ENTRO
EASTERN NILE TECHNICAL REGIONAL OFFICE

BARO-AKOBO-SOBAT MULTIPURPOSE WATER RESOURCES DEVELOPMENT STUDY PROJECT

Feasibility study for the Majang multipurpose project

Vfin July 2017

LIST OF DELIVERABLES

The Baro-Akobo-Sobat Multipurpose Water Resources Development Study Project has generated a set of deliverables which are summarised in the table below. This deliverable is highlighted in grey below.

THE BARO-AKOBO-SOBAT MULTIPURPOSE WATER RESOURCES DEVELOPMENT STUDY PROJECT	
A. The Integrated Water Resources Development and Management Plan	
A.1	Inception report
A.2	Consultation and Communication Plan
A.3	Scoping report
A.4	Baseline, Development Potentials, Key issues and Objectives report
A.5	Strategic Social and Environmental Assessment
A.6	Integrated Water Resources Development and Management Plan
B. Medium and Long-term Projects: Terms of references for feasibility studies	
B.1	The Integrated BAS Hydropower, Irrigation and Multipurpose Development Programme - Phase 1. Baro-Sobat component
B.2	The Akobo-Pibor Transboundary Multipurpose Development Project
B.3	Livelihood-based Watershed Management - Taking to Scale for a Basin Wide Impact
C. Short-term Project: Feasibility studies	
C.1	Feasibility Study for the Kinyeti River Multipurpose Development Project
C.2	Feasibility Study for the Majang Multipurpose Project
C.3	Design Details for the Akobo-Gambella floodplains Transboundary Development Programme
D. Project brochure	
D.1	The Baro-Akobo-Sobat Multipurpose Water Resources Development Study Project: General overview
D.2	The Baro-Akobo-Sobat Multipurpose Water Resources Development Study Project: Medium and Long-term Projects

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BARO-AKOBO-SOBAT MULTIPURPOSE WATER RESOURCES DEVELOPMENT STUDY PROJECT

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TABLE OF CONTENTS

1. INTRODUCTION 2

1.1 Context of the short-term projects within the BAS study 2

1.1.1 General Context 2

1.1.2 The BAS sub-basin 2

1.2 Objectives of the short-term projects 5

1.2.1 Objectives and principles of the short-term projects 5

1.2.2 Specific objectives of the Majang multipurpose project 6

1.2.3 Timeline 8

1.2.4 Objective of this report 8

1.3 Project area 8

2. PROJECT AREA - BASELINE 11

2.1 Introduction 11

2.2 Bio-physical Environment 11

2.2.1 Baseline situation 11

2.2.2 Key issues and challenges 17

2.3 Socio-economic Aspects 17

2.3.1 Baseline situation 17

2.3.2 Key issues and challenges 31

2.4 Institutional baseline 32

2.5 Needs and potentials 33

2.5.1 Overall needs 33

2.5.2 Specific needs and potentials 33

2.6 Conclusions 34

3. PROJECT DESIGN 35

3.1 Hydropower 35

3.1.3 Sustainability of micro-hydropower schemes 39
3.2 Aquaculture 41
3.2.1 Introduction 41
3.2.2 Production potential and sizing 41
3.2.3 Costs and benefits 42
3.3 Irrigation 42
3.3.1 Project Description 42
3.3.2 Selection of command area location and option for water abstraction method 46
3.3.3 Implementation modalities 47
3.3.4 Project Area and the Need for Irrigation 48
3.3.5 Current farming Practice and Crop production 49
3.3.6 Operation and Management 49
3.4 Watershed Management 52
3.4.1 Major Land Use Types and their Challenges 52
3.4.2 Major livelihood potentials of the watershed 53
3.4.3 Needs and Potentials for Improved Livelihood of the Watershed Community 54
3.4.4 Measures Recommended for Improved Livelihoods and Conservation in Dunchaye Watershed 54
4. POTENTIAL ENVIRONMENTAL AND SOCIAL IMPACTS 58
4.1 Introduction 58
4.2 Source of information 58
4.3 Impacts of the proposed Majang multipurpose project 58
4.4 Conclusion 67
5. COST-BENEFIT ANALYSIS 67
5.1 Benefits of the Majang multipurpose project (Dunchaye Pilot) 68
5.1.1 Financial benefits 68
5.1.2 Positive externalities 70
5.2 Costs of the Majang multipurpose project 70
5.3 Main results of the cost-benefit analysis (Dunchaye Pilot) 71
5.4 Sensitivity analysis 73
6. CONCLUSIONS AND RECOMMENDATIONS 76
ANNEXES 77
Annex 1: Bibliography 78
Annex 2: Dunchaye Irrigation and drainage project 80
Annex 3: Digital Elevation Model 110

TABLES AND FIGURES

LIST OF FIGURES

Figure 1-1: Location of the three short-term projects 3
Figure 1-2: Location of the Baro-Akobo-Sobat sub-basin within the Eastern Nile sub-basin 4
Figure 1-3: Location of the Majang catchments (Gunchi, Achani, Beguha and the Dunchaye pilot) 7
Figure 1-4: Proposed timeline for implementation of the Majang multipurpose water resources development project 8
Figure 1-5: Village centre of the Dunchaye kebele 9
Figure 1-6: Location map for the Majang multipurpose project 10
Figure 2-1: Longitudinal profile of Dunchaye River 12
Figure 2-2: BAS sub-basin: relief and drainage 14
Figure 2-3: On the left plantation of Coffea Arabica in Dunchaye catchment (Baya government coffee plantation) – on the right landscape around the potential site for hydropower (with Colobus guereza in the trees) 15
Figure 2-4: Land use in Dunchaye catchment 16
Figure 2-5: Dunchaye catchment: overall situation 18
Figure 2-6: Coffee beans, Baya plantation 23
Figure 2-7: On the left: maize field in Dunchaye kebele and on the right banana trees at the edge of the coffee plantation 23
Figure 2-8: Traditional beehives in Dunchaye kebele 25
Figure 2-9: Women collecting water in Dunchaye kebele 27
Figure 2-10: Track in Dunchaye kebele (May 2016) during field visit 31
Figure 2-11: Identified site for small scale hydropower offtake 34
Figure 3-1: Layout of the hydropower system 35
Figure 3-2: Location of the proposed Hydropower works on the Dunchaye River 36
Figure 3-3: Layout of penstock, turbine and generator 38
Figure 3-4: Installation of crossflow turbine at Kisiizi Hospital, Uganda (left). Schematic of Ossberger crossflow turbine (rights) 38
Figure 3-5: Costs of proposed micro-hydropower scheme on Dunchaye River 40
Figure 3-6: Location and access to the proposed irrigation site 44
Figure 3-7: Dunchaye irrigation design plan (includes aquaculture ponds) 45
Figure 5-1: main results of the sensitivity analysis 74

LIST OF TABLES

Table 2-1: Population demographics for the catchment, at kebele level 19
Table 2-2: Population and migrants by sex for SNNPR and Gambella region 19

Table 2-3: Population by religion at regional and woreda level 20
Table 2-4: Farmland Size for Agriculture Production in Godere Woreda 20
Table 2-5: Population above 5 years old by literacy and sex 22
Table 2-6: Population above 5 years old by school attendance and sex 22
Table 2-7: Number of Beehives and Volume of Honey Harvested in 2010 in Majang Zone 24
Table 2-8: Housing units by type of fuel for cooking in rural areas in Yeki and Godere woredas 26
Table 2-9: Housing units of towns by type of lighting for Yeki and Godere woredas 26
Table 2-10: Main Disease Prevalent in the Project Affected Woredas 27
Table 2-11: Housing units by source of drinking water 28
Table 2-12: Housing units by type of toilet facility 28
Table 2-13: Women 10 years old and older, children ever born and children surviving 29
Table 2-14: Major Ethnic Groups in Godere and Yeki Woredas 30
Table 2-15: Social Services and Infrastructures in Sheka Zone and Yeki Woreda 30
Table 2-16: Social Services and Infrastructures in Sheka Zone and Yeki Woreda 31
Table 3-1: National and actual average crop yield in Megeng Zone, Gambella (tonne/ha) 49
Table 3-2: Summary of Costs for the Development of Dunchaye SSI 52
Table 3-3: Costs associated with bee keeping development 55
Table 3-4: Costs associated with fruit production 55
Table 3-5: Costs associated with soil and water conservation measures 56
Table 3-6: Costs associated with reforestation measures 56
Table 3-7: Costs associated with the training of staff and targeted communities on technical issues related to the proposed interventions 57
Table 3-8: Costs for hand tools, survey equipment and planting materials to be used for soil and water conservation and reforestation 57
Table 4-1: Summary of environmental and Social impacts and proposed mitigation and enhancement measures 59
Table 5-1: Financial costs and benefits and externalities of the project 68
Table 5-2: Yields and benefits associated to the development of irrigation 69
Table 5-3: Investments and operation and maintenance costs for Dunchaye Pilot and overall Majang Project 71
Table 5-4: Indicators of the economic profitability of the project 72
Table 5-5: Indicators of the financial profitability of the project 73

ACRONYMS AND ABREVIATIONS

BAS	Baro Akobo Sobat
CBA	Cost Benefit Analysis
CRA	Cooperative Regional Assessment
DEM	Digital Elevation Model
EEPCO	Ethiopian Electric Power Corporation
EIA	Environmental Impact Assessment
ENSAP	Eastern Nile Subsidiary Action Plan
ENTRO	Eastern Nile Technical Regional Office
FAO	Food and Agriculture Organization
GIS	Geographic Information System
GTP	Growth and Transformation Plan
MoANRD	Ministry of Agriculture and Natural Resources Development
MWh/y	MegaWatt hour/year
HEP	Hydroelectric Power
IDEN	Integrated Development of Eastern Nile
IWRDMP	Integrated Water Resources Development and Management Plan
IWRM	Integrated Water Resource Management
MASL	Meters Above Sea Level
SDG	Sustainable Development Goals
MW	Mega Watt
NBI	Nile Basin Initiative
NGO	Non-Governmental Organization
SAP	Subsidiary Action Program
SLMP	Sustainable Land Management Program
SNNPR	Southern Nations, Nationalities and Peoples' Region
SRTM	Shuttle Radar Topographic Mission
SSEA	Strategic Social and Environmental Assessment
SSI	Small Scale Irrigation
UNDP	United Nations Development Program
USAID	United States Agency for International Development
WaSH	Water Sanitation and Hygiene
WUA	Water Users Association

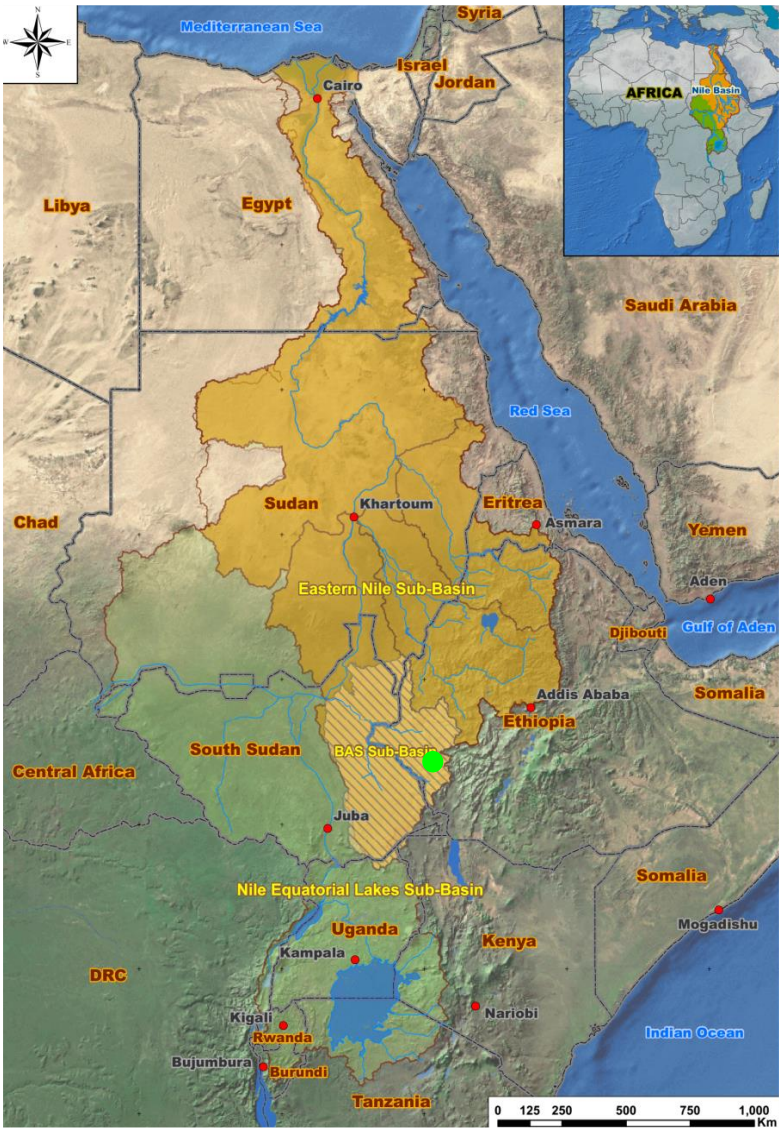
EXECUTIVE SUMMARY

The Majang multipurpose development project is one of the three short-term projects proposed as part of the Baro-Akobo-Sobat multipurpose water resources development study project. The three short-term projects are based on the sustainable development of water resources. They aim at providing inter-sectoral benefits and improving people's livelihoods in the sub-basin.

The project area is in and close to the Godere woreda (Majang zone) in Ethiopia. The pilot project for which this feasibility study has been detailed lies within the Dunchaye kebele within the Godere woreda. This short-term project has been designed in accordance with the major needs of the area: improvement of food security, economic development, access to the markets and protection of the forests (the project is located within a biosphere reserve)

The Majang multipurpose development project is based on the following components:

- Micro-hydropower: this is particularly indicated as this remote area is not going to be connected to the national electric grid. A first assessment of the potential of the Dunchaye river gives a production of 1 GWHrs/annum.
- Small scale irrigation: 220 ha for the following crops: maize, sorghum, potatoes, soybeans, dry beans, avocados and vegetables.
- Aquaculture: an initial development of 20 ponds is proposed
- Watershed management: livelihood based watershed management activities are proposed such as bee keeping, reforestation and fruit production.



Location of the Majang multipurpose development project (green dot)

1. INTRODUCTION

1.1 CONTEXT OF THE SHORT-TERM PROJECTS WITHIN THE BAS STUDY

1.1.1 General Context

Work on the Baro-Akobo-Sobat (BAS) multipurpose water resources development study project commenced in March 2015. The overall objective of the study is to assist ENTRO in preparing an Integrated Water Resources Development and Management Plan (IWRDMP) based on a Strategic Social and Environmental Assessment (SSEA), and further develop investment packages for cooperative development in the Baro-Akobo-Sobat sub-basin. The study comprises 4 components:

- Component 1: Strategic Social Environmental Assessment (SSEA) and Integrated Water Resources Development and Management Plan (IWRDMP)
- Component 2: Identification and preparation of short-term projects
- Component 3: Identification and profiling of medium and long-term projects
- Component 4: Project implementation support

The Majang multipurpose project is one of the three feasibility studies included in Component 2. The two other feasibility studies are the following:

- The Kinyeti river multipurpose dam (located in South Sudan)
- The Akobo-Gambella floodplains transboundary development programme (shared between Ethiopia and South Sudan)

The three short-term projects are shown on Figure 1-1. They have been selected during the baseline workshop held in Adama in April 2016 by the key stakeholders of the basin. Seven short-term projects were initially proposed in a concept note for discussion and selection during the workshop.

1.1.2 The BAS sub-basin

The BAS sub-basin is part of the Eastern Nile as shown in the location map (see Figure 1-2). The location of the Majang multipurpose project is indicated with a green dot on the map. This sub-basin is characterised by distinct wet and dry seasons and the spatial variation of precipitation across the basin is considerable.

Figure 1-1: Location of the three short-term projects

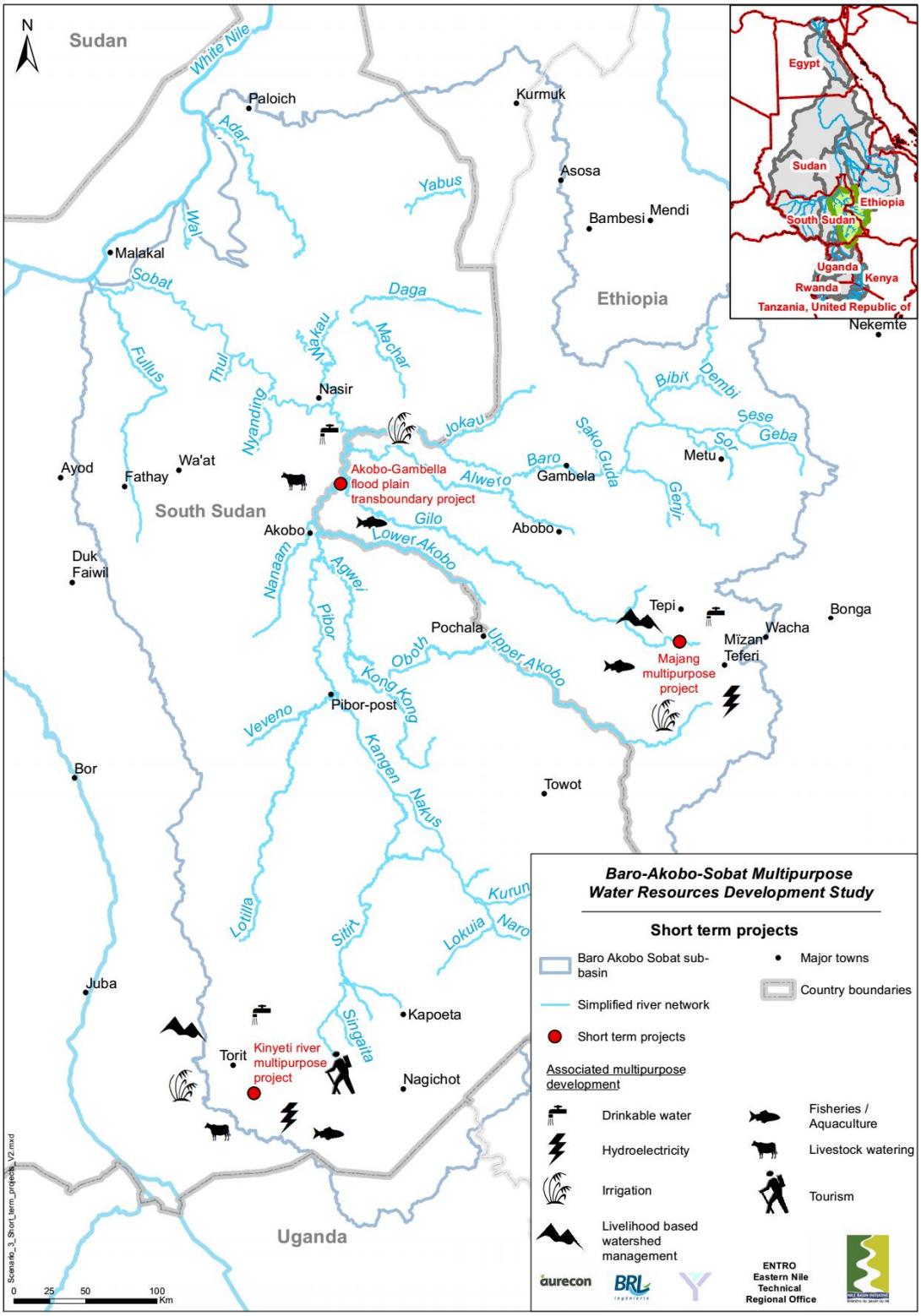
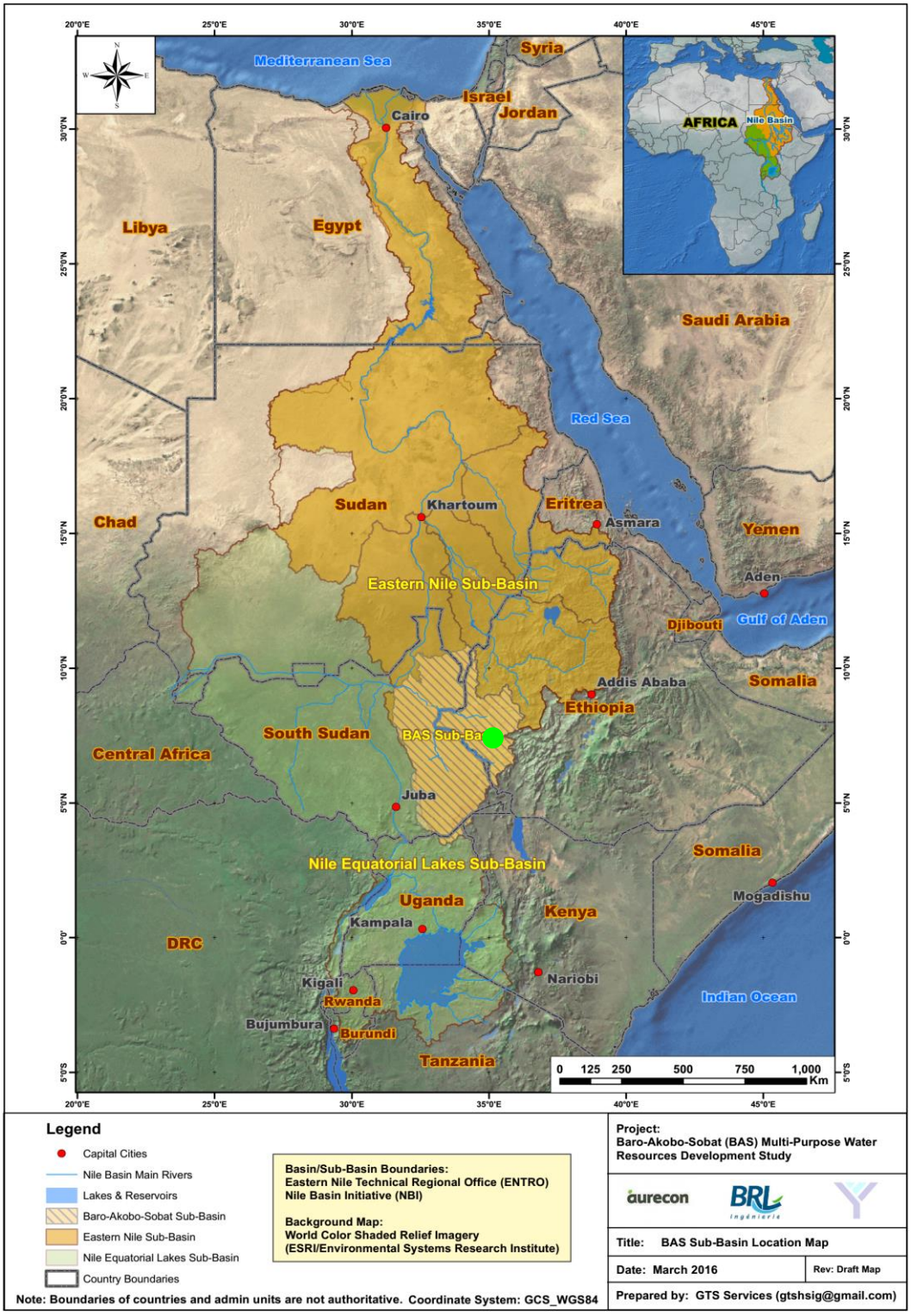


Figure 1-2: Location of the Baro-Akobo-Sobat sub-basin within the Eastern Nile sub-basin



1.2 OBJECTIVES OF THE SHORT-TERM PROJECTS

1.2.1 Objectives and principles of the short-term projects

OBJECTIVES OF THE SHORT-TERM PROJECTS

As stated in the general context, the feasibility studies for the short-term projects form Component 2 of the BAS multipurpose water resources development study project. The objectives of the short-term projects have been defined in accordance with the environmental and social work carried out in the baseline study and follow the guiding principles provided by the term of references for the study. The main considerations of the short-term projects are the following:

- Strategies to improve livelihoods and reduce poverty;
- Strategies to reduce conflicts over the resource (especially regarding livestock watering);
- Strategies to implement an enabling environment, favourable for moving towards the vision of the basin in the future, especially when supported by the implementation of medium and long-term projects and the taking of short-term demonstration type projects to scale.

Furthermore, it should be noted that these short-term projects have been designated in accordance with the sustainable development goals (SDGs) and more particularly with the following goals:

- Goal 1. End poverty in all its forms everywhere
- Goal 2. End hunger, achieve food security and improved nutrition and promote sustainable agriculture
- Goal 3. Ensure healthy lives and promote well-being for all at all ages
- Goal 5. Achieve gender equality and empower all women and girls
- Goal 6. Ensure availability and sustainable management of water and sanitation for all
- Goal 7. Ensure access to affordable, reliable, sustainable and modern energy for all
- Goal 13. Take urgent action to combat climate change and its impacts

PRINCIPLES BEHIND THE SELECTION OF THE SHORT-TERM PROJECTS

The respect of IWRM principles is critical to ensure the sustainable use of the resources

IWRM principles have been central in the definition of these projects:

- Water resources development must be sustainable and integrate environmental, social and economic issues/potentials of the area.
- Water resources development must be based on local needs and include the consultation of key stakeholders.
- Water resources development must be coherent at the scale of the basin. Development upstream must not have harmful impacts on downstream water users and on the environment.
- Water resources development must provide shared benefits at basin scale.

The project must be designed in accordance with the vision defined for the basin as part of the IWRDM Plan

The vision represents the desired future state for the Baro-Akobo-Sobat sub-basin to be achieved by implementation of the IWRDM Plan. This vision was defined by key stakeholders from Ethiopia, Sudan, South Sudan and ENTRO during the baseline workshop held in Adama, Ethiopia on April 16th, 17th and 18th 2016. The three short-term projects must contribute to reaching the vision which is as follows:

"A sustainably managed and developed BAS river sub-basin with prosperous, connected, peacefully and mutually co-existing societies."

The projects must provide inter-sectoral benefits

The three selected short-term projects are **multipurpose projects**: the proposed infrastructure can be shared by a number of development sectors (potable water supply, livestock watering, small scale irrigation, fisheries, hydropower, etc.).

The services provided by water resources depend on the well-being of the related ecosystems

Emphasis has been put on **ecosystem services** and the need to sustainably develop water-related projects. The definition of ecosystem services by the Millennium Ecosystem Assessment is the following: "*Ecosystem services are the benefits people obtain from ecosystems. These include provisioning services such as food and water; regulating services such as flood and disease control; cultural services such as spiritual, recreational, and cultural benefits; and supporting services, such as nutrient cycling, that maintain the conditions for life on Earth."* The livelihood conditions of people in the basin depend directly or indirectly on the services provided by the ecosystems for potable water, sanitation, fisheries activities, agriculture, etc. In order to develop the livelihoods in the basin, it is thus essential to develop, optimize and ensure the sustainability of these ecosystem services. It should be stressed, therefore, that the concept of sustainability places emphasis on the economic self-sufficiency of the proposed project, since the environmental sustainability that the project should bring, can only be achieved if the economic sustainability is assured through the improved livelihoods of the beneficiaries.

1.2.2 Specific objectives of the Majang multipurpose project

The Majang multipurpose project is located within the Ethiopian part of the Baro-Akobo-Sobat (BAS) sub-basin. This project aims at taking advantage of the numerous opportunities to develop water resources in this area of the basin to address the needs of local communities. With the large network of streams, there is an opportunity to develop micro-hydropower for local reticulation and improve livelihoods. The project is designed to be a multipurpose project and the following components are integrated:

- Micro-hydropower
- Small-scale irrigation
- Aquaculture
- Watershed management

Several field missions have been crucial to define the needs and potentials of the area and select appropriate sites, and in particular for the pilot. The four small catchments of the Dunchaye, Gonchi, Achani and Beguha rivers (all tributaries of the Gilo River) were selected for the project. These area shown in Figure 1-3. Of these, the Dunchaye River in the Dunchaye kebele (Godere woreda, Majang zone, Gambella Region) was selected in May 2016 to be the pilot and to be investigated at the feasibility study level. The beneficiaries of the project will mostly be the population of this kebele although adjacent kebeles will also beneficiate from this project through the development of road infrastructure, production of food and perhaps electricity if the production exceeds the kebele demand (which is most likely). Moreover, this multipurpose project was designed in such a way that it is highly replicable in other areas of the basin and it should be seen as a pilot project in the area.

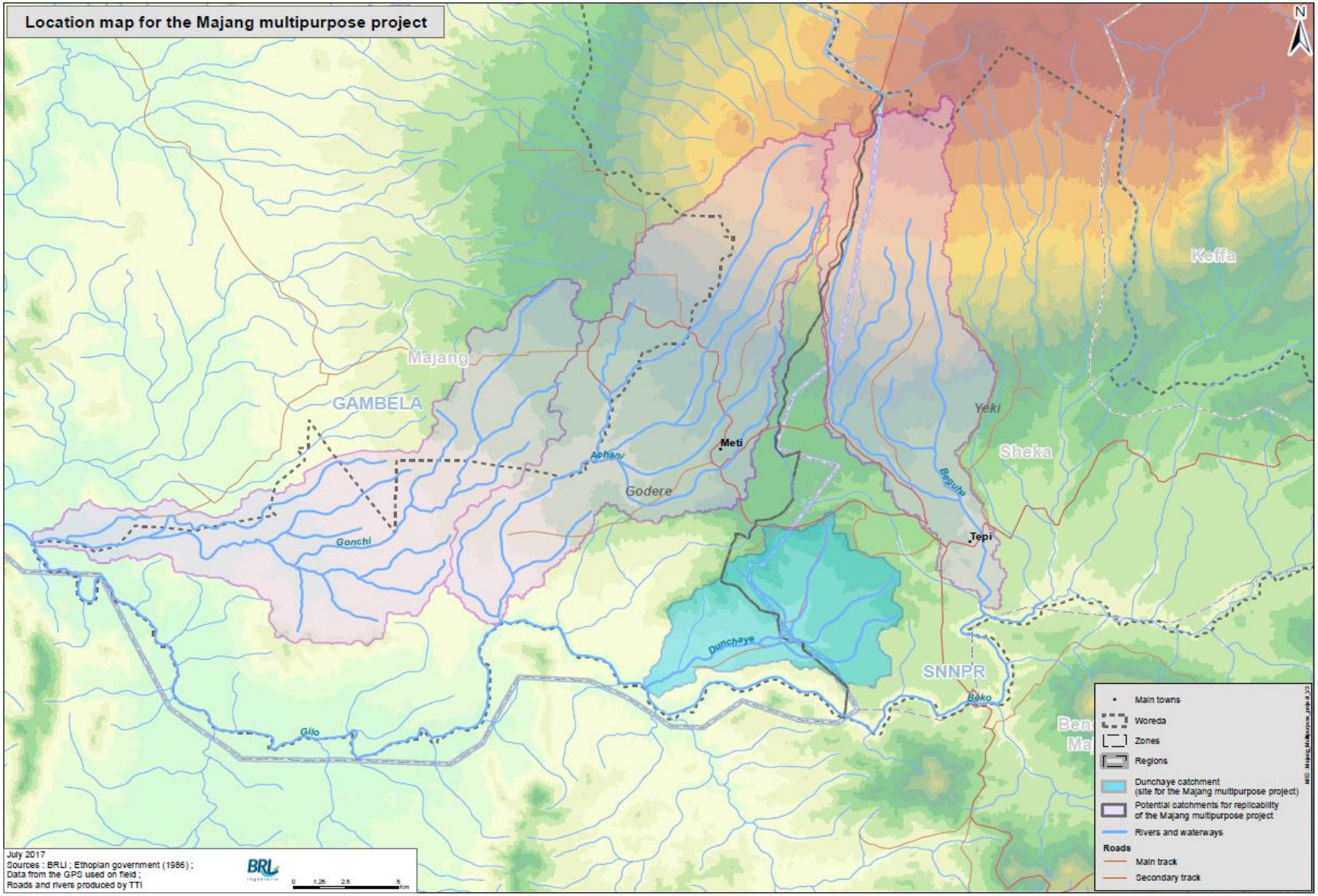


Figure 1-3: Location of the Majang catchments (Gunchi, Achani, Beguha and the Dunchaye pilot)

1.2.3 Timeline

The proposed timeline for implementation of the overall Majang multipurpose water resources development project is shown in Figure 1-4.

Project Components	Years				
	1	2	3	4	5
Implementation of the Dunchaye pilot multipurpose water resources development project					
Detailed feasibility studies for Gunchi, Achani and Beguha catchments					
Implementation of the Gunchi catchment multipurpose water resources development project					
Implementation of the Acahni catchment multipurpose water resources development project					
Implementation of the Beguha catchment multipurpose water resources development project					
Monitoring and Evaluation of the implemented Majang Project					

Figure 1-4: Proposed timeline for implementation of the Majang multipurpose water resources development project

Figure 1-4 shows the timeline for the overall project. This feasibility study is focussed on demonstrating the feasibility of the project by focussing on one of the catchments, the Dunchaye catchment. The approach adopted is that implementation of the project will proceed immediately. During the first year of implementation, feasibility studies would be completed for the other three catchments, at the same time benefitting from lessons learned from implementation of the Dunchaye pilot.

1.2.4 Objective of this report

This report presents the feasibility study for the Dunchaye pilot of the Majang multipurpose project, it will be presented to donors identified by ENTRO during a round table early in 2017. It includes the following elements:

- Baseline analysis of the area where the project will be implemented (Chapter 2)
- Project design with implementation modalities (Chapter 3)
- Environmental and Social Impact Analysis of the proposed project (Chapter 4)
- Cost benefit analysis to help decision making (Chapter 5)

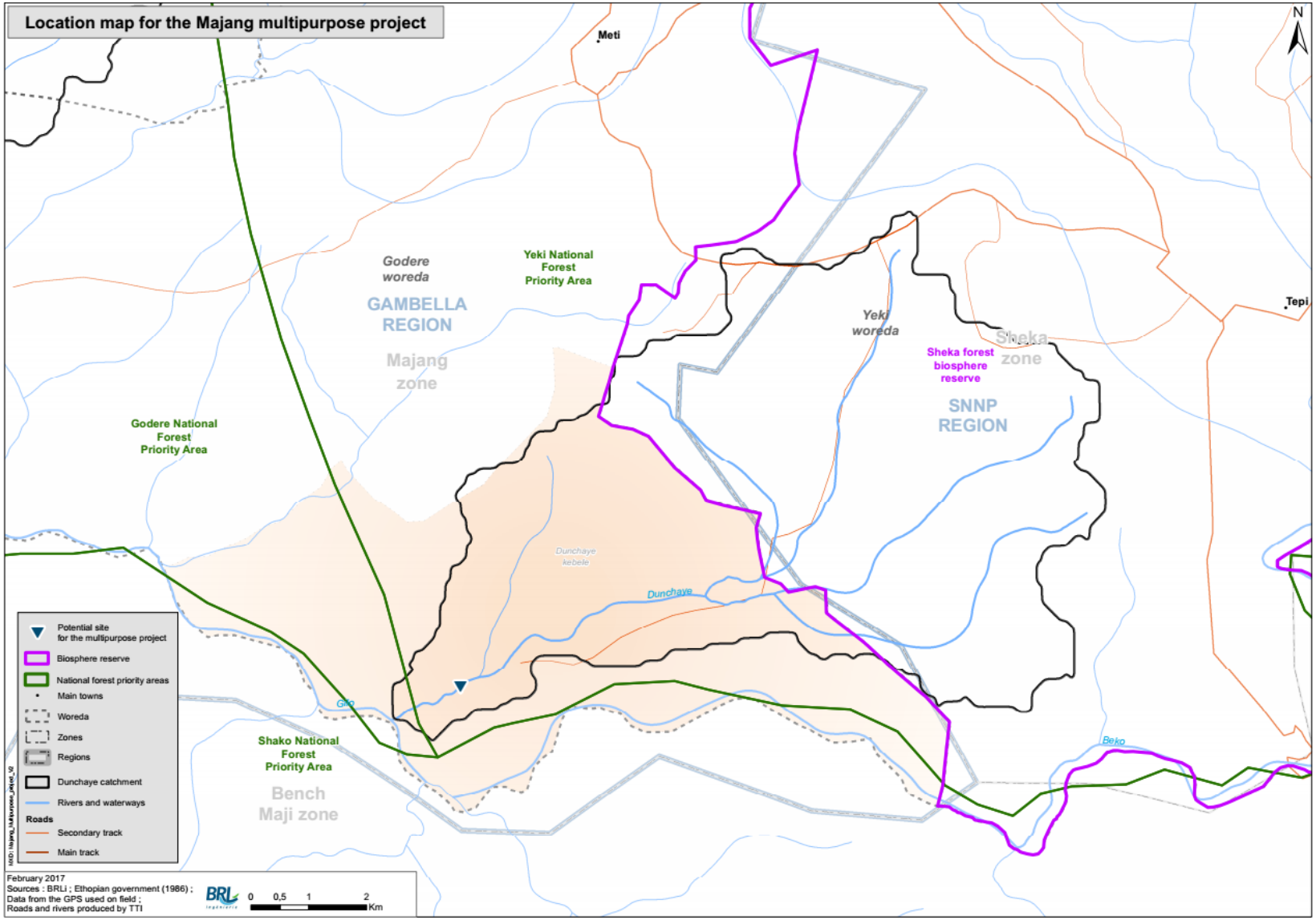
1.3 PROJECT AREA

The proposed site for small scale hydropower and the related activities are located in Dunchaye kebele Ethiopia. However, the catchment of the selected stream (Dunchaye) is shared between Gambella region (Dunchaye kebele - Godere woreda - Majang zone) and SNNPR region (Darimu kebele, Baya government coffee plantation kebele, Tsao kebele, Yeki kebele - Yeki woreda - Sheka zone). The Dunchaye catchment has an area of 6,425 ha (64.5 km²).

Figure 1-5: Village centre of the Dunchaye kebele

A location map is given hereafter (see Figure 1-6).

Figure 1-6: Location map for the Majang multipurpose project



2. PROJECT AREA - BASELINE

2.1 INTRODUCTION

The baseline information given in this section relates to environmental, socio-economic and institutional information to understand the situation in the kebele (and more broadly the situation in the catchment). Having a clear picture of the current situation enables to identify the needs and potentials of the area and justify the proposed multipurpose project.

2.2 BIO-PHYSICAL ENVIRONMENT

2.2.1 Baseline situation

2.2.1.1 Physical environment

TOPOGRAPHY

The upstream part of the Dunchaye catchment reaches an altitude of 1,270 masl and the lowest point of the catchment - at the confluence with the Gilo river - reaches an altitude of around 780 masl. The identified site for the hydropower works is located 1.3 km upstream of the confluence, at an altitude of 850 masl.

Longitudinal profile of Dunchaye River (see Fig-3.3) was generated by using DTM-DEM derived from ALOS PRSIM stereoscopic high resolution satellite images. The profile shows that the change in elevation between the source of the river (1,300 masl) and just upstream the confluence of the river with Gilo River (780 masl) along the river course is 520 m over a distance of about 15 km (average river bed slope of 3.5%).

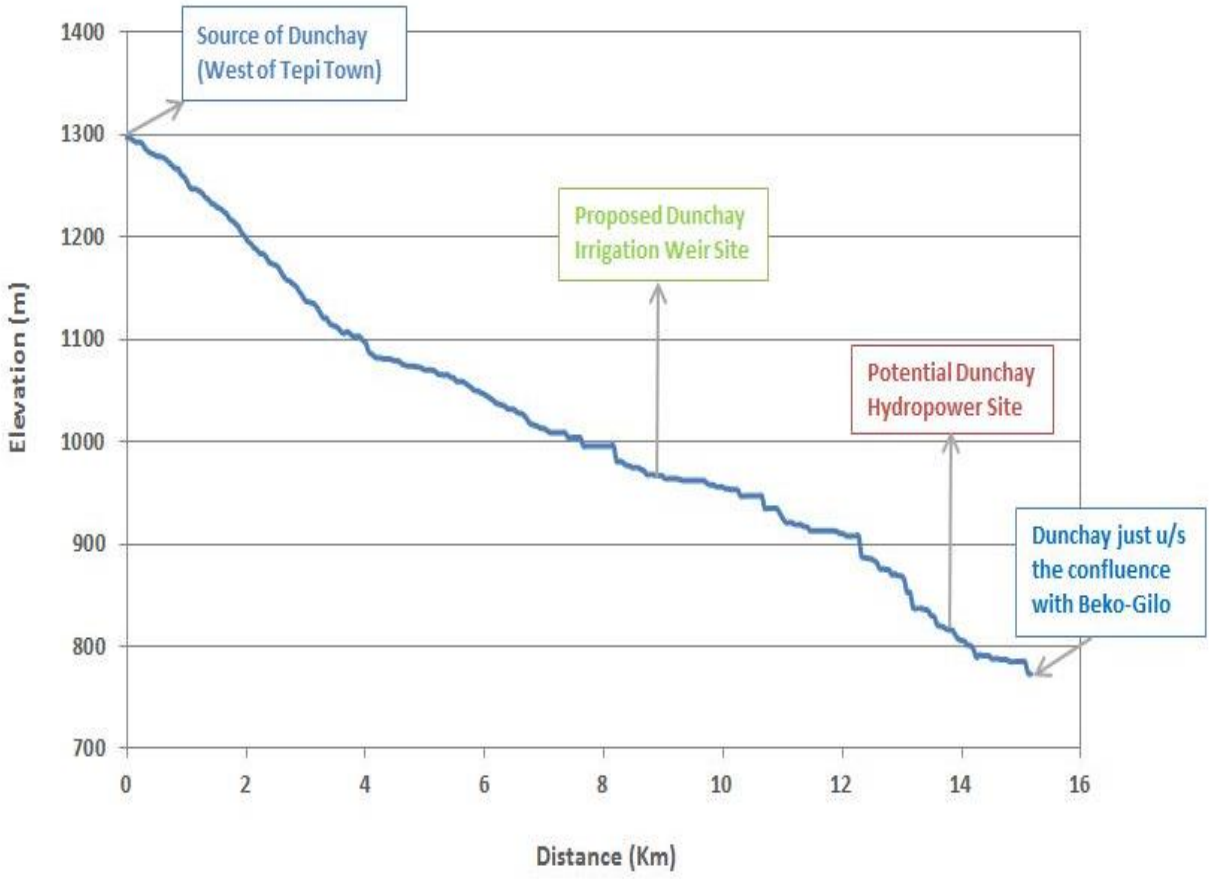


Figure 2-1: Longitudinal profile of Dunchaye River

Source of Elevation Data: DTM - DEM derived from ALOS PRSIM stereoscopic high resolution satellite images

CLIMATE

The Dunchaye catchment is located in the upstream part of the Gilo sub-basin, in the Ethiopian escarpment of the BAS sub-basin (see; the location of the Dunchaye catchment is indicated with a black dot). This catchment receives significant precipitation throughout the year, between 1,500 to 1,750 mm of rainfall. The wettest months are July and August and the driest months December, January and February. It is interesting to note that in this area, the mean annual potential evapo-transpiration is 1,400 mm which is, on average, inferior to the precipitations. The temperature varies from 13 to 26 degrees during the year.

WATER RESOURCES

The river takes its source from the Chambey mountain range, 10 km north of the diversion site, and joins the Gilo River in the upper reaches as a right bank tributary. There are many springs in the area and some of these have been developed for potable water supply. Indeed, during the second site visit the team were informed that the flow in the Dunchaye River does not drop significantly below the level observed at that time. This is because the baseflow is supported to a large extent by springs and an influent system.

There are no useful hydrological records available. While estimates could be made through the applications of methods for ungauged catchments, the observations made by the team during the May 2016 mission are considered the most useful. At the proposed hydropower offtake site it was estimated that the flow was around 1.5m^3/s, perhaps as high as 2m^3/s. Representatives from the Kebele who are intimately familiar with the behaviour of the river indicated that the flow does not drop much lower. Clearly the maintenance of this baseflow, as well as the prevention of peak floods will depend on the continued protection of the source areas in the mountains.

2.2.1.2 Biological environment

The catchment is located in the "Tropical forest ecosystem" biogeographical ecoregion as indicated in the nomination form for the Sheka biosphere reserve (Tadesse Woldemariam Gole & Fite Getaneh, 2011). The forest vegetation can be categorized as transitional rainforest. The composition of these forests is described in Feyera Senbeta Wakjira (2006), it is known to support wild populations of *Coffea arabica* and includes the following:

- **Major forest tree species**: Baphia abyssinica, Celtis toka, Diospyros abyssinica, Lecaniodiscus fraxinifolius, Pouteria alnifolia, Zanha golungensis, Alstonia boonei, Antiaris toxicaria, Melicia excelsa, Celtis gomphophylla, Zanthoxylum leprieurii, *Pouteria atissima, Anthocleista schweinfurthii, Celtis philippensis, C.zenkeri, Eugenia bukobensis, Garcinia huillensis, Manilkara butugi, Morus mesozygia, Strychnos mitis, Trichilia dregeana, and Trilepisium madascariense* .
- **Shrub layer**: *Alchornea laxiflora, Argomuellera marcophylla, Oxyanthus specisous, Rinorea ilicifolia and Whitfieldia elongata.*
- **Climbing plant species**: *Capparis erythrocarpos, Paullinia pinnata, and Hippocratea africana*

The Sheka forest biosphere reserve application form (Tadesse Woldemariam Gole & Fite Getaneh, 2011) lists the common mammals and birds found in this area. These are given hereafter (Tadesse Woldemariam Gole & Fite Getaneh, 2011 from EWNHS, 1996)[1]:

- **Mammals** : *Hystrix cristata* (porcupine), *Cercopithecus aethiops* (Chlorocebus), *Cercopithecus mitis* (blue monkey), *Cercopithecus neglectus* (De Brazza's monkey), *Papio anubis daguera* (baboon), *Colobus guereza* (colobus monkey), *Syncerus caffer* (African buffalo), *Tragelaphus scriptus* (bushbuck), *Redunca redunca* (Bohor reedbuck), *Tragelaphus strepsiceros* (greater kudu), *Sylvicapra grimmia* (common duiker*), Phacochoerus aethiopicus* (warthog), *Leptailurus serval* (serval), *Lycaon pictus* (wild hunting dog), *Potamochoerus larvatus Panthera leo* (lion), *Panthera pardus* (leopard), *Civettictis civetta* (African civet), *Genetta abyssinica* (Abyssinian genet), *Lepus fagani* (Ethiopian hare), *Orycteropus afer* (aardvark), *Viverrdae sanguineus* (shelmitmat), and many bats.
- **Birds** : *Oriolus monacha* (Abyssinian black-headed oriole), *Bucorvus abyssinicus* (Abyssinian ground hornbill), *Turdus piaggiae* (Abyssinian ground thrush), *Dendropicos abyssinicus* (Abyssinian woodpecker), Alcippe abyssinica (African hill babbler), Lybius guifsobalito (banded barbet*), Agapornis taranta* (black-winged lovebird), *Francolinus leucoscepus* (chestnut-naped francolin), *Nectarinia olivacea* (olive-bellied sunbird), *Rougetius rougetii* (Rouget's rail), *Apus myioptilus* (scarce swift), *Cinnyricinclus sharpei* (Sharpe's starling), *Cossypha niveicapilla* (snowy-headed robin chat), *Poeoptera stuhlmanni* (Stuhlmann's starling), *Tauraco ruspolii* (white-checked turaco), *Poicephalus flavifrons* (yellow-fronted parrot), *Bostrichia caruculata* (watttled ibis), *Cyanochen cyanoptera* (blue winged goose), *Parophasma galinieri* (Abyssinian cat bird), *Parus leuconutus* (white backed black tit), *Onchoganthus albirotris* (white-billed starling), and *Caruvus crassirostris* (thick-billed raven)

[1] These are the species that might be found in the catchment according to the characteristics of the ecosystem. It does not imply that all these animals have been observed during the missions.

Figure 2-2: BAS sub-basin: relief and drainage

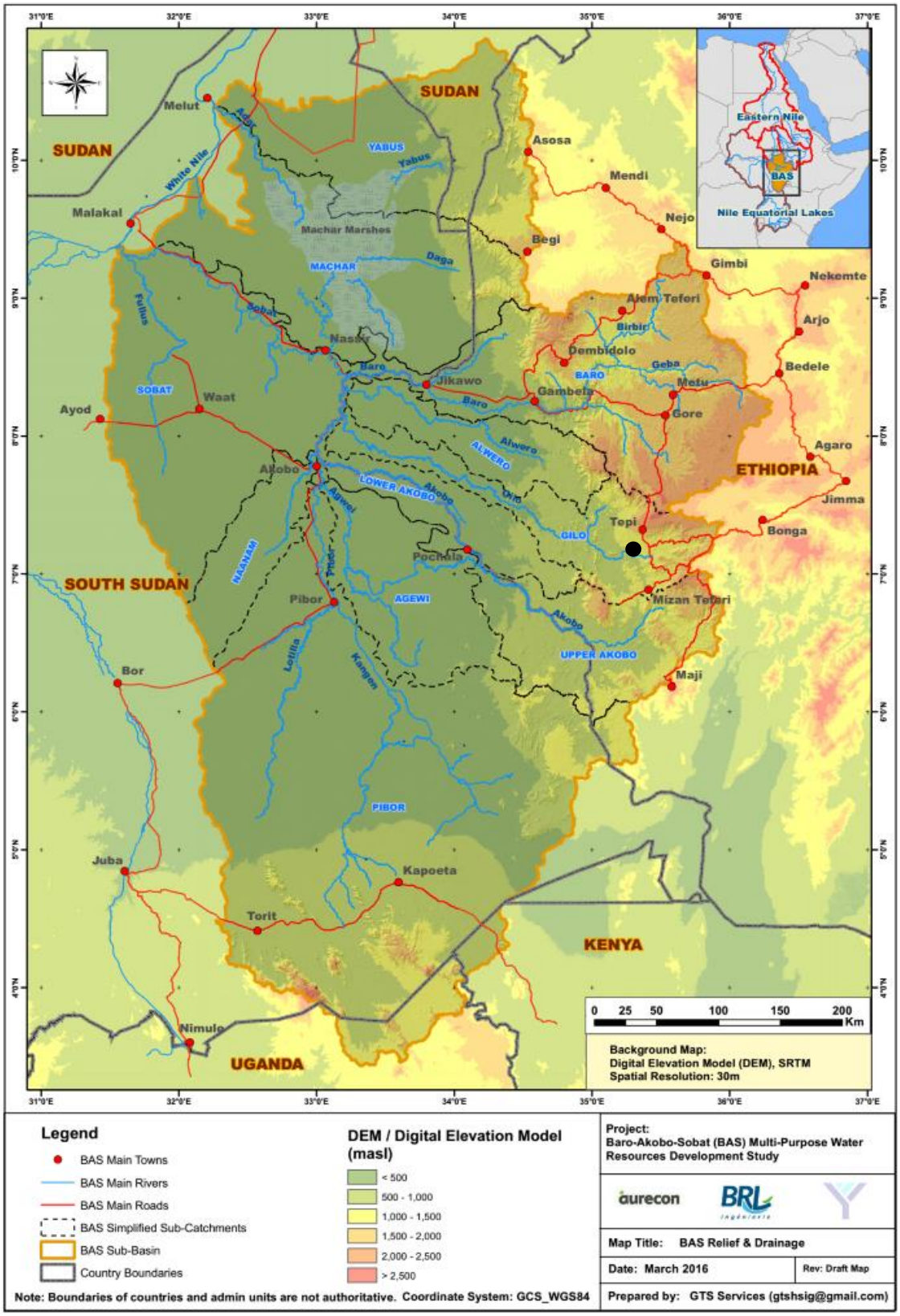


Figure 2-3: On the left plantation of Coffea Arabica in Dunchaye catchment (Baya government coffee plantation) – on the right landscape around the potential site for hydropower (with Colobus guereza in the trees)

2.2.1.3 Land use and land cover

The Dunchaye catchment includes large areas of cultivated lands for local consumption, the main crops being maize and sorghum. There is also one commercial coffee plantation: the Baya government coffee plantation (see picture above). Remnant forests are found in the north-western part of the catchment, an area with high slopes.

More details on the land use and land cover of the Dunchaye catchment are given in the map hereafter.

2.2.1.4 Areas with special status

As already emphasized, part of the catchment is located in the Sheka biosphere reserve (areas of the catchment located in Sheka zone: Yeki, Tsao, Darimu, Hibiret Fire and Baya government coffee plantation kebeles are part of the biosphere reserve). Areas with special status are shown on Figure 1-6.

Biosphere reserves are protected areas under a programme launched by the UNESCO-MAB (United Nations Educational, Scientific and Cultural Organization – Man and the Biosphere). These reserves are selected upon environmental, social and economic criteria and the biosphere reserves network aims at promoting the sustainable development of these areas. They are traditionally classified in three zones:

- **Core areas**: this refers to central areas of the biosphere reserve, devoted to long-term conservation (according to the conservation objectives of the biosphere reserve).
- **Buffer zones**: these zones are contiguous to the core areas and activities compatible with the conservation strategies are allowed.

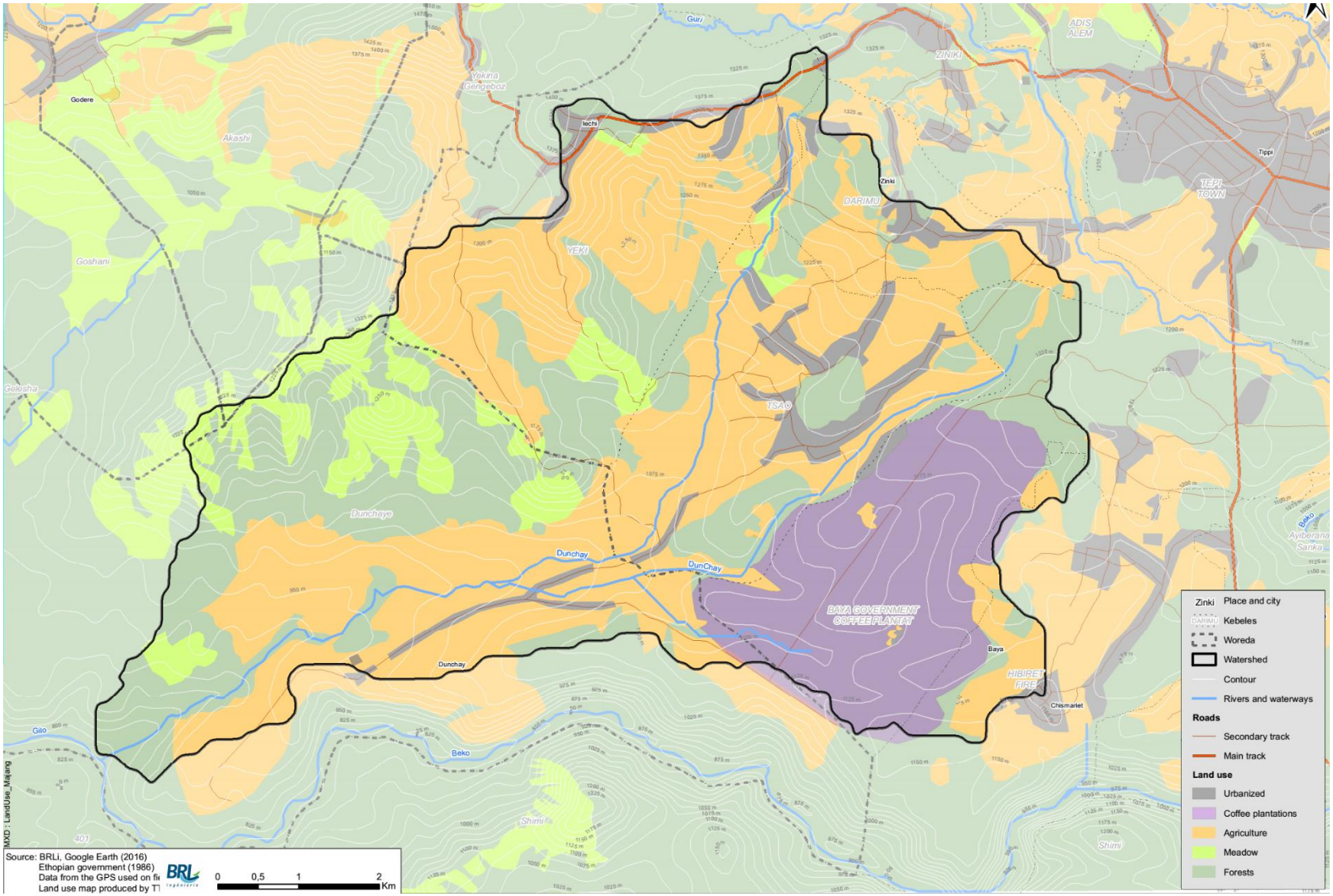


Figure 2-4: Land use in Dunchaye catchment

- **Transition areas**: these areas are at the edge of the reserves and sustainable management practices are promoted and developed.

The total area of the biosphere reserve is 238,750 ha of which 4,300 ha are located within Dunchaye catchment (1.8% of the total area of the biosphere reserve, 67% of the total area of the catchment). The portion of the biosphere reserve located within the catchment is a transition area and is mostly covered by the coffee plantation and agricultural lands (refer to Figure 2-4).

It should be noted that the rest of the catchment located in Majang zone is included in the ongoing application for the Majang biosphere reserve (application carried out by Melca Ethiopia).

2.2.2 Key issues and challenges

This catchment is already largely developed for agriculture for food and coffee production and most of the lands are anthropized. The key environmental issue in the catchment relates to deforestation to cultivate the land. The major impacts of deforestation are the following:

- Loss of biodiversity
- Increase of erosion and loss of soils
- Sedimentation of the streams

One of the key challenges in the catchment will be to conserve the forest through watershed management activities.

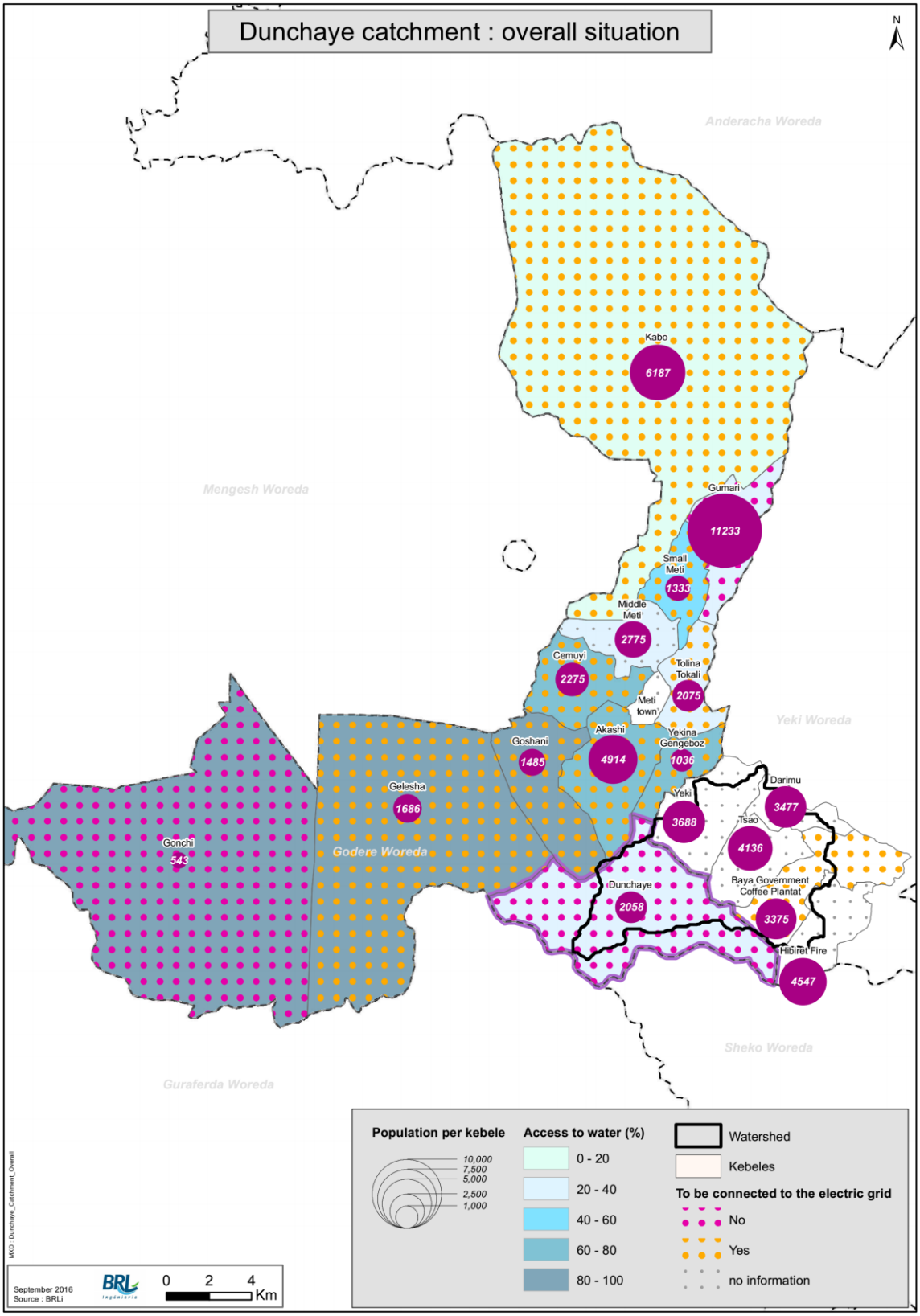
The presence of the coffee plantation limits deforestation although juvenile trees are not retained. Preserving the remaining forest areas is a key challenge especially on the north-western part of the basin where the forest is located on high slopes. Further deforestation would lead to soil erosion and sedimentation of the Dunchaye River.

2.3 SOCIO-ECONOMIC ASPECTS

2.3.1 Baseline situation

Information provided in this section relies mostly on data collected during a mission carried out in May 2016 in Godere administration office located in Meti and on a census realised by the Central Statistical Agency (CSA) in 2007 for the different regions. The overall situation in Dunchaye is presented in Figure 2-5 hereafter.

Figure 2-5: Dunchaye catchment: overall situation



2.3.1.1 Population demographics

Population demographics information is given in Table 2-1 for the kebeles part of the catchment.

Table 2-1: Population demographics for the catchment, at kebele level

		Census 2007 (1)	Projection CSA 2016 (2)	Growth rate / annum between 2007 and 2016 (3)	Projection 2041 (Population growth = 1.68% per annum) (4)
Population demographics	Godere woreda	38,741	51,760	3.27%	78,505
	Dunchaye kebele	1,536	2,052	3.27%	3,112
	Yeki woreda	136,808	178,268	2.98%	270,372
	Yeki kebele	3,688	4,804	2.98%	7,285
	Tsao kebele	4,136	5,387	2.98%	8,170
	darimu kebele	3,477	4,529	2.98%	6,869
	Baya government coffee plantation kebele	3,375	4,396	2.98%	6,667
	Hibiret Fire kebele	4,547	5,922	2.98%	8,982

Source: CSA, 2007

(1) A census was carried out throughout Ethiopia in 2007 at kebele level. Information is available on the "Central Statistical Authority (CSA) of Ethiopia" website.

(2) A projection for the population at woreda level was realised by the CSA for the year 2016. The woreda growth rate (3) has been applied to estimate the kebele population in 2016.

(4) The national growth rate used in the SSEA study has been applied to the kebeles to assess population growth between the years 2016 and 2041.

Gambella region, inlcuding for example, Godere woreda is one of the core areas where resettlements programmes of the previous government took place. However, it should be noted that there is no figure showing the percentage of indigenous people and recent settlers at kebele level. For information, the ratio of migrants in SNNPR and Gambella region is given in Table 2-2. Source: CSA, 2007

Table 2-3 presents information relative to the religion of Godere and Yeki woredas.

Table 2-2: Population and migrants by sex for SNNPR and Gambella region

Population and migrants by sex		**Population total**	**Percent Migrants**		
			Both sexes	Males	Females
	SNNPR	14,931,032	14%	13%	14%
	Gambella region	307,296	47%	49%	45%

Source: CSA, 2007

Table 2-3: Population by religion at regional and woreda level

		Total	Orthodox	Protestant	Catholic	Islam	Traditional	Other
Population by Religion: 2007	SNNPR	14,929,548	20%	55%	2%	14%	7%	2%
	Yeki woreda	134,519	45%	30%	0.5%	22%	2%	1%
	Gambella	307,096	17%	70%	3%	5%	4%	1%
	Godere Woreda	38,781	42%	35%	0%	21%	1%	1%

Source: CSA, 2007

2.3.1.2 Land Tenure and Land Holding Size

LAND TENURE AND FARMLAND SIZE

The land tenure system of the catchment areas can be grouped into the following (GNRS/LUEPA,2012).

a) ***Private stallholder holdings*** – which is mainly used for cereal crop cultivation and individually owned coffee farms; originally these were places of dense forests, but cleared and vanished through time and have become crop lands and coffee producing areas.

b) ***Traditional forest land holdings*** of the Majanger and the Shekkacho people respectively. These are primarily used for honey production by both the groups in which the Majangir and the Shekkacho have traditional ownership right to Jagn and Kobbo forests respectively.

c) ***Investment land*** – land provided to investors and occupied by the same in the project area as well as outside of it.

d) ***Land holding by large scale coffee plantations***; these places are located in the zone. The state-owned coffee plantation is the largest farm covering more than 5 kebeles and different individuals holding more than 4 hectares.

HOUSEHOLDS' HOLDING SIZE FOR AGRICULTURE PRODUCTION

Table 2-4: Farmland Size for Agriculture Production in Godere Woreda

Woreda	Land Holding Category (in ha)	% Households
Godere	Below 0.5h	23.1
	0.51 -1	64.7
	1.1 - 2	0.6
	None	11.6
	Total	100

Source: (GNRS/LUEPA, 2012)..

A survey conducted in Godere Woreda indicated that farmland effective holdings have become insufficient over time. The survey revealed that farmland reduction is attributed to land degradation (14.4%), land sliding (27%), poor soil fertility/reduction of productivity (21%), farmland fragmentation (58%), land allotment for investments (3.1%), and others (4.1%) (GNRS/LUEPA,2012). This result suggest that crop production is being constrained by insufficient cropping land, and thus it needs to diversity local livelihoods and intensification of agriculture itself via adoption of new technologies such irrigation schemes, and application of other inputs (fertilizer and improved seeds) for increasing crop productivity.

2.3.1.3 Education

As can be seen in Table 2-5, the literacy rate in the catchment is around 45% (44% for the rural area of Majang zone and 48% for the rural Sheka zone). There are significant disparities between the regions as the literacy rate in Gambella region (rural) is 70% while it is only 38% in the SNNPR (rural). Moreover, the difference of literacy rate between males and females is high (20%):

- 53% of the males are literate in Majang zone against 34% of females
- 58% of the males are literate in Sheka zone against 39% of females

More information on education and school attendance is provided in Table 2-6.

Table 2-5: Population above 5 years old by literacy and sex

		Total population	literacy rate	Male Population	Literacy rate	Female population	Literacy rate
Population 5 years old and older by literacy and sex	Gambella region - rural	197,324	42%	101,921	49%	95,403	36%
	Majang zone - rural	43,846	44%	22,680	53%	21,166	34%
	SNNPR - rural	11,258,068	38%	5,558,735	47%	5,699,333	29%
	Sheka zone - rural	139,042	48%	70,145	58%	68,897	39%

Source: CSA, 2007

Table 2-6: Population above 5 years old by school attendance and sex

Population 5 years old and older by school attendance and sex		**Population total (1)**	**Currently attending**				**Attended in the past**				**Never attended**			
			Total	Compared to (1)	Of which m.	Of which f.	Total	Compared to (1)	Of which m.	Of which f.	Total	Compared to (1)	Of which m.	Of which f.
	SNNPR	12,589,770	2,624,993	21%	56%	44%	2,567,458	20%	64%	36%	7,397,319	59%	42%	58%
	Sheka zone	169,731	42,041	25%	55%	45%	49,879	29%	63%	37%	77,811	46%	41%	59%
	Gambella region	265,258	70,558	27%	58%	42%	59,191	22%	61%	39%	135,509	51%	45%	55%
	Majang zone	50,209	10,746	21%	58%	42%	14,296	28%	64%	36%	25,167	50%	43%	57%

Source: CSA, 2007

m. males
f. females

2.3.1.4 Sources of livelihood

COFFEE PRODUCTION

Coffee is Ethiopia's number one source of export revenue generating about 25-30 percent of the country's total export earnings. The Baya coffee plantation has an area of around 1,000 ha. The presence of this large commercial coffee plantation creates opportunity for local population and attract migrant workers who – in some cases - settle permanently in the area.

Figure 2-6: Coffee beans, Baya plantation

FOOD CROP PRODUCTION

The main crops produced in the area are maize, sorghum and banana trees for local consumption.

For maize, the planting season is around March and April and the harvest during the months of September and October. For sorghum, the planting season is July and the harvest is during the dry months of December and January. Banana trees mature in three to seven years and harvest can occur at any times of the year.

The main issues encountered by the population relate to crop diseases and access to market. Dunchaye kebele is not connected to Meti or Tepi market due to the poor condition of the road.

Figure 2-7: On the left: maize field in Dunchaye kebele and on the right banana trees at the edge of the coffee plantation

LIVESTOCK

The presence of livestock is limited due to limited access to pasture as a result of the coffee plantation and the forest cover. Contrary to most areas in Ethiopia, the main determinant of wealth there is not the number of heads of livestock but rather the cultivated surface area owned.

BEE KEEPING

Bee keeping is already an important activity in the area and the technique used is traditional. The beehive is a long cylindrical basket made of wood and is placed in the forest tree tops.

The common trees used for bee keeping activities are the following (Shibru D., et al., 2016) Pouteria adolfifriedrichi, Croton macrostachyus, Polyscias fulva, Schefflera abyssinica, Syzygium guineense, Vernonia amygdalina, Ilex mitis, Maesa lanceolata, Allophylus abyssinicus, Phoenix reclinata, Olea welwitschi, and Dracaena afromontana.

The maximum yield from the traditional beehive is 7kg and the minimum is 5kg, whereas about a maximum of 30kg and a minimum of 25kg of honey are harvested from the modern beehives in Godere Woreda. Table 2-7 presents the number of beehives and volume of the honey harvested in 2010 production year. For same year, in the Woreda, there were 29, 345 beehives with total yield of 223, 400 honey. The selling price was 25 Birr per kilogram of honey, and total estimated cash income was 5,585,000 Birr Honey is the most important indicator of wealth in Majang zone (GNRS/LUEPA,2012).

Table 2-7: Number of Beehives and Volume of Honey Harvested in 2010 in Majang Zone

District	Beehives	Yield (in Kg)	Selling price	Estimated cash income
Godere	29,345	223, 400	25	5,585,000
Mengeshi	65,680	1,970,400	30	59,112,000
Total	95,025	2,193,800	27.5	60,329,500

Source: (GNRS/LUEPA,2012)

Figure 2-8: Traditional beehives in Dunchaye kebele

SOURCE OF ENERGY

As shown in Table 2-8, the main source of energy used for cooking is firewood for both Yeki and Godere woredas. This is not surprising as there is almost no electricity in the area and the presence of the forest facilitates the collection of wood. It should be noted that most of the kebeles in Godere are going to be connected to the electric grid, however, Dunchaye is one of the three kebeles for which there are no plans to connect to the national grid. No information could be found for the source of energy used for lighting in the rural areas (the sources used in urban areas are given in Table 2-9 for information).

Table 2-8: Housing units by type of fuel for cooking in rural areas in Yeki and Godere woredas

		All housing units	Electricity	Gas	Kerosene	Charcoal	Firewood	Dung	Bio-Gas	Other
Housing units by type of fuel for cooking in rural areas	SNNPR	2,650,822	0.2%	0.04%	3.5%	1.9%	89.0%	17.3%	0.4%	23.6%
	Yeki Woreda	25,272	0.0%	0.0%	2.8%	3.2%	92.8%	0.2%	0.1%	11.9%
	Gambella region	44,613	1.2%	0.0%	2.1%	4.4%	82.8%	11.8%	0.5%	29.2%
	Godere Woreda	7,377	0.2%	0.1%	4.0%	4.1%	84.9%	0.3%	0.3%	24.2%

Source: CSA, 2007

Table 2-9: Housing units of towns by type of lighting for Yeki and Godere woredas

		All housing units	Electricity/ meter private	Electricity/ meter shared	electricity from generator (no meter)	solar energy	lantern	Bio-gas	lamps	Candle /wax candle	firewood
Housing units of towns by type of lighting	SNNPR - urban	342225	22.9%	48.1%	3.1%	0%	3.2%	0.1%	20.8%	0.6%	1.2%
	Yeki Woreda - urban	7184	23.2%	54.4%	4.8%	0%	1.0%	0.1%	15.2%	0.8%	0.5%
	Gambella region - urban	19080	15.5%	43.6%	2.1%	0%	3.5%	0.1%	11.2%	14.9%	9.0%
	Godere Woreda - urban	2116	19.4%	63.4%	0.5%	0%	1.4%	0.2%	13.9%	1.2%	0%

Source: CSA, 2007

2.3.1.5 Health status

COMMON HEALTH PROBLEMS IN THE CATCHMENT AREA

Table 2-10 shows common diseases which are prevalent in Godere and Yeki Woredas. Water-related insect vectors, such as mosquitoes, may spread diseases, including malaria.

Table 2-10: Main Disease Prevalent in the Project Affected Woredas

Common Diseases	Woreda	
	Godere	Yeki
Malaria	x	x
TB	x	x
Gastritis	x	x
Typhoid fever	x	x
Diarrhoea	x	x
Amoebae	x	
Eye disease	x	
Intestinal parasite	x	x
Tonsillitis	x	
STD	x	
Sleeping sickness	x	

SOURCE: (GNRS/LUEPA, 2012)

DRINKING WATER AND SANITATION

The situation for drinking water and sanitation in the catchment is better than in Gambella Region and SNNPR, especially in Godere woreda. In this woreda, 46.8% of the population has access to a protected well or spring for drinking water (compared to 20.4% for the entire region). For sanitation, in Godere, 40.4% of the population has a private pit latrine compared to only 9.9% in Gambella Region. Indeed, 82.1% of the rural population in Gambella has no toilet facility compared to 40.8% in Godere woreda.

More information on drinking water and toilet facility for rural areas of the regions and woredas is given in Table 2-11 and Table 2-12.

Figure 2-9: Women collecting water in Dunchaye kebele

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Table 2-11: Housing units by source of drinking water

		All housing units	tap inside the house	tap in compound private	tap in compound shared	tap outside compound	protected well or spring	unprotected well or spring	river/lake pond
Housing units by source of drinking water	SNNPR - rural	2,650,822	0.3%	0.1%	0.9%	18.1%	18.2%	32.8%	29.6%
	Yeki woreda - rural	25,273	0.1%	0.04%	0.9%	8.5%	27.4%	41.0%	22.0%
	Gambella region - rural	44,612	1.4%	0.1%	2.1%	9.8%	20.4%	16.1%	50.0%
	Godere woreda - rural	7,377	0.1%	0.1%	0.1%	3.2%	46.8%	41.5%	8.1%

Source: CSA, 2007

Table 2-12: Housing units by type of toilet facility

		All housing units	No toilet facility	flush toilet private	flush toilet shared	VIP latrine private	VIP latrine shared	Pit latrine private	Pit latrine shared
Housing units by type of toilet facility	SNNPR - rural	2,650,822	51.7%	0.4%	0.1%	0.7%	0.2%	39.6%	7.3%
	Yeki woreda - rural	25,272	31.0%	0.04%	0.1%	0.1%	0.4%	44.8%	22.7%
	Gambella region - rural	44,613	82.1%	0.6%	0.3%	0.5%	0.3%	9.9%	6.3%
	Godere woreda - rural	7,377	40.8%	1.6%	0.4%	0.6%	0.2%	40.4%	16.1%

Source: CSA, 2007

SURVIVAL RATE OF CHILDREN

Table 2-13 below shows the survival rate of children at birth and surviving for women 10 years old and older. It should be noted that in this table, the proportion of children surviving is for all the children born from women above 10 years old. It includes for instance children born from women who are today more than 75 years old. In the complete table from the census, we can see that the proportion of children surviving has increased continuously from women aged more than 75 years old (this category of women has had on average 4.9 children of which 66.9% survived) to women aged more than 35 years old (this category of women has had on average 5.4 children of which 84% survived). For women aged from 15 to 19, the proportion is the highest - 93.4% - but this figure should be read carefully as the average of children is only 0.2 and these women will most probably give birth to more children.

These figures show improved birthing conditions and an improved level of care of newborns.

Table 2-13: Women 10 years old and older, children ever born and children surviving

Women 10 years old and older, children ever born and children surviving		Total women	All children		
			Total	Surviving	proportion of children surviving
	SNNPR	5,018,059	13,136,299	10,839,237	83%
	Sheka zone	67,798	162,401	133,781	82%
	Gambella region	105,293	216,158	190,304	88%
	Majang zone	19,770	41,522	34,457	83%

Source: CSA, 2007

2.3.1.6 Ethnic groups

RELIGIOUS AND ETHNIC COMPOSITION IN PROJECT AFFECTED WOREDAS

There are over eight ethnic groups in project affected Woredas. The five largest ethnic groups in the Woredas included Kefficho, Amhara, Majenger, Oromo and Shekecho (Table 2-14). The Kefficho, Majenger and Shekecho are indigenous people to the area.

Table 2-14: Major Ethnic Groups in Godere and Yeki Woredas

Ethnic groups	Godere Woreda (%)	Yeki Woreda (%)
	%	%
Amhara	27.0	29.48
Bench	1.3	7.33
Kefficho	25.1	29.78
Mejenger	16.8	-
Nuwer	2.0	-
Oromo	9.0	11.67
Shekecho	11.6	7.26
Tigre	3.0	-
Mocha	-	7.45
Others	4.2	7.03
Total	100	100

Sources: (CSA), The 1 994 and 2007 Population and Housing Censuses

2.3.1.7 Agricultural markets

The main agricultural markets are located in Meti, Tepi and Mizan Teferi.

2.3.1.8 Social Services and Infrastructure available in Project Affected Zones and Woredas

Table 2-15 gives information on major social services and infrastructure for Majang Zone and Godere Woreda.

Table 2-15: Social Services and Infrastructures in Sheka Zone and Yeki Woreda

Zone/ Woreda	Social facilities and Infrastructures					
	education facilities	health facilities	water facilities	infrastructure services	commercial services	agricultural development centres
Majang zone	34	34	58	-	30	16
Godere woreda	19	15	35	-	10	11

Source: CSA (2014a): Ethiopia's Rural Facilities and Services, Atlas 2104 for Gambella Region.

Information on major social services and infrastructures is given in Table 2-16 for the Zone and Yeki Woreda.

Table 2-16: Social Services and Infrastructures in Sheka Zone and Yeki Woreda

Zone/ Woreda	Social facilities and Infrastructures					
	education facilities	health facilities	water facilities	infrastructure services	commercial services	agricultural development centres
Sheka zone	79	29	198	26	118	46
Yeki woreda	49	20	138	11	111	22

Source: CSA (2014b): Ethiopia's Rural Facilities and Services, Atlas 2104 for SNNPR.

2.3.1.9 Infrastructure

The road infrastructure is in a very poor condition in the catchment. From the main road which goes from Mizan Teferi to Tepi, there is a small track going through the coffee plantation and the different kebeles. The area is difficult to access from October to June and not accessible by car from July to September.

Figure 2-10: Track in Dunchaye kebele (May 2016) during field visit

2.3.2 Key issues and challenges

Key issues in Godere and Yeki woredas relate to food security and economic development. Economic development is constrained by a lack of services and infrastructure including roads and electricity.

2.3.2.1 Issues and challenges related to crop production

DISEASES AFFECTING COFFEE PLANTATIONS

There are two main diseases affecting coffee production:

- The **coffee berry disease** caused by the fungus *Colletotrichum coffeanum* which produces spores which attack the coffee berries.

- The **coffee wilt disease** is caused by the fungus *Gibberellic xylarioides* which is highly contagious and attacks all the production systems of the plant. The wilt disease has long-term impacts on production as to eradicate the disease, the affected plant must be burnt. Then, the replanted coffee plant will be productive 3 to 4 years after the plantation.

DISEASES AFFECTING LIVESTOCK

Livestock diseases affect all households and are serious hazard.

CLIMATIC VARIATIONS

Although the area has significant rainfall throughout the year, delay of the beginning of the rainy season can lead to some delays planting and thus harvesting. This can lead to food insecurity in the area. On the other hand, heavy rainfalls can damage the crops and reduce the yield of the harvest and create also food insecurity.

It is important to stress the very close relationship between the livelihoods of the majority of the catchment's population and the condition of the natural resources in the catchment. The condition of water and land resources are threatened by population pressures, poor land-use practices and an apparent increase in the frequency of extreme events in the form of longer dry periods and heavier rain events. As with many catchments in the uplands of BAS sub-basin, the Dunchaye and the other Majang catchments experience several challenges. The high risk of soil erosion, landslides, floods, soil fertility loss, deforestation and wetland degradation is likely to be exacerbated by climate change and the likelihood of more frequent extreme events. The resultant land degradation is serious not only from an environmental perspective, but also from a socio-economic one since there is a shortage of farming land and the further loss of land is unsustainable.

At the transboundary level, the degradation of the uplands contributes to an increase in sediment transport, reduced dry-season river flows and increased floods.

2.3.2.2 Issues and challenges related to economic development of the area

Access to market is impeded by the poor state of the tracks. The main markets are in Meti, Tepi and further in Mizan Teferi but the time required to reach these centres does not allow people from the kebele to go and sell their products.

2.4 INSTITUTIONAL BASELINE

As already mentioned, the Dunchaye catchment encompasses two different Ethiopian regions: SNNPR and Gambella region. In Ethiopia, there are 4 main administrative levels which are the following (from the largest to the smallest):

- Region
- Zone
- Woreda
- Kebele

The project is centred on Dunchaye kebele although in order to have an integrated approach all the kebeles within the catchment are studied. Furthermore, as already emphasized, it is expected that benefits of the project will be shared beyond the limits of the kebele. Kebeles included in the catchment are the following:

- **Dunchaye kebele** (Godere woreda, Majang zone, Gambella region)

  The administrative center of Godere woreda is located in Meti (6 km north of Dunchaye kebele). Meti is also the town where are located the zonal offices. The capital of Gambella region is Gambella town.
- **Yeki kebele** (Yeki woreda, Sheka zone, SNNPR)
- **Darimu kebele** (Yeki woreda, Sheka zone, SNNPR)
- **Tsao kebele** (Yeki woreda, Sheka zone, SNNPR)
- **Baya government coffee plantation kebele** (Yeki woreda, Sheka zone, SNNPR)
- **Hibiret Fire kebele** (Yeki woreda, Sheka zone, SNNPR)

  The administrative center of Yeki woreda is located in Tepi while zonal offices are located in Masha (80 km north of Tepi). The capital of SNNPR is Hawassa.

2.5 NEEDS AND POTENTIALS

2.5.1 Overall needs

Needs can be deduced from the identified key social and environmental issues/challenges in the catchment. There is an **overall need** to build resilience against the threats of land and water degradation, especially since these threats are **further exacerbated by climate change**. In order for this to be sustainable, a key need is the improvement of livelihoods. Measures to protect the catchment's natural resources have to go hand in hand with socio-economic measures and this concept has to be at the centre of this project. This is line with Strategic Objective 1 of the BAS IWRDMPlan, "to contribute to food security, livelihood enhancement, poverty reduction and the protection and conservation of natural resources through stakeholder-driven management of wetlands, watersheds and other important natural resources".

In conclusion, there is an urgent need to i) properly mainstream the existing and potential impacts of climate variability change into the planning and development process at the micro-catchment level and ii) pursue an aggressive programme of implementation of resilience building measures. The solutions are not only technical. There is an urgent need to engage with the communities and to introduce improved farming practices and other measures to support improved livelihoods.

2.5.2 Specific needs and potentials

Based on the assessment of the project area, the specific needs and potentials have been identified as follows:

- **Improve food security**: this need will be addressed through the development of aquaculture and irrigation and watershed management activities such as bee keeping.
  - **Aquaculture** is both a need and a potential. This area is indeed favourable for the development of aquaculture with high production levels and it can be seen as an alternative to provide animal proteins as animal husbandry is impeded by the forest cover.
  - **Irrigation** will be particularly important to secure crop production for years with a delayed rainy season.

- **Bee keeping** is already present in the catchment but could be further developed. It would contribute to food security as well as economic development of the area, provided that the road infrastructure is improved.

- **Foster economic development**: the above activities will also contribute to the economic development of the area. Access to market will be a key component as it is currently highly challenging to reach towns such as Meti or Tepi to sell the production of the kebele.
- **Protect the remnant forest of the catchment**: the upstream part of the watershed is included in the transition zone of the Sheka biosphere reserve and sustainable management practices must be implemented. In addition, the remnant "natural" forest (i.e not exploited) must be maintained to prevent soil erosion and sedimentation of the Dunchaye River.

The main **potentia**l of the area is the **production of electricity**. A site has been identified to produce micro-hydropower (see Figure 2-11 below). The production of electricity in the kebele is a key component to limit deforestation. It will also contribute to improving food security and foster economic development (notably through the development of food processing activities and preservation). Production of hydropower can also be seen as a need as Dunchaye is one of the three kebeles of Godere which is not going to be connected to the electric grid.

It is worth noting that the two crucial needs which were raised by the population in the kebele are access to electricity and improvement of the road to access the markets.

Figure 2-11: Identified site for small scale hydropower offtake

2.6 CONCLUSIONS

Chapters 1 and 2 provide the elements for understanding the baseline situation in the Dunchaye kebele and show the relevance of this multipurpose project. The following sections present the technical details for implementing the project for the different sectors. As already emphasized, this project has been designed in such a way that it is highly replicable in other areas of the BAS basin.

3. PROJECT DESIGN

3.1 HYDROPOWER

3.1.1 Layout

The layout of the proposed system is indicated in Figure 3-1and Figure 3-2.

Figure 3-1: Layout of the hydropower system

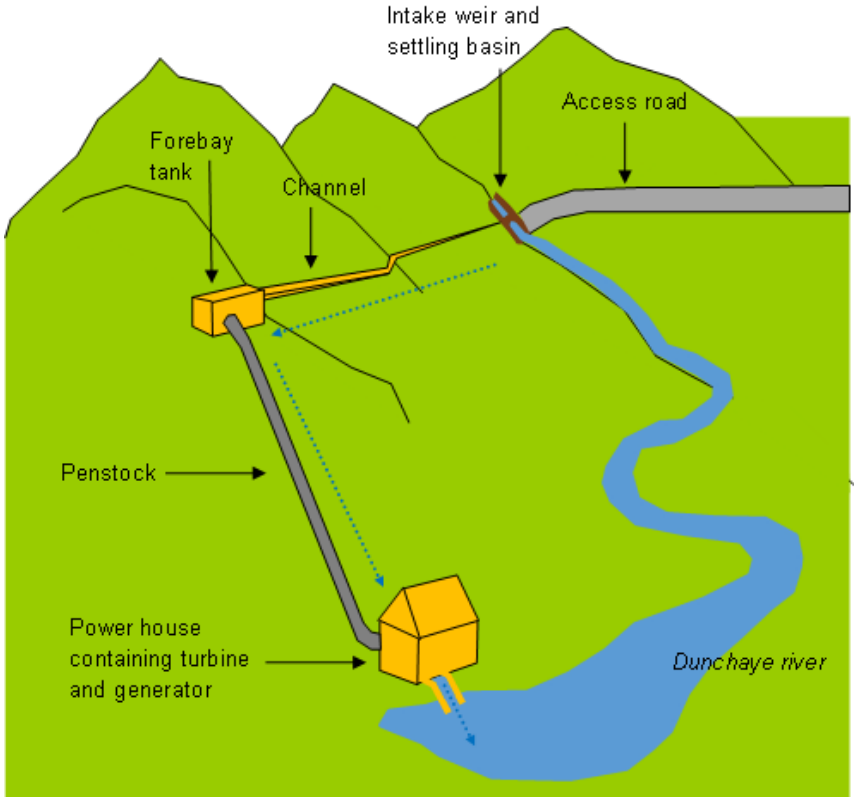


Figure 3-2: Location of the proposed Hydropower works on the Dunchaye River

3.1.2 Component details

INTRODUCTION

The components of the proposed hydropower generation system are as follows:

- Intake weir to allow diversion of flow into the diversion canal
- Diversion canal
- Forebay tank
- Penstock
- Power house incorporating turbine, generator and ancillary structures

INTAKE WEIR

The intake weir will be constructed on the rocky foundation at the top of the water fall shown in Figure 3-2. The width is approximately 10m. The weir will allow ponding of water in order to feed the diversion canal on the right bank. Above this level, water will flow over a lower portion of the weir during periods of low flow and over the remainder of the weir during periods of high flow.

The weir will be constructed during the dry season from concrete. The configuration of the falls will allow temporary diversion of the flow using sand bags so that construction can be carried out easily.

DIVERSION CANAL

The diversion channel will follow the contours on the right bank bit with a slope of 3%. This equates to a fall of 2.2m over a distance of 220m. A masonry canal is proposed which would be appropriate for labour-intensive construction by the community. Assuming an approximately rectangular cross-section in order to minimise the crest width, with a width of 1.4m and a water depth of 0.75m, a discharge of up to 2.12 m^3/s would be possible. The canal would accommodate overflow structures at regular intervals to ensure that overtopping does not occur. There would be a need for at least one significant cross-drainage structure.

FOREBAY TANK

A simple forebay tank is proposed with dimensions of 2m x 2m and a total depth of 3m. This would include allowance for an overflow of excess water, large enough to accommodate the maximum flow of the canal in case of shutdown of flow through the penstock.

PENSTOCK

A steel penstock with a maximum length of 30m is proposed. The required diameter to accommodate a maximum discharge of $2m^3/s$ is calculated at 1.2m.

The layout of the penstock and powerhouse showing the position of the crossflow turbine, generator and controller is provided in Figure 3-3.

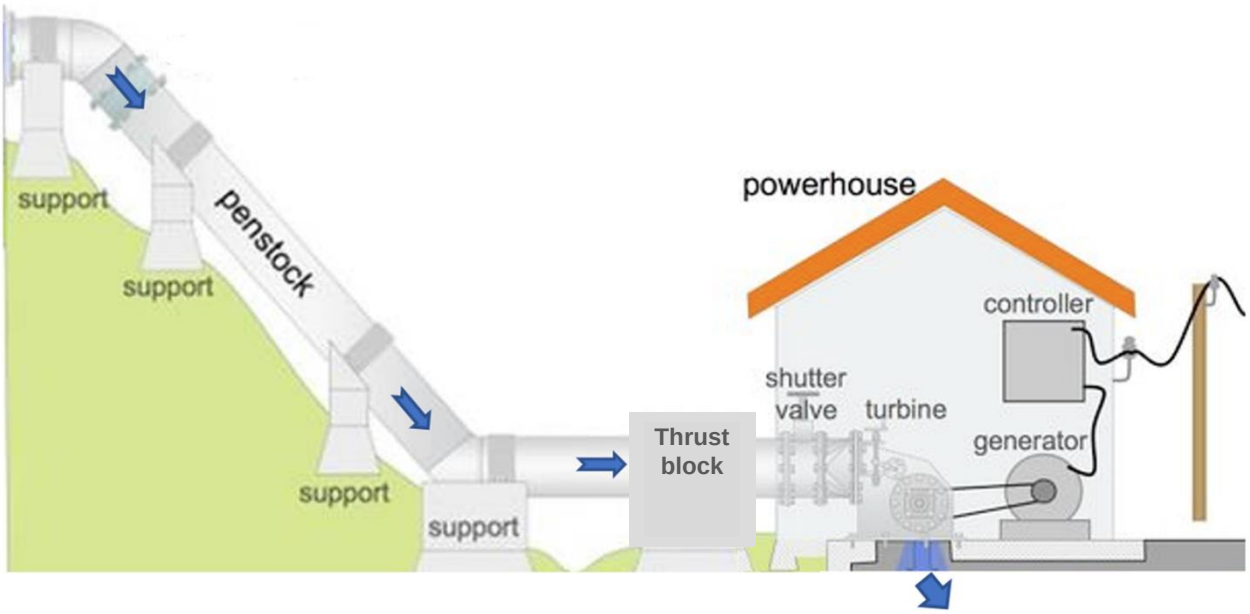


Figure 3-3: Layout of penstock, turbine and generator

POWER HOUSE AND TURBINE

The power house will be constructed as close as possible to the normal high flood level in order to maximise the head available. A reinforced concrete foundation is required to accommodate the turbine and to receive the penstock, as well as to provide a solid foundation for the generator. The concrete slab will be constructed over an excavated tailrace allowing discharge of the turbined water directly into the river.

A crossflow turbine is proposed. These turbines are cost-effective and low maintenance. Several Ossberger turbines have been successfully installed in both Uganda and Rwanda, often as privately operated micro-hydropower installations.

Figure 3-4: Installation of crossflow turbine at Kisiizi Hospital, Uganda (left). Schematic of Ossberger crossflow turbine (rights)

HYDROPOWER CAPACITY AND PRODUCTION

Although there are no comprehensive flow records for the Dunchaye river, the minimum flow was observed in May 2016, just before the beginning of the rainy season and was estimated to be at least 1m^3/s, perhaps significantly more. The following are the main characteristics considered to assess the turbine capacity and the potential production.

- Maximum flow running through the turbine: 2 m^3/s
- Hydraulic head: minimum of 10 m

The capacity of the dam depends primarily on the discharge and the hydraulic head. It estimated through the following relationship:

$$P = \eta \rho g Q H$$

Where:

P is the hydropower capacity (MW), η is the turbine efficiency (usually 0.8), ρ is water density (kg/m^3), Q is discharge (m^3/s), g is gravity (9.81 m/s^2), H is hydraulic head (m)

Using this relationship, a capacity of around **160 kW** is proposed.

ESTIMATION OF THE HYDROPOWER PRODUCTION

The average flow going through the turbine is estimated to be around 1.5 m^3/s which gives a production of around **1 GWHrs/annum**.

3.1.3 Sustainability of micro-hydropower schemes

The development of micro-hydropower in Ethiopia does not have a good track record. The majority of schemes developed in the past have not been sustainable. In order for the proposed project to succeed it is important to both understand the reasons and address them. In a recent (2016) study, the GIZ, working with the Government of Ethiopia, assessed the role of micro-hydropower (MHP) in Ethiopia. Some of the key findings are presented and discussed in the following paragraphs.

The following general observations were made:

- 15 % of the overall hydropower **potential** is from unregulated river runoff usually in the category of pico, micro and mini hydropower plants. The total **potential** for micro hydropower (defined as having an installed capacity of < 500 kW) is estimated to be 100 MW.
- 85 % of Ethiopia's population is living in rural areas while only 10 out of 100 households have access to electricity. Much of this rural population is living in remote areas far from existing connections, but close to potential sources of micro-hydropower

The study looked in detail at four pilot MHP plants implemented in Sidama Zone (SNNPR) with the aim of learning lessons for future schemes. The key lessons learned include:

- There is a need for clearly identified roles and responsibilities among stakeholders.
- The principles, priority and objectives need to be clearly communicated to all stakeholders.
- There must be a clear and transparent concept for sustainable operation and maintenance cost-sharing mechanisms.

- The zonal and community stakeholders have to be involved from the beginning in the awareness raising.
- Off-grid opportunities should be main target

There were a number of lessons related specifically to the participating beneficiary communities. :

- There should be participation of the community in infrastructure and plant management, operation and maintenance
- Communities should be well-prepared, informed and organised and involved in the entire MHP process, from the idea until operation of the MHP scheme.
- There should be a significant contribution by the community, through labour and supply with raw locally-available materials should be considered to reduce the costs.

In conclusion,

- MHP schemes should be owned and operated by the rural community that benefit from electricity supply. This can be achieved in form of a cooperative management supported with different capacity building works (awareness raising, management training, financing and technical training for operators etc). This approach does not preclude sub-contracting technical aspects to the private sector
- Links between the cooperatives and other stakeholders (the Bureau of Water, Mines and Energy, cooperatives Office, administrators and companies who were involved in the construction) must be created
- The responsibility for repairs and maintenance must be clearly identified from the beginning.
- The use of appropriate technology should be maximised
- It is important to stress the need for the communities to see the MHP component as part of an integrated project which promotes the environmentally sustainable improvement of livelihoods. A healthy base flow depends on a healthy watershed and the generating of electricity for the community depends on a healthy baseflow.

3.1.4 Estimation of the costs

A study carried out by the International Renewable Energy Agency in 2012 - based on the review of numerous hydropower projects - shows that the total installed costs for small scale hydopower projects can be estimated around 4,000 USD/kW (including civil work).

Figure 3-5: Costs of proposed micro-hydropower scheme on Dunchaye River

Item	Details	Cost (USD)
Intake weir and setting basin	Concrete weir with low flow notch for environmental flows	50,000
Diverson channel	220 m long masonery or concrete canal (labour-based contruction)	50,000
Forebay tank	Masonary or concrete tank; 1.5 x 1.5m x 2m deep	25,000
Penstock	High pressure steel pipe	25,000
Power house with turbine and generator	Installed capacity, 160kW	490,000
	TOTAL	**640,000**

With a capacity of 160 kW, the investment cost is estimated at **640,000 USD.**

A second site visit had been planned for October 2016 but it was not possible to make for security reasons. One of the main purposes of the visit would have been to investigate the proposed hydropower site in more detail.

3.2 AQUACULTURE

3.2.1 Introduction

The Dunchaye area in Majang Zone is very suitable for capture fisheries and aquaculture as it is located at lower altitude and there is high temperature and good quality water, which are important factors for high fish production. Some members of the communities of Dunchaye Kebele practise capture fisheries in the tributaries of Gilo River are hence well positioned to practise fish farming.

Those individuals who had prior experience with fishing practices could be organized in cooperatives and provided with inputs (such as training, fishing gears and preparation of ponds, and management of the fishes and the ponds) so that they can make the most out of the fishing sector. The small scale ponds could be managed by the community provided that the necessary training is given and also the administration of the cooperatives is well organized. Implementation modalities

DESIGN OF THE PONDS

The size of each pond should be about 200 m^2 (a rectangular pond with length of 20 m and width of 10 m and a depth of 1.5 m). Such types of small ponds could easily be managed by the farmers and any possible epidemic on the fishes could easily be contained within that pond. The dykes on all sides of the ponds could be strengthened by plants/fruit trees on the embankments. The number of ponds would depend on the area available for the cooperative.

FERTILIZATION OF THE PONDS

The ponds could be integrated with the development of irrigation in which the waste from the fish could be used as fertilizers for the farm plots. The ponds will be earthen ponds being fertilized with agricultural by products. Cattle dung (100 g/m^2) or chicken manure (50 g/m^2) can be applied once every 2 weeks as fertilizers.

3.2.2 Production potential and sizing

Aquaculture yields vary according to the technology used. Thus, intensive tilapia farming attain yields that exceed 10 tons/ha; semi-intensive 3 to 5 tons/ha; and extensive farming in reservoirs produce less than 1.5 tons/ha. Since the ponds are earthen ponds, and the fishermen can use some supplementary feed, we can consider a semi intensive production of about 3 to 5 tons/ha/year. This is about 60-100 kg per 200m^2 pond/year (1 hectare is 10,000m^2 and 1 tonne is 1000 kg.).

There could be separate ponds for hatchery purposes, where parent stock could be kept and the fingerlings would be introduced into the nursery ponds.

Smaller ponds, usually with a size of about 100 m^2 and with a depth of 70-80 cm are most common for keeping the brood stock and serving as nursery pond to keep the hatched ones for sometimes. Two to three thousand 2-cm fry can be stocked in a 100 m^2 pond, for culture up to fingerling size (5 cm). The grow-out ponds can be stocked with a density of 2 fingerlings/m^2.

Fish farming will be associated with the development of irrigation and it is proposed to develop 20 ponds. The proposed location of the ponds is shown in Figure 3-7.

3.2.3 Costs and benefits

CONSTRUCTION COSTS OF A 200 M² POND WITH A DEPTH OF 1.5 M

The major cost is labour cost, which could be on the average (in that locality) about 1000 Birr (US$45) for about 10 m^2 area with a depth of 1.5 m. So, construction of a 200 m^2 pond may cost up to 20,000 Birr (US$ 900). Some pipes and plumbing works may be required for inlets and outlets of the water to and from the ponds but these will simple in design and construction.

Geo-membrane lining may be required if the soil is not clay and the pond cannot retain water. Geo-membrane lining can cost 50 Birr /m^2 (US$ 2.25) and the total would be about 10,000 Birr (US$455).

The anticipated cost to build 20 ponds is 32,000 USD.

TRAINING:

A one-week training course is required on how to manage the ponds and the fishes regularly; use of fishing gear; preparing supplementary feeds; etc. The training expenses could be estimated from the number of potential trainees and can be integrated in the enhancement measures proposed in the ESIA.

FISHING GEARS AND OTHER FACILITIES:

There is a need for beach seine nets to collect the fishes from the ponds and some other facilities such as collecting plastic jars; cold storage facility, etc. A 30- meters long beach-seine net may cost up to US$100.

MARKET:

It may be difficult to find appropriate market in and around the project area. A kg of fish (Nile tilapia) may be sold in the towns nearby the project area (e.g. Tepi, Meti) for 15 Birr. So the annual yield that could be obtained from a 200 m^2 pond (about 100 kg) could be sold for 1500 Birr (US$70).

3.3 IRRIGATION

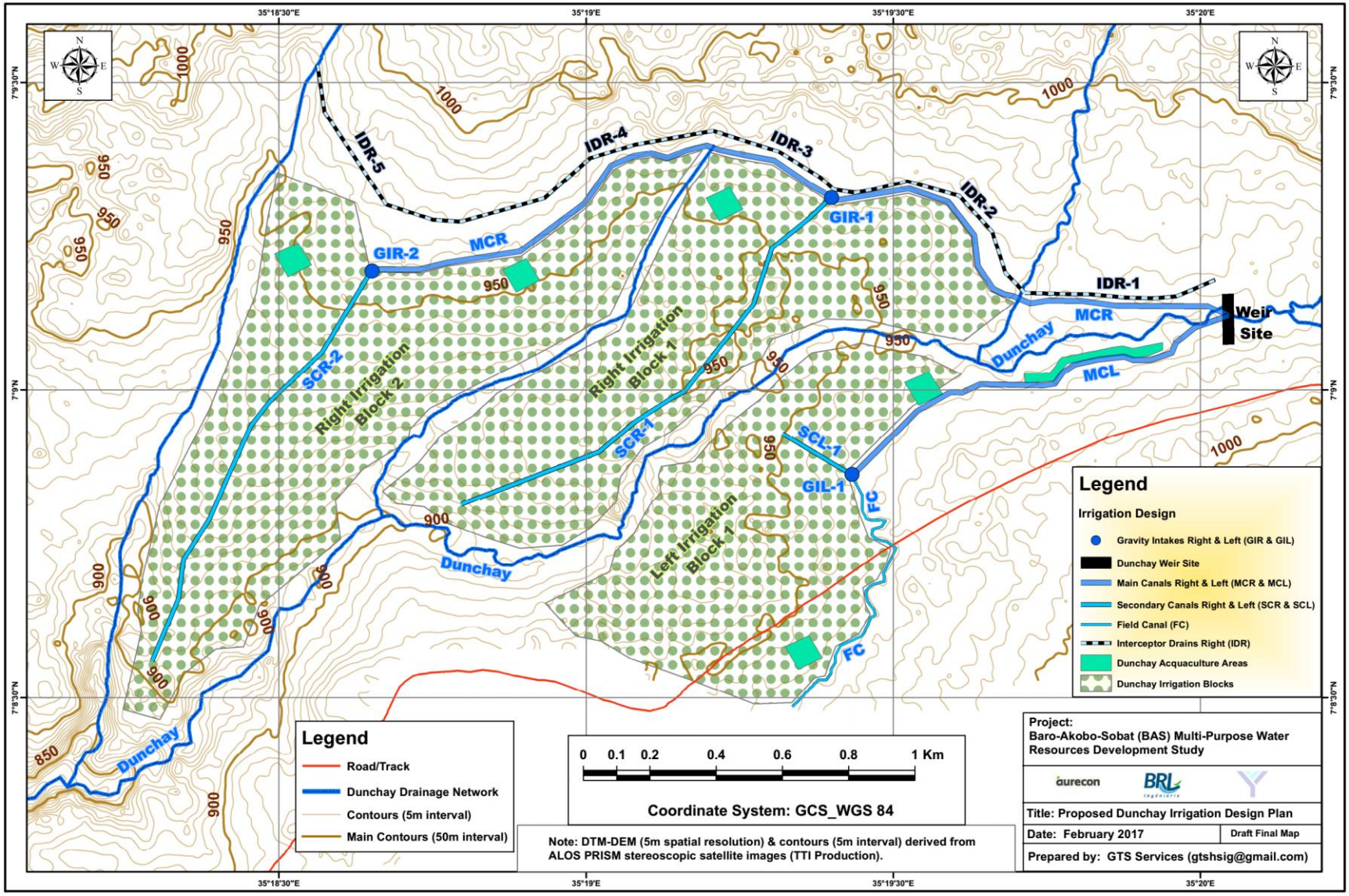
3.3.1 Project Description

Dunchaye Small Scale Irrigation (SSI) project is initiated as one of the short-term investment ready project and an integral part of an Integrated Water Resources Development and Management Plan (IWRDMP) under the BAS Multipurpose Water Resources Development Study Project.

The SSI project will involve the development of 220 ha of SSI schemes that would benefit 580 HH with 3900 people in the Dunchaye kebele in Godare Woreda of Gambella Peoples' National Regional State. The irrigation water for the scheme will be diverted from Dunchaye River by means of a diversion weir to be constructed across the river at the latitude 7º 9' 3.34'' N and longitude 35º 19'44.02'' E. The command area lies on both sides of the River 1 km downstream of the diversion headwork site between geographic coordinate of 7°7'36.45'' - 7°9′2.59″ N latitude and 35°17′54.64″- 35°19′19.61″ E longitude about 28 km South of Woreda and Zone town, Meti. The site is accessible from Tepi through 12 km dry weather road. Figure 3-6 shows the location and access to the project site.

Figure 3-6: Location and access to the proposed irrigation site

Figure 3-7: Dunchaye irrigation design plan (includes aquaculture ponds)



Based on the analysis of the topography and characteristics of water sources, the surface irrigation method, which is a gravity flow system distributing water at field level by free surface overland regime, was proposed. The irrigation system consists of the area to be irrigated (command area), diversion weir headwork, main, secondary, and field canal system. The diversion weir across the Dunchaye River will divert and control the river water and regulates the supplies into the main canals. The main canals taking off directly from the diversion weir are divided out into secondary canals before they reach the area to be irrigated. The secondary canals taking from the main canals supply water to the field canals. Field canals taking off directly from the secondary canals supply water through outlets to the irrigation fields. The field canals are smaller canals carrying discharge of less than 30l/s and supply water to the irrigation units. A surface drainage system would also be included and the system would discharge any excess flow from irrigation and storm water to the natural drainage creeks in the area. Figure 3-7 illustrates the main irrigation system's alignment.

This report presents summary of the current farming practices of the proposed project area, implementation modalities including cost summary for the proposed scheme. Details of the technical viability including outline design based on the identified resources are presented in Annex 2.

3.3.2 Selection of command area location and option for water abstraction method

Reports on previous investigations carried out in the locality were reviewed and contain relevant information and data on existing agricultural practices and land use that were supportive in the scheme planning.

Geo-referenced Topographic map of the area prepared at 1:50,000 scale from Ethiopian mapping Agency (EMA) in conjunction with 1m and 5 m contour interval from DTM-DEM derived from ALOS PRSIM stereoscopic high resolution satellite images (please see Annex 3 for detail) that covers the project area were used to assess the river course and the topography of the adjacent land to decide on the probable command area location and water abstraction method for the proposed irrigation scheme. The maps show roads, location of villages, existing land use pattern and the water source. The site and elevation of the off-take and the upper and lower elevations of the proposed irrigation site noted from the maps were substantiated by project site visit where physical observation of the existing land and water resources and consultation with the user community were conducted.

LOCATION OF COMMAND AREA

The Dunchaye River traverses the catchment from North-West to South East. The upper reach of Dunchaye River catchment is mountainous with high slope greater than 12% which is characterized by forests and rain fed agricultural production system for local consumption. The lower reach is sub mountainous with slope reaching up to 12% which is also characterized by wood land and rain fed agricultural production system for local consumption. The slope of the land decreases from high above 12% to 4% towards the Dunchaye River. To the west, it is crossed by several dry streams joining the Dunchaye River from the right and left. Therefore, the land adjacent to the Dunchaye River that is found on the right and left sides of the river in lower reach (please see Fig 3.1 above) between geographic coordinate of 7°7'36.45'' - 7°9′2.59″ N latitude and 35°17′54.64″- 35°19′19.61″ E longitude is selected as project command area for the irrigation due to:

- suitable topography for surface irrigation with slope less than 5%
- the fact that the area is under subsistence rainfed agriculture and appropriate for the development of farmers managed small scale irrigation.
- no requirement of land clearing
- closeness to the proposed diversion head work and hence short idle length of main canal and accessibility

METHOD OF WATER ABSTRACTION

The River is characterized by high banks, narrow section and steep gradient that make it suitable for location of gravity diversion head work. Longitudinal profile of Dunchaye River (please see Fig-3.3 below) was generated by using DTM-DEM derived from ALOS PRSIM stereoscopic high resolution satellite images (refer to Annex 3 for detail). The profile shows that the change in elevation between the source of the river (1,300 masl) and just upstream the confluence of the river with Gilo River (780 masl) along the river course is 520 m over a distance of about 15 km (average river bed slope of 3.5%). This is steep slope that need short idle length of only 1-1.5 km of the main canal to command sufficient land areas in the case of gravity diversion. Furthermore, gravity diversion structure across the Dunchaye River with short crest length and low height can raise the required water level on the upstream side to create the necessary head to divert the flow by gravity through the canal intake.

Therefore, for Dunchaye Small Scale Irrigation Project, gravity water diversion with Masonry weir/ concrete structure is preferred over other type of river diversion headwork due to the following factors:

- The river has well-defined boundaries with high banks and narrow river section and thus cost of construction of diversion weir structure is less
- The site is near the command area and hence the idle length of the main canal is small.
- Appropriateness of the technology to the level of operational capacity of the users (easiness of operation).

3.3.3 Implementation modalities

3.3.3.1 Scheme Execution and Coordination

The Ministry of Agriculture and Natural Resources Development (MoANRD) is the federal institution responsible for the promotion and development of Small Scale Irrigation (SSI). The responsibility for the study, design, and implementation of small scale irrigation has been delegated to the regional Bureau of Agriculture and Natural Resources Development in the case of Gambella region. The Bureau is also responsible for providing agricultural extension services and guidance to small–scale farmers on O&M of irrigation schemes. Subject matter specialists (SMSs) from the Bureau are deployed at the Woreda level and development agents (DAs) at kebele level to provide the required advisory services. There is also the Bureau of Cooperatives that assists grassroots farming communities to organize into different forms of cooperatives, including WUA, marketing cooperatives and even unions.

At the grassroots level, the user community organized into Water Users Association (WUA), mobilizes their members to participate in the operation and maintenance of small–scale irrigation. Upon completion of implementation, the scheme will be handed over to the WUAs, who will ensure day–to–day on–farm O&M of the scheme. Woreda Agricultural office will oversee O&M of the scheme by the WUA.

3.3.3.2 Institutional Arrangements

The Ministry of Agriculture and Natural Resources Development (MoANRD) will take overall responsibility for the project execution. A focal person will be assigned within the MoANRD to coordinate the activities of the scheme implementation. The coordinating entity will be the SSI Team of Natural Resources Development Directorate of the MoANRD. The focal person in the MoANRD will oversee the implementation, coordinate and liaise with other relevant federal level project-implementing units and ensure the submission of periodic reports regarding the scheme.

The scheme is at feasibility study level and requires detail design for implementation. The responsibility for the detail design work and implementation of the schemes lies with regional Agricultural and Natural Resources Development Bureau. However, there is a capacity limitation and technical assistance in the form of domestic consultancy service is required to support the efforts of Regional Bureau of Agriculture in the detail engineering design of the small–scale irrigation schemes. A cost provision for such service is built in the unit investment cost of the schemes. Moreover, based on the existing modalities, scheme construction shall be contracted out to local private contractor**.**

The user community will participate fully in the development of the scheme through WUA. They will be backed by the regional Agricultural Bureau and the Woreda Agricultural Development Office during the operation phase. In implementing the Scheme, the line structure of the MoANRD and Cooperative bureaus at the Regional, Zonal, Woreda and kebele level will participate.

3.3.4 Project Area and the Need for Irrigation

The climate of the project area is characterized by midland agro-ecological zones. The main rainy season in the area is from mid-April to October. The area receives mean annual rainfall of about 1592 mm. It has a single peak with a maximum value of 229 mm in August and average rainfall less than 100 mm that occurs from November to March. On average November, December, January, and February are the dry months whereas 82% of the rainfall occurs during April to October and 18% between November and February. The average maximum temperature is about 31^0 C in the months of January through March and Mean minimum temperature is about 15.44^0C, which occurs in the months of July to August. Estimated Potential Evapotranspiration (PET) is about 1372 mm per year with mean maximum monthly PET of 134 mm in the months of March and April and mean minimum monthly PET of 96.84 mm in the months of July and August. Though the area receives considerable rainfall, it is mostly seasonal and often erratic.

Agro-ecologically and topographically, the area is suitable for irrigated agriculture with sufficient land and water resources. According to the traditional agro-ecological classification, the area is categorized under sub-humid midland, which is suitable for the production of tropical and sub-tropical crops. The main economic base of the area is mixed farming, in which crops are produced and animals reared side-by-side. Crop production which is supplemented by traditional bee keeping and livestock production plays a leading role in the annual income. Despite its leading role, crop production is constrained by low agricultural productivity causing high vulnerability to weather-induced shocks.

More than 80% of the households in the area experience food shortage from February to June for about five months. More importantly, May is the most severe food shortage month where about 86% of households were reported to be food insecure. After such stressful months, food availability starts to recover in July (Socioeconomic Survey Report, 2008). Low subsistence level of the farmers and their small surplus lead to acute famine causing impoverishment and starvation in the dry season. Though the area receives considerable rainfall, it is seasonal and often erratic. About 82% of the annual rainfall occurs during month of April to October. There is little rainfall from November to March, but during the rest of the year it is abundant. Irrigation is necessary for successful agriculture in the dry season to extend the growing period and improve the yields of existing ones.

Thus, it is considered that irrigation can improve farmers' income through increased agricultural production and productivity as well as reduce ever-increasing deforestation caused by increased population in the area by increasing the productivity of a unit of land. Furthermore, irrigation plays an important role in combating the effects of erratic rainfall pattern and sustains production with efficient and effective use of the available resources.

3.3.5 Current farming Practice and Crop production

The current farming practices of the area are dominated by traditional crop farming mixed with beekeeping and livestock raring. People living in this kebele also produce coffee to smaller extent. The common farm practice is to grow the crops with limited access to improved agricultural technology and the farmers living in the area are among the most vulnerable to poverty.

Currently, the area has solely rain fed cereal production based cropping system where the main crops grown include, maize and sorghum. In most cases, farming is practised using hand tools and animals are rarely used for farming. The size of land holding of household living in the command area varies from 0.5 to 1.0 ha. In spite of the potential and the need, the level of control over, and access to, water resources for agricultural use is nonexistence and there is no irrigation development practice in the entire Kebele.

The yields of the crops are very low. Data from Zonal Agricultural Office for the production year of 2015/16 show that crop yields of about 1.76 tones/ha for maize and 0.84 tones /ha of sorghum. In contrast, yield of crops for private peasant holdings for Meher Season 2015/16 shows 3.387 tones/ha for maize and 2.331 tones/ha for sorghum (CSA, 2016). This shows that the staple crops, maize and sorghum yield in the project area are much lower than the national average for the same year. Low agricultural productivity can be attributed to limited access by smallholder farmers to agro-chemicals, financial services, improved production technologies, irrigation and agricultural markets as well as poor land preparation.

Table 3-1: National and actual average crop yield in Megeng Zone, Gambella (tonne/ha)

	Crop Type	**Total actual yield -1**	**National Average** (CSA, 2016) **-2**
	Maize	1.76	3.387
	Sorghum	0.84	2.331
1- Megeng Zone Agricultural Office (2016) *2-CSA 2016*			

3.3.6 Operation and Management

3.3.6.1 General

The user communities shall be encouraged to set up formal scheme level Water User Association (WUA) prior to the commencement of scheme construction phase for Operation and Management (O&M) of the newly developed irrigation facilities to achieve a sustainable irrigation scheme. Upon completion of the construction work, the scheme will be handed over to the WUA, who will ensure day–to–day on–farm O&M. Under the project, all–round support aimed at equipping the user communities with basic operation and maintenance skills for irrigation facilities will be initiated.

Once WUA formed, the district and local level Agricultural Offices shall put emphasis on awareness creation of the user communities so that they have knowledge of responsibility and general information of the facilities. The WUA will be backed by the Zonal and the Woreda Agricultural Development Offices during the operation and maintenance phase. DAs will play a critical role in this respect.

SAVING FOR MINOR AND PREVENTIVE MAINTENANCE

Fund saving by the user community shall be promoted through the Kebele, and District Agricultural, Cooperative and other relevant offices for minor and preventive maintenance.

SUPPORT TO WUA

The user community, organized into Water Users Associations (WUAs), will take overall responsibility for continuous functioning and maintenance of the facilities. Therefore, the project will support the community so that WUAs become a self-help organization. This will include training in mechanism of decision-making, operation, and maintenance of the schemes facilities, irrigation water, and crop management as well as rudimentary bookkeeping and management including roles and responsibilities of each actor. .

Accordingly, to strengthen the community's capacity to operate and maintain the facilities, the project will train the user communities and WUA committees' members to improve knowledge and skills of the user communities to influences their attitude and behaviour towards operation and management of the facilities. The DA of the project kebele adapts an awareness creation procedure, on scheme operation, money saving for minor and preventive maintenance, roles and responsibility including support to the WUAs .

3.3.6.2 Operation

Scheme Operation is one of the most important tasks of WUA to deliver irrigation water to the users. This includes timing, flow rate and duration of irrigation application based on the planned method for irrigation water distribution and irrigation planning and scheduling The aim is to deliver the right amount of water to the farmers at the right time for better revenue from production as well as attract the farmers for further effective works..

WATER DISTRIBUTION METHODS

The sources of water that would be used for the scheme is the Dunchaye River. Irrigation water supply for the scheme will be made available by gravity by constructing a diversion weir across the river. Proper water distributions network, best suited to topography was prepared to achieve optimum land and water use. This network preparation took into account the operation system, which will involve equitable distribution of water to all fields within a fixed time to meet the crop water requirement with least human intervention. Map drawn to a convenient scale showing detailed network system will be provided to the WUA; who are accountable for operation and maintenance. On this layout map, all the specific features will be indicated. Operation and maintenance manual, describing concise instruction for operation of the scheme, shall be prepared and provided to WUA, DA and District Agricultural Office during detail engineering design phase of the scheme for the day - to- day operation as well as for long-term activities.

SEASONAL IRRIGATION PLANNING

Irrigation planning involves making decisions on the cropping pattern and calendar for the coming irrigation season and making decisions on what crops to grow. The aim of irrigation planning is to describe the allocation and distribution of the available water supply to various interested groups. In the project there is no shortage of water, the base flow of the river is sufficient for the planned 220 ha of land on continues daily supply based on 10 hrs irrigation periods. As per the scheme water requirement analysis, daily maximum water demand for the entire scheme is only 26% (0.53 m^3/s) of the estimated minimum flow rate of (2 m^3/s) River Dunchaye .

IRRIGATION SCHEDULING

Irrigation scheduling is a prerequisite for timely supply of irrigation water and mandatory to obtain optimum yield. Both over and under irrigation will result in reduction of crop yield. Excess water on the other hand causes water logging. Therefore, it is necessary to assess the actual weekly crop water requirement in advance, considering the moisture depletion and sustained crop-growth and prepare a schedule of irrigation, for frequency of watering and quantum of water necessary. This will depend upon rainfall, crop development stage, soils, fertilizer, and climatic condition and crop factors. The schedule shall be communicated to all farmers so that they are ready to utilize the water efficiently. The schedule should match the water potential available. Generally, this is done at an interval of one week or multiple of weeks, to maintain the rotation water system.

3.3.6.3 Maintenance

Maintenance of these facilities can be done by the users community themselves or otherwise by skilled artisans, such as a mason or a carpenter. The user community could be organized in groups, which will be given training in routine maintenance and emergency works.

WUA committee members will then lay down rules and regulations for the utilization of the facilities to ensure order and proper utilization of the facilities. Under these committees, groups of farmers will be organized who will be oriented in the basic maintenance activities. These farmers groups will be responsible for the implementation of the regulations and maintenance of order during utilization of the facilities. As far as physical maintenance is concerned, the users are expected to contribute in terms of labour, local materials, as well as money where financial outlay is needed for skilled artisans. The WUA members will accomplish the task under the direct supervision of technical staff from the responsible public office in the case of major maintenance work associated with the headwork and maintenances of canal.

3.3.6.4 Monitoring and evaluation by line departments

District Agricultural Offices have an important role to play in providing technical support beyond the capacity of the WUA. The Agricultural Bureau will facilitate development of memorandum of understanding between district Agricultural Office and WUA outlining regulatory mechanism and the roles and responsibility of each actor.

Already, there exists a government policy, too, for village level organization to ensure the success of water resources point development efforts. Accordingly, monitoring and evaluation of the schemes will be strengthening, determining their method, such as frequency, monitoring index, and so on.

3.3.6.5 Identified Issues and Proposed Actions

The institutional capacity of the Agricultural Bureaus at the regional, zonal and Woreda levels is very limited in terms of trained work force. Moreover, the farmers are practicing agriculture without essential expertise on crop production. Hence, to redress this situation, capacity building should be given priority attention. This includes, providing different types of short–term training to various categories of personnel, including social workers, agronomist, irrigation technicians, and farmers. Hence, capacity building of the user communities and advisory service providers are vital to realize the objectives of the proposed SSI project. A cost provision for such service is included in the overall SSI project.

3.3.6.6 Cost Estimate

At current prices, the scheme would cost an estimated USD 1,403,000. This includes a provision of 15% of total baseline costs for physical and price contingencies, 10 percent of the baseline costs for capacity building and 10 percent of the baseline costs for detail engineering design of the scheme including construction supervision and other administrative costs. The cost estimate also includes cost for construction of access road to the site, which accounts for 38% of the overall total cost estimate. The cost estimates are based on the current rate of wage and unit cost of the materials in the project areas.

A summary of the costs is presented in Table 3-2 below.

Table 3-2: Summary of Costs for the Development of Dunchaye SSI

S/No	Item	Total Amount	
		(Birr)	USD
1	General Provision	**115,000**	5,077
2	Diversion headwork	**3,349,011**	147,859
3	Main Canal	**670,226**	29,590
4	Irrigation and Drainage system	**8,672,153**	382,876
4.1	Supply and installation of PN 4 PVC Pipe	*7,548,139*	333,251
4.2	Field canals	*935,424*	41,299
4.3	Drainage work	*188,590*	8,326
5	Canal intake Structures	**221,303**	9,770
6	Total before VAT	**13,027,694**	575,174
7	VAT (15%)	1,954,154	86,276
8	Total Including VAT	**14,981,848**	661,450
9	Detail Engineering Design & Construction supervision (10%)	1,498,184	66,145
10	Capacity Building (10%)	1,498,184	66,145
11	Price and Physical Contingency (15%)	2,247,277	99,217
12	**Total Irrigation and Drainage**	**20,225,495**	**892,957**
13	Access road construction to the project site	10,050,000	443,708
14	Total before VAT	1,507,500	66,556
15	Total Including VAT	11,557,500	510,264
16	**G. Total Irrigation and Road**	**31,782,995**	**1,403,222**

3.4 WATERSHED MANAGEMENT

3.4.1 Major Land Use Types and their Challenges

Dunchaye kebele is divided into four major land use types which include the following:

- Crop land (836 ha),
- Forest land (3,448 ha),
- Woodland (475 ha) and
- Grazing/grass land (28 ha)

The vast area of the kebele is mainly covered with forests including wood lands. The cultivated area is not significant compared to the forest land area coverage.

There are challenges affecting the natural forest due to encroachment made for cultivation by new settlements and investors. The cultivated fields in the watershed have some degree of land degradation due to traditional farming system that had been practiced by farmers in the past.

Part of the catchment is included in the Sheka biosphere reserve and the other part is included in the area under application for the Majang biosphere reserve (in preparation by MELCA Ethiopia). Biosphere reserves are subdivided into three major zones, namely Core, Buffer and Transitional where:

- The core is the densest and fully protected;
- The buffer zone is between the core and transitional zones and requires special care for protection and conservation and
- The transitional ones are used by the communities through conservation based livelihood intervention to sustain the natural forest environment.

Most of the economic interactions made by the communities residing in the forest for meeting their livelihood is in the transitional zone. Thus, this zone is the most affected in terms of degradation and require utmost attention for rehabilitation and conservation that would bring sustainable natural resources management.

Thus, Dunchaye watershed is predominantly covered with transitional forest zone that requires proper conservation and management due to the encroachment made for cultivation and other livelihood interventions worth mentioning such as bee keeping and fruit production.

3.4.2 Major livelihood potentials of the watershed

The non-timber forest products are the main source of livelihood and include honey, bush meat, wild edible plants, medicine, and coffee production (Tadesse and Feyera). Many cultivated or semi-cultivated plant species are grown in home gardens. These plant species include cereal crops (maize and sorghum), various root crops, fruit crops, and different tree species that are being used for different purposes. Some of these cultivated crops include banana, orange, lemon, mango, papaya, pineapple, coffee and others. Most of these crops/plants are the main source of livelihoods for many households in the kebele. The cultivation of these crops helps to minimize the pressure on natural forests and the improved productivity of the crops would benefit to the community (through the use of improved inputs and access to markets).

Bee keeping is the major source of income for the Dunchaye watershed community. This is due to the abundance of honeybee swarm, availability of honeybee flora, socio-economic value of honeybee, demand of honeybee product and experience of honey beekeeper in the areas. However, these potentials are still under exploited due to existence of constraints requiring immediate intervention, particularly on improved technology, knowledge and skills of beekeepers.

3.4.3 Needs and Potentials for Improved Livelihood of the Watershed Community

According to MELCA, the transitional areas of the biosphere reserves which are relatively degraded and with sparse density of forests require due attention for conservation and utilization by the local community through engagement in NTFPs (Non-Timber Forest Products) such as bee keeping/honey, fruits, and spices production that could economically sustain the local community and minimize pressure on the Core and Buffer areas of the forest.

Cultivated lands with slopes greater than 3% require physical soil and water conservation measures with integrated biological measures for reduction of soil erosion and improved agricultural production and productivity.

The experience of SLM (Soil and Land Management) project in the zone with emphasis on implementation of soil and water conservation and livelihood activities for improved agricultural productivity will complement the effort for overall management of the watershed.

3.4.4 Measures Recommended for Improved Livelihoods and Conservation in Dunchaye Watershed

Following the land use/land cover of the watershed as well as the approach for biosphere conservation and protection by MELCA, the following measures are recommended for improved livelihood of the watershed community. These measures will be implemented based on the needs and potentials of the respective land uses in the watershed.

3.4.4.1 Bee keeping

A study made on bee keeping in Majang (Shibru D., et al., 2016) shows that there is a huge potential in terms of production and market. However, this potential are still underexploited. Modern bee keeping technologies require training and demonstration with the targeted community members. In Dunchaye, an initial target of 50 households is proposed with two bee hives provided to each household.

The market price for honey is around 30 Birr/kg in the village and 45 Birr/kg in nearby market like Meti and Tepi. Traditional beehives are mostly managed by men who can climb in trees whereas modern beehives could also be managed by women by placing them on accessible ground surface. In terms of production, the intermediate/modern beehives have higher productivity where honey can be harvested 2-3 folds compared to honey produced from the traditional beehives.

Table 3-3: Costs associated with bee keeping development

Apiculture/bee keeping equipment	Unit	Unit Cost(USD)	Quantity	Total cost (USD)
Modern bee hives	No	25	100	2,500
Wax	Kg	1	50	50
Extractor	No	5	100	500
Casting mold	No	5	100	500
Total				**3,550**

3.4.4.2 Fruit production

Since there are various fruits being produced locally, it is important to improve and graft them for better production and meet market demand. Thus, it is important to produce seedlings of selected fruits with an intention of production at scale. The seedlings will be produced at a nursery site managed by technical experts from the Woreda Agriculture Office that have the experience of producing improved seedlings. Since the farmers in the watershed have the experience of planting fruits and other perennial crops in their homesteads, almost all farmers could plant 4-5 seedlings each.

Table 3-4: Costs associated with fruit production

Fruit seedlings production	Unit	Quantity	Unit cost(USD)	Total Cost (USD)
Mango	No	8,000	2	16,000
Avocado	No	7,000	2	14,000
Citrus	No	4,000	2.5	10,000
Banana	No	1,000	2	2,000
Total				**42,000**

3.4.4.3 Conservation and Rehabilitation of degraded areas

These measures will be implemented where there are significant human interventions for economic activities such as crop farming. These areas have some degree of soil erosion due to the soil erodibility and erosion. There are others areas as well with erosion hazards such as river banks and gullies where good structures such as gabion and rock check-dams are required. These activities are recommended based on the experiences of MELCA and Sustainable Livelihood Management Project of the Majang proposed biosphere project and Watershed management interventions respectively.

Table 3-5: Costs associated with soil and water conservation measures

Selected measures	Unit	Quantity	Work norm/Unit Price	PD requirement		Total (USD)
				Total PD	Cost per PD (USD)	
Soil conservation structures						
Soil bunds	Ha	400	250 PD/Ha	100,000	2	200,000
Stone faced soil bunds	Ha	200	250 PD/Ha	50,000	2	100,000
Loose rock check-dam	M3	2000	0.5 M3/PD	4000	2	8,000
Gabion check dams	M3	300	1PD/0.25M3	1200	2	2,400
Gully revegetation	Ha	5	500 PD/Ha	2500	2	5,000
Gully cut /fill /levelling and reshaping	M3	200	IPD/1 M3	200	2	400
Sub total						**315,800**

3.4.4.4 Reforestation with forest tree seedlings

Reforestation is proposed to be implemented in the transitional areas with focus on plantation of indigenous and multipurpose species which could be used for fodder/forage and conservation. These seedlings could be planted in 4-5 year time.

Table 3-6: Costs associated with reforestation measures

Forest development activities	Unit	Quantity	Unit cost (person/days)	Total PD	Unit cost (USD)	Total Cost
Tree Seedlings production	No	300,000	15 PD/1000 seedlings	4,500	2	9,000
Agroforestry seedlings production	No	50,000	15 PD/1000 seedlings	7,50	2	1,500
Pitting	No	350,000	1PD/15 pits	23,000	2	46,000
Planting seedlings	No	350,000	1PD/50 plants	7,000	2	14,000
Sub-total						**70,500**

3.4.4.5 Cross cutting activities

Additional costs related to the training of staff and targeted communities and to the purchase of tools are given in the tables hereafter.

Table 3-7: Costs associated with the training of staff and targeted communities on technical issues related to the proposed interventions

Trainings/ reviews	Number of participants	Number of days	Cost (USD)
Trainings			
Watershed training	30	7	6,000
Forestry and agro forestry training	30	3	3,000
Vegetable and fruit production training	25	3	3,000
SWC training	40	5	5,000
M&E training (results-based training)	30	3	3,000
Business skills planning and development training	40	3	3,500
Experience sharing			
Organizing experience sharing visits within the region	20	5	2,000
Total			**25,000**

Table 3-8: Costs for hand tools, survey equipment and planting materials to be used for soil and water conservation and reforestation

Materials list	Unit	Quantity	Unit price (USD)	Total Budget required (USD)
Hand tools and surveying materials				
Pick axe	No	1000	25	25,000
Spade hoe	No	500	25	12,500
Spade /shovel	No	500	30	15,000
Fork hoe	No	300	30	9,000
Rake	No	100	35	3,500
Wheel barrow	No	50	100	5,000
Watering can	No	150	35	5,250
Crow bar	No	300	50	15,000
Sledge hummer	No	100	40	4,000
Polythene bags for fruit seedlings	Roll	100	60	6,000
Polythene bags for tree seedlings	Roll	400	50	20,000
Chemical sprayers	No	20	80	1,600
Gabion meshes	Roll	1000	50	50,000
Sub-total				**171,850**
Surveying materials				
Line level	No	100	100	10,000
Nylon string	Roll	10	40	400
Poles	No	200	10	2,000
Compass	No	10	50	500
Clinometer	No	10	80	800
Sub total				**13,700**
Total				**185,550**

4. POTENTIAL ENVIRONMENTAL AND SOCIAL IMPACTS

4.1 INTRODUCTION

The objectives of identifying potential environmental and social issues are to:

- Describe the baseline (current state) of the environment and socioeconomics,
- Describe what will change with the Project from the current state (positive and negative impacts),
- Propose enhancement and mitigation measures.

The baseline situation is presented in section 2 of the report. The description of anticipated changes, enhancement and mitigation measures is included in section 4.3.

4.2 SOURCE OF INFORMATION

The approach and methodology used for acquisition of relevant data and information, prediction and evaluation of potential environmental and social impacts and development of mitigation and management plan for the Majang multipurpose project include the following:

- Review of relevant environmental policies, strategies, legislations and guidelines;
- Review of relevant previous studies in the region and relevant literature;
- Review of ESIA studies of similar projects in the region or similar environment;
- Secondary data collection from National, regional and levels below;
- Field investigation and consultations in Majang area;

4.3 IMPACTS OF THE PROPOSED MAJANG MULTIPURPOSE PROJECT

The expected positive and negative impacts of the project are summarized by sector in Table 4-1.

Table 4-1: Summary of environmental and Social impacts and proposed mitigation and enhancement measures

Impact Description	Proposed Mitigation & Enhancement Measures	Responsible Agency/ Organization	Cost (USD)
SMALL SCALE IRRIGATION			
***Positive Impacts* and Enhancement Measures**			
- *Increased food production of the beneficiaries* - *Reduced food insecurity;*	- Adopt well established farm management system; - Provide access to market; - Select suitable crops that have food as well as commercial value; - Promote consultation and participation of the targeted communities during the selection of crop type and seeds; - Ensure targeting food insecure households/vulnerable groups; - Provide training as how to schedule the farm products for subsistence and market purposes; - Provide training on balance diet; - Reduce product waste during the harvest; - Training of beneficiaries (producers/famers) by Farmers' Training Centers (FTC) on agronomy;	- Zone/woreda agriculture office/cooperative promotion offices; - Development Agents (DAs); - NGOs operating in communities.	Part of the project management cost 9,000 USD for training of beneficiaries.
- *Improved livelihood of the local community;* - *Direct and indirect employment opportunities.*	- Promote an economic use of the products; - Provide on-farm training about the selection of crop types and farm management for the targeted beneficiaries; - Involving women groups in the planning and implementation of project activities; - Training of beneficiaries (producers/famers) by Farmers' Training Centers (FTC) on agronomy; - Assist communities in establishing water users' associations (WUAs) for irrigation.	- Zone/woreda agriculture office/cooperative promotion offices. - Zone/woreda land administration and environment office. - Development Agents (DAs). - NGOs operating in communities.	*N/A*

Impact Description	Proposed Mitigation & Enhancement Measures	Responsible Agency/ Organization	Cost (USD)
Infrastructure development in the area such as improved access roads.	- Construction of access roads and ancillary facilities needs to be considered as part of the project component to enhance the benefit of the proposed multipurpose project. Timely maintenance of access roads by the responsible offices at zonal and woreda levels would enhance the benefit of the project.	- Rural road construction office at zonal and woreda level.	Part of their annual budget
Reduced women's workload.	- Involve women groups in the planning and implementation of project activities; - Creation of skills, development and training opportunities associated with the construction and operation of the irrigation component	- Zone/woreda land administration and environment office; - Development Agents (DAs); - NGOs operating in communities.	*N/A*
Negative Impacts of the Irrigation Component and Proposed Mitigation Measures			
Reduction of downstream river Flow	- Establish hydrological gauging station at the appropriate locations of the Dunchaye river and monitor the river flows on a regular basis (daily, over a full hydrological year); - Optimize abstraction and supply equipment to improve the water efficiency of the irrigation scheme and reduce water losses; - Optimize abstraction and supply rules to improve the water efficiency of the irrigation scheme and reduce water losses; - Define and preserve environmental flows at the abstraction point along the main water course, which cannot be less than the minimum flow occurred at the driest month; - Respect allocation rules all along the water course and ensure satisfying the downstream users water demand.	- Federal Ministry of Water, Irrigation and Energy (MoWIE) in collaboration with ENTRO, Environmental protection office at woreda level, project client	9,000 USD for purchasing hydrology measurement instruments
Increase in malaria and other water related diseases	- Avoid excess water in the irrigation field; - Drain out water holding spots; - Clear the irrigation channels and its shores to avoid weeds; - Maintain flow speed of water in the channel to more than 1 m/second; - Put boots while working in the irrigation field to prevent penetration of foot by the larvae of Schistosomiasis; - Provide mosquito nets for the people residing around the irrigation farm.	- Woreda health office in collaboration with project owners	45,000 USD for farm management and for the provision of mosquito nets

Impact Description	Proposed Mitigation & Enhancement Measures	Responsible Agency/ Organization	Cost (USD)
Forest degradation and loss of habitats and biodiversity	- Avoid expansion of irrigation farm into forested areas; - While clearing and preparation of irrigation field maintain some indigenous trees; - Plant indigenous trees along the road sides and canal sides; - Protect river buffer zones between the irrigation field and the river channel; - Plant compensation tree plantation in consultation with local environmental protection offices; - Conduct watershed management activities such as construction of terraces, soil bunds, tree plantation, etc.; - Support the establishment of Majang Forest Biosphere reserve; - Initiate biodiversity protection awareness campaign in the community and schools; - Promote traditional ways of forest protection; - Provide training on biodiversity protection for volunteers; - Introduce coffee bricks from coffee husk for energy/cooking; - Construct mini hydropower and provide electricity for the local community at subsidize rate to suppress use of fire wood; - Promote income generating activities related to forest products and support the establishment of cooperatives on spice production and marketing, bee-keeping and marketing and animal fattening. Include jobless youth in these organizations.	- MOEFCC, Environmental protection office at woreda level, project client, MELCA	Part of the budget allocated to livelihood based watershed management measures (see specific section)
Water and soil pollution	- Avoid use of herbicides, and promote hand-picking of weeds; - Minimize use of fertilizers and pesticides; - Collect drain water from the irrigation farm and treat before discharging into the environment or the downstream river system; - Establish water quality monitoring sites, take regular water samples and conduct water quality tests to monitor water pollution; - Ensure proper pesticides handling, application and management at farm fields and stores. - Provide training on application of pesticides and fertilizers to the beneficiaries (producers/farmers).	- Environmental protection office at woreda level, project client or project implementer, beneficiaries of the project, Water and energy office at zone and woreda level; - Development Agents; - Health extension workers; - Woreda health and water offices; - NGOs operating in communities.	1,800USD/year for water quality monitoring
Increased soil salinity	- Apply only required amount of water based on the crop water requirement. Avoid over use; - Test water and soil quality before applying; - Treat soil acidity with limestone;	- Irrigation management unit/implementers of the irrigation and agricultural office at woreda level	Part of the project operation cost

Impact Description	Proposed Mitigation & Enhancement Measures	Responsible Agency/ Organization	Cost (USD)
Improved access to the area	- Improved access to the area will also increase risk of poaching and illegal logging etc. - Impact on scared sites and heritage resources	- Irrigation management unit/implementers of the irrigation and agricultural office at woreda level	Part of the project operation cost
Economic displacement of people	- Economic displacement and impact on access to grazing areas that may be cut off by the irrigation scheme natural resources that may be lost	- Irrigation management unit/implementers of the irrigation and agricultural office at woreda level	Part of the project operation cost
Negative impact on bee keeping	- Introduce modern beehives and provide forage for the bees at the spot; - Avoid or minimize use of pesticides; - Avoid use of herbicides and pick weeds by hand.	- Irrigation management unit/beneficiaries; Agricultural Office of the Woreda; environmental protection office of the woreda,	Part of the budget allocated to livelihood based watershed management measures (see specific section)
Deteriorated sacred sites due to project activities.	- Ensure that sacred and cultural heritage sites are not affected by the scheme and its activities if any.	- Zone/woreda culture and tourism offices. - Zone/woreda environmental protection offices - Beneficiaries (producers/famers).	Part of the routine budget of each relevant office
MICROHYDROPOWER COMPONENT			
Positive Impacts and Enhancement Measures			
- *Improved electricity access and provision;* - *Improved job diversity;* - *Improved conditions for beekeeping (The proposed hydropower will promote beekeeping for the fact that electricity substitute wood for cooking, heating and lighting purposes. By doing so it will*	- Positive impacts of generating hydropower will be sustained through regular maintenance. A maintenance team, consisting in local beneficiaries, shall be trained on day to day management of the system. Subsidizing or reducing service charge of electricity below the cost of fire wood will enhance the positive impacts anticipated on the forest and biodiversity. Introducing energy saving lamps, electric stoves for cooking would also enhance the benefit to be obtained from the power generation.	- EEP, project owner/beneficiaries	

Impact Description	Proposed Mitigation & Enhancement Measures	Responsible Agency/ Organization	Cost (USD)
reduce burden of trees which serve as forage for bees); - *Improved health of the local people*			
- *Creation of opportunities to support socio-economic development and modernize the local economy through the provision of affordable and reliable energy;* - *Employment and skills development associated with the construction of project and associated infrastructure;* - *Act as catalyst for infrastructure development;* - *Improve local key services, such as health care, schools, government services, through the provision of affordable and reliable energy.*	- Give priority of electricity for communal social services such as health centres, schools, water supply, etc	- EEP, project owner/beneficiaries	Part of project maintenance cost
Negative Impacts of the Proposed Mini Hydropower and Proposed Mitigation Measures			
Forest degradation and loss of habitats and biodiversity.	- Plant indigenous tree species to compensate any loss of trees from the diversion canal construction line and powerhouse construction sites. Plant at least 15 tree seedlings for the removal of one mature tree; - Set-up subsidies to decrease electricity cost so that even poor family can opt to use electricity for cooking and lighting purposes rather than cutting trees for fire wood.	- MoEFCC, Environmental protection office at woreda level, project client, MELCA	Part of the budget allocated to livelihood based watershed management measures (see specific section)
AQUACULTURE DEVELOPMENT			
Positive Impacts and Enhancement Measures			

Impact Description	Proposed Mitigation & Enhancement Measures	Responsible Agency/ Organization	Cost (USD)
- *Improved food security;* - *Improved diversity and nutritive value of the food production (proteins and balanced diet);* - *Improved utilization of natural resources;* - *Diversification of local communities' livelihoods;* - *This project will be a pilot program to be used as a demonstration and to be replicated.* - Creation of skills development and training opportunities associated with the construction and operation of the aquaculture component.	- Providing training for the beneficiaries on pond construction, application of fertilizers, aeration of ponds and harvesting and storing of aquaculture products would enhance the above mentioned benefits of aquaculture farm. Creating access to credit and creating linkage with local and central markets would also promote sustainable production and improvement of the livelihood of the beneficiaries.	- Fishery and aquaculture development office, NGOs working in the area of aquaculture	Part of the budget allocated to livelihood based watershed management measures (see specific section)
Negative Impacts of Aquaculture Farm			
Pollution of the water course and groundwater	- Properly manage the drainage water that laden with fertilizers and other chemicals used in the process of aquaculture farming; - Collect and treat the drainage and monitor the water quality standard before discharging into the environment; - Recycle the water used in the fish ponds; - Avoid use of toxic and long-lasting chemicals.	- Project owners/beneficiaries; environmental protection office at woreda level; fishery and aquaculture development office	Part of the project operation cost
LIVELIHOOD BASED WATERSHED MANAGEMENT			
Positive Impacts			
- *Increased food availability through improved soil fertility and crop productivity.*	- Ensure active participation of communities in selecting watershed management activities to implement in the Dunchaye catchment. - Ensure that watershed management activities are developed within the context of the local key livelihood activities.	- Zone/woreda environmental protection office - Woreda water and energy offices. - Woreda agriculture office.	To be costed separately as a self-content project

Impact Description	Proposed Mitigation & Enhancement Measures	Responsible Agency/ Organization	Cost (USD)
- *Decreased soil/land degradation and sedimentation*		- DAs	
Soil and water conservation and Rehabilitation of degraded areas	- Construct physical soil and water conservation measures at cultivated lands with slopes greater than 3% for reduction of soil erosion and improved agricultural production and productivity. - Integrate physical soil and water conservation measures with biological measure such grassing, tree planting at the boundaries of the farm, etc. - Promote the experience of SLM (Soil and Land Management) project in the zone with emphasis on implementation of soil and water conservation and livelihood activities for improved agricultural productivity and for overall management of the watershed. - Control soil and water degradation ; - Improve productivity of land ; - Improve soil fertility, - Improve water quality - Stabilize river banks, - Conserve biodiversity of the area.	- Woreda level land use management and environmental protection office	Part of the budget allocated to livelihood based watershed management measures (see specific section)
Improve livelihood of the beneficiaries by promoting Bee keeping	- Introduce modern bee keeping technologies - Provide training and demonstration with the targeted community members. - Start with initial target of 50 households with two bee hives provided to each household, - Promote women to involve in managing modern beehives by placing them on accessible ground surface. - Create market access to the honey and its by-products	-	Part of the budget allocated to livelihood based watershed management measures (see specific section)
Reduce poverty and food shortage by promoting high quality of Fruit production	- Improve and graft existing fruit trees for better production and meet market demand. - Produce seedlings of selected fruits with an intention of production at scale. The seedlings can be produced at a nursery site managed by technical experts from the Woreda Agriculture Office that have the experience of producing improved seedlings. - Promote each farmer/household to plant 4-5 seedlings each.	- Woreda level land use management and environmental protection office and agricultural and horticulture offices at Zonal and woreda level	Part of the budget allocated to livelihood based watershed management measures (see specific section)

Impact Description	Proposed Mitigation & Enhancement Measures	Responsible Agency/ Organization	Cost (USD)
Reforestation with forest tree seedlings	- Maintain indigenous tree species in the area ; - Conserve soil and water of the area ; - Conserve biodiversity, - Contribute for carbon sequestration and control of climate change ;	- Woreda level land use management and environmental protection office and agricultural and horticulture offices at Zonal and woreda level	Part of the budget allocated to livelihood based watershed management measures (see specific section)
Cross cutting activities	- Conduct training of staff and targeted communities and purchase necessary tools to implement watershed management project	- As above	Part of the budget allocated to livelihood based watershed management measures (see specific section)
WATER SUPPLY AND SANITATION			
Positive Impacts and enhancement Measures			
- Improved access to safe and adequate water supply; *- Improved health status thereby reducing child mortality rate.*	- Ensure that households/communities with unsafe sources are priority beneficiaries of the scheme; - Ensure active participation of women groups in scheme site selection and realization.	- Woreda water and energy - Health extension workers. - NGOs operating in communities.	NA
CUMULATIVE IMPACT OF THE MULTIPURPOSE PROJECT			
Local development / Population increase / Demographic Change	- Give job opportunity for the local people; - Monitor illegal settlement and illegal clearance of forest by migrant people from other parts of the country; - Penalize those who illegally clear the forest; - Build the capacity of woreda level environmental protection offices.	Woreda administration; woreda level environmental protection office	NA
		Total Environmental Mitigation and Enhancement Cost	**108,000 USD**

4.4 CONCLUSION

The implementation of the proposed multipurpose project will provide alternative electricity for the community who otherwise depends on forest to satisfy fire wood demand. The development of irrigation, aquaculture and watershed management activities shall also sustain food production for the community, strengthening food security. These different project components will support the local economic development and reduce the dependence of the community on forest-related products (fire wood, charcoal, timber products, bush meat, etc), preventing further degradation of the forest ecosystem and enabling the establishment of the biosphere reserve. The identified adverse impacts (water and soil pollution, modification of the hydrological regime of surface and ground-water resources, increased sedimentation, people resettlement, etc) shall be genuinely mitigated by adapted construction and operation practices by the Contractor, as recommended in the table above.

5. COST-BENEFIT ANALYSIS

The cost-benefit analysis (CBA) determines **the financial and economic relevance of a project** (or programme) by evaluating the differential of costs and benefits between the situation with project and the situation without project (baseline scenario). In the current study, the CBA aims at assessing:

- The financial feasibility of the different activities (Hydropower, Irrigation & Aquaculture and Bee Keeping) (*i.e. Are the benefits higher than the costs? What is the payback period?)*
- The socio-economic relevance of the project (*i.e. Are the socio-economic indirect impacts positive? Do they justify the project?)*

Two analysis are conducted:

- **A financial analysis** which allows the assessment of the profitability of each activity in the investors' point of view. The analysis takes into account the financial costs and benefits, i.e. the investments and O&M costs and the revenues of the activity implemented (hydropower, irrigation & aquaculture, bee-keeping).
- **An economic analysis** which evaluates the viability of the projects from the society's point of view. This analysis takes into account the financial costs and benefits plus the externalities of the projects.

  An externality is a cost or benefit generated by an activity and that affects a party that did not choose to incur this cost or benefits (e.g. improvement of health for beneficiaries, indirect employment, etc.). It makes it possible to appreciate the relevance of the project for the society as a whole.

The following table presents the financial costs and benefits and the externalities of the project. All these costs and benefits have been evaluated in the CBA.

Table 5-1: Financial costs and benefits and externalities of the project

Benefits of the project	Costs of the project
Financial costs and benefits	
Revenue from electricity sales Revenue from irrigation Revenue from aquaculture Revenue from bee keeping	Investment costs O&M costs Mitigation costs
Externalities	
The avoided extra cost for electricity using the next best alternative energy source to hydroelectricity Value of avoided carbon emissions thanks to hydroelectricity Avoided deforestation thanks to hydroelectricity	Environmental externalities are internalized thanks to the implementation of mitigation measures

5.1 BENEFITS OF THE MAJANG MULTIPURPOSE PROJECT (DUNCHAYE PILOT)

Financial benefits and positive externalities are distinguished in order to carry out a financial analysis, distinct from the economic analysis.

- Financial benefits are monetary gains resulting directly from the project. These benefits are used to carry out the financial analysis.
- Positive externalities are indirect monetary and non-monetary benefits resulting from the project. Non-monetary positive externalities have been monetarized in order to carry out the economic analysis.

5.1.1 Financial benefits

The following benefits were identified:

HYDROPOWER

The estimation of electricity sales depends on the production of hydropower and the selling price of electricity. For a price of 0.1 USD/kWHrs and a production of 1 GWHrs/annum, electricity sales are estimated to be around 100,000 USD.

The benefits generated from electricity sales have been included in the sensitivity analysis (selling price of hydropower varies from -20% to +20%).

IRRIGATION

Current yields in Dunchaye catchment are quite low. It is anticipated that irrigation development will be complemented by an improved access to quality seeds which should result in a significant increase of the yields.

Selling price of the crops has been determined in accordance with the values used in the economic model of the Baro-Akobo-Sobat IWRDMP. Yields have been defined according to the values reported on the FAO country portal website. Irrigation benefits are presented in Table 5-2 below. This excludes operation and maintenance costs associated to irrigation (are included in the analysis).

Table 5-2: Yields and benefits associated to the development of irrigation

Crop	Wet season	Dry Season	yield (T/Ha)	Production (T/Year)	Selling price (USD/T)	Selling price of the production USD
	Area (%)	Area (%)				
Maize	38	40	3.4	583	215	125,000
Sorghum	30	31	2.3	309	230	71,000
Potato	9	13	13.7	663	343	227,000
Soybean	3	6	2	40	343	14,000
Dry beans	7	0	1.5	23	100	2,500
Banana	1	1	8.9	39	229	9,000
Avocado	2	2	3.9	34	229	8,000
Vegetables	0	5	3	33	197	6,500
Cropping intensity	90	98				**463,000**
Overall cropping intensity	188					

The benefits generated from the development of irrigation have been included in the sensitivity analysis (benefits vary from -20% to +20%).

AQUACULTURE

The net value of production associated with the development of aquaculture depends on the productivity of the ponds and the wholesale price of fish. A productivity of 100 kg fish/pond/year and a selling price of fish of 0.7 USD per kg gives a net value of production of 1,120 USD for 20 ponds.

The benefits generated from the development of aquaculture have been included in the sensitivity analysis (benefits vary from -20% to +20%).

WATERSHED MANAGEMENT

There will be direct financial benefits with the implementation of livelihood based watershed management activities. These benefits will be for the following activities:

Beekeeping

The beekeeping activity could generate up to 5,400 USD considering the following assumptions:

- 100 modern beehives will be implemented,
- The selling price of honey in Meti/Tepi market could be up to 45 Birrs/kg,

- The production of honey could be up to 30 kg of honey per beehive.

FRUIT SEEDLINGS AND PRODUCTION OF AGROFORESTRY PRODUCTS

This activity could generate significant benefits from the 10th year of implementation of the project (time for the trees to achieve maturity).

- Fruit production could generate up to 210,000 USD/annum for 70 Tons of fruits produced (selling price estimated to be around 3 USD per kilo)
- Agro-forestry products could generate up to 320,000 USD/annum for an area of 40 ha (benefits could be up to 8,000 USD per hectare).

5.1.2 Positive externalities

The positive externalities of the project are the following:

- The avoided cost of next best alternative energy source (fuel)
- The value of avoided carbon emissions thanks to hydroelectricity
- The value of avoided deforestation thanks to hydroelectricity

These externalities have been estimated with the **avoided costs method**. This method assumes that the costs of avoiding damages, health issues, pollution, ecosystem losses, etc. is a useful estimate of the positive externalities provided by the different project components.

The working assumption is that hydropower will provide energy which would otherwise be provided by fuel (50%) and charcoal (50%).

5.2 COSTS OF THE MAJANG MULTIPURPOSE PROJECT

Investment, operating and maintenance costs were calculated for the Ducnahye Pilot and this was used as a baiss for estimating the cost of the total Majang project as summarized in the following table:

Table 5-3: Investments and operation and maintenance costs for Dunchaye Pilot and overall Majang Project

Component	Dunchaye Pilot Project		Overall Majang Project	
	Investment costs (USD)	Operation and maintenance costs	Investment costs (USD)	Operation and maintenance costs
Hydropower	640,000	25,000	2,560,000	100,000
Irrigation (includes road access)	1,400,000	200,000	5,600,000	800,000
Aquaculture	32,000	-	128,000	-
Watershed management	640,000	-	2,560,000	-
ESIA- mitigation and enhancement costs	108,000	-	432,000	-
Total	**2,820,000**	**225,000**	**11,280,000**	**900,000**

The costs, as calculated for the Dunchaye pilot , have been taken forward to the cost-benefit analysis.

5.3 MAIN RESULTS OF THE COST-BENEFIT ANALYSIS (DUNCHAYE PILOT)

The following assumptions are made for the analysis:

- The **discount rate is 6 %.**
- Investment costs are covered by a loan and the **interest rate of the loan is 4% (current rates in Ethiopia).**
- The **repayment period of the loan is 20 years** and the repayment only starts the 5th year of the project.
- There are no benefits or positive externalities the two first years of the project (time for implementation of the components).
- Two main loans are contracted:
  - 1 loan for the hydropower component contracted by the company who will operate the hydropower production
  - 1 loan for irrigation, aquaculture and livelihood based watershed management activities contracted by the company who will operate the schemes and the ponds. For the cost-benefits analysis, it is assumed that the operator will be the same for the three activities.
  -

ECONOMIC PROFITABILITY OF THE PROJECT

The main results with the above assumptions for the economic analysis of the project are presented in Table 5-4 below.

Table 5-4: Indicators of the economic profitability of the project

Economic profitability of the project	
IRR	58%
NPV	3 000 000 USD
Benefits/Costs	1.74
Payback period	5 years

The economic analysis takes into account the financial benefits but also the externalities of the project. As it can be seen in the table, the project has an Internal Rate of Return (IRR) of 58% and a Net Present Value (NPV) of around 3 000 000 USD. This fully justifies the project.

FINANCIAL PROFITABILITY OF THE PROJECT

The main results with the above assumptions for the financial analysis of the project are presented in Table 5-5 below.

Table 5-5: Indicators of the financial profitability of the project

Hydropower – financial analysis	
IRR	176%
NPV	390 000 USD
Benefits/Costs	1.54
Payback period (years)	3
Irrigation and aquaculture – financial analysis	
IRR	38%
NPV	1 300 000 USD
Benefits/Costs	1.46
Payback period (years)	8
Bee-keeping – financial analysis	
IRR	68%
NPV	30 000 USD
Benefits/Costs	9.40
Payback period (years)	3
Fruits and agroforestry production - financial analysis	
IRR	17%
NPV	2 500 000 USD
Benefits/Costs	2.40
Payback period (years)	15

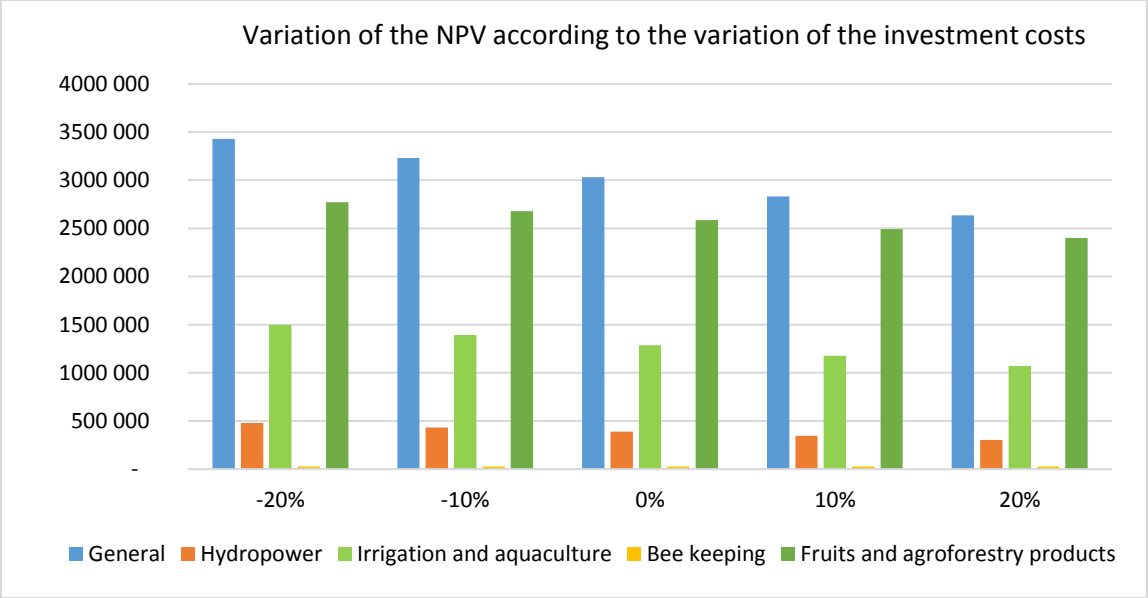
5.4 SENSITIVITY ANALYSIS

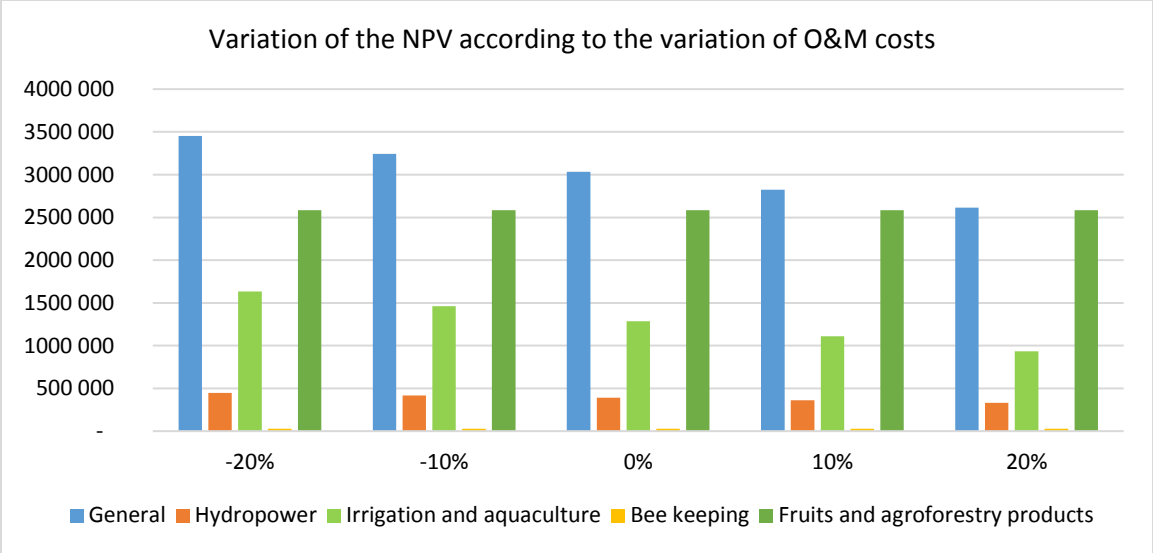
A sensitivity analysis was carried out to estimate the variation of the NPV in response to the uncertainty of different factors such as:

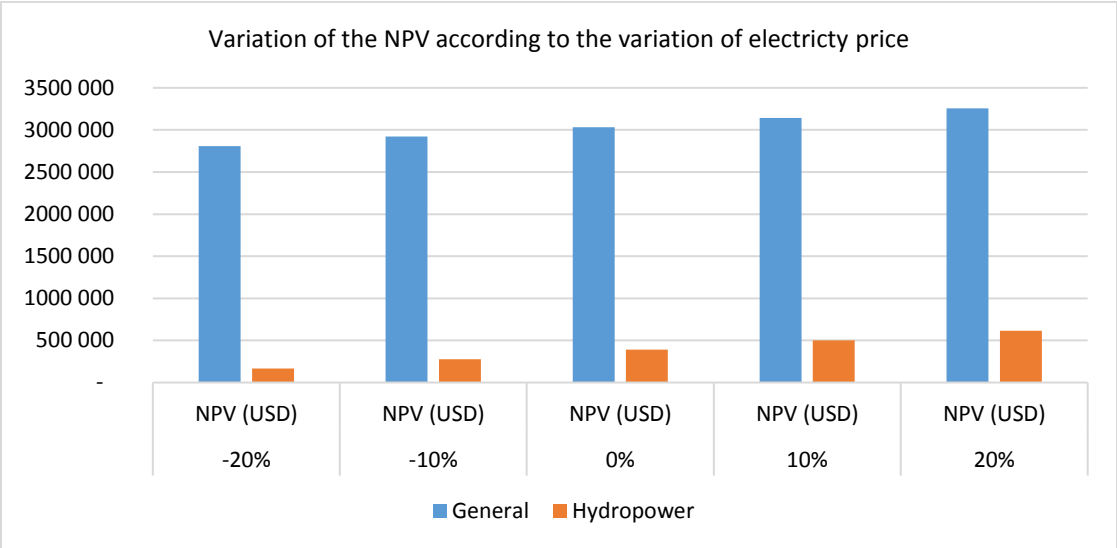
- Uncertainty regarding the investments costs, operation and maintenance costs, electricity selling price and crops selling price,
- Uncertainty regarding the loan, the interest rate and the possibility of a grant.

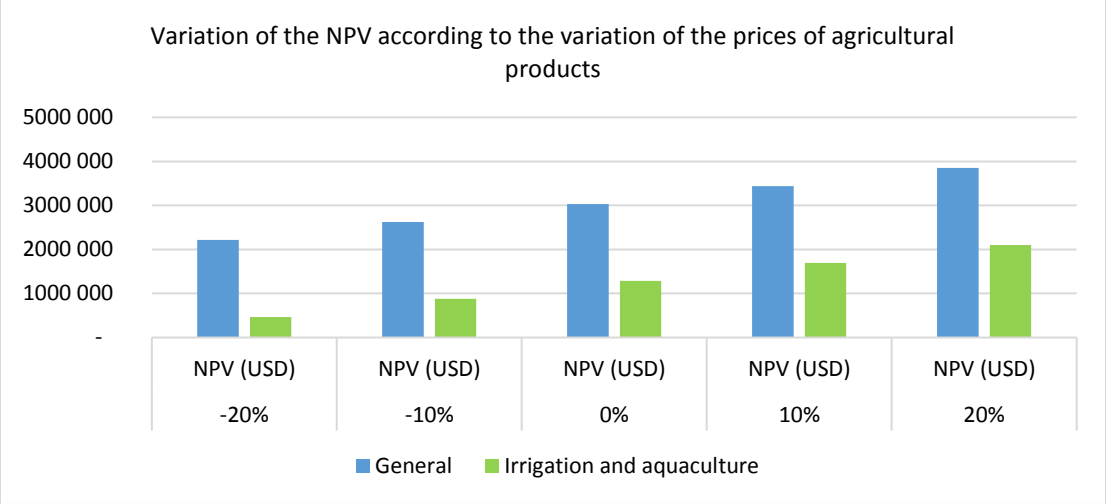
The main results are featured in Figure 5-1 below and highlight that the project is robust. **Considering that the project is feasible and profitable when the NPV is positive, then, there is no combination where the project is not profitable.**

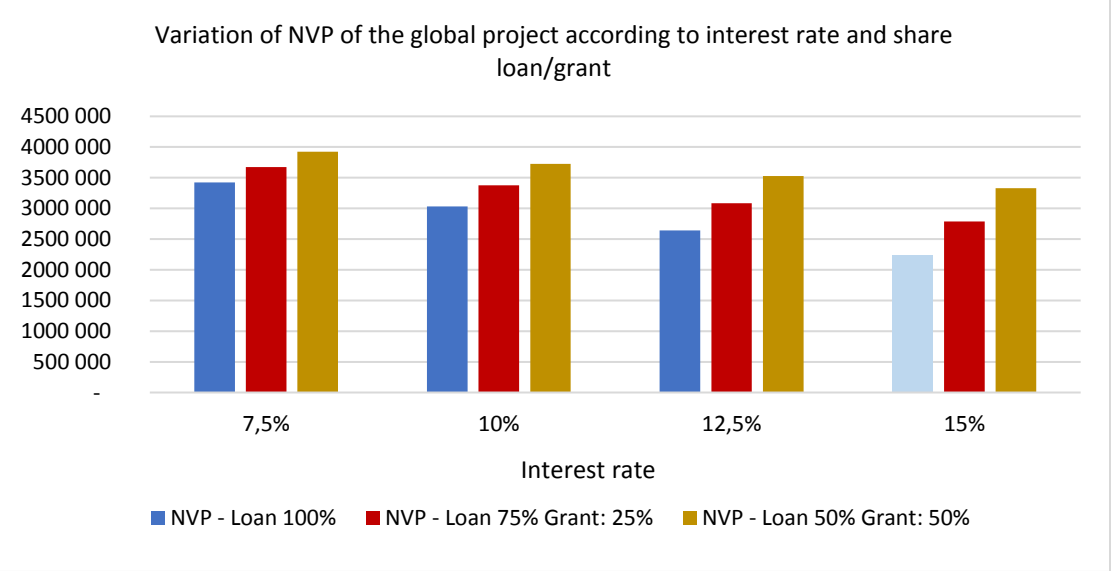
Figure 5-1: main results of the sensitivity analysis






Variation of the NPV according to the variation of electricty price
3500 000
3000 000
2500 000
2000 000
1500 000
1000 000
500 000
-
NPV (USD) -20%
NPV (USD) -10%
NPV (USD) 0%
NPV (USD) 10%
NPV (USD) 20%
General
Hydropower


Variation of the NPV according to the variation of the prices of agricultural products
5000 000
4000 000
3000 000
2000 000
1000 000
-
NPV (USD) -20%
NPV (USD) -10%
NPV (USD) 0%
NPV (USD) 10%
NPV (USD) 20%
General
Irrigation and aquaculture


Variation of NVP of the global project according to interest rate and share loan/grant
4500 000
4000 000
3500 000
3000 000
2500 000
2000 000
1500 000
1000 000
500 000
-
7,5%
10%
12,5%
15%
Interest rate
NVP - Loan 100%
NVP - Loan 75% Grant: 25%
NVP - Loan 50% Grant: 50%

6. CONCLUSIONS AND RECOMMENDATIONS

The proposed pilot project has been shown to be feasible and would meet some major needs in the Dunchaye and surrounding area. Most significantly, access to electricity will result in numerous direct and indirect social and economic benefits. The proposed irrigation scheme will also provide a much greater level of food security and will create significant levels of income for a large number of households. The availability of electricity will support the development of value added activities. The cost of the pilot project is 2,820,000 USD, and the overall Majang project is estimated at 11,280,000 USD.

An important need in terms of supporting the project is improved access. An all-weather road as far as the hydropower site and the irrigation command areas is critical. This will provide access to market as well as other services. Most of the kebele is also not covered by the mobile phone network so this issue will also need to be addressed.

The proposed project can serve as an excellent demonstration of multipurpose IWRM applied at the small scale with direct and sustainable socio-economic and livelihood benefits for the communities. There are opportunities for replicability through experience sharing and this should be a clear strategic action of the overall IWRDMPlan.

There are opportunities to increase the economic feasibility of the proposed project through agro-processing and other value-added activities. It would also be possible to intensify aquaculture production and increase yields significantly. There are opportunities for ecotourism as well and these would add to the feasibility of the proposed project.

It is important to stress that the economic viability of the project depends on it being possible to implement in its full multipurpose nature. This will require a multi-sectoral approach with a high level of cooperation from the various institutions at the woreda level.

As indicated earlier in the report, it was not possible to make a second site visit to the project area because of security issues. It was also not possible to hold more discussions with stakeholders. This has resulted in some assumptions and areas of uncertainty which should be investigated before final site selection and proceeding to design:

- There is no information on peak floods in the basin. Values have been based on experience in other studies and from other observations. A detailed reconnaissance on the ground will inform this aspect.
- One of the purposes of the proposed visit had been to look in detail at the proposed hydropower site. It may be possible to exploit a greater operating head than has been assumed.
- As part of the design process it will be important to discuss the detailed plans with stakeholders in order to ensure their buy-in.

The project will play a major role in contributing towards resilience to climate variability and climate change. In the Dunchaye and other identified Majang catchments, just as in large areas of the sub-basin's highlands, there is an urgent need to i) properly mainstream the potential impacts of climate change into the planning process and ii) pursue an aggressive programme of implementation of resilience building measures. The solutions are not only technical. There is an urgent need to engage with the communities and to introduce improved farming practices and other measures to support improved livelihoods. Once achieved at the micro-catchment level, bearing in mind that it is these micro-catchments that are the sources of the large rivers of the BAS sub-basin, scaling up basinwide will maximize resilience to climate change both basin-wide and at all levels.

ANNEXES

Annex 1: Bibliography

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Annex 2: Dunchaye Irrigation and drainage project

1. INTRODUCTION

1.1 OUTLINE OF THE IRRIGATION PLAN

The Proposed Irrigation system consists of the Diversion weir headwork, the main, secondary and field canals and 220ha command area. The water source is the Dunchay River located at latitude 70 9' 3.34'' N and longitude 350 19'44.02'' E in Dunchay Kebele Administration. The river takes off from Chambey mountain range 10 km north of the diversion site and finally join the Gillo River in the upper reaches as right bank tributary. The command area lies on both sides of the River 1 km downstream of the diversion headwork site between geographic coordinate of 7°7'36.45'' - 7°9′2.59″ N latitude and 35°17′54.64″-35°19′19.61″ E longitude about 28 km South of Woreda and Zone town, Meti. The site is accessible from Tapi through 12km dry weather road.

Diversion weir with vertical drop is proposed to ensure a regulated constant and continous flow of water supply into the main canals. The proposed weir type is broad crested, which has a length of 30m and a height of 1.00 meter with 1.5m top width and 3m bottom width. Two irrigation head regulators and two under sluice would be provided for the diversion headwork, one intake together with under sluice on each bank. The capacities of the intake structure are 0.42m3/s and 0.11 m3.s for right and left main canals respectively. The right bank intake would serve 173.66 ha on the right bank and the left intake would serve 46.36ha on the left bank. The diversion site is located at the upper reach of the river where bed and bank erosions are less of a problem and the bed consists of a mixture of boulders and gravel with course sand.

1.2 OBJECTIVES OF THE PROJECT

The goal of the project is to reduce poverty, Improve food security and livelihood of the user communities in the project area. The primary objective of the proposed irrigation scheme would be to develop 220ha of small-scale irrigation to produce cash and food crops for local self-sufficiency that would benefit 580 HH with 3900 people in the Dunchay Kebele administration of Godare district.

1.3 OBJECTIVE OF THE REPORT

The present report relates to the feasibility level study conducted to provide an assessment of the technical, viability of the proposed Dunchay Small Scale Irrigation Scheme.

2. IRRIGATION SYSTEM PLANNING

2.1 SELECTED METHOD OF IRRIGATION

The planned small-scale irrigation system uses surface irrigation method, which is gravity flow system, distributing water at field level by free surface overland regime. The selected field irrigation methods are furrow and border strip to spread water as uniformly as possible in the soil to irrigate the crops. The choice between the two irrigation methods is governed by the prevailing topographic conditions of the farmland.

Furrow irrigation has been selected for land slope less than 3% while border strip method is selected for land slope between 3%-5%. Furrows on ground slope less than 2% are aligned down the main slope. Whereas, cross furrows alignments are set for ground slope greater than 2% and less than 3%,. only border strips method is recommended for ground slope between 3% - 5%. Both methods are supplied with irrigation water from a head field canal. A field drains channels at the end of the run collects water to dispose. Plastic or aluminum siphon pipes are the best way of taking out water from the head field/tertiary canal.

2.2 OPERATION PERIOD

The operation period is daily operation hours of the system that the irrigation system is designed to operate. The most common practice, which is followed in public run medium and large scale irrigation schemes, is to operate the system for 24 hours a day. But, where the schemes are farmers managed, irrigation water is generally supplied to the fields through operation of subsidiary system on 10-12hour per day basis, thus stopping all irrigation operations during nighttime. Implications of providing 10-12 hours irrigation or less hours of daily operation against 24- hour irrigation is cost variation in the implementation of the project. The design of canals to run for 24 hours would decrease their capacities, and no additional cost would be required owing to earthwork, structuresof the canals. However, there could be a possibility that cultivators in the project might be reluctant to do irrigation during nighttime. In such a case, there would be a possibility of damage to water conveyance system and water wastage during nighttime, unless the system is kept closed during nighttime. Thus, based on the similar inference drawn from various other areas in the country, irrigation arrangement for 10 -hour continuous operation during daytime has been adopted in this project instead of operating it continuously for 24hours.

3. IRRIGATION WATER REQUIREMENTS

3.1 GENERAL

Knowledge of the rate of water use by crops is fundamental in the design of the water supply and scheduling of irrigation system. The rate of water use by plant is largely influenced by proposed cropping pattern, crop calendar, assumed scheme efficiency, and planted areas. The pattern of crop water use, allowing for rainfall and operational losses, determine the flow capacity of the water delivery system.

3.2 CROPPING PATTERNS & CALENDAR

The Project is planned for cultivation of cereals, vegetables, and perennials crops in the entire command area by considering the agro climatic zone of the area, farmers' preference, and market opportunity. Possible cropping patterns also have been proposed with 198% annual cropping intensity in two growing seasons. Thus, the proposed intensity of crops will be 90% in the wet and 98% in the dry season. Therefore, the crop water requirement has been calculated for the entire crops. Accordingly, two growing seasons have been assumed, for crop water requirement calculation based on the calculated values of ET_O and Kc and overall irrigation efficiency of 50%. Adapted cropping pattern and calendar is presented in Table2 below.

Table 1:- Copping Pattern Data

No	Crop	Wet season	Dry Season
		Area (%)	Area (%)
1	Maize	38	40
2	Sorghum	30	31
3	Potato	9	13
4	Soybean	3	6
5	Dry beans	7	0
6	Banana	1	1
7	Avocado	2	2
8	Vegetables	0	5
	Cropping Intensity	90	98
	Overall cropping intensity		188

3.3 CROP WATER REQUIREMENT

The crop water requirement for proposed cropping pattern was calculated by using the climatic data from nearest station, Tapi, which is 12 km from the project site with similar agro ecological zone. This has been calculated in accordance with FAO Cropwat 8.0 Program for Windows that uses the FAO (1992) Penman-Monteith methods for calculating reference crop evapotranspiration. Evapotranspiration (ETc) for crop was computed by multiplying ETO by crop factor (Kc), which varies according to stage of crop growth. For the project-cropping pattern, a calendar of sowing dates to harvesting dates was prepared for each type of crop. Crop water requirement in mm was computed on monthly basis. For crops grown in wet season, possible effective rainfall contribution in each month was worked out by using 80% dependable rainfall with above-mentioned CropWat software programme. Effective rainfall contribution was then deducted from gross crop water requirement to get net crop water requirement for each month at the field level. Table 2 below presents monthly crop water requirements as calculated by CropWat 8 window version 4.3

SCHEME WATER REQUIREMENT AND CANAL CAPACITY

The peak discharge requirement (design discharge) for the canals was calculated on the basis of peak crop water requirement ET_C, which was based on the values of potential evapotranspiration (ET_O) & peak value of crop co-efficient (KC). This was calculated and the summery is presented in the Table 2. The table presents monthly water requirements and rate of water flow for 10hr and 24-hour daily operation of the system. Accordingly, maximum water requirement is for the month of January, which is 2.2l/sec/ha for the 10 hours daily operation. However, for planning purpose the peak was taken as 2.4 l/sec/ha with flexibility factor of 10% in the canal. Thus, the design discharge is taken as .0.42 m^3/s .at the head of the right main canal and 0.11m^3/s at the head of left main canal. This canal capacity can take of 10% variation in future irrigation planning that might be necessary at the time of construction or later.

Table 2:-Irrigation Water Requirement

Precipitation	36.15	25.53	99.85	150.73	213.68	188.73	208.58	229.4	196.98	122.35	75.40	44.53	1591.9
Field water requirement (mm)													
Wet Season													
Maize	0	0	0	0	0	0	0	0	0	0	0	0	0
sorghum	0	0	0	0	0	0	0	0	0	0	0	0	0
Potato	0	0	0	0	0	0	0	0	0	0	0	0	0
Soybean	0	0	0	0	0	0	0	0	0	0	0	0	0
Dry beans	0	0	0	0	0	0	0	0	0	0	0	0	0
Subtotal for wet season	-	-	-	-	0	0	0	0	0	0	-	-	0.00
Dry Season													
Banana	1.3	1.41	0.89	0.00	0.00	0.00	0.00	0.00	0.00	0.28	0.74	1.10	5.76
Avocado	2.8	2.77	2.00	0.89	0.00	0.00	0.00	0.00	0.07	1.41	2.07	2.50	14.45
Maize	58.3	42.72	1.04	0.00	0.00	0.00	0.00	0.00	0.00	0.00	3.16	40.32	145.56
Sorghum	37.4	32.49	2.51	0.00	0.00	0.00	0.00	0.00	0.00	0.00	2.05	25.85	100.25
Potato	17.7	16.87	3.33	0.00	0.00	0.00	0.00	0.00	0.00	0.00	2.87	12.61	53.42
Vegetables	4.1	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.67	2.82	5.46	13.07
Soybean	3.1	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.07	3.32	7.41	13.85
Subtotal for Dry season	124.7	96.3	9.8	0.9	0.0	0.0	0.0	0.0	0.1	2.4	17.0	95.2	346.4
Net scheme irrigation req.													
in mm/day	4	3.4	0.3	0	0	0	0	0	0	0.1	0.6	3.1	
in mm/month	124.7	96.2	9.8	0.9	0	0	0	0	0.1	2.4	17	95.3	346.4
in l/s/h	0.46	0.39	0.04	0	0	0	0	0	0	0.01	0.07	0.36	
Irrigated area (%)	98	87	87	2	0	0	0	0	2	14	98	98	
Gross Irrigation Water Requirement at 50% irrigation efficiency, including field, distribution and conveyance losses and waste.													
in mm/day	8.0	6.8	0.6	0.0	0.0	0.0	0.0	0.0	0.0	0.2	1.2	6.2	
in mm/month	249.40	192.40	19.60	1.80	0.00	0.00	0.00	0.00	0.20	4.80	34.00	190.60	692.80
in l/s/h/24 hr	0.93	0.87	0.08	0.00	0.00	0.00	0.00	0.00	0.00	0.03	0.15	0.80	
in l/s/h/10 hr	2.2	1.7	0.2	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.3	1.6	
Flexibility factor (10 %)	2.4	1.9	0.2	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.3	1.8	

4. WATER DELIVERY SYSTEM

4.1 IRRIGATION SYSTEM COMPONENTS

The irrigation system consists of the area to be irrigated (command area), diversion weir headwork, main, secondary, and field canal system. The diversion weir across the Dunchay River will divert and control the river water and regulates the supplies into the main canals. The main canals off taking directly from the river divided out into secondary canals before it reaches the area, which it is to irrigate. The secondary canals off taking from the main canals supply water to the field canals. The field canals are smaller canals carrying discharge of less than 30l/s and supply water to the irrigation units. A surface drainage system would also be included and the system would discharge any excess flow from irrigation and storm water to the natural drainage creeks in the area.

4.2 PROJECT TOTAL COMMAND AREA AND LAYOUT

The command area is characterized by the steep slopes in the range of 3-5% over large portions of the area that lies along both sides of the Dunchay River. About 79% of the area lies on the right side while 21% of the command area lies on the left side of the river. The gross command area is 287.6 ha with net irrigable area of 220ha.The adapted layout system for the demarcated command area was mainly governed by land topography. Land areas with ground slope up to 5% have been delineated as suitable while any land areas having ground slope greater than 5% have been excluded. Generally, the topographic feature of the area has resulted in an uneven farm unit sizes.

The secondary canals are aligned across contour along ridges where possible. While Field canals are aligned along contours and consequently furrows run crosswise to the contours. The main collector drains collect all the water from the field drains to the river. Field drainage canals collect excess water from the field.

Accordingly, the whole command area was divided into three primary blocks depending on the gullies and streams bisecting the area. Table3 below summarizes the irrigation blocks, available areas, and slopes of the blocks.

Table 3:- -Detail of Gross command area and Net Irrigable Area

Canal	Block	Length (km)	GCA (Ha)	NIA (Ha)
MCR		3.1	227	173.66
SCR-1	BR 1-1+BR 1-2	1.6	96	73.44
SCR-2	BR.2-1+ BR.2-2	1.27	131	100.22
Sub Total for SCR		*2.87*	*227*	*173.66*
MCL		1.37	60.60	46.36
SCL-1	BL-1-1+BL 2-2	0.80	60.6	46.36
Total	6	8.14	287.6	220

The Net Irrigable Areas (NIA) were estimated on the basis of Gross Command Area (GCA), 15% was deducted and assumed to be non irrigable due to being occupied by streams, rocky areas, land areas with slope greater than 5% slope, and further reducing the resulting areas by 10% to account for irrigation and other infrastructures, such as road and villages.

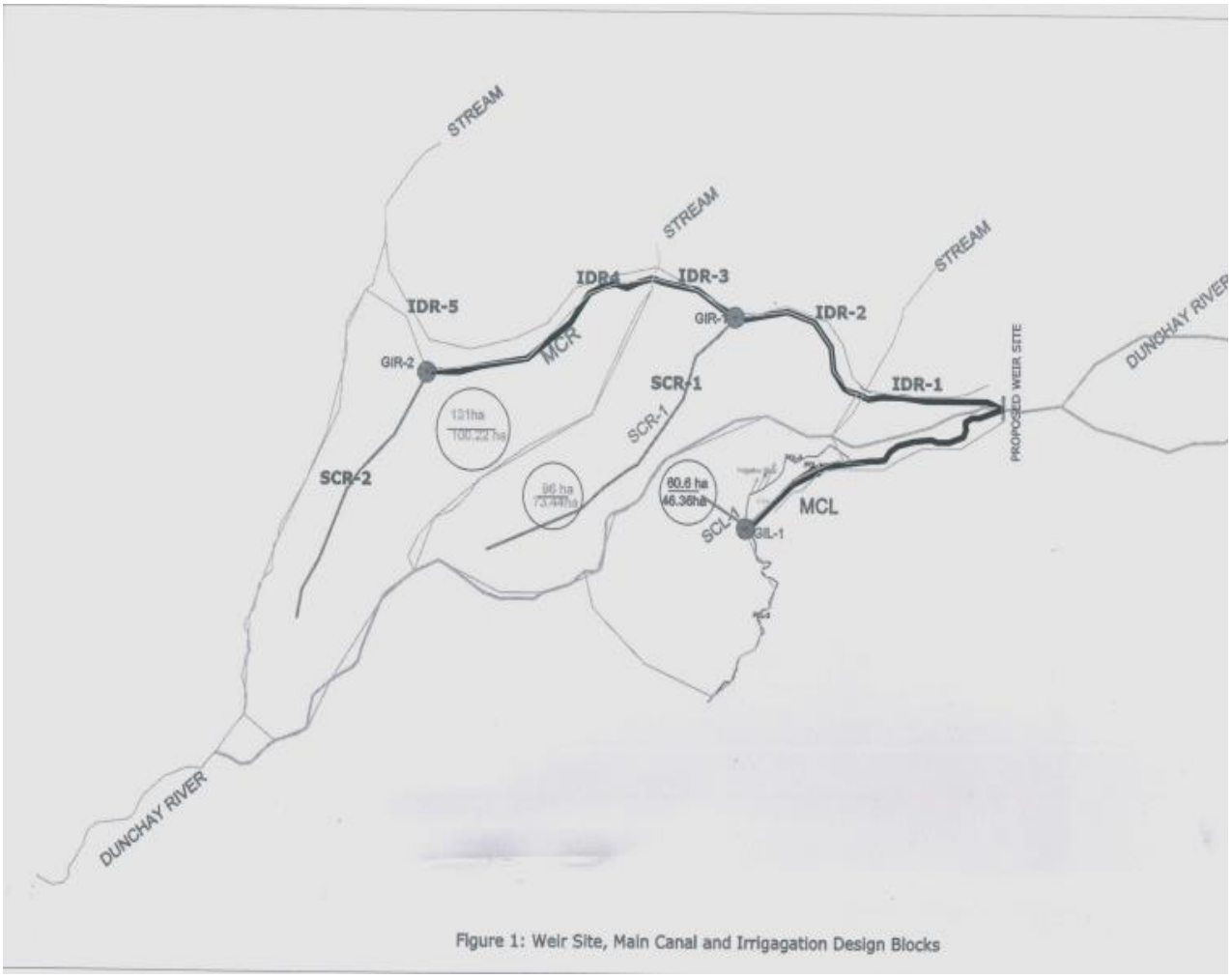


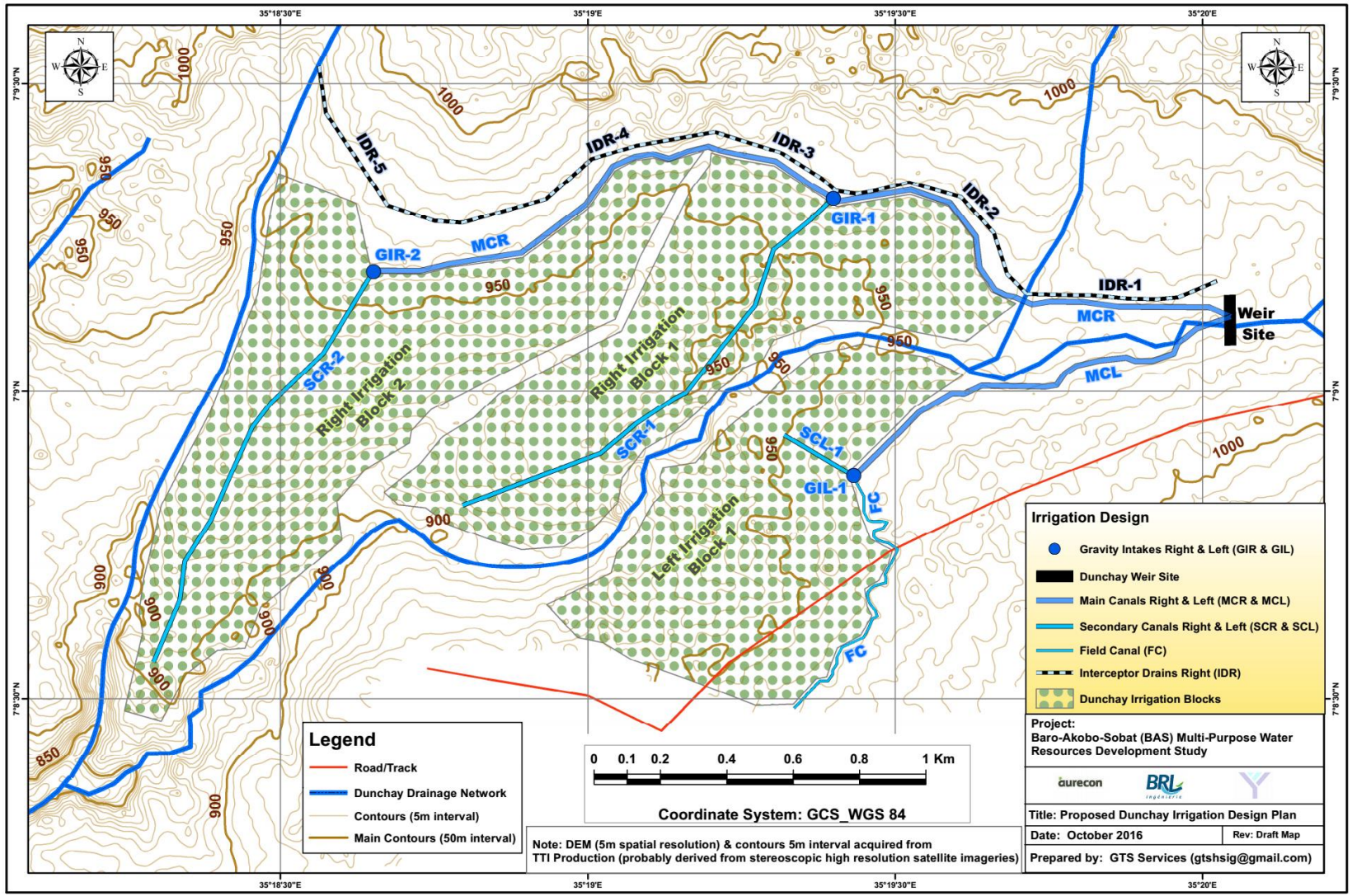
Figure 1: Weir Site, Main Canal and Irrigagation Design Blocks

SUB- AREAS SERVED BY THE MAIN CANALS

Two main canals (MCs) will deliver the water to the following distinctive sub-areas (Figure 1 below)

- Right Main Canal (MCR) – area confined between the Right MC and the Dunchay River. MCR covers a gross area of 227ha and net area of 173.66 ha.
- Left Main Canal (MCL) – area confined between the Left MC and the Dunchay River. MCL covers a gross area of 60.6ha and net area of 46.36ha.

Figure 1: Irrigation design plan



4.3 MAIN CANAL: (MC)

The alignment of main canal follows a contour line, which runs along the right and left flank of Dunchay River as the command areas are located on both banks of the River Dunchay, which suggests one main canal on the right and one on the left side of the diversion weir headwork. The Right Main Canal (MCR), with a longitudinal slope of 1.65 m/km, commands four irrigation Blocks, RB-1.1, RB-1.2, RB-2.1 and RB-2.2 on the right bank, and The Left Main Canal (MCL) with a longitudinal slope of 3.96 m/km, commands Blocks LB-1 and LB-2, on the left bank of the Dunchay River. All the blocks lie at an elevation lower than the MCs and will be irrigated by gravity from the canals

The canals were aligned as falling contour canal supplying irrigation water from two off take structures located at each flank of the diversion weir and brings water to the secondary canals. The system would consist of 3.1 km long main canal on the right bank with designed discharge of 420 l/s and 1.37km long on the left bank with design discharge of 110l/s at the head. The canals are unlined and aligned nearly along the contour lines of 972mt. to minimize lose of head. Consequently, the canal is totally dugout type nearly all along except for few meters of localized depressions, which requires minor filling.

4.4 SECONDARY CANAL/ CONDUIT (SC)

The SC takes off from the MC. It runs on the ridge across the contour down the prevailing steep slope of 3-5%, which is very steep for earthen canal and requires several drop structures. The canal system layout was prepared taking into consideration the general topographic condition of the land. In general, the secondary canals were aliened on the ridges across the contour to serve areas between two valley lines.. Therefore, the sizes of the SCs vary depending on the area serviced by each secondary canal. There are three secondary Canals (SCs), two SCs on the right and one SC on the left. The size and area commanded by each SC is given in Table 3 above. All the SCs are designed as close conduit by considering the higher cost of canal preparation because of the steep slopes that required several drops.

4.5 FIELD CANALS (FC)

FCs are planned to take-off directly from the SCs and supplying irrigation water to the farm unit they run along the contour lines and serve the irrigated fields. The FCs serves plots of 4 ha – 7ha. The design discharge of field canal has been taken as less than 30l/s based on the handiness of water rotation within the tertiary. An effort has been made to keep the farm flow within tolerable range, between 15lit/sec- 30lit/sec, as optimum, which can be managed by individual farmers. All FCs are connected to the gravity pressure pipes proposed as secondary conduits. by a proportional division box. The connection of the FC to SC is presented in Figure 2.

4.6 IRRIGATION EFFICIENCY AND WATER DUTY

Currently, there is no irrigation scheme in the area and the farmers of the project area have no knowledge in irrigation water management. Based on the level of the technical and management capacity of the user communities, an overall efficiency of 50% was established for flow in the main canal. The different components of the subsidiary canals like secondary, tertiary and the field canals have been designed with different values of efficiency to account for the transit losses at various levels of the delivery system. Table 4 below summarizes the efficiency used in the system design.

Table 4:-Adapted Irrigation efficiency and corresponding Water Duty for the canals system

System	Efficiency (%)	Overall Efficiency (%)	Duty at Inlet		
			24 Hr operation (l/s/ha)	10 Hr` Operation (l/s/ha)	Plus 10% Flexibility Factor (10 Hr operation)
Application	65	65.00	0.67	1.6	1.6
Field Canal	88	57.00	0.73	1.8	1.9
Secondary (Pipeline)	98	56.00	0.79	1.9	2.1
Main canal	90	50.00	0.92	2.2	2.4

5. DESIGN OF CANAL SECTION

In accordance with the proposed cropping pattern and cropping calendar, maximum water duty is 2.4l/s/ha, which occurs in the month of January and the value has been taken as design duty for the main canal. This was calculated with 50% overall irrigation efficiency and 10 hours daily operation period including a flexibility factor of 10% to cater to any future changes in irrigation planning. The different components of the subsidiary canal like, Secondary and the Farm canals have also been designed with a range of duties as shown in table 4 above to account for the transit losses. Hydraulic parameters of the canals are presented in Table 5. The canals are designed as earthen trapezoidal cross-section, using standard Manning's formula

$$Q = AV; V = \frac{1}{n} R^{2/3} \sqrt{S}$$

Where

Q = Design Discharge (M^3/sec)
A = Cross-sectional area in (M^2)
V = Mean velocity (m/sec)
R = Hydraulic mean depth (m)
S = Slope of canal (m/m)
n = Manning's Roughness Co-efficient, (adapted value 0.025)

Table 5:- main and Field canal parameters

canal	Q m^3/sec	S m/km	B m	y m	z	A m2	P m	R	V m/s	Fb m
MCR	0.42	1.65	0.46	0.55	1	0.56	2.02	0.28	0.75	0.25
MCL	0.11	3.96	0.24	0.29	1	0.16	1.07	0.15	0.7	0.13

FCL-1	0.008	9.3	0.2	0.1	1	0.02	0.34	0.05	0.5	0.10
FCL-2	0.012	9.3	0.2	0.1	1	0.02	0.34	0.05	0.5	0.10

6. DESIGN OF GRAVITY LEAD (FORCED PIPE) IRRIGATION

There are three secondary canals off taking from the main canals. All are running across the contour ranging between 3 to 5% slopes and therefore, designed as gravity lead pressurized system because of the steep slopes, that require too many drops. Accordingly, three gravity intakes were proposed on the main canal and the location of each gravity intake is summarized in Table 6 below.

Due to the steep slopes, pipe conveyance is proposed, rather than frequent high drop structures separated by unlined length of canal. In a gravity lead pressurized irrigations system, water will be conveyed from main canal to the head of field canals by PVC pipes, fed by gravity from the main canal gravity intakes. Because of the natural longitudinal slope of the ground, water will be put under pressure naturally. The pipe will be laid across the contour, on the ridge to have Field canals on the left and on the right side of the secondary pipe. An available head of 4 to 5 m at the downstream end of pipe will allow irrigation of the respective area under pressure, without pumping.

Table 5:- Gravity Intakes - Location and Capacity

Parent Canal	**Chainage, km**	**Gravity Intake Name**	**Net Command Area,**	**Discharge,**
			(ha)	**(l/s)**
MCR			**173.66**	**420**
SCR-1	1.27	Intake, GIR.I-1	73.44	150
SCR-2	1.6	Intake, GIR.1-2	100.22	210
MCL			46.36	110
SCL-1	1.37	Intake , GIL.I-1	46.36	100
Total			220	

6.1 MAIN DATA

Net peak daily water requirement amounts to 4 mm/day for the proposed cropping pattern and cropping calendar. The seasonal net water requirement is 346.4 mm.

Taking into account irrigation efficiency described in the Table 4 above and 10 hours daily operation including 10% flexibility factor, Gross peak water requirement of 2.1 l/s/ha was assumed at the head of secondary conduits off taking from MCs

Head losses in pipes were computed using Darcy-Weisbach Friction Loss Equation and the computation was made by the use of Pipe Flow Expert Software to estimate the head loss in the pipes. The calculations results and hydraulic parameters of the pipes lines are presented in Table 7 and the formula for Darcy-Weisbach Friction Loss Equation is as follows:

$$h_f = f \frac{L}{D} \frac{V^2}{2g}$$

Where

h_f = Major head loss (m)
f = Friction factor
L = Pipe length (m)
D = Pipe diameter

V = Flow velocity in the pipe (m/s)
g = Acceleration due to gravity = 9.81 m/s^2.

6.2 LAYING OF PIPES

The pipes will be buried at a depth of 80cm below the ground surface to prevent any risks of damage by agricultural machinery. The required head at the tertiary canals was estimated at an average of 4.0 meter of head or 0.4 bars with flow velocity of 1.8m/s in the pipes

Table 6:- Pipes Data

Pipe name	Length	Discharge	Pipe Diameter	Velocity	Elevation			Total head loss, H_L	Available Head
	(m)	(m^3/s)	(mm)	m/s	Origin	End	ΔZ		
					OE	EL	m	m	m
SCR-1	87.32	0.15	0.35	1.56	961.59	955.00	6.59	0.48	6.11
	67.00	0.15	0.35	1.56	955.00	950.00	5.00	0.37	4.63
	60.00	0.15	0.35	1.56	950.00	945.00	5.00	0.33	4.67
	405.00	0.15	0.35	1.56	945.00	940.00	5.00	2.24	2.76
	279.00	0.15	0.35	1.56	940.00	935.00	5.00	1.54	3.46
	274.00	0.15	0.35	1.56	935.00	930.00	5.00	1.51	3.49
	211.50	0.15	0.35	1.56	930.00	925.00	5.00	1.17	3.83
	72.00	0.15	0.35	1.56	925.00	920.00	5.00	0.40	4.60
	62.20	0.15	0.35	1.56	920.00	915.00	5.00	0.34	4.66
Total	20.00	0.15	0.35	1.56	920.00	915.00	5.00	0.11	4.89
SCR-2	139.74	0.21	0.4	1.67	957.84	955.00	2.84	0.78	2.06
	171.00	0.21	0.4	1.67	955.00	945.00	10.00	0.95	9.05
	218.46	0.21	0.4	1.67	945.00	940.00	5.00	1.21	3.79
	266.00	0.21	0.4	1.67	940.00	930.00	10.00	1.48	8.52
	223.30	0.21	0.4	1.67	930.00	920.00	10.00	1.24	8.76
	178.00	0.21	0.4	1.67	920.00	910.00	10.00	0.99	9.01
	203.00	0.21	0.4	1.67	910.00	905.00	5.00	1.13	3.87
SCL-1	90.00	0.10	0.30	1.4	961.69	960.00	1.69	0.51	1.18
	121.00	0.10	0.30	1.4	960.00	955.00	5.00	0.69	4.31
	96.20	0.10	0.30	1.4	955.00	950.00	5.00	0.55	4.45

7. DRAINAGE SYSTEM

Interceptor Drain (ID) was proposed along the right side of MCR and left side of MCL to intercept the water entering the main canal from the adjacent catchments. These drain canals follow the main canals from the diversion structure site up to the end tail. The total catchments area of the drainage is 850ha and 160ha for MCR and MCL respectively. The catchment has an average slope of 12.5% with a specific discharge of the catchment, at the broader, estimated to be 0.36.1l/s/ha. The figure was estimated based on the design discharge of Gillo River sub basin in the Baro-Akobo River basin Master Plan Study. The drain therefore, has been designed to accommodate the corresponding flood flows. Hydraulic parameters of the canals are presented in Table 8. The canals are designed as earthen trapezoidal cross-section, using standard Manning's formula broad

Table 7:-ID parameters

Drain	**Q, head**	**S**	**B**	**y**	**z**	**V**	**Fb**	**A**	**P**	**R**	**L**
	l/s	*m/km*	*m*	*m*		*m/s*	*m*	M^2	*m*	*m*	*m*
IDR-1	25.20	3.4	0.20	0.20	1	0.6	10.0	0.08	0.6	0.08	557
IDR-2	36.72	3.4	0.20	0.20	1	0.6	10.0	0.13	0.6	0.13	510
IDR-3	61.20	2.4	0.20	0.25	1	0.5	12	0.13	0.95	0.13	650
IDR-4	58.68	2.5	0.20	0.25	1	0.5	12	0.12	0.93	0.12	760
IDR-5	52.56	2.6	0.2	0.25	1	0.5	11	0.12	0.88	0.12	807

8. DIVERSION WEIR AND CANALS STRUCTURES

8.1 DIVERSION HEADWORK AND INTAKE

Diversion weir with vertical drop is proposed to ensure a regulated constant and continuous flow of water supply into the main canals. The proposed weir type is broad crested, which has a length of 30m and a height of 1.06 meter with 1.5m top width and 3m bottom width. Two irrigation head regulators and two under sluice would be provided for the diversion headwork, one intake together with under sluice on each bank. The capacities of the intake structure are 0.42m3/s and 0.11 m3.s for right and left main canals respectively. The right bank intake would serve 173.66 ha on the right bank and the left intake would serve 46.36ha on the left bank. The site is located at the upper reach of the river where bed and bank erosions are less of a problem and the bed consists of a mixture of boulders and gravel with course sand. Table 8,1 presents the principal characteristics of the weir. The cost estimate for the weir is given in Table 11.

8.2 DESIGN CONSIDERATION OF THE DIVERSION WEIR

The design of weir includes computing the elevation of weir crest, length of weir, computing the forces acting on the weir and checking the safety of the weir from all aspects like overturning, sliding, crushing etc. All are worked out using standard formulas and excel sheet as summarized in the table 8.1 below.

8.2.1 Weir crest level and height

There are various factors that affect the elevation of the crest, but in our case, diversion of water is the purpose and the height should be sufficient to pond the water at a level that can facilitate design flow in the intake. The height of the weir (crest elevation) was fixed based on the requirement of canal intake and command topography (canal full supply). The maximum (allowable) upstream water surface elevation was also considered in selecting the crest elevation. Hence taking into account all these factors, the weir height of 1.06m would deliver in the required water level and discharge for the proposed command area

Table 8-1:-Weir Height and crest level

1	Average River Bed level at weir axis, RBL = (masl)	967.00
2	Water depth in the canal (m)	0.8
3	length of main canal from the head regulator to the 1st off-take (m)	1600
4	Bed slope of the main canal, S	0.00195
5	Head loss at the head regulator,	0.16
6	Operational head losses	0.1
7	Peak irrigable land level in the command area (masl)	963.88
8	Head loss along MC, hf= (3 x4)	3.12
9	Water surface level at 1st off-take down the main canal (7+2)	964.68
10	Therefore, Weir Crest Level = (9+8+6+5)	968.06
11	Weir Height = (10-1)	1.06

8.2.2 Length of the weir

The length of the weir has to be designed to allow the design flood to safely discharge over the weir. It is governed by the physical feature of the site and the value of afflux permitted. As a general rule, the crest length should be taken as the average wetted width during flood so that the natural regime of flow will not alter the hydraulic as well as the sediment carrying characteristics of the river. The actual length of the weir cross section during the high flood level is estimated to be 30m and this was taken as the length of the weir. In light of this, 26m is taken as the effective length of the weir section while the remaining 4 m is prearranged for the wing wall and under-sluice portion.

8.2.3 Rating Curve

The estimation of tail water depth at the weir site provides information on downstream flood level that can be used for the design of downstream retaining wall, protection work and stability analysis of the weir. There is no stage-discharge data for Dunchay River at the weir site and hence, synthetic rating curve was produced using the longitudinal profile, river cross section at the weir axis and characteristics of the river as it is accounted by the manning roughness using manning equation.

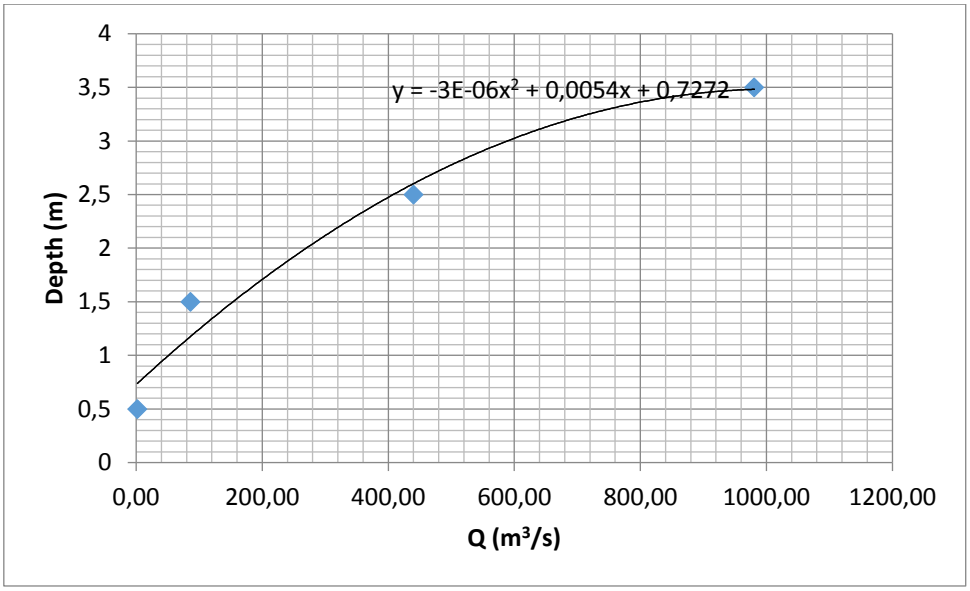
Table 8:-: Hydraulic Parameters of Stage-Discharge Curve at selected Weir Site

Estimated peak flow of the river			41.53m^3/s			
Slope		0.017767				
Coefficient of Roughness		0.035				
Elevation (m)	Depth (m)	Water area (m2)	Wetted Perimeter (m)	Hydraulic radius(m)	Velocity (m/s)	Discharge (m3/s)
967.00	0.5	1.32	5.4	0.24	1.49	1.97
968.00	1.5	24.33	27	0.90	3.559	86.45
969.00	2.5	77.12	42	1.84	5.719	440.41
970.00	3.5	142.2	58.33	2.44	6.90	981.00

TAIL WATER DEPTH ESTIMATION

The stage discharge relationship was plotted based on 1m contour interval map prepared for the river cross-section at selected weir site and the stage discharge curve was computed and plotted as shown in figure below.

The value of 41.53m3/s was taken as peak discharge for the design of headwork structures. Depth of water corresponding to this discharge is read to 0.9566m from the tail water curve and this match to 967.9566mas.



8.3 WATER DEPTH OVER THE CREST

PEAK RUNS OFF CALCULATION

An Empirical Formula developed for the highland of the country (Admasu) is used for estimating the maximum flood based on catchment parameters

Catchment area(km^2)	A	44
Annual mean maximum flood (m^3/sec)	$Qmd = 0.878(A)^{0.7}$	12.41
Factor	$Cf = 1+5*(A)^{-0.2}$	3.35
Maximum possible flood	Qp = Cf*Qmd	41.53

The head-discharge equation for the flow over the weir crest:

$$Q_0 = CL_0H_e^{\frac{3}{2}}$$

Where

Q_o = Design discharge of the weir=41.53 m^3/s
C = Coefficient of discharge (1.71 for broad crested weir)
L = Length of the weir= 26 m
He = Specific energy over the crest=0.99 m

The specific energy over the crest of the weir from the above equation becomes 0.659.

$$H_e = 0.959m$$

The approach velocity head:

$$H_a = H_e - H_d \text{ ----------} Eqn-1$$

$$H_a = \frac{V_a^2}{2g}, \text{----} V_a = \frac{Q_0}{A} = \frac{Q_0}{L_0(h+H_d)}$$

$$H_a = \frac{Q_0^2}{2g(L_0^2+H_d)^2} \text{ ----------} Eqn-2$$

H_d and H_a can be computed from Eqn 1 &2 by trial and error

The upstream &downstream energy levels

Ha = 0.032
H_d = 0.927
U/SHFL = $Z_O + H_W + H_d$
Z_O = Elevation of river bed at the weir axis = 967.00masl
U/SHFL = 967.00 + 1.06 + 0.927 =968.987.5masl
USTEL = U/SHFL + .032 = 968.987 +.032 = 969.019mas =
D/S HFL = $Z_O + D_3$ =
D_3 = tail water depth = 1.00m
D/S HFL = 967.00+1.00 =968.00 masl
D/S TEL = D/S HFL +

8.3.1 Section of the weir body

A masonry broad crested weir is selected due to the simplicity of construction. The weir is designed as a gravity weir whereby all the external forces acting on the weir are resisted by the weight of the weir. The dimension of weir body is governed by the stability condition whereby all the external forces acting on the weir should be counter balance by the weight of the weir body. The Preliminary dimension of the weir body was fixed based on Bligh's recommendation and evaluated by the stability design. Various sections of the weir are computed using standard formulas format in the spread sheet for the purpose and the results are used in sketching the weir body from which quantities were drawn for cost estimate.

According to Bligh's formula, the basic section of weir body for the unnumbered condition is determined as follows.

$$A = 0.55 = \left(\sqrt{H} + \sqrt{d}\right)$$

$$B = \frac{H + d}{\sqrt{S_g}}$$

Where

A = Top width of the weir= 1.5
B = Base width of the weir wall=5
H = Height of the weir= 1.06m
d = Depth of flood above the weir crest, 1.6
S_g = The specific gravity of the material of the weir wall, 2.4

APRON LENGTH AND THICKNESS

Total length of creep required including creep along the cut off

$$L > CH_W$$

Where

L = Total length of creep, 12.72 m
C = Blight's Percolation Coefficient = 12 depending on the nature of the site
H_W = Seepage head, weir height in our case= 1.06

The length of downstream floor is given by

$$Lc = 2.21 \times C\sqrt{\frac{H_W}{10}}$$

Where

L_C = D/s impervious floor length = 8.62 m
C = Blight's Percolation Coefficient = 12 depending on the nature of the site
H_W = Height of the weir= 1.06

Therefore, the d/s apron should be greater than 8.64m in order to prevent piping.

D/S RIPRAP PROTECTION

This is pervious apron build with materials such as dumped stone in conjunction with the masonry or gabion to protect the downstream and the total length of the downstream protection was computed from Blight's formula. The thickness can be in the range of 0.5 to 0.8, and in the case of this project 0.5 was adapted.

The length of downstream pervious stone apron is given by the following equation

$$L_d^{/} = 18C\sqrt{\frac{H_W}{10} \times \frac{q}{75}} - 2.21C\sqrt{\frac{H_W}{10}}$$

Where

L_d = Length of d/s stone protection length =4.68m, say 5m
C and H_W = The same as above
q = Discharge per unit of length, 2.69m

UPSTREAM PROTECTION

The length of u/s pervious protection may be kept as equal to half the length of d/s protection, i.e. 2.5m

Table 9- Salient features of the Weir

No		
	Length of the weir	30
	Height of the weir	1.06
	Top width of the weir	1.5
	Bottom width of the weir	3
	Weir Crest Level	968.06
	U/s HFL	968.987
	U/s wing wall height	2.42
	D/s wing wall height	1.63
	Total creep length	12.72
	d/s floor length	13.5

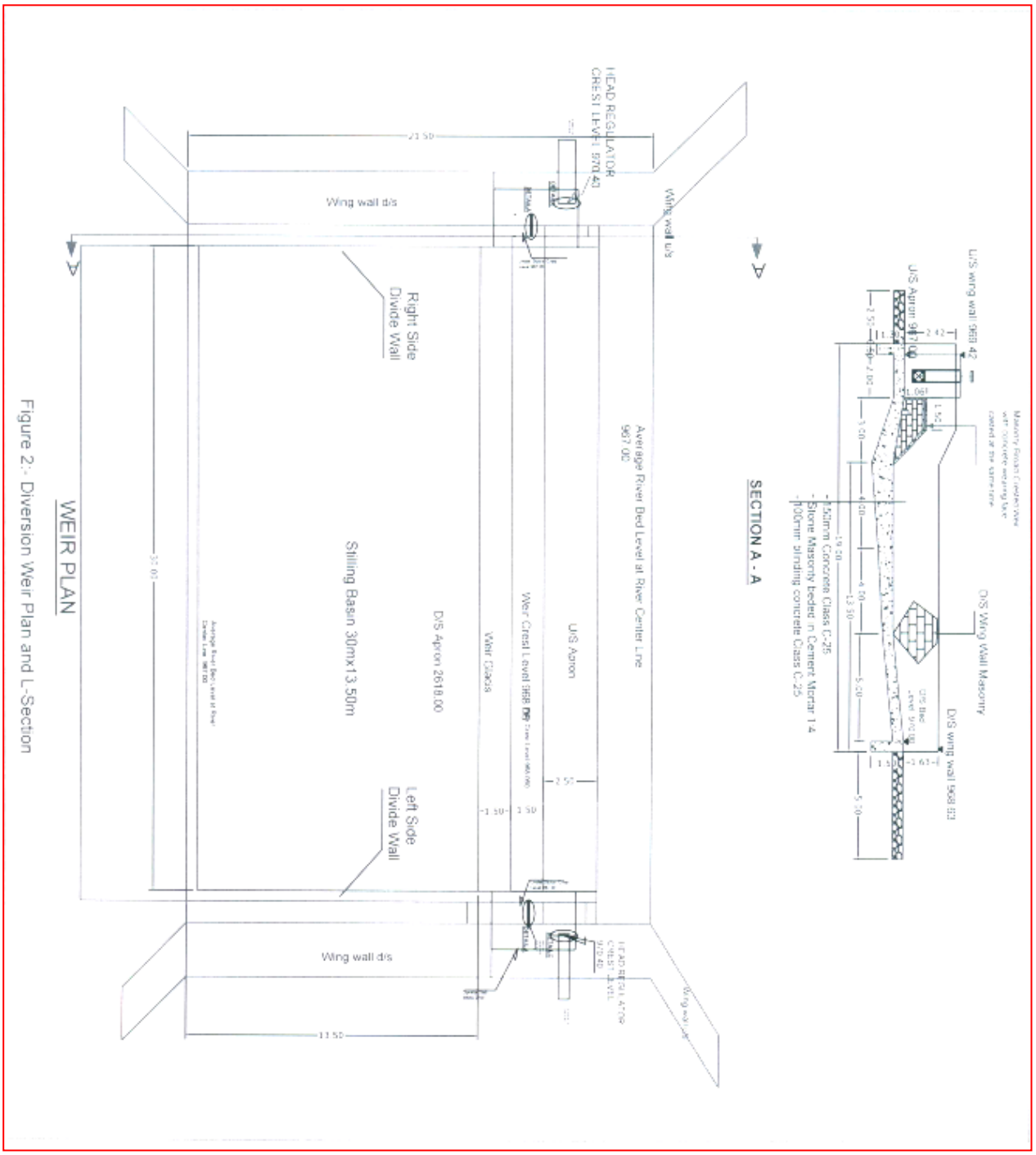


Figure 2:- Diversion Weir Plan and L-Section

8.4 INTAKE HEAD REGULATOR

The Intake structures are provided at the right and left sides of the river to regulate the supply of water into the off taking canals; to control entry of silt and other material into the off taking canal as well as to exclude high flood from entering the off taking canal. The intake structures consist of a circular pipe for conveying water to the downstream canal and intake gate for flow regulation.

The dimension and discharge capacity of the intake opening was computed with the orifice formula and the results are tabulated in the following table.

$$Q = C_d A\sqrt{2gh}$$

Where

- Q = Discharge through the opening
- C_d = Coefficient of Discharge, 0.65
- A = Area of the gate opening, m^2
- h = Head of water above the center of the opening, m or working head ≈ 0.1m
- g = Acceleration due to gravity = 9.81 m/s

Recommended Pipe Diameter for the intake structures at the head of MCs

	Q (M3/s)	RC Pipe diameter (m)
MCR	0.42	0.80
MCL	0.11	0.50

8.5 UNDER-SLUICE

Under-sluice is provided adjust to the head regulators on both sides of the river where the off taking canal draws water for the command. The function of the under-sluice/scouring sluice is to intercept the bed loads as it approaches the canal intake and discharge it, with its bed load, downstream of the weir. This allows drawing comparatively silt free water to the off-taking canal. The floor level of the under-sluice was kept 20cm below the head regulator to create pool condition for silt settlement and freely exclusion of silt.

The under-sluice is regulated by sliding sheet metal inserted in the grove made by standard angle section in the wall of the weir and wing wall. It is recommended that the under-sluice portion should be capable of passing 10% to 20% of maximum discharge during high flood and 2 to 5 times the canal discharge during pond flow condition to ensure good scouring capacity.

8.6 CANALS STRUCTURES

GENERAL

Various types of canal structures are planned for a proper operation of the canal system. These include outlet structures from main canal to secondary and from secondary canals to Field canals. Consequently, a division box and orifice type outlet structures were adapted for the system:

Division box

Division box is used to facilitate the passage of appropriate portion of the flow from the main canal to the secondary pipe lines that runs across the slope. The structure is capable of dissipating an excess head, discharging a tranquil flow to the downstream canal. Manually operated Sheet metals gate is provided at the entrance to the throat of the structure, which slides in grooves. The gate also permits closing down the installation for maintenance or for the end of the seasonal operation.

ORIFICE TURNOUT

Orifice turnout structures are used for connecting close conduit secondary line to open field canals. The structure is proposed for passage of flow from pipe line to the field canals. According to the adapted layout, there are 16 Turnout located on the pipe lines proposed as secondary supply lines.

9. PROVISION OF ROAD

Currently, the project area is accessed through Godare-Tapi all weather road. However, there is no proper road that links to the project site either from Tapi or Godare to the project site. Therefore, it is recommended to construct 15km long and 6m wide access road for the project area to ensure transport of inputs, produce and operation of the system.

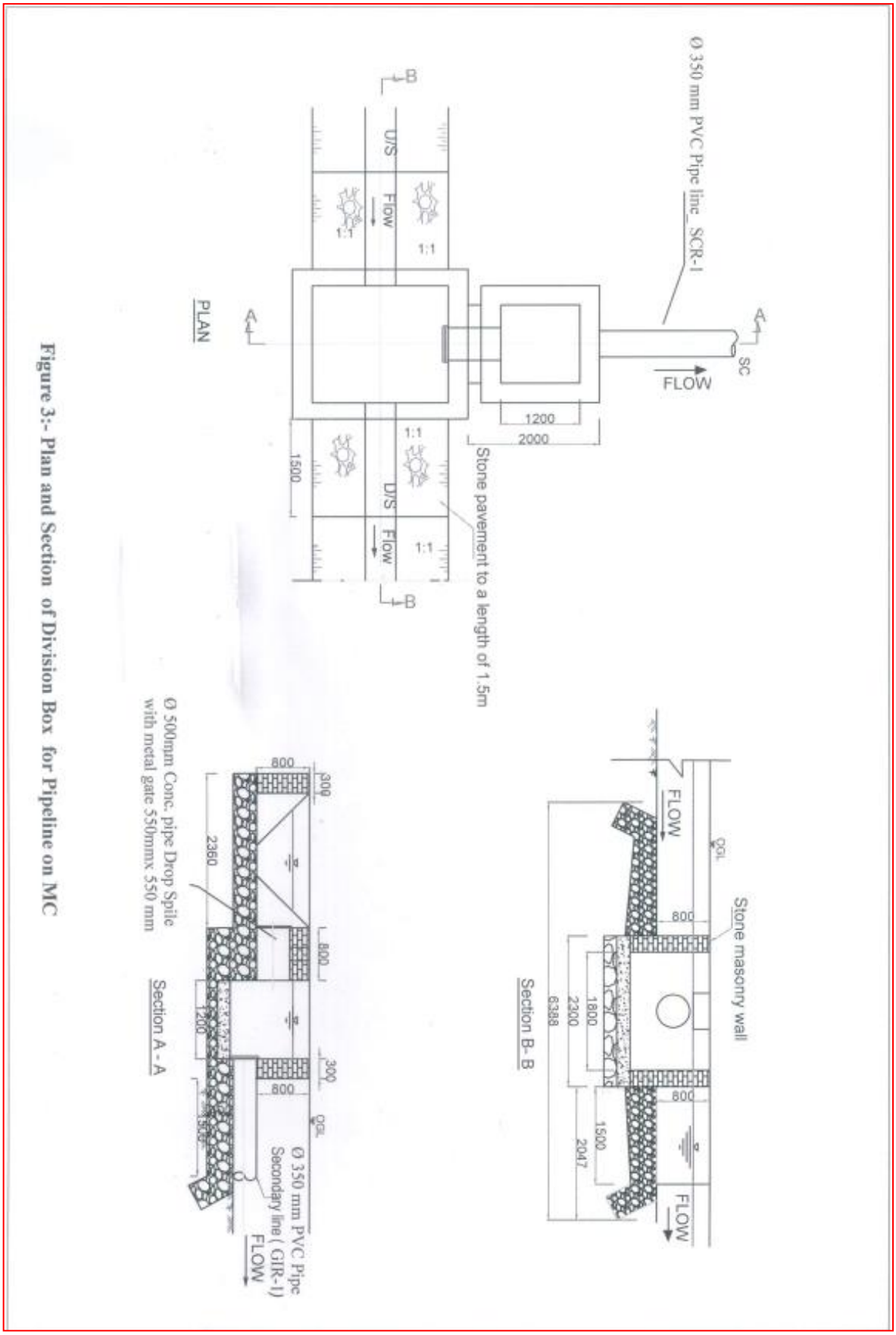


Figure 3:- Plan and Section of Division Box for Pipeline on MC

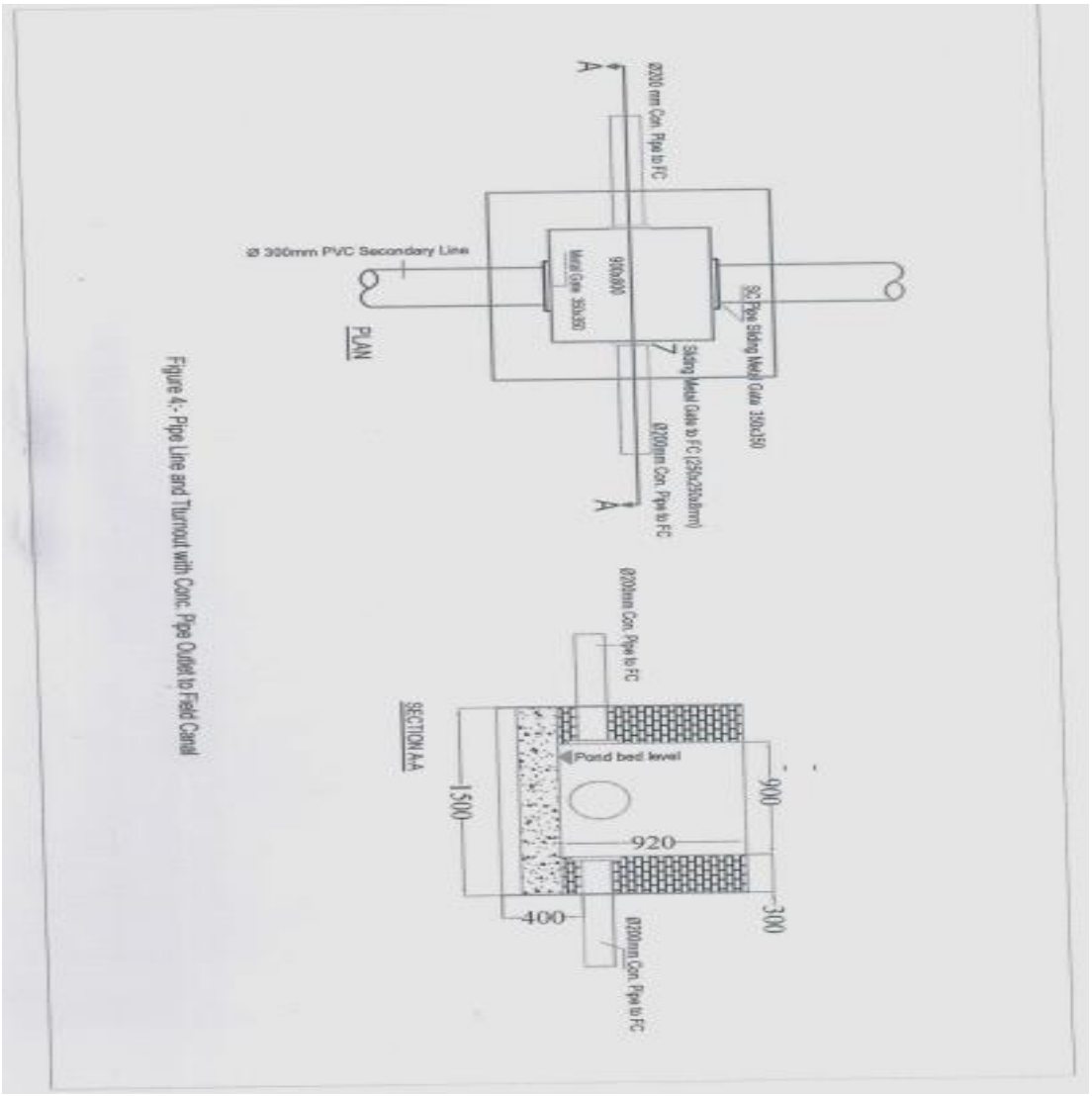


Figure 4:- Pipe Line and Turnout with Conc. Pipe Outlet to Field Canal

10. ESTIMATE OF COST AND QUANTITIES

Project cost was calculated through detail estimate for headwork, main and secondary canals in combination with cost estimate of the selected sample model areas in the case of on farm works.

Quantities of entire earth work volume for the headwork, main canals and secondary pipe lines were worked out from respective dimensions on the drawing of the structure to provide complete list of quantities in order to prepare respective cost estimate for the work.

Regarding on farm work, the work volume was worked out on the basis of the selected sample model areas to develop cost per hectares for on farm works which includes farm structures such as farm canals and turnout. Block served by the secondary canal one on the left side (SCR-1) was selected for detail cost analysis to develop the cost per hectare for on -farm irrigation facilities. Accordingly, longitudinal section of these selected farm canals and turn outs details were considered for preparing cost estimate for the work volumes. Finally, combinations of the two type of cost estimate constitute total project cost. Summary of the BoQ is presented in Tables 11 below.

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Table-10:- Dunchay SSI Bill of Quantity

S/ No	**Description of items**	**Unit**	**Qt**	**Rate**	**Total Cost**	
				Birr	**Birr**	USD
A	Construction of Access Road					
I	Access road construction	km	15	670,000.00	10,050,000.00	443,708.61
II	Irrigation and Drainage					
A	**General Provision**					
1	Mobilization & demobilization	No	1.00	75,000.00	75,000.00	3,311.26
2	Camping	LS			40,000.00	1,766.00
	Sub Total for General Provision				**115,000.00**	**5077.26**
B	**Headwork**					
1	Site clearing to remove top soil to an average depth of 0.20 m	m^2	1500.00	20.00	30,000.00	1,324.50
2	Cart away	m^3	210.00	24.00	5,040.00	222.52
3	Coffer dam construction with sand filled bags for temporary flow through PVC from U/S to D/S of Diversion Weir and removing it at the end of construction	Ls			8,093.00	357.31
4	Excavation for foundations to each structure including working space					
4.1	ordinary soil excavation		1189.73	102.00	121,352.46	5,357.72
4.2	Fractured Soft Rock		152.00	588.98	89,524.96	3,952.54
4.3	Hard Rock		69.10	914.28	63,176.75	2,789.26
4.4	Cart away surplus excavations		735.29	24.00	17,647.07	779.12
5	**Masonry works**					
5.1	Hard basaltic or equivalent masonry bedded and join in cement mortar 1:3	m^3	454.07	1,768.93	803,225.70	35,462.50
5.2	Apply three coats of cement mortar plaster 1:3 to all internal walls including bottom surface of the weir structures	m^2	127.68	146.50	18,705.12	825.83
5.3	Supply and fix in position Ø50cm Con. Pipe	Pcs	20.00	900.00	18,000.00	794.70
5.4	Supply and fix in position Ø80cm Con. Pipe	Pcs	17.00	1300.00	22,100.00	975.72
5.5	Construction of Manhole 1m x 1m with Reinforced concrete on each side of intake	No	2.00	2482.00	4,964.00	219.16

Table-11:- Dunchay SSI Bill of Quantity

S/ No	**Description of items**	**Unit**	**Qt**	**Rate**	**Total Cost**	
				Birr	**Birr**	USD
5.6	**Concrete works**					

5.6.1	Hard core & compaction under the Headwork	m^3	144.74	839.00	121,440.22	5,361.60
5.6.2	Supply, cut, fix and install reinforcement bars on D/S Apron(Stilling Basin)					
5.6.3	Ø 12mm Reinforcement bar	kg	278.00	49.61	13,791.58	608.90
5.6.4	Ø 10mm Reinforcement bar	kg	222.00	49.61	11,013.42	486.24
5.6.5	Concrete works(1:2:4 mix)	m^3	429.25	3973.75	1,705,732.19	75,308.26
5.7	Back fill with selected material & compaction on outer face of wing walls	m^3	88.77	112.70	10,004.69	441.71
5.8	Gabion work with well graded basaltic stone for d/s and u/s apron protection	m^3	107.50	1600.00	172,000.00	7,593.82
6	**Gate Installation**					
6.1	Intake gate operated by spindle and shaft with square thread, plate size is 700x700x5mm as per drawing and specifications, fixed in position	Pcs	1.00	28,300.00	28,300.00	1,249.45
6.2	Intake gate operated by spindle and shaft with square thread, plate size is 1100x1100x5mm as per drawing and specifications, fixed in position	Pcs	1.00	28,300.00	28,300.00	1,249.45
6.3	Silt gate operated by spindle and shaft with square thread, plate size is 1200 mmx1200mmx5mm as per drawing and specifications, fixed in position	Pcs	2.00	28,300.00	56,600.00	2,498.90
	Sub Total for Headwork				**3,349,011.15**	**147,859.21**
C	**Main Canal**					
1	**Right Main Canal (MCR)**					
1.1	Site clearing to remove top soil to an average depth of 0.20 m	m^2	7984.00	18.00	143,712.00	6,344.90
1.2	Canal Excavate to an average depth of 0.5mt from the reduced level in an ordinary soil and shaping to the required shape as per the drawing and direction of the site engineer	m^3	3831.92	102.00	390,855.43	17,256.31

Table12:- Dunchay SSI Bill of Quantity

S/ No	**Description of items**	**Unit**	**Qt**	**Rate**	**Total Cost**	
				Birr	**Birr**	USD
	Sub Total for Right Main Canal excavation				**534,567.43**	**23,601.21**
2	**Left Main Canal (MCL)**					
2.1	Site clearing to remove top soil to an average depth of 0.20 m	m^2	2831.63	20.00	56,632.58	2,500.33
2.2	Canal Excavate to an average depth of 0.5mt from the reduced level in an ordinary soil and shaping to the required shape as per the drawing and direction of the site engineer	m^3	774.76	102.00	79,025.99	3,489.01

	Sub Total for Left Main Canal excavation				**135,658.56**	**5,989.34**
3	Supply, lay, join and buried PN 4 PVC Pipe at a depth of 80 cm below the ground surface					
	DN 400mm	m	1632.00	2,230.00	3639360.00	160,678.15
	DN 350mm	m	1740.00	1,960.00	3410400.00	150,569.54
	DN 300mm	m	343.00	1,453.00	498379.00	22,003.49
	Sub Total for PVC Pipe				**7,548,139.00**	**333251.17**
4	**Field canals**					
4.1	**Field Canal Left 2-1 (FCL-1)**					
4.1.1	Site clearing to remove top soil to an average depth of 0.20 m	m^2	409.8	20.00	8,196.00	361.85
4.1.2	Canal Excavate to an average depth of 0.2mt from the reduced level in an ordinary soil and shaping to the required shape as per the drawing and direction of the site engineer	m^3	54.64	102.00	5,573.28	246.06
4.2	**Field Canal Left 2-2 (FCL -2)**					
4.2.1	Site clearing to remove top soil to an average depth of 0.20 m	m^2	564.6	20.00	11,292.00	498.54
4.2.2	Canal Excavate to an average depth of 0.2mt from the reduced level in an ordinary soil and shaping to the required shape as per the drawing and direction of the site engineer	m^3	75.28	102.00	7,678.56	339.01
4.2.3	Total for field canal Left 1 (7.7 ha)	ha	7.7		32,739.84	1,445.47

Table13:- Dunchay SSI Bill of Quantity Con't

S/ No	**Description of items**	**Unit**	**Qt**	**Rate**	**Total Cost**	
				Birr	**Birr**	USD
	Total for Field canal	ha	220	4,251.93	**935,424.00**	**41299.07**
5	**Interceptor Drain Right (ICD-R)**					
5.1	**Interceptor Drain Right (ICD-R)**					
5.1.1	Site clearing to remove top soil to an average depth of 0.10 m	m^2	3603.20	20.00	72,064.00	3,181.63
5.1.2	Excavation of drain to an average depth of 30cmin an ordinary soil and shaping to the required shape as per the drawing and direction of the site Engineer	m^3	964.30	102.00	98,358.68	4,342.55
5.2	**Interceptor Drain Right (ICD-L)**					
5.2.1	Site clearing to remove top soil to an average depth of 0.10 m	m^2	570.45	18.00	10,268.02	453.33

5.2.2	Excavation of drain to an average depth of 30cmin an ordinary soil and shaping to the required shape as per the drawing and direction of the site Engineer	m^3	77.45	102.00	7,900.09	348.79
	Sub Total For ICD				**188,590.79**	**8326.30**
6	**Canal Intake structures**					
6.1	**Turn outs**					
6.1.1	Excavation	m3	2.5	102.00	255.00	11.26
6.1.2	30 cm thick hard basaltic or equivalent stone masonry wall including floor, bedded and jointed in cement mortar 1:3	m^3	2	1,768.93	3,537.86	156.20
6.1.3	Back fill the sides of the wall with selected materials and well compacted	m^3	1	112.70	112.70	4.98
6.1.4	20 cm thick mass concrete to the bottom surface of the box over 20cm hard core	m^2	1	1,668.93	1,668.93	73.68
6.1.5	Apply three coats of cement mortar plaster 1:3 to all internal walls including external above the ground as well as bottom surface of the structure	m^2	9.5	136.50	1,296.75	57.25
6.1.6	supply and fixe Ø 20cm Con. pipe including 8 mm x400mm x 400mm sheet metal slides in grooves for regulating discharge into the off take	pcs	2	500.00	1,000.00	44.15

Table14:- Dunchay SSI Bill of Quantity Con't

S/ No	**Description of items**	**Unit**	**Qt**	**Rate**	**Total Cost**	
				Birr	**Birr**	USD
6.1.7	Stone pitching outside the stone masonry wall	m^3	1	1,183.00	1,183.00	52.23
6.1.8	Sub Total Cost for one Turn out	no	1		9,054.24	399.75
6.1.9	total cost for Turn out on SCL-1 (46.36ha)	no	4	9,054.24	36,216.96	1,598.98
	Total Turn Out for the project (220ha)		16	9,054.24	**144,867.84**	**6395.93**
6.2	**Division Box**					
6.2.1	Excavation	m^3	56	95.60	5353.60	236.36
6.2.2	30 cm thick hard basaltic or equivalent stone masonry wall including floor, bedded and jointed in cement mortar 1:3	m^3	7.4	1,668.93	12350.08	545.26
6.2.3	Back fill the sides of the wall with selected materials and well compacted	m^3	2	102.00	204.00	9.01
6.2.4	20 cm thick mass concrete to the bottom surface of the box over 20cm hard core 1:2:4	m^3	0.8	3,800.00	3040.00	134.22

6.2.5	Apply three coats of cement mortar plaster 1:3 to all internal walls including bottom surface of the box structures	m^2	12.5	136.50	1706.25	75.33
6.2.6	supply and fixe Ø 50 cm Conc. pipe including 8 mm sheet metal slides gate in grooves for regulating discharge into the off take	no	1	900.00	900.00	39.74
6.2.7	Stone pitching for protection work	m3	1.5	1,283.00	1924.50	84.97
6.2.8	Sub Total Cost for one Division Box				25,478.43	1,124.88
6.2.9	Sub Total Cost for Division Box	no	3	25,478.43	**76,435.30**	3,374.63

Table15:- Dunchay SSI Bill of Quantity

S/ No	**Description of items**	**Unit**	**Qt**	**Rate**	**Total Cost**	
				Birr	**Birr**	USD
	Total Cost for irrigation and Drainage before VAT				**13,027,694.07**	**575,174.13**
	VAT (15%)				1,954,154.11	86,276.12
	Total Including VAT				14,981,848.18	661,450.25
	Detail Engineering Design & Construction supervision (10%)				1,498,184.82	66,145.03
	Capacity Building (10%)				1,498,184.82	66,145.03
	Price and Physical Contingency (15%)				2,247,277.23	99,217.54
	Total including VAT				20,225,495.04	892,957.84
	Access road construction to the project site				10,050,000.00	443,708.61
	Total before VAT				1,507,500.00	66,556.29
	Total Including VAT				11,557,500.00	510,264.90
	G. Total Irrigation and Road				31,782,995.04	,403,222.74

Annex 3: Digital Elevation Model

I/ SELECTED IMAGES

• ALOS PRISM image characteristics

OPERATING ALOS SATELLITE			
Main data			
Name	ALOS "DAICHI"		
Constructor / Operator	JAXA	**Nationality**	Japanese
Archives	Multidates		
Delivery time	3 days to 2 weeks		
Coverage	World	**Internet On-line sale**	Yes
Resolution	2.5m (PAN) 10m (MS) 6.25 (SAR)	**Technology**	Visible and IR image SAR
Repetition	46 days 2 days with different viewing angles	**Orbit altitude**	691.65 km

Satellite history			
Name	**Date of launch**	**State**	**Sensors**
ALOS	2006	Lost	PRISM, AVNIR, PALSAR

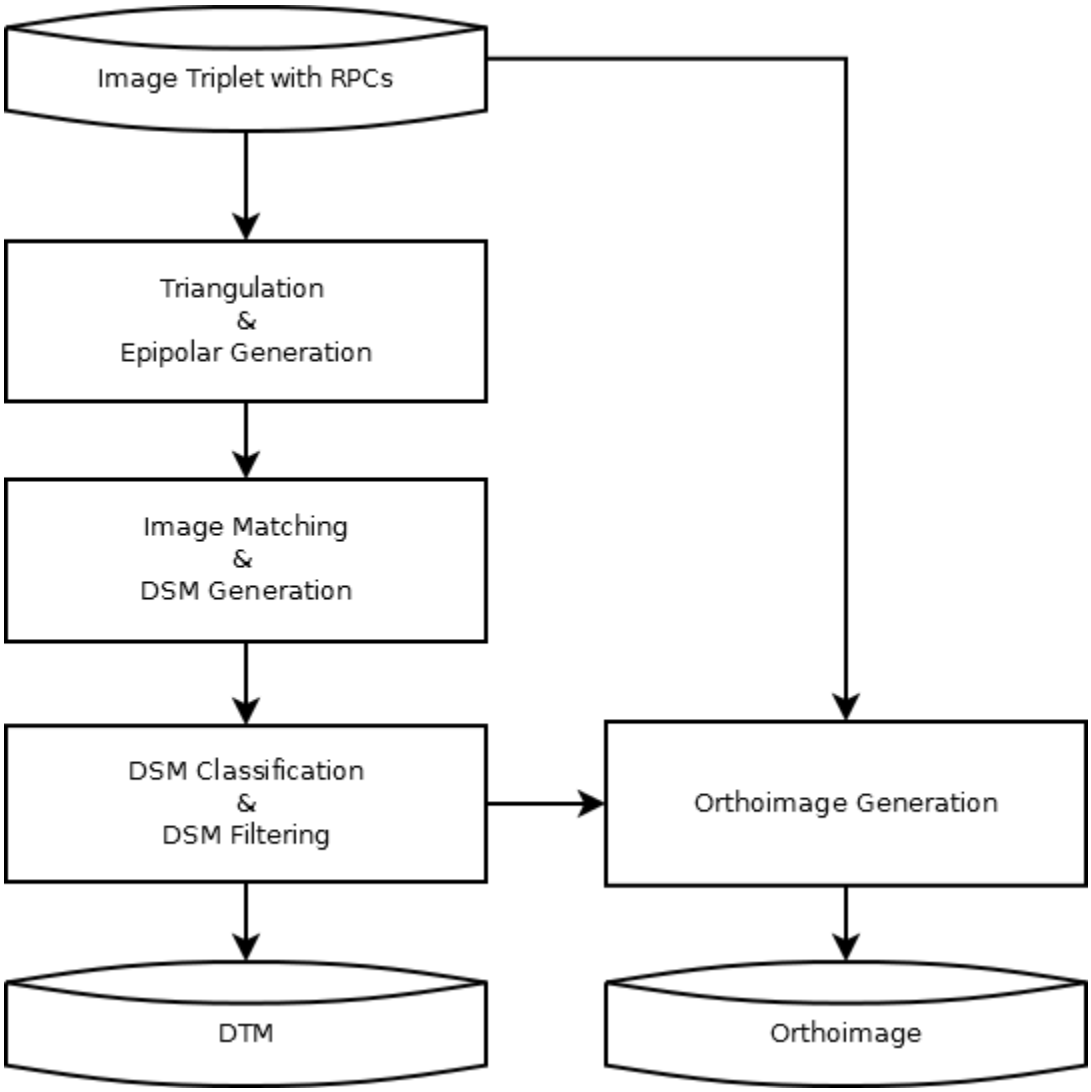
ALOS SATELLITE SENSORS			
PRISM			
Present on :	ALOS		
Resolution	Pixel size : 2.5 meters	**Number of bands**	1 band : Panchromatic
Scene size	35 Km x 35 Km	**Bit length**	8 bits
Stereoscopy	Triplet : Backward / Nadir / Forward	**Wavelength**	0.52 to 0.77
Characteristics	Grey scale image		

- **ALOS PRISM images list :**

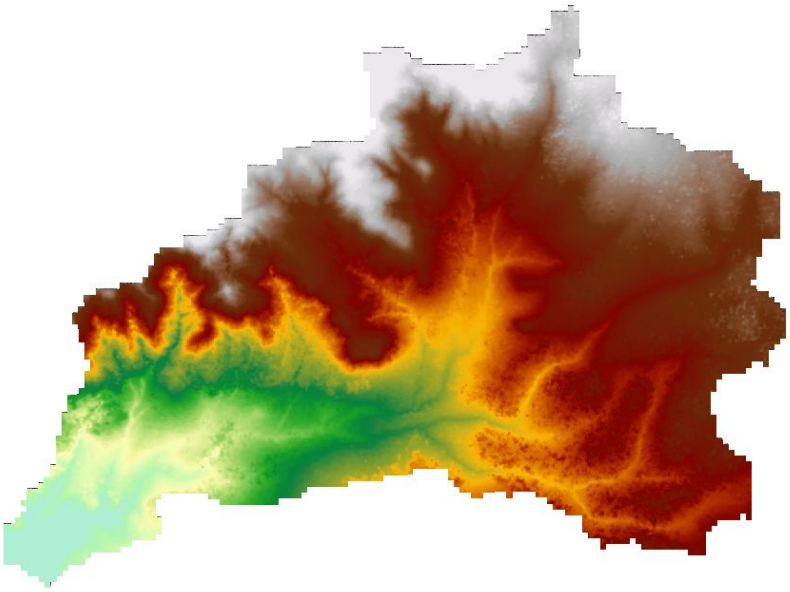
Ethiopia AREA : One triplet was necessary to cover the study area.

Image number	Acquisition date	Path/Row	Pixel size
ALPSMB201193510	2009-11-03	250-3510	2.5 m (1 band)
ALPSMN201193455	2009-11-03	250-3455	2.5 m (1 band)
ALPSMF201193400	2009-11-03	250-3400	2.5 m (1 band)

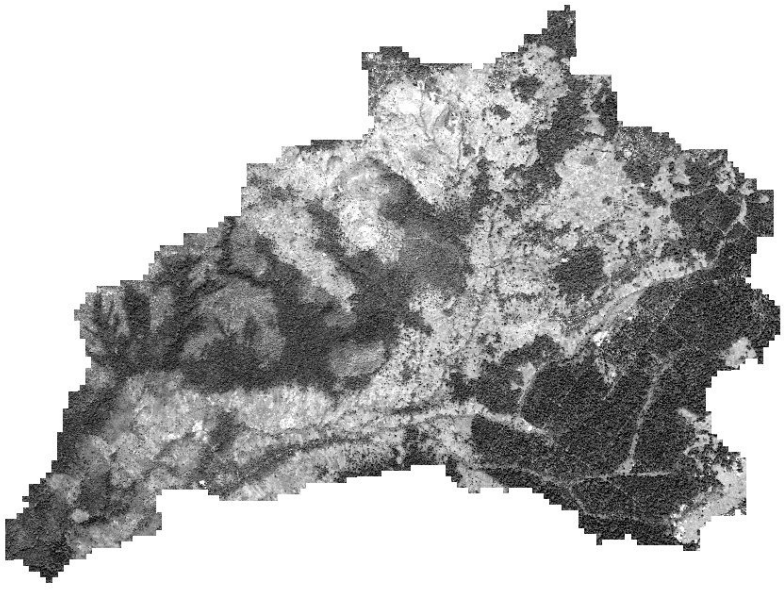
III/ IMAGE PROCESSING



III/ RESULTS



DTM



Orthoimage