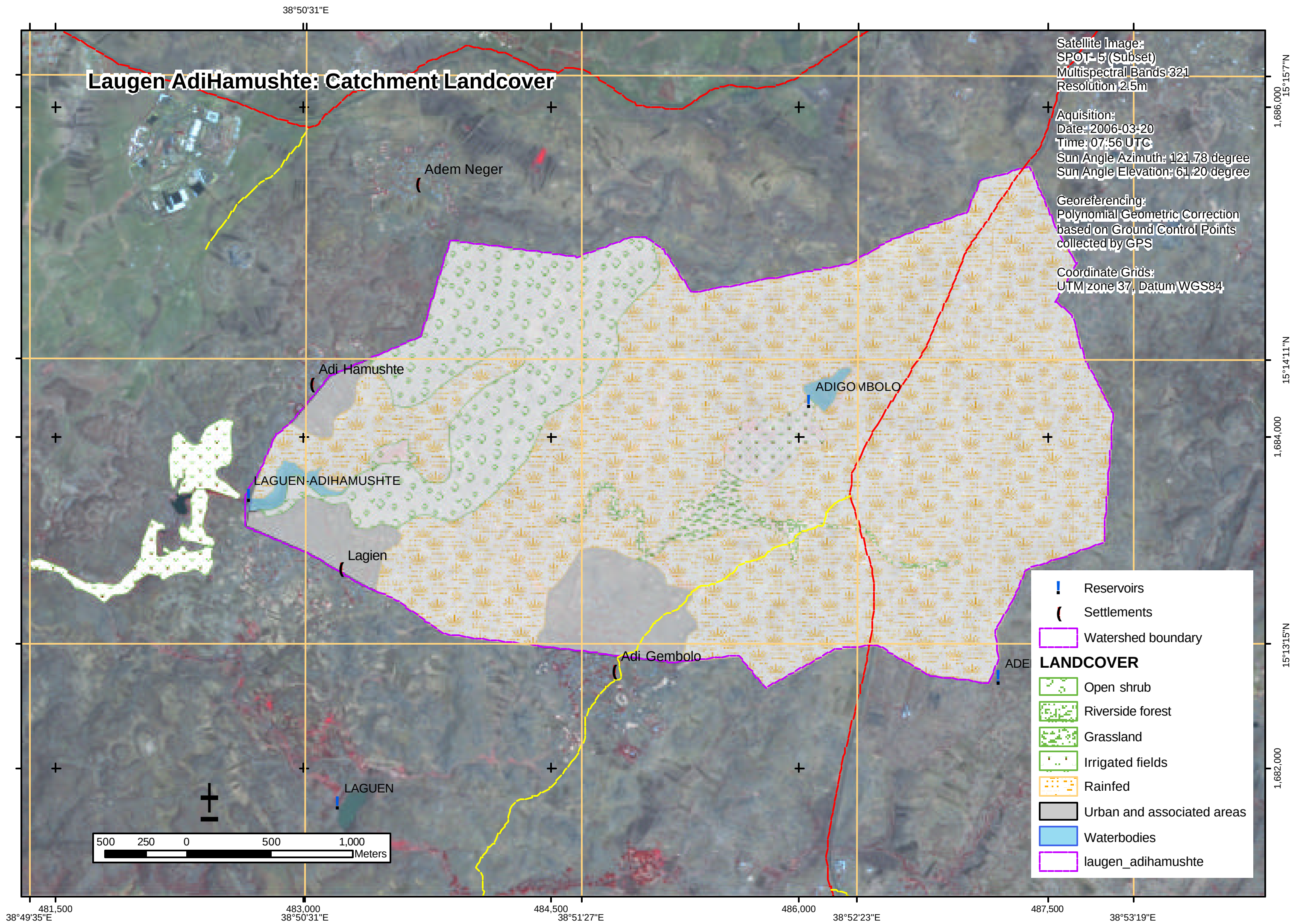
Livestock Watering

Type and number of livestock and daily and yearly consumption of water in Laugen-AdiHamushte is presented in Table 4.23.

Table 4.23 Type and Number of Livestock, Laugen-AdiHamushte

Type of Livestock	Daily water Consumption (litres/head)	Total number of animals	Water consumption per year (m^3)
Cattle	20	350	2562
Sheep and Goats	2	1500	1098
Equines	10	250	915
Total			**4,575**

Other uses: No other use.



Map 4.8 Catchment land cover map of Laugen AdiHamushte dam

4.9 Himbrti Gomini Dam

Himbirti is a village located in Subzoba Galanefhi. Himbrti Gomini dam was rehabilitated and its height increasedby 1.5 meters in 2004. As a result its capacity has increased to 450,000m^3 with reservoir area increase from 9.9ha to 11.8ha

General Information

Location: 37 474224 E, 1689001 N
Date of Construction: 1989
Constructed by: MoA
Design capacity: 330,000 m^3
Actual capacity: 337,829 m^3

Actual water volume at the time of survey: 66,208 m^3
Dam crest length: 229 m
Dam height: 11 m
Type of dam: Earth fill

Photo 45.Side view of Himbrti Gomini dam

Condition of Catchment:

Catchment area: 1,129 ha (11.29 km^2)

Slope: Mainly undulating with small flat and slightly steep slope areas

Catchment land cover types: (See Table 4.24)

Table 4.24 Catchment Land Cover Types, Himbrti Gomini

Land Cover Type	Area (ha)	% Catchment Cover
Artificial Waterbodies	4.8	0.4
Irrigated Herbaceous Fields	100.3	8.9
Rainfed Small Herbaceous Fields	884.9	78.4
Open Shrubs	79.9	7.1
Sparse Shrubs	16.7	1.5
Artificial water bodies	42.4	3.8
Total	1129	100.0

Irrigation

Number of beneficiaries: 600 households

Area of currently irrigated fields: 42.9 ha

Potential irrigable area: 40 ha

Main horticultural crops: (See Table 4.25)

Table 4.25 Horticultural Crops Grown in Himbrti Gomini

Common Horticultural crops grown	Coverage in %	Planting time	Harvesting time	Yield Quintal/ha	Average price NKF/kg
Alfa alfa	30	Any time	After 3 months	50	1.30
Cabbage	25	Dec	March	330	4
Onion	20	Oct	Feb	200	7
Potato	10	Feb	May	190	10
Tomato	10	Feb	May/June	325	5
Garlic	5	Nov	Feb	100	40

Irrigation Intensity: Twice or three times per year

Irrigation Interval: Once a week

Irrigation system: Furrow and basin

Water conveyance system: Pipe channel

Physical properties of the soil of the irrigable areas: Loam to silty loam

Frost occurrence: December – February

Market: Asmara

Percent of marketable produce: Over 90%

Production Constraints: shortage of Agricultural inputs like fertilizer, pesticides; fuel etc.; shortage of water, lack of agricultural extension services, and unleveled land

Domestic Water Use:

No

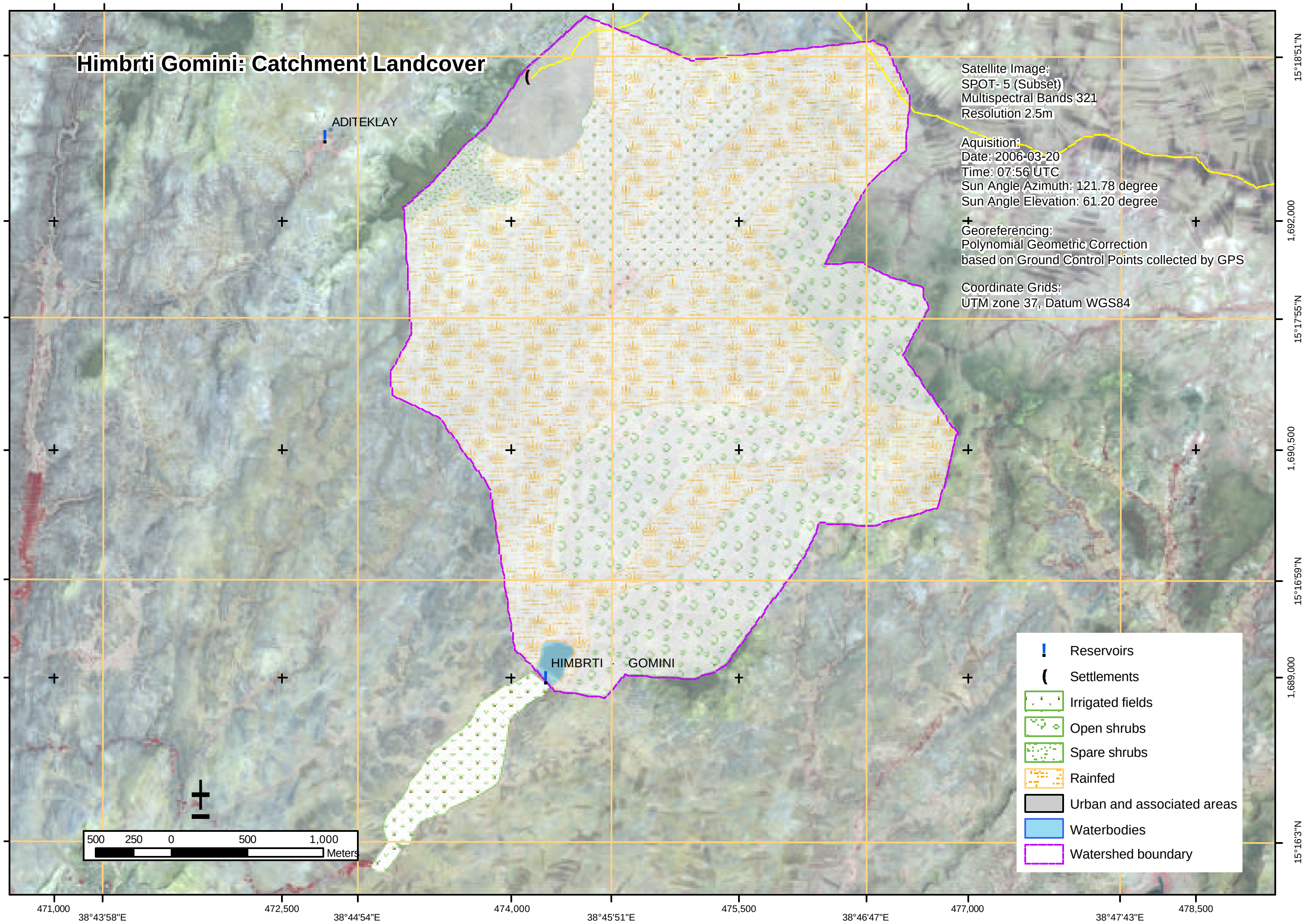
Livestock Watering

Type and number of livestock and daily and yearly consumption of water in Himbrti Gomini is presented in Table 4.26.

Table 4.26 Type and Number of Livestock, Himbrti Gomini

Type of Livestock	Daily water Consumption (litres/head)	Total number of animals	Water consumption per year (m^3)
Cattle	20	3400	24,888
Sheep and Goats	3	1000	1,098
Equines	10	100	366
Total			**26,352**

Other uses: No other uses



Map 4.9 Catchment land cover map of Himbrti Gomini dam

5 CONSCLUSIONS AND RECOMMENDATIONS

5.1 Conclusions

Water productivity can be used as a strategy for allocating scarce water resources for attaining optimum societal benefits. The water productivity strategy, however, should be complimented with holistic information about the resources available and wide stakeholder consultations to derive the optimum societal benefits.

In the first phase of the study a sufficient and reliable and above all holistic database was developed regarding the current status of the reservoirs, their corresponding catchment areas, downstream irrigation activities and other competitive water uses. The survey of the 75 reservoirs in Zoba Maekel including DekiZeru from Zoba Anseba shows that an estimated 67 million m^3 of water is reserved in these reservoirs out of which 32 million m^3 is reserved in 49 small to large dams in the Upper Anseba Catchment. This shows that the potential for surface reserved water in Zoba Maekel and particularly in the Upper Anseba Catchment is very substantial and needs special attention. The data collected is a great achievement to prioritize areas of intervention and identify areas of further investigation.

Reservoirs may not be sustainable as they eventually lose their storage capacity through filling up with sediments. The detailed survey of the nine reservoirs and their corresponding catchments revealed that the dams are losing their corresponding storage capacities at a rate of 0.5 – 2% annually. This estimate was based on comparison of the design (original) capacity obtained from archives of MoA and the current or actual capacity obtained by reservoir resurvey. Results from the catchment characterization showed that sediment yield varies spatially between catchments, i.e., from 262 t/km^2/year in Hayelo-Geshnashm to 1769 t/km^2/year in AdiAsfeda with an average of 856 t/km^2/year. On the other hand, the sediment deposition data obtained from bathymetric survey shows that SSY ranges between 132 m^3/km^2/yr and 1846 m^3/km^2/yr with a mean SSY of 703 m^3/km^2/yr. The MoA is trying to remedy the problem by rehabilitating the dams by increasing height but it is incurring an extra cost.

An attempt was made to estimate the reserve capacity of the Upper Anseba Catchment. The surface reservoirs in this catchment have a potential reserve capacity of 32 million

m^3 of water. Given majority, 88% of the dams and ponds are constructed before a decade, the dams and ponds are considerably silted. If we assume, based on the survey carried in this study, that 23% of this potential reserve capacity is silted, the reserve capacity in this catchment would be roughly around 24.5 million m^3. This means that the reserve capacity of the surface reservoir in this catchment is almost 70% of the annual yield calculated for the whole catchment.

Not much study was carried out to quantify the extent of groundwater residence time in a basin or in this kind of geology. It requires future meticulous efforts to understand the potential of the groundwater and the potential groundwater reservoir in this area. Nonetheless, the recharge rate indicates the amount of water that is wasted from the surface water to the groundwater reserve. Assuming that the rate of recharge is uniform in all the catchment the yearly groundwater recharge is roughly around 23 million m^3 of water per annum.

The survey revealed that the total currently irrigated land in Zoba Maekel reaches 487 ha out of which 322 ha is situated in the Upper Anseba Catchment. The total number of beneficiaries from these reservoirs was estimated to be 11,720 households in Zoba Maekel. In addition to the 487 ha of irrigation practiced on the class one active reservoirs for irrigation around 40 ha is irrigated in some of the class two reservoirs.

The potential irrigable area in Zoba Maekel was supposed to be 1026 ha based on the amount of water that can be reserved as estimated from the design capacity. But from the bathymetric survey an estimated 23% of the reservoirs capacity has been lost due to siltation. This indicated that the potential irrigable area decreased to 790 ha and 62% of this potential irrigable area is used or utilized currently. In other words, considering the potential for expansion in irrigated area and the assessments made it is estimated that additional 300 ha can be irrigated using reservoir water. In the upper Anseba Catchment similar analysis revealed that the potential irrigable area reaches 454 ha out of which almost 76 % (346 ha) is currently under irrigation.

Remotely sensed satellite images and GPS data analysis using GIS helped to have an accurate estimation of the current irrigated fields in the nine selected reservoirs. Even though the extent of irrigated area from reserved water is increasing in recent years it is still not satificatory compared to the number of reservoirs and the aggregate volume of reserved water. In View of the inadequacy and unreliability of rainfall in Eritrea, irrigation will have to play an important role in improving the security of crop production. Thus, much remains to be done to use the available water resources in an efficient and sustainable way.

Inefficient irrigation not only wastes water and resources, but it can also leach off important nutrients from the top layer of the soil and other amendments. Conversely, if insufficient water is applied, productivity of the soil is impaired affecting crop production. Therefore, a major part of irrigation management is deciding when to irrigate and how much water to apply. This requires a basic knowledge and understanding of soil-water-plant relationships. In this study a set of climatic, soil and crop data have been used to estimate the crop water requirement of four commonly grown crops (potato, tomato, carrot and cabbage) as a pilot. Thus it is observed that there is an urgent need for the implementation of an efficient irrigation management especially in the field of water budgeting and irrigation scheduling.

Participatory Rural Appraisal (PRA) and group discussions were practiced in order to have an insight on the perception and ambition of the communities towards reservoirs. Prioritization of activity and its contribution to the household income in the villages indicate the commitment of the villages to that activity. The higher the source of income from an activity, the higher is the commitment of the villagers to that source or activity. It was found unique that the community mentioned financial and material resources at the end of the priority. This indicates a relatively low economic disparity among the rich and the poor of the village in terms of financial or material measurements.

All the villages stated water and shortage of land are the main constraints in the practice of irrigation. The second and third major constraints are, mainly, insecure land tenure system and limited supply of improved seed, fertilizer and pesticide. Lack of market, transportation, and shortage of irrigation materials and tools are also mentioned as some of the main problems. The problems have added up to substantially constraint irrigation activity and thus the benefits from the activity.

A bylaw drafted by the MoA Maekel branch is the only currently available bylaw related to water management aimed to ensure the efficient use of dams and their downstream irrigable areas in this catchment. The bylaw was effective since of June 2004. During the field survey the positive and negative impacts of the byelaw were evaluated.

From the inventory and digital maps produced for the study area in question 31 reservoirs were identified as class one. These reservoirs are active for irrigation and the efficiency and utilization of water use is better in these reservoirs relatively. These 31 reservoirs were further ranked as 1, 2 and 3 (Table 5.1) by comparing and contrasting the irrigation activities being carried out, the strength of the water use associations and the unit agricultural production per m^3 of water used. Therefore these villages with reservoirs ranked as number one can be taken as role models and their experiences have to be shared to the other villages with reservoirs by undertaking farmers' field day or any other awareness campaign.

Table 5.1Class One Reservoirs for Irrigation priorized into three classes

S.No	RESERVOIR	YEAR OF CONST.	DESIGN CAPACITY (M^3)	CURRENT IRRIGATION (HA)	POTENTIAL IRRIGABLE (HA)	PRIORITY CLASS
1	Hazega	1982	40,000	7	4	3
2	Tseazega	1988	453,420	33.5	45	1
3	Shinjibluk	2007	350,000	10	35	2
4	Adi Kontsi	1970	250,000	2	25	2
5	Ametsi	1988	180,000	30	18	1
6	Adi Asfeda	1988	200,000	32	20	1
7	Adi Habteslus	1941	80,000	4	8	3
8	Adisheka	Before 1930	5,100,000	12	20	2
9	Adikolom	1989	270,000	5	27	3
10	Embaderho	1992	330,000	24	35	1
11	Guritat	2006	300,000	6	30	1
12	Hayelo	1995	1,000,000	40	100	1
13	Mekerka	2003	270,000	16	27	1
14	Mesfinto	1995	60,000	9	6	1
15	Shmangus laelai	1985	400,000	15	40	2
16	Shmangus Tahtai	1992	230,000	15	23	2
17	Teareshi	1989	280,000	11	28	2
18	Adi Nefas_D01	Before 1930	600,000	30	-	3
19	Adi Nefas_D02	1941	200,000	20	-	1
20	Daero Paulos	1987	60,000	2	6	3
21	AdiGhebru- AdiTeklay	1985	160,000	6	16	3
22	Tselot_D03	1989	250,000	2	25	2
23	Tselot_D02	2005	300,000	3	30	2
24	Adi-Ahderom	2007	250,000	12	25	1
25	Laguen-AdiHamushte	1995	1,300,000	29	130	2
26	Himbrti Shaka	1985	400,000	11	40	2
27	Himbrti Gomini	1989	450,000	15	45	3
28	Laguen	1987	200,000	15	20	1
29	Adi Gombolo	1982	150,000	7	15	2
30	Adi Hawesha	1988	150,000	5	15	3
31	Lamza	1986	500,000	18	50	1

- Reservoirs assigned Serial No 1-19 are situated within the Upper Anseba Catchment while the rest are outside of the catchment but located within the Administrative boundaries of Zoba Maekel.

5.2 Recommendations

The following recommendations have been made after concluding the study.

- The study provided a wide range of information on number and distribution of reservoirs in Zoba Maekel and specifically the Upper Anseba Catchment. The design and actual capacities have been estimated, siltation rate assessed and the irrigation activities in the area were studied in detail. This valuable information can be use to secure food in the area by optimizing dam water management and use in a sustainable way.
- Though it is very difficult to propose the construction of new dams in the catchment it is possible to come up with a recommendation on the upgrading and efficient use of the existing reservoirs. In table 2 reservoirs were prioritized in to three classes. Here priority is given for maintaining or upgrading the reservoirs, in making more efficient water use by strengthening the water use committees and/ or secure supply chains for agricultural production.

Table 5.2 Priority List of Reservoirs for Future Developments in Zoba Maekel

A. Priority Class One Reservoirs

S. NO	NAME OF DAM	CAPACITY (m^3)	CIA	PIA	BENEFICIERY	YEAR OF CONS.
1	Lamza	442,780	20	43	196	1986
2	Ametsi	118,000	45	12	230	1988/2004
3	AdiAsfeda	200,000/365,755	25	30	210	1988/2002
4	Embaderho_D01	330,000			300	1965-70
5	Mekerka	270,000	16	27	350	2003
6	Tseazega	230,000/453,421	25	36	750	1988/2000
7	Hayelo-Gheshnashm	1,000,000	23	90	224	1995/1997
8	Laugen	200,000	15	20	567	1987
9	Mesfnto	80,000	9	9	123	1995
10	Laugen-AdiHamushte	1,300,000	20	120	913	1995
11	Himbrti -Shaka	400,000	11	35	1410	1985
12	Shmangus tahtai	230,000	15	23	120	1992
13	Shmangus laelai	400,000	15	20	350	1985/2006
14	Guritat_D01	300,000	6	24	200	2006
15	Taareshi	280,000	11	20	198	1989
16	Himbrti -Gomini	450,000/337842	6	40	1410	1989/2004
17	Shnjibluk	350,000	10	35	185	2006/07
18	AdiAhderom	250,000.00	12	30	185	2006/07
19	Adikolom	270,000	5	26	490	1989
20	Tselot_D	250,000		25	960	2007
21	Kodadu	700,000		70	449	1995/6
22	AdoGombolo	150,000	7	15	316	1982
		7,050,780	296	750	9936	

B. Priority Class Two Reservoirs

S. NO	NAME OF DAM	CAPACITY	CIA	PIA	BENEFICIERY	YEAR OF CONS.
1	AdiHawesha	150,000	5	23	406	1988
2	Tseazega	150,000		15	750	1983
3	Zagr	150,000	2	15	814	1984
4	AdiKontsi	250,000	2	25	388	1970/ 2007
5	AdiSheka	5,100,000	12	20	213	Before 1930/1986
6	Tselot	300,000	3	30	960	2005
7	Tselot	250,000		25	960	2007
8	Himbrti-Chea	150,000	2	15	1410	1986
9	AdiKntsi-AdiYakob	200,000		20	250	2007
10	Adi Ghebru-Adi Teklay	160,000	6	16	300	1985
11	Hazega	250,000	Livestock, Domestic use	20	250	1989
12	Tsaedachristian	130,000	Livestock, Domestic use	12	400	1983
13	DaeroPaulos	60,000	2			1987
14	AdiHabteslus	80,000	4	8		1941
15	Adearada	200,000	3	20	260	2006/07
16	Guritat_D02	180,000	3	18	220	1997
		7,760,000	44	282	7581	

C. Priority Class Three Reservoirs

S.NO	NAME OF DAM	CAPACITY	CIA	PIA	BENEFICIERY	YEAR OF CONS.
1	Adibide	90,000	9		235	2006/07
2	Adimerawi	110,000	3		80	1992
3	Hazega	40,000	7		250	1982
4	Tsaedachristian	80,000	4	8	400	1944
5	Adimusa	250,000	2.5	25	150	1992
6	Aditeklay	53,000	3	6	150	1988
7	Adighebru	80,000		8		2000
8	Tsaadaemba	55,000	2.5	6	250	1980
9	Wokiduba	25,000	Livestock, Domestic use		350	1985
10	AdiKontsi	70,000	Livestock, Domestic use	7		1970
11	AdiKontsi	50,000	Livestock, Domestic use			1970
12	AdiYakob	80,000	3	8	200	1993
13	Adisegudo	120,000	4	12	220	1983
14	Tselot	50,000		5		1984
15	Tselot	250,000	2			1989

16	AdiKeih	40,000.00	Domestic use		50	2007
17	Embeito	130,000	Livestock, Domestic use	10	282	1993
18	Merhano_D01	250,000		25	334	1988
19	Merhano_D02	60,000				1998
20	Adiguadad	150,000	Livestock, Domestic use	15	520	1981
21	Selaadaro	80,000	6	8	245	1981
22	AdiKeshi	250,000	2	20	102	1988
23	Ademzemat	50,000	Domestic use		200	2006
24	Embaderho_D01	60,000			100	1965-70
25	AdiAbeyto	110,000	Livestock, Domestic use			1985
		2,583,000	48	163	4118	

- The study demonstrates the value of a comprehensive data or information on natural resources like reserved water in a catchment as a tool for optimizing land-use and management strategies to reduce reservoir sedimentation in the highlands of Eritrea.
- The results from this study can provide the basis for proposing land management options for efficient water use and food security plans and strategies.

- There is a great deal of local information and knowledge which relevant policy makers and Ministry of Agriculture need to build on and should invite local farmers to be part of the problem identification and development process.

- Catchments where rapid introduction of soil and water conservation or other measures is essential to obtain a reasonable dam life were identified and presented in the database for remedial activities to have a significant impact on dam siltation. More over it is necessary to carry out maintenance and long-term soil and water conservation activities in all the catchments. In addition, land redistribution should be elongated from the current practice of 7 years to motivate long term investment of the farmers on their lands.

- Siltation as series problem to reservoirs should be discussed by coordinated technical, institutional and legal frame work with integration of all stakeholders. Sediment management in reservoirs like desilting might be an effective approach towards maintaining the existing storage capacity.

- Agricultural inputs like seed, fertilizer, and plant protection chemicals should be made available at affordable price to farmers. In addition, it is important to set favorable marketing and credit services to encourage small scale farmers.

- The irrigation system in the area is still traditional and it is clear that such a system or management practice doesn't allow efficient and sustainable use of the available water. Thus good irrigation management is required for efficient and profitable use of water for irrigating agricultural crops. There is an urgent need of implementing irrigation scheduling in the study area. Another way of improving efficiency of water use is using pipe channel system to convey water from the reservoirs to the irrigated fields.

- Most of the villages surveyed produce two irrigation crops per year because it is not common to grow crops during the coldest months of the year mainly November to January. But frost tolerant crops can be grown during the cold season and make use of the reserved water efficiently before it gets evaporated. Crop selection can also be helpful in identifying less water demanding crops to increase the production per m^3 of reservoir water consumed.

- Spatial coverage of meteorological stations doesn't allow a good modeling exercise in the catchment that additional metreological stations need to be installed in the catchment.

- Animal watering should not be directly from the dam, it is advisable to have troughs on the downstream.

- Establishment of water user's associations and strengthening institutional and organizational structures through training and provision of incentives is very important. Comprehensive water use bye-law should also be prepared. It is also advisable to prepare coordinated water use and development master plan at catchment level. Thus creation of effective community water management committees needs to be given top priority.

- To supplement the reserved water in the catchment it is necessary to exploit other sources of water like fog harvesting, roof catchment water harvesting and others.

- Awareness creation and dissemination of findings among policy makers and beneficiaries is essential to attain a sustainable land and water development in the Upper Anseba Catchment. Capacity building of farmers and extension agents could be promoted through training, farmers' day and field visits to villages with good or examplenary irrigation systems that were identified as Class One reservoirs in this study.

- Standardization of appropriate methodologies for predicting sediment yield, irrigation scheduling should be given top priority.

- Although this paper has mostly performed quantitative analyses, semi-quantitative expert-based techniques were employed to determine the severity of sedimentation, efficiency of irrigation systems, water balance, catchment reserve capacity, and crop water requirement of selected crops. In future work, more detailed quantitative assessments need to be performed. For instance, further research is needed on siltation rates of reservoirs with time and assess the factors aggravating the problem that vary spatially.

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7 APPENDICES

7.1 Appendix 1: Mean Annual Rainfall in mm for Selected Stations (1997-2007) in Zoba Maekel

Stations	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	Average
Bet Giorgis				365.5	603.9	372.4	394.7	288.1	485	642.1	575.2	465.9
Adi Nefas							393.7	294.4	590.1			426.1
Tsaedachristian	717.3	439.8	332.4	499.6	530.6	383.8	366.9	301.1	498.6	391.9	409.2	442.8
Tseazega	556.5	343.3	243.1	351.2	506.0	221.8	278.6	292.4	378.1	368.5	401.3	358.3
Hazega	591.0	344.0	295.5	531.7	819.3	380.3	422.1	296.1	541.2	398.5	473.6	463.0
Afdeyu	648.0	618.8	601.9	407.1	625.9	179.5	405.6	430.8	324.0			471.3
Hayelo				388.0	564.4			351.4				434.6
Geremi				568.2	607.9	220.7	415.5	421.1	630.0			477.2
Embaderho				372.6	814.0	327.8	383.2	391.8	463.9	405.9	533.1	461.5
Serejeka				436.0	576.0	273.1	397.1	413.7	587.5	617.4	349.0	456.2
Adi Hawesha	450.7	364.4	249.5	372.2	364.2	339.3	208.5	156.2	402.9	466.2	353.8	338.9
Merhano				311.6	449.0	341.3	375.4	277.4	479.8	416.6	423.3	384.3
Selaedaero				287.7	475.8	249.3	294.5	230.5	429.2			327.8
Himbrti	416.7	409.3	269.4	335.6	526.5	275.3	417.5	278.2	391.5	288.9	222.5	348.3
Tredishi				108.9	190.2	40.0	126.0	21.0				97.2
Average	563.4	419.9	332.0	402.1	574.1	297.1	365.6	315.9	477.1	444.0	415.7	418.8

Source: MoA-Zoba Maekel

7.2 Appendix 2: Techniques of Data Collection

Section 1: Questionnaire

An Appraisal of the Current Status and Potential of Surface Water in the Upper Anseba Catchment	Questionnaire No. ________ Date: ___________________

General information

1. Name of dam (if applicable): ___ ____________________________

2. Village name: ____

3. Administrative village: _____________________________________

4. Subzoba: ____

5. Location in UTM: E _____________________

N _____________________

6. Date of construction: ____________________

7. The dam was constructed by:

MOA b. NGOs c. Community d. Other, specify

____

8. Purpose or use:

Irrigation b. Domestic c. Livestock d. Fishing

Other, specify_____________________

9. Current use if different from the purpose: ______________________________

10. Condition of the dam:

Functional b. Not functional

If not, why? (Silted or not, or if damaged or not)

____

11. Type of dam:

a. Earthen b. Masonry c. Rock d. Other, specify

____

12. Spill way type

a. Natural b. Retaining wall c. Weir

d. Other, specify ___________________________________

13. Is there any possibility of upgrading? Yes or No

If yes how? ________________________________

Reservoir water actual and potential use

13. Where are the irrigated fields located?

a. Downstream of the dam b. Upstream of the dam

14. What is water-lifting mechanism (Water conveyance system) in the area?

a. Electric pump b. Shadoff c. Diesel pump d. Petrol pump

Specify the number and type of pumps: ________________________

15. The type of irrigation system practiced in the area:

a. Furrow b. Spate c. Sprinkler d. Basin d. Other, specify

____

16. Water conveyance system

a. Open channel b. Lined channel c. Pipe channel d. Other, specify

____

17a. Common horticultural crops grown:

Type of crops grown	Planting time	Maturing time	Production per ha	Average Price/Kg	Irrigation intensity

17b: Where do you sell your produce and how much is consumed at home, and how much is sold (%, estimate)? ____

18. Is there any frost occurrence? Yes/ No

19. If yes, when? From _________________ to__________________ (Date and month)

20. Does the frost occurrence have any negative impact on irrigated crops?
Yes or No

21. How is the irrigation timing or intensity? _______________Days/ week

22. If the dam is used for domestic purposes, is it for rural or urban water supply? ____

23. How do you access the dam water for domestic use?

a. Well on downstream

b. Direct from dam

24. How do you water your livestock?

Directly from the dam

Using basins or watering points

From wells dug downstream from the dam

25. Is there any industrial activity related to the dam water use? If yes, what type of activity _____________________________________

Community ambition and perception

26. What is the most important infrastructure you have in the village? Prioritize

School ()

Clinic()

Dam()

Water supply system()

Sanitation facility()

27. What is the most important contribution of the dam in your life?

Irrigation only

Animal watering only

Good name only (pride)

Fishing

Combination of all

28. Do you think what you have got what expected to get from your dam?

Yes

No

In the middle, why? ____

29. Do you think you are using the water from the dam efficiently?

a. Yes

b. No why? ____________________________________

30. Do you have any regulation on the use of water from the dam?

Yes, any reservation? Why?

____

No, do you think you need one? Why?

____

31. What do you think should be done for future to improve efficiency?

____

____

32. Do you have any fear or concern that might hinder the well being of your dam?

No

Yes, what?

____

____

Section 2: Interviews

Interview with administrator, water committee or development committee

Who uses the water from dam? Name all the users (stakeholders) including groups who use for irrigation, domestic purposes, industrial uses (making bricks and others), fishing, recreation activities (including swimming and fishing), and watering animals and so on.

What is the water from the dam used for? Name all use of water from the dam?

Is there any dedicated body or committee to administer or manage water resources in the village?

If there is a committee, who elect the committee? How many are the member of the committee? What is power extent?

Who decides on the allocation of water resources from the dam? How are the community of the village and other several stakeholders involved?

How is allocation of resources across sectors, users and time made? What are important factor? Or what is the priority?

Do users pay for water from the irrigation?

Who protects the water source in case of improper use (like for example pollution factor, overuse or foreign intervention (use)?

How large is the area of irrigated field allocated for each farmer (in hectares or tsmdi)?

Is there any fishing activity? If yes when was it introduced and do you think that it has any economic benefit?

Informal interview to farmers:

How much water (average) do you use over a period of time?

Do you have any water shortage for irrigation or other purposes from the dam, across all seasons?

If there is shortage of supply, what do you think is the reason? Over usage, poor management, low efficiency, small reserve capacity of dam. (Subjective question)

Do you pay for the water you use from the dam?

Interview with government offices, group discussion, and literature review

What is the extent of the current irrigated fields?

Who manages water in the upper Anseba catchment? Who approves dam construction or any other water extraction facilities?

Any knowledge of bylaws? If yes, how was your institution participation in drafting the document?

How are issues or competition resolved across ministries for different uses, (agricultural, domestic, industrial uses)? Who is in control and how are activities and needs integrated?

Is there any an established regulation or procedure o construct a dam in this catchment?

Focus Group discussion points

(The questions here can be added or deducted according to the reason of selection of the case study)

What was the village involvement in the planning, design and implementation of the dam?

How is the dam importance rated when compared with other infrastructures?

How efficient do you think you are using your water?

Who manage the water from the dam (allocation and protection the safety of users and the dam)

Do you have any regulations? A Village dam management institution? If no, why not? If yes: does it work? If no: why not?

Do you think you should pay for water from the dam? Why? *Or: Why not (gift of god….)?*

What impacts have you seen due to the upstream dam construction?

What are the factors (land, water or other impacts) of conflict? How do you think you will solve this issue?

Do you have any bylaws? Did you find it workable? What do you think about it?

Section 3: Checklist for field observation

Condition and extent of irrigated fields

Water conveyance system and its state

Soil type and condition in irrigated fields

Horticultural crops, their status and disease occurrence

Fishing in reservoirs

Catchment treatment: SWC measures and occurrence of erosion hotspots

Reservoir key values: - has the dam water permanently throughout the year?

- how much, at maximum (m3, estimated), in which month?
- how much, at minimum (m3, estimated, in which month?

7.3 Appendix 3: Catchment Characterization Form

Factor	**Extreme**	Score	High	**Score**	Normal	Score	Low	Score
Soil type	No effective Plant cover, Either rock or thin Shallow soils	40	Poorly drained compacted soils, Much ponding on soil surface after Heavy rains	30	Moderately well drained medium textured soils, Some ponding on soil surface after heavy rains	20	Well drained coarse textured soils, little ponding on soil surface after heavy rains	10
Vegetation condition over whole catchments	Little effective plant cover, ground bare or very spare cover over 80%	40	Fair cover >50% of catchments is cultivated with annual crops	15	Good cover 20%-50% of catchments is cultivated with annual crops	10	Excellent cover<20% of the catchments is cultivated with annual crops	5
	Over 80%		<30%of Catchments is under Good grass cover or protected forest cover	15	30-60% of catchments is under good grass land or protected forest cover	10	>60% of catchments is under well maintained grassland /or protected forest cover	5
Sign of active soil erosion	Many actively eroding gullies draining directly into dam and /or water courses; active under cutting of river banks along main water courses	40	Some actively eroding gullies draining into dam and/or water course; little under cutting of river banks along main river water courses	20	Few actively eroding gullies draining directly into dam and /or water courses; no under cutting or river banks along main water courses	10	No actively eroding gullies draining directly in to dam and /or water courses; no under cutting of river banks along main water courses	5

7.4 Appendix 4: Characteristics of Surveyed Reservoirs

A. Characteristics of surveyed reservoirs in Upper Anseba Catchment

	Location (Zone P 37)										
RESERVOIR	X-UTM	Y_UTM	Year	**CONST. BY**	**DC (M^3)**	**CL (M)**	**DH (M)**	**CA (HA)**	**CIR (HA)**	**PIR (HA)**	**HH**
Adikolom	480841	1714035	1989	ERRA	270,000	165	10.5	383.5	5	27	490
Adisheka	488407	1712801	Before 1930	Italians	5,100,000	403	20	3741.7	12	20	213
Beleza	491141	1704784	1958	Italians	1,200,000	120	12	597.4	-	-	-
Embaderho_D01	488655	1705052	1992	Evangelical	330,000	180	8	239.2	24	33	300
Embaderho_D02	489084	1704885	1965	Private	60,000	73	6	179.8	-	-	100
Guritat_D01	482488	1719380	2006	MoA	300,000	120	11	306.6	6	30	200
Guritat_D02	483941	1718483	1997	MoA	180,000	96	10	223.0	3	18	200
Hayelo	482621	1716791	1995	MoA	1,000,000	80	18	1035.4	40	100	438
Mekerka	483629	1709868	2003	MoA	270,000	100	12	825.9	16	27	350
Mesfinto	486300	1712087	1995	Kale Hiwet	60,000	73	8	97.8	9	6	123
Shmangus laelai	484236	1711011	1985	MoA	400,000	230	9	705.2	15	40	350
Shmangus Tahtai	479493	1713149	1992	Evangelical	230,000	130	8	876.6	15	23	120
Teareshi	481613	1709749	1989	Evangelical	280,000	80	8	1341.1	11	28	198
Zagr	488333	1718554	1984	MoA	150,000	101	7.5	284.4	2	15	814
Adi Merawi	483975	1699660	1992	MoA	110,000	132	8	29.2	3		80
Hazega	482109	1701803	1982	MoA	40,000	45	6	129.4	7		250
Hazega	480910	1703668	1989	MoA	250,000	91	7	123.7	-	25	250
Tseazega	480226	1696267	1988	Evangelical	230,000	230	10.5	3761.7	33.5	23	750
Tseazega	477888	1697066	1983	MoA	150,000	213	8	946.2	-	15	750
TsaedaChristian	483027	1693762	1983	MoA	130,000	200	7.5	184.5	-	13	400
TsaedaChristian	482145	1694886	1944	MoA	80,000	114	6	228.8	4	8	400
Adi Musa	481423	1692616	1992	MoA	250,000	150	8	514.1	2.5	25	150
Adi Ghebru	474135	1696085	2000	Villagers	80,000	90	12	188.2	-	8	655
Tsaeda Emba	484346	1693322	1980	Villagers	55,000	120	5	68.1	2.5	6	250
Wekiduba	488616	1698799	1993	MoA	220,000	226	7	134.5	-	22	350
Shinjibluk	484497	1702572	2007	KR2/MoA	350,000	148	11	232.6	10	35	185
Adi Bidel	478139	1707709	2007	KR2/MoA	90,000	73	9	91.8		9	235

RESERVOIR	Location (Zone P 37) X-UTM	Y_UTM	Year	CONST. BY	DC (M^3)	CL (M)	DH (M)	CA (HA)	CIR (HA)	PIR (HA)	HH
Adi Kontsi_D01	481555	1696180	1970	Villagers	250,000	160	7.5	451.8	2	25	388
Adi Kontsi_D02	481328	1694660	1970	Villagers	70,000	270	4	287.8		7	388
Adi Kontsi_D03	482137	1697270	1970	Villagers	50,000	131	5	85.5			388
Adi Kontsi/ Adi Yacob	480222	1699695	2007	KR2/MoA	200,000	93	10.5	118.6	-	20	250
Ametsi	485355	1706555	1988	ECS	180,000	116	10	166.0	30	18	230
Adi Asfeda	484950	1700905	1988	MoA	200,000	120	11	785.8	32	20	210
Adi Yacob	482128	1700369	1993	MoA	80,000	116	8	133.3	3	8	200
Toker	482403	1706782	2000	Municipality	14,000,000	285	73	14135.8	-	-	
Adi Habteslus	486247	1700699	1941	Italians	80,000	157	8	489.1	4	8	170
Adisegudo	490128	1697030	1981	MoA	150,000	120	7	521.3		-	
Tselot_D04	495318	1690282	1984	MoA	50,000	160	8	15.5	-	5	519
Merhano_D02	492125	1690028	1988	MoA	60,000	208	6	753.2	-	-	334
AdiNfas_D01	493423	1700860	Before 1930	Italians	600,000	190	10	389.2	30	-	300
AdiNfas_D02	493225	1703000	1941	Italians	200,000	191	9	317.5		-	
AdiAbeyto	491612	1698765	1985	Kale Hiwet	110,000	124	5.5	70.7			
MaiAnbesa_old	494068	1698395	1941	Italians	250,000	132	12	150.0			
MaiSirwa	489171	1702196	1963	Italians	2,150,000	174	15	3078.9			
Betmekae	490106	1695039	1989	Kale Hiwet	120,000	70	5	124.8			
Valle-Gnocchi	491253	1702300	Before 1930	Italians	600,000	120	12	1555.0			
Laelay Kelay	493720	1698866	1941	Italians	200,000	100	8	172.4	20		
MaiAnbesa_new	494203	1699060	1988	ECS	350,000	165	8	101.0			
Deki-Zeru	479955	1719039	1987	ECS	50,000	75	8	212.1			500
Adengoda	490641	1711336	1940	Italians	100,000	80	10	492.5			
Afdeyu	484943	1713140	1985	MoA	150,000	120	11	282.3			
Quazien	490809	1708150	1930	Italians		190		109.6			

DC- Design Capacity, CR- Crest length, DH- Dam height, CA- Catchment area, CIR- Currently irrigated area, PIR- Potential irrigable area, HH- Beneficiary households

*Adengoda and Quazien are completely silted and Afdeyu was broken shortly after construction.

Asmara town water supply reservoirs

B. Characteristics of surveyed reservoirs in zoba Maekel: Subzoba Serejeka

	Location (Zone P 37)										
RESERVOIR	X-UTM	Y_UTM	Year	**CONST. BY**	**DC (M^3)**	**CL (M)**	**DH (M)**	**CA (HA)**	**CIR (HA)**	**PIR (HA)**	**HH**
Adikolom	480841	1714035	1989	ERRA	270,000	165	10.5	383.5	5	27	490
Adisheka	488407	1712801	Before 1930	Italians	5,100,000	403	20	3741.7	12	20	213
Beleza	491141	1704784	1958	Italians	1,200,000	120	12	597.4	-		-
Embaderho_D01	488655	1705052	1992	Evangelical	330,000	180	8	239.2	24	33	300
Embaderho_D02	489084	1704885	1965	Private	60,000	73	6	179.8	-	-	100
Guritat_D01	482488	1719380	2006	MoA	300,000	120	11	306.6	6	30	200
Guritat_D02	483941	1718483	1997	MoA	180,000	96	10	223.0	3	18	200
Hayelo	482621	1716791	1995	MoA	1,000,000	80	18	1035.4	40	100	438
Mekerka	483629	1709868	2003	MoA	270,000	100	12	825.9	16	27	350
Mesfinto	486300	1712087	1995	Kale Hiwet	60,000	73	8	97.8	9	6	123
Shmangus laelai	484236	1711011	1985	MoA	400,000	230	9	705.2	15	40	350
Shmangus Tahtai	479493	1713149	1992	Evangelical	230,000	130	8	876.6	15	23	120
Teareshi	481613	1709749	1989	Evangelical	280,000	80	8	1341.1	11	28	198
Zagr	488333	1718554	1984	MoA	150,000	101	7.5	284.4	2	15	814
Adengoda	490641	1711336	1940	Italians	100,000	80	10	492.5			
Afdeyu	484943	1713140	1985	MoA	150,000	120	11	282.3			
Quazien	490809	1708150	1930	Italians		190		109.6			

DC- Design Capacity, CR- Crest length, DH- Dam height, CA- Catchment area, CIR- Currently irrigated area, PIR- Potential irrigable area, HH- Beneficiary households

*Adengoda and Quazien are completely silted and Afdeyu was broken shortly after construction.

C. Characteristics of surveyed reservoirs in zoba Maekel: Subzoba Berik

	Location (Zone P 37)											
RESERVOIR	X-UTM	Y_UTM	Year	**CONST. BY**	**DC (M^3)**	**CL (M)**	**DH (M)**	**CA (HA)**	**CIR (HA)**	**PIR (HA)**	**HH**
Adi Merawi	483975	1699660	1992	MoA	110,000	132	8	29.2	3		80
Hazega	482109	1701803	1982	MoA	40,000	45	6	129.4	7		250
Hazega	480910	1703668	1989	MoA	250,000	91	7	123.7	-	25	250
Tseazega	480226	1696267	1988	Evangelical	230,000	230	10.5	3761.7	33.3	23	750
Tseazega	477888	1697066	1983	MoA	150,000	213	8	946.2	-	15	750
TsaedaChristian	483027	1693762	1983	MoA	130,000	200	7.5	184.5	-	13	400
TsaedaChristian	482145	1694886	1944	MoA	80,000	114	6	228.8	4	8	400
Adi Musa	481423	1692616	1992	MoA	250,000	150	8	514.1	2.5	25	150
Adi Ghebru/ Adi Teklay	474129	1694254	1985	MoA	160,000	104	10	324.2	6	16	300
Adi Teklay	472778	1692557	1988	MoA	53,000	105	7	194.0	3	6	150
Adi Ghebru	474135	1696085	2000	Villagers	80,000	90	12	188.2	-	8	655
Tsaeda Emba	484346	1693322	1980	Villagers	55,000	120	5	68.1	2.5	6	250
Wekiduba	488616	1698799	1993	MoA	220,000	226	7	134.5	-	22	350
Shinjibluk	484497	1702572	2007	KR2/MoA	350,000	148	11	232.6	10	35	185
Adi Bidel	478139	1707709	2007	KR2/MoA	90,000	73	9	91.8		9	235
Adi Kontsi-D01	481555	1696180	1970	Villagers	250,000	160	7.5	451.8	2	25	388
Adi Kontsi-D02	481328	1694660	1970	Villagers	70,000	270	4	287.8		7	388
Adi Kontsi-D03	482137	1697270	1970	Villagers	50,000	131	5	85.5			388

Adi Kontsi/ Adi Yacob	480222	1699695	2007	KR2/MoA	200,000	93	10.5	118.6	-	20	250
Ametsi	485355	1706555	1988	ECS	180,000	116	10	166.0	30	12	230
Adi Asfeda	484950	1700905	1988	MoA	200,000	120	11	785.8	32	30	210
Adi Yacob	482128	1700369	1993	MoA	80,000	116	8	133.3	3	8	200
Toker	482403	1706782	2000	Municipality	14,000,000	285	73	14135.8	-		
Daero Paulos	485855	1690172	1987	MoA	60,000	117	7	207.9	2	6	
Adi Habteslus	486247	1700699	1941	Italians	80,000	157	8	489.1	4	8	170
Adisegudo	490128	1697030	1981	MoA	150,000	120	7	521.3			

DC- Design Capacity, CR- Crest length, DH- Dam height, CA- Catchment area, CIR- Currently irrigated area, PIR- Potential irrigable area, HH- Beneficiary households; ECS- Eritrean Catholic Secretariat

Toker is Asmara town water supply reservoir

D. Characteristics of surveyed reservoirs in zoba Maekel: Subzoba Galanefhi

	Location (Zone P 37)										
RESERVOIR	X-UTM	**Y-UTM**	Year	**CONST. BY**	**DC (M^3)**	**CL (M)**	**DH (M)**	**CA (HA)**	**CIR (HA)**	**PIR (HA)**	**HH**
Tselot_D04	495318	1690282	1984	MoA	50,000	160	8	15.5	-	5	519
Tselot_D03	495718	1687661	1989	ERRA/MoA	250,000	213	8	230.6	2		519
Tselot_D02	496476	1688180	2005	MoA	300,000	92	14	490.7	3	30	519
Tselot_D01	496992	1689892	2007	GMA, MoA	250,000	101	10.5	152.1	-	25	519
Adi Arada	498920	1677829	2007	MoA	200,000	79	12	161.1	3	20	260
Adi-Ahderom	495426	1678399	2007	MoA	250,000	78	12	372.6	12	25	185
Adi Keih	492037	1679069	2007	MoA	40,000	50	7	44.1	-		58
Laguen-AdiHamushte	482664	1683651	1995	MoA	1,300,000	190	22	1093.7	29	130	913
Himbrti Shaka	470634	1687023	1985	ERRA/MoA	400,000	190	10.5	535.5	11	40	1410
Himbrti Gomini	474224	1689001	1989	MoA	450,000	229	11	1128.9	15	45	1410
Himbrti Chea	472628	1685830	1986	ECS	150,000	85	8	721.1	2	15	1410
Embeyto	495617	1682751	1993	MoA	130,000	108	9	167.8	-	13	282
Laguen	483204	1681792	1987	MoA	200,000	137	9	1212.7	15	20	283
Merhano_D01	492468	1687428	1988	Evangelical	250,000	473	8	114.9	-	25	334
Merhano_D02	492125	1690028	1988	MoA	60,000	208	6	753.2	-	-	334
AdiGudad	488495	1687974	1981	MoA	150,000	73	6	272.7	-	15	520
Adi Gombolo	486057	1684220	1982	MoA	150,000	97	7.5	294.7	7	15	316
Kodadu	494668	1681638	1996	MoA	700,000	195	22	457.7	-	70	449

Adi Hawesha	496685	1684824	1988	Evangelical	150,000	105	8	487.6	5	15	406
Selaadaero	487129	1681149	1981	MoA	80,000	113	8	176.2	6	8	245
Adi Keshi	493482	1683585	1988	ERRA	250,000	246	9	165.4	2	25	102
Adi-Tsenaf	491154	1681523	2005	MoA	400,000	170	13	232.6	-	40	1055
Lamza	491234	1683301	1986	MoA	500,000	201	12.5	852.3	18	50	196
Ademzemat	487210	1682548	2006	MoA, RC	50,000	81	4.5	44.0	-	-	200
Mainefhi	476740	1686165	1971	Municipality	26,000,000	200	26	8742.8	-	-	

DC- Design Capacity, CR- Crest length, DH- Dam height, CA- Catchment area, CIR- Currently irrigated area, PIR- Potential irrigable area, HH- Beneficiary households; ECS- Eritrean Catholic Secretariat, RC- Red Cross

E. Characteristics of surveyed reservoirs in zoba Maekel: Four subzobas of Asmara

	Location (Zone P 37)										
Reservoir	X-UTM	Y-UTM	Year	**CONST. BY**	**DC (M^3)**	**CL (M)**	**DH (M)**	**CA (HA)**	**CIR (HA)**	**PIR (HA)**	**HH**
AdiNfas_D01	493423	1700860	Before 1930	Italians	600,000	190	10	389.2	30		300
AdiNfas_D02	493225	1703000	1941	Italians	200,000	191	9	317.5			
AdiAbeyto	491612	1698765	1985	Kale Hiwet	110,000	124	5.5	70.7			
MaiAnbesa_old	494068	1698395	1941	Italians	250,000	132	12	150.0			
MaiSirwa	489171	1702196	1963	Italians	2,150,000	174	15	3078.9			
Betmekae	490106	1695039	1989	Kale Hiwet	120,000	70	5	124.8			
Valle-Gnocchi	491253	1702300	Before 1930	Italians	600,000	120	12	1555.0			
Laelay Kelay	493720	1698866	1941	Italians	200,000	100	8	172.4	20		
MaiAnbesa_new	494203	1699060	1988	ECS	350,000	165	8	101.0			

DC- Design Capacity, CR- Crest length, DH- Dam height, CA- Catchment area, CIR- Currently irrigated area, PIR- Potential irrigable area, HH-Beneficiary households; ECS- Eritrean Catholic Secretariat

7.5 Appendix 5: Water Use By-law, Maekel Zone

WORK GUIDANCE (BI-LAW) ON USE OF DAMS AND SURROUNDING AGRICULTURAL LAND IN ZOBA MAEKEL

INTRODUCTION

In Zoba Maekel dams has been under construction since the Italian colonial era for different purposes like irrigation, domestic use, flood control, cooling power for generators and others.

After independence, in 1991about 50dams have been built in Zoba Maekel for irrigation and domestic use. These dams are designed to hold nearly 13,000,000m^3 of the water, with irrigation potential for 1000ha. Total construction cost of the dams reach about 100,000,000Nacfa with out considering the cost of land leveling and irrigation infrastructure works. But even thought the investment and the irrigation potential of the dams are high, currently irrigated land from the dam is not more than 200ha, which is no more than 20%. This signifies that the dams are under utilized despite the expectation.

The objective of the dams is to promote irrigation to serve for 2-3 times harvesting of vegetables, fruits, flowers spices and animal forage per year. By so doing farmer's income will increase and the dependency of farmers on the unreliable rain fed crops will be reduced. This will contribute to improve the livelihood of the farming society.

In order to correct this problem formulating, binding and motivating work guidance bi-low is the result of several workshops and field trips conducted for about three years between the stakeholders. That is benefiting farmers, village elders, women, MOA, administration from Zoba MLW&E at levels agreed and endorsed by high authority.

Definition

Dam: is a structure built on or off stream used to collect water from catchments.

Infrastructure: Hydraulic structure like, dam, outlet spilling, division boxes, gate values, canals, drop structures, drainage canals …etc.

Users (beneficiaries): The villagers who use the dam and the nearby lands.

Ministry of Water Land and Environment: means HWL & E delegates/ offer at different levels.

Administration: Government at different levels/ Zoba, Sub Zoba i.e. Ministry of Local Government offices in Zoba, Sub Zoba.

Ministry of Agriculture: MoA at different levels, in this regard Zoba Maekel and sub zobas in Zoba Maekel.

Work Directive: Means that verify the ownership, management, and utilization of the water, land, infrastructure and the irrigation activity.

Command area: Land to be irrigated by the dam. The land should be suitable for irrigation and is located down or up the stream

Irrigation from the dam: This is production of vegetables, fruits, animal feed, flowers, spices etc by irrigating directly from the dam or from a down stream wells recharged by the dam.

Article one:

Heading:

1.1. Work guidance for utilization of dam and nearby agricultural land in Zoba Maekel (Central zone).

Article two:

Regarding ownership of dam

Dams are owned by the government, the farmer's villages around have the right to use as communal or individual or as investor.

The users have to keep, maintain and properly use of the dam. Assistance can be asked from the government for serious structural problem over and above the capability of the users.

Village/ Kebabi administration and concerned government body are responsible to control weather the dam is properly utilized.

Village/ Kebabi administration if it is over and above, it will be solved by the higher administrative body.

Article three:

Land use of the irrigable area.

According to the 2.1 land is owned by government, village/ kebabi administration in collaboration with the government body have the right to distribute and manage the land near the dam or (irrigable area).

3.1.1. Village or kebabi administration in cooperation with the government.
Body has the authority or power to distribute the irrigable land to
Individual farmers, communal irrigators or investors.
3.1.2. If land is distributed for irrigation has not been used within six months after distribution of the land:

Additional three months will be given to him/her to start using the land

If the farmer did not use the land with in the given time frame, the village administration can hand over the land and distribute it to others. In collaboration with the concerned government bodies such as Ministry of Agriculture and Ministry of Land, Water and Environment.

3.1.3. Village/ Kebabi administration will be responsible if the land
Distribution around the village is not properly developed. Desk
Committees have the right to distribute the land to investor or.
Individuals from the village that have the capacity to develop the area
Properly

Article Four:

Dam management and care

4.1. The village/ kebabi administration and the direct beneficiaries have the
Responsibility to take care, manage, maintain and properly use the dam in
Their vicinity or village. The beneficiaries are responsible for problems faced due to negligence

Article Five:

5*. Duty and responsibility of the irrigation development committee (from dam)*

Committees at zoba, desk and village level will be set to monitor the development process.

5.1. Duty and responsibility of zonal committee

1. Zonal committee will be composed of members from zoba (zonal) administration and branches of ministry of MoA, MWLE and other concerned bodies in the zoba
2. Provide training and due information to beneficiaries or irrigators. Conduct and organize farmer- to-farmer extension and experience sharing from zone to zone
3. Cooperate for technical matters beyond, MoA desk office.

4. Cooperate and help, so that farm inputs, like fertilizer, seeds, hand tools etc will be available to farmers on credit and cash basis.

5. Analyze reports delivered by desk.

6. Monitor the dam and other hydraulic structures have been abused. If this happened the loss or damage will be made paid.

7. Conduct surveys on market, land fertility, irrigation systems, irrigable land and work for further development.

5.2. Duty and responsibility of desk committee

1. Desk committee will be formulated from desk administration, branch of MoA And Water, Land and environment and the concerned bodies in the desk (suzoba)

2. Desk committee will report to the zoba committee

3. Desk committee, motivate, give training and due information to farmers.

4. Assist farmers when they face challenging technical problems i.e. over their capacity.

5. Cooperate farmers to get form inputs on credit or cash. The committee will also convey their demands to concerned body.

6. The committees shall advice and control the beneficiaries not to abuse the dam and infrastructure built for them. If any damage occurred due to negligence or mismanagement the beneficiaries will be responsible and the committee will resolve it legally.

7. Desk committee will deliver report every three months to zoba committee

5.3. Duty and responsibility of Village/ Kebabi committee

1. The village committee will be composed of the village/ kebabi administrator, anebaberti (elected village executives work loosely with the administrator) and village executives work loosely with the administrator) and village development committee.

2. Village/ Kebabi committee will report to desk committees.

3. Distributed land to beneficiaries, investors in collaboration with concerned government body.

4. Control, monitor weather the land distributed to beneficiaries is properly Developing.

5. Advice to the lagging farmers or investors to use the land allotted. If not the village committee will take action and inform to the desk committee will take action and inform to the desk committee.
6. Control the dam and irrigation infrastructure from being abused. If damaged the committee will do proper maintenance major in collaboration with the government body.
7. The committee will organize village labor and in collaboration with MoA experts renovate the dam body, the irrigation infrastructure and cut irrelevant trees from the irrigable area.
8. Give advice to farmers to use water efficiently and select crops or vegetables that require minimum water, high yielding in relatively shorter time. Farmers who don't comply will be punished.
9. Inform and worn the villagers not to send their animals to the dam and down stream irrigation area. If happened action will be taken to the individual by. village administration.
10. Control weather the outlet of the dam, pump or siphons is operated by the authorized individual.

5.4. Role of beneficiary farmers

1. Beneficiaries are obliged to develop the land on time.
2. Beneficiaries should take care of the dam, irrigation infrastructures like canals, division boxes, drop structures etc and use it wisely.
3. If farmers are not able to develop the land they received, they are obliged to inform the village and desk committee on time.
4. Farmers shall use the technical and professional guidance by the MoA experts in the vicinity.
5. Farmers/ beneficiaries should use the water and land resources they have efficiently.

5.5. Role of communal or community irrigation

In this case a community will be set at village/ kebabi level to assure fair distribution of water, land and control proper utilization of the dam and irrigation infrastructure. The committee will also be responsible for infrastructure maintenance incase of problem. This committee can be called as “water users association” or “committee of water users”.

5.5.1. Role and responsibility of "water users association"

1. In collaboration with the village/kebabi administration the committee/ association will make irrigation scheduling so that all the potential command area will be developed. They will also prepare cropping pattern.
2. In collaboration with the village/kebabi administration perform infrastructure m maintenance work. If the problem is over their capacity, the committee should report to desk committee via village development committee.
3. Implement the technical and professional advice given by MoA expert Regarding irrigation, water management, crops and cropping, plant protection, fertilizer application etc.
4. Organize service operative that can help in marketing. The association can ask credit for service giving institutions.
5. Pushing members who violate the regulation of the association for serious cases transfer the issue to higher administration body.
6. In collaboration with the village administration distribute water, prepare schedule, employ trained operator. He will be in charge of running motor, open gate and control the system in general paid bb the association or growers.
7. The association/ committee shall draft internal bi-law guarding the routine operational aspects like: settling payments of fuel, oil, maintenance, and operator etc. Regarding water payments will be according to the rate set by the ministry of Land Water and environment.

Article six:

Land management of the area developed by dams

As stated in article three, sub article 1 number 1(3.1.1) all land is owned by government, village/ kebabi administration in collaboration with concerned government body can allocate the irrigable land around the dam by the following four ways:

1. On village basis under the "water user association".
2. On rental to other farmers
3. Rest of share with external investor
4. If government wants to introduce better system priority will be given.

Article Seven:

7. *Land management*

7.1. All the rent and sharing agreement should be in line or in accordance with the civil code of Eritrea.

Article Eight:

8. Punishment

8.1. Anyone antagonizing this working guidance will be punished.

Article Nine:

9. Time of implementation

9.1. This working guidance will be active from 16/6/2004.

7.6 Appendix 6: Input and output parameters for irrigation scheduling

A. Root depths of crops grown in the study area

CROP	DEPTH(CM)`
BROCCOLI	61
CABBAGE	61
CARROT	60
CAULI FLOWER	61
CUCCUMBER	30-60
GARLIC	30-60
CROPS	150
LETTUCE	30-60
ONION	30-60
PAPERS	30-60
POTATOES	60-90
PUMPKINS	90-120
SPINACHE	30-60
TOMATO	90

B. BASIC INFILTRATION RATES FOR VARIOUS SOIL TYPES

Soil type	Basic infiltration rate (mm/hour)
sand	less than 30
sandy loam	20 - 30
loam	10 - 20
clay loam	5 - 10
clay	1 - 5

Source: FAO, 2005.

C. Available water content of different soils

Soil	Available water content in mm water depth per m soil depth (mm/m)
Sand	25 to 100
Loam	100 to 175
Clay	175 to 250

Source: FAO, 2005.

D. Soils Data

Depth	Place	PH	Texture class	Texture100%			EC MS/CM	OM (%)	P/ PPM	N(%)	Extructable C mol/kg	CEC meq/100 gm soil
				Sand	Clay	Silt					Ca^{++} ,Mg^{++} ,K^{+} ,Na^{+}	
0-25	H Adesfeda imbirty	7.42	Siltloam	22.8	26.6	50.6	0.07	2.29	13.09	0.09	20 ,7 ,0.23 ,0.87	28.1
0-80	Embaderho	7.96	Loam	45.2	19.4	35.4	0.17	2.25	8.48	0.08	22, 8, 0.15, 1.39	31.54
25-90	Embaderho	7.64	Siltloam	27.5	22.2	50.3	0.11	3.48	7.38	0.13	23, 5, 0.19, 1.18	29.37
0.60	Shimangus Laalay	7.28	Loam	37.7	18.5	43.8	0.09	1.78	13.09	0.07	21, 8, 0.18,0.85	30.03
0.50	Tseazega	7.72	Loam	38.3	23.4	38.3	0.08	2.46	35.42	0.09	21, 5, 0.28, 0.9	27.18
0.60	Adesfeda	6.93	Loam	46.6	18.7	34.7	0.10	2.12	18.23	0.08	19, 6, 0.2, 0.84	26.04
0-10	Adesfeda ADS-SA1	7.55	Sandy loam	71.6	4.2	24.3	0.04	1.14	7.62	0.08	7, 3, 0.16, 0.19	10.4
0-20	Adesfeda ADS-AC1	8.41	Loam	51.2	9.6	39.2	0.2	2.53	72	0.15	18, 5, 0.18, 0.85	24.3
0-20	Ametsi AME-SA1	8.15	Sandyloam	72.6	7.8	19.6	0.09	0.86	30	0.07	15, 4, 0.15, 0.34	19.5
0-20	Ametsi AME-SB1	7.61	Loam	32.7	17.8	49.5	0.13	2.97	37.9	0.14	16, 4, 0.22, 0.42	20.7
0-20	Ametsi AME-SC1	7.93	Loam	44.6	11.1	44.3	0.31	6.19	176	0.36	32, 8, 0.61, 1.05	41.7
0-20	Hayelo/Geshnashm HA-SA1	7.45	Sandyloam	74	10.3	15.7	0.06	1.06	26.6	0.08	15, 4, 0.08, 0.22	19.3
0-20	Hayelo/Geshnashim HA-SB1	8.07	Sandyloam	63.3	11.1	25.6	0.08	1.71	27.7	0.08	10, 3, 0.18, 0.20	13.4
0-20	Laguen-Adihamushte HMT-SA1	8.19	Sandyloam	72.1	11.4	16.4	0.11	1.38	14	0.1	27, 6, 0.63, 0.79	24.5
0-20	Laguen-Adihamushte HMT-SB1	8.24	Sandyloam	57.2	15.9	26.9	0.08	0.96	2.64	0.06	31, 8, 23, 0.74	40.2
0-20	Laguen-Adihamushte HMT-SC1	8.29	Loam	30.5	26.8	42.7	0.15	3.34	29.9	0.18	40, 11, 1.23, 1.18	53.5
0-20	Lamza LMZ-SA1	8.31	Sandyloam	54.4	16.4	29.2	0.17	2.13	29.3	0.15	26, 6, 0.50, 0.67	33.2
0-20	Lamza LMZ-SB1	8.28	Loam	24.9	25.2	49.9	0.21	2.4	54.2	0.15	32, 10, 0.42, 0.69	43.1
0-20	Lamza LMZ-SC1	8.15	Loam	41.3	18.4	40.3	0.27	3.48	60.3	0.19	30, 10, 1.18, 0.77	41.9
0-20	Himbirty-GominiHRT-SA1	7.74	Loam	36.1	23.3	40.6	0.08	3.31	3.65	0.20	24, 6, 0.2, 0.74	31.2
0-20	Tseazega TSZ-SA1	6.87	Clayloam	36.2	28.3	35.5	0.04	1.48	1.73	0.08	12, 3, 0.16, 0.26	15.4
0-20	Tseazega TSZ-SB1	8.15	Loam	41.3	17	41.7	0.11	1.46	4.47	0.07	12, 3, 0.17, 0.78	16.1
0-20	Zagir ZA-SA1	6.7	Loam	48.1	16.4	35.5	0.06	2.3	30.9	0.12	11, 3, 0.16, 0.22	14.4

Comments and recommendation

As per the test result, soil samples 1,3,6,7,8,9,15 and 16 (Adisfeda, Amesi, Hayelo-Geshnashim, Laguen-Adi hamushte, and Teazega) have got low N and OM, so have to be supplied with additional corresponding fertilizer either in artificial or natural form. All soil samples except 1,8,9,14,15, and 16 (Adiasfeda, Laguen- Adihamushte,Himbirty-Gomini,Tseazega)have sufficient P, so the deficient ones have to be enriched with additional P fertilizer. All samples except 5, 8, 10, 11, 12, and 13(Ametsi, Laguen-adihamushte, Lamza) have low K and so the deficient ones have to be supplied with K fertilizers. All soil samples range between slightly alkaline and moderately alkaline and so are not detrimental to plant growth. The textural classes are mostly sandy loam and loam but only one sample (TSZ-SA1) is clay loam and so all are acceptable for agricultural purposes provided other plant growth conditions such as water-plant-soil management practices are fulfilled. All samples are free from salinity hazards (EC values of all samples are within the norms).Other basic cations and CEC values are within the norms except sample no. 1(of Adiasfeda), which can be improved by adding decomposed OM (humus). Hence, if all the recommended factors for healthy factors for healthy growth of crops such as optimum addition of nutrient elements for the deficient soil samples and proper water-crop-soil management practices are fulfilled, any type of crop which is convenient for the climatic conditions can be grown well. For the low N soil samples, up to 100kg N/ha in the form of urea can be added in two or three splits if sufficient soil moisture or water input is available. For the low P soils, up to 25kg P/ha in the form of TSP or DAP can be added during sowing or planting the crop. For the low K soils, up to 100 kg/ha in the form of KCL or NPK fertilizers can be added during sowing or planting the crop. It is worth noting that higher productivity can be found if additional natural fertilizer is added with the mentioned artificial fertilizers for the N, P, K and OM deficient soils. Natural fertilizer (decomposed animal or plant manure) or humus can supply all the necessary plant nutrient elements such as S and micronutrients in addition to the major plant nutrients (NPK). In general, the chemical, physical and biological conditions for the healthy growth of the plant (crop) selected should be fulfilled.

E. Crop water Requirement Table for some common crop in zoba maakel

Crop Tomato   Time step 7   Irrigation efficiency % 50

Date	ETO (mm/Period)	Crop area (%)	Crop KC	CWR (ETM) (mm/ period)	Total rain (mm/ period)	Effect rain (mm/ period)	Irrigation Req. (mm/period)	FWS (L/S/ha)
2\2	31.10	100.00	0.6	18.66	0.00	0.00	18.66	0.62
9\2	32.21	100.00	0.6	19.33	0.00	0.00	19.33	0.64
16\2	33.16	100.00	0.6	19.90	0.00	0.00	19.90	0.66
23\2	33.95	100.00	0.6	20.37	0.00	0.00	2.37	0.67
2\3	34.57	100.00	0.63	21.76	0.00	0.00	21.76	0.72
9\3	35.02	100.00	0.72	25.35	0.00	0.00	25.35	0.84
16\3	35.33	100.00	0.82	28.97	0.00	0.00	28.97	0.96
23\3	35.48	100.00	0.92	32.51	1.19	0.00	32.51	1.08
30\3	35.50	100.00	1.01	35.94	2.37	0.00	35.94	1.19
6/4	35.39	100.00	1.11	39.24	2.93	0.00	39.24	1.30
13/4	35.18	100.00	1.15	40.45	3.63	0.00	40.45	1.34
20/4	34.86	100.00	1.15	40.09	4.36	1.00	39.09	1.29
27/4	34.47	100.00	1.15	39.64	5.00	4.19	35.44	1.17
4/5	34.00	100.00	1.15	39.10	5.38	4.93	34.17	1.13
11/5	33.48	100.00	1.15	38.50	5.33	5.10	33.40	1.10
18/5	32.92	100.00	1.15	37.86	4.65	4.55	33.31	1.10
25/5	32.34	100.00	1.13	36.65	3.11	3.07	33.58	1.11
1/6	31.74	100.00	1.06	33.54	0.66	0.65	32.89	1.09
8/8	31.14	100.00	0.97	30.36	0.00	0.00	30.36	1.00
15/6	30.55	100.00	0.89	27.30	0.00	0.00	27.55	0.90
22/6	21.47	100.00	0.82	17.68	0.13	0.13	17.55	0.81
Total	693.85			643.21	38.74	23.63	619.58	[0.99]

CWR: Crop water requirement for a specific crop calculated as ETo x Kc also called consumptive use (cu).

IR: Irrigation requirement for a given crop in(mm) for a given time set up.

(IR = CWR-P_{eff}) i.e crop water requirement minus effective rain fall.

FWS = Field water supply in l/s/ha assuming continuous supply.

Irrigation efficiency for surface irrigation is taken as 50%

Crop CABBAGE **Time step 7** **Irrigation efficiency % 50**

Date	ETO (mm/Period)	Crop area (%)	Crop KC	CWR (ETM) (mm/period)	Total rain (mm/ period)	Effect rain (mm/period)	Irrigation Req. (mm/period)	FWS (L/S/ha)
1/9	26.62	100.00	0.70	18.64	37.42	24.40	0.00	0.00
8/9	26.55	100.00	0.70	18.58	24.96	18.89	0.00	0.00
15/9	26.50	100.00	0.70	18.55	12.47	11.95	6.60	0.22
22/9	26.47	100.00	0.71	18.76	2.69	2.69	16.07	0.53
29/9	26.47	100.00	0.77	20.38	0.00	0.00	20.38	0.67
6/10	26.47	100.00	0.84	22.23	0.00	0.00	22.23	0.74
13/10	26.47	100.00	0.91	24.09	0.00	0.00	24.09	0.80
20/10	26.46	100.00	0.98	25.93	0.00	0.00	25.93	0.86
27/10	26.44	100.00	1.04	27.54	0.00	0.00	27.54	0.91
3/11	26.40	100.00	1.05	27.72	0.00	0.00	27.72	0.92
10/11	26.33	100.00	1.05	27.64	0.00	0.00	27.64	0.91
17/11	26.22	100.00	1.05	27.53	0.00	0.00	27.53	0.91
24/11	26.08	100.00	1.03	26.86	0.00	0.00	20.86	0.89
1/12	25.90	100.00	0.98	25.47	0.00	0.00	25.47	0.84
8/12	7.36	100.00	0.95	7.02	0.00	0.00	7.02	0.81
Total	376.73	-	-	336.94	77.54	57.92	285.08	[0.66]

CWR: Crop water requirement for a specific crop calculated as ETo x Kc also called consumptive use (cu).

IR: Irrigation requirement for a given crop in (mm) for a given time set up.

(IR = CWR-P_{eff}) i.e crop water requirement minus effective rain fall.

FWS = Field water supply in l/s/ha assuming continuous supply.

Irrigation efficiency for surface irrigation is taken as 50%

Crop CARROT **Time step 7** **Irrigation efficiency % 50**

Date	ETO (mm/Period)	Crop area (%)	Crop KC	CWR (ETM) (mm/period)	Total rain (mm/ period)	Effect rain (mm/ period)	Irrigation Req. (mm/period)	FWS (L/S/ha)
1/6	31.74	100.00	0.70	22.22	0.66	0.65	21.56	0.71
8/6	31.14	100.00	0.70	21.80	0.00	0.00	21.80	0.72
15/6	30.55	100.00	0.70	21.44	0.00	0.00	21.44	0.71
22/6	29.98	100.00	0.76	22.73	0.81	0.81	21.93	0.73
29/6	29.44	100.00	0.84	24.73	8.01	8.01	16.72	0.55
6/7	28.94	100.00	0.92	26.67	18.66	17.01	9.67	0.32
13/7	28.48	100.00	1.00	28.58	30.32	23.65	4.92	0.16
20/7	28.07	100.00	1.05	29.47	41.32	28.80	0.67	0.02
27/7	27.71	100.00	1.05	29.09	50.28	32.32	0.00	0.00
3/8	27.39	100.00	1.05	28.76	56.07	34.13	0.00	0.00
10/8	27.13	100.00	1.05	28.49	57.96	34.22	0.00	0.00
17/8	26.92	100.00	1.04	28.08	55.59	32.65	0.00	0.00
24/8	26.76	100.00	1.01	27.03	49.08	29.54	0.00	0.00
31/8	26.46	100.00	0.97	25.97	39.07	25.12	0.85	0.03
7/9	7.59	100.00	0.95	7.23	8.97	6.22	1.02	0.12
Total	408.50	-	-	372.29	416.79	273.13	120.57	[0.28]

CWR: Crop water requirement for a specific crop calculated as ETo x Kc also called consumptive use (cu).

IR: Irrigation requirement for a given crop in(mm) for a given time set up.

(IR = CWR-P_{eff}) i.e crop water requirement minus effective rain fall.

FWS = Field water supply in l/s/ha assuming continuous supply.

Irrigation efficiency for surface irrigation is taken as 50%

7.7 Appendix 7:

A. Extension workers (Enumerators)

S.N	*Name of Participants*	*Organization*	*Job title/post*
1	*Kesete G/giogis*	*MoA*	*Senior soil and water conservation expert*
2	*Musie Welday*	*MoA*	*soil and water conservation expert*
3	*Samul Mosazghi*	*MoA*	*Senior soil and water conservation expert*
4	*Ghebrezgabhier Yemane*	*MoA*	*Agri. Engineer*
5	*Yohanse Tecle*	*MoA*	*Agri. Engineer*
6	*Zeray Gibaat*	*MoA*	*Agri. Engineer*
7	*Ghimay Hintsa*	*MoA*	*Agri. Engineer*
8	*Hrui Amanuel*	*MoA*	*Agri. Engineer*
9	*Amine Teclay*	*MoA*	*Crop production*

B. Workshop Participants (1st workshop held on September 18, 2007)

S.N	Name of Participants	Organization	Job Title/Post
1	AMANUEL NEGASSI	MOA H,Q	DIRECTOR , IRRIGATION
2	BELAY HABTEGABR	MOA H,Q	SINOR IRRIGATION,EXPERT
3	KIFLEMARYAM MHRETEAB	MOA H,Q	SINOR IRRIGATION,EXPERT
4	MHRETEAB BEYENE	MOA BERIK	AMIMAL RESOURSES
5	MEARAF SOLOMON	MOA	FORESTRY
6	MUSSIE HAGOS	REG. ADMINISTRATION	SUB.REGION GOVERNOR BERIK
7	HZKYAS WELDET	ADMINISTRATION	SUB.REGION GOVERNOR
8	ABRAHAM DANIEL	MOA MAAKEL	HEAD IRRATION UNIT
9	BERHANE ANDEMESKEL	M.O.I	JOURNALIST
10	TESFAHIWET MERESEA	ADMINISTRATION	SUB.REGION GOVERNOR,SEREJEKA
11	BIRHANU MAHAMEDNUR	MOA-MAAKEL	HORTICULTURE
12	AYNOM TESFAY	MOA H,Q	IRRIGATION,HYDROLOGIST
13	MUNA ABDELKADR	MOA-MAAKEL	LAND RESOURCE & ENVT
14	HAILE TEKLE	MOA-MAAKEL	HORTICULTURE
15	ASRAT HAILE	MOA-MAAKEL	CROP PRODUCTION
16	RUSSOM ALEM	MOA-MAAKEL	HEAD MOA SEREJEQA
17	TIBERH GAYM	MOA-MAAKEL	HORTICULTURE
18	KESETE GEBREGERGSH	MOA-MAAKEL	SOIL & WATER CONSERVATION
19	ANDETSION ZERAY	MOA-MAAKEL	HEAD MOA BERIK
20	ASMEROM MESFUN	MOA-MAAKEL	CROP PROTECTION
21	TSEGAY YACOB	MOA-MAAKEL	SOIL & WATER CONSERVATION
22	HAILEMICHAEL BERHE	MOA-MAAKEL	HEAD MOA GALANEFHI
23	ZERSENAY KELKEL	MOA-MAAKEL	HORTICULTURE
24	SAMUEL MOSAZGHI	MOA-MAAKEL	SOIL & WATER CONSERVATION
25	YOSIEF TEWELDE	MOA-ASMARA	HORTICULTURE
26	FILMON TESFASLASIE	NWSSA	HYADROGEOLOGIST
27	ZERAY GEBRIHIWET	MOA-GALANEFHI	SOIL & WATER CONSERVATION
28	MUSSIE ISSAC	MOA-ASMARA	SOIL & WATER CONSERVATION
29	MULGETA SIUM	MOA-GALANEFHI	HORTICULTURE
30	TEWELDEBRHAN KIDANE	MOA-ASMARA	ANIMAL SCIENCE
31	TSEGA FESHASION	MOA-SEREJEQA	SOIL & WATER CONSERVATION

32	*MUSSIE TEKESTE*	*MOA-MAAKEL*	*REGULATORY SERVICES*
33	*SGALET BAHTA*	*MOA-MAAKEL*	*ANIMAL RESOURSES*
34	*SAMRAWIT TESFAGABR*	*MOA-BERIK*	*HORTICULTURE*
35	*KIBRA ASMELASH*	*MOA-SEREJEQA*	*SOIL & WATER CONSERVATION*
36	*ZAID HAILE*	*MOA-GALANEFHI*	*SOIL & WATER CONSERVATION*
37	*SELAMAWIT TESFAY*	*-*	*GIS EXPERT*
38	*MNEY BERHANE*	*MOA-BERIK*	*HORTICULTURE*
39	*ROSINA KIFLE*	*MOA-BERIK*	*HORTICULTURE*
40	*MERHAWI OKBAY*	*MOA-BERIK*	*AGRI-ENGINEERING*
41	*G/HER YEMANE*	*MOA-BERIK*	*AGRI-ENGINEERING*
42	*TEKESTE ABRAHAM*	*MOA-MAAKEL*	*ANIMAL SCIENCE*
43	*MUSSIE WELDAI*	*MOA-MAAKEL*	*SOIL & WATER CONSERVATION*
44	*YEMANE ABRHA*	*MOA-MAAKEL*	*DOCUMANTATION*
45	*SEMERE TESFAI*	*MOA-MAAKEL*	*PLANING & STA*
46	*MEBRAT HABTEMICHAEL*	*MOA-MAAKEL*	*FINANCE*
47	*ASMERET ZEKARIAS*	*MOA-MAAKEL*	*AGRONOMIST*
48	*TSEGEWEYNI YEEBYO*	*MOA-MAAKEL*	*HOME ECONOMICS*
49	*ABEBA G/AMLAK*	*MOA-MAAKEL*	*ANIMAL SCIENCE*
50	*MEBRAT TEWELDE*	*MOA-MAAKEL*	*ARD*
51	*ALMAZ SEMERE*	*MOA-MAAKEL*	*ANIMAL FEED*
52	*YOHANNES NEGASH*	*MOA-MAAKEL*	*REGIONAL INSP*
53	*GHENET MELES*	*MOA-MAAKEL*	*MARKETING*
54	*HAILE GHIDE*	*MOA-MAAKEL*	*MOA-MAAKEL ZOBA HEAD*
55	*HAILEAB G/HIER*	*MOA-MAAKEL*	*HEAD OF LAND RESOURCE*
55	*JEMAL SRAJ*	*MOA-MAAKEL*	*PLANNING*
56	*BEREKET ABRHA*	*MAAKEL ADMINISTRATION*	*HEAD, ECONOMIC AFFAIRS*
57	*SOLOMON G/HIER*	*MAAKEL REGION ADMINISTRATION*	*ECONOMIC AFFAIRS*
58	*HELEN HABTE*	*MOA, HEAD OFFICE*	*SOIL & WATER CONSERVATION*
59	*GHENET G/HIER*	*MOA-MAAKEL*	*AGRONOMIST*

C. Workshop Participants (2nd workshop held on August 22, 2008)

S.N	NAME OF PARTICIPANT	ORGANAZATION	JOB TITLE/POST	REMARK
1	H.E TEWELDE KELATI	ADMINISTRATION MAAKEL REGION	GOVERNOR	
2	BERHANU MEHAMEDNUR	MOA	HORTICULTURE	
3	TECLEAB MENGSTU	MOA	SUBZOBA HEAD	
4	HAILE TECLE	MOA	HORTICULTURE HEAD	
5	ANDEZION ZERAI	MOA	SUBZOBA HEAD	
6	AMAHASION GHRMAI	AD.Z.M	ADMINSTRATOR	
7	KIFLEZGHI KIFLEMARIAM	S.Z.BERIK	SOCIAL SERVICE	
8	GEBREKIDAN GIRMAZION	AWSD	HEAD OF DEP	
9	KIDANE K	AWSD	DIVISION HEAD	
10	KIFLEMARIAM MHRETAB	MOA	IRRIGATION ENG	
11	YOHANNES TECLE	MOA-GALANEFHI	AGRICULTURAL ENG	
12	KIDANE YEMANE	MOA-GALANEFHI	ANIMAL SCIENCE	
13	ZERESENAY KELKEL	MOA-SEREJEQA	HORTICULTURE	
14	MEHRETAB BEYENE	MOA-GALANEFHI	ANIMAL SCIENCE	
15	TESGA TESFASION	MOA-SEREJEQA	IRRIGATION	
16	FILMON TESFASLASIE	NWSSA	WATER MANAGEMENT	
17	TRHAS WELDAI	MOA-GALANEFHI	SWC	
18	ZAID HAILE	MOA-GALANEFHI	IRRIGATION	
19	GEBREZGABHIER YEMANE	MOA-BERIK	AGRICULTURAL ENG	
20	AMANUEL MISGHNA	MOA-GALANEFHI	AGRICULTURAL ENG	
21	TESFAMICAEL YOHANNES	MOA-ASMARA	AGRONOMY	
22	FILMON TESGAI	MOA-ASMARA	HORTICULTURE	
23	MUSSIE HAGOS	GALANEFHI-ADMINSTRATION	ADMINSTRATOR	
24	DAWIT ARAYA	MOA-GALANEFHI	HORTICULTURE	
25	GHEBRAI TECLEAB	MOA-GALANEFHI	FORESTRY	
26	KIFLE GHEBRAI	MOA-ZOBA	POULTRY	
27	ISAIAS ZEWELDI	MOA-ASMARA	DAIRY	
28	ASMEROM TESFALDET	MOA-ASMARA	LAND RESOURCE	
29	MUSSIE WOLDAI	MOA-ZOBA	SWC	
30	MERHAWI OKBAI	MOA-BERIK	AGRICULTURAL ENG	
31	ZERAI GIBAAT	MOA-GALANEFHI	SWC	

32	SEMERE TESFAI	MOA-ZOBA	PLANNING	
33	YEMANE ABRHA	MOA-ZOBA	DOCUMENTATION	
34	SOLOMON GOITOM	MOA-SEREJEQA	SWC	
35	TESFAHIWET MERESEA	SUBZOBA SEREJEQA	ADMINISTRATION	
36	KIBRA ASMELASH	MOA-SEREJEQA	SWC	
37	SOLOMON G/HER	ECONOMIC DEVELOPMENT	HEAD OF ADMINSTRATION	
38	EMBAYE BOKRETSION	ECONOMIC DEVELOPMENT	STATISTICS	
39	SAMUEL MOSAZGHI	MOA-BERIK	SWC	
40	RIBKA MICHAEL	MOA-ZOBA	FORESTRY	
41	BELAY HABTEGABR	MOA	IRRIGATION ENG	
42	AMANUEL NEGASI	MOA	DIRECTOR	
43	HAILEAB G/HER	MOA-ZOBA	HEAD OF L.R.C.P	
44	KESETE GEBREGERGSH	MOA-ZOBA	SWC	
45	SELAMAWIT TESFAI	-	GIS EXPERT	
46	EDEN SOLOMON	MOA-ZOBA	FORESTRY	
47	BERHANE KIFLE	SUBZOBA-SEREJEQA	DEVE-SUBZOBA	
48	TESGAI YACOB	MOA-ASMARA	SWC	
49	ZEMEDE TECLE	MOA-BERIK	FORESTRY	
50	MUSSIE HADGU	MOA-	ANIMAL SCIENCE	
51	ASMEROM MESFN	MOA-ZOBA	REGULATORY	
52	EYOB TEKLEMARIAM	MOA-BERIK	SWC	
53	IDRIS ALI MOHAMED	MOA-ZOBA	VETERNARY	
54	HAILEMICHAEL BERHE	MOA-BERIK	SUBZOBA HEAD	
55	MEBRAT TEWELDE	SUBZOBA-SEREJEQA	ARD	
56	JEMAL SERAJ	MOA-ZOBA	PLANNING	
57	HAILE GHIDE	MOA-ZOBA	HEAD-ZOBA	
58	ABRAHAM DANIEL	MOA-ZOBA	IRRIGATION UNIT HEAD	
59	MEBRAT H/MICHAEL	MOA-ZOBA	FINANCE	
60	AKBERET GHEBRAI	MOA-ZOBA	FINANCE	