WAHARA - Report Series

Study Site Database of Spatial and non-Spatial Data

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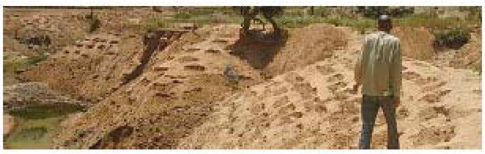
WAHARA



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SEVENTH FRAMEWORK PROGRAMME

WP1: The potential for WH in an array of biophysical and human environmental settings in rainfed Africa

D1.1 STUDY SITE DATABASE OF SPATIAL AND NON-SPATIAL DATA

by

M. Ouessar, M. Ben Zaied, R. Hessel, M. Sghaier, C. Ritsema

March 2012

1. Context

Within WAHARA, WP1 is dealing with the potential for WH in an array of biophysical and human environmental settings in rainfed Africa. As part of this work, an inventory of the study watershed(s) selected in WAHARA is performed. This inventory in the study sites included a detailed characterisation of catchment hydrology, farming systems, land and water use, existing land and water management interventions and current and potential provision of environmental services. The inventory will result in an ArcGIS database and associated Access database for non-spatial data. The primary aim of the inventory is to systematically collect data for internal use within the project, including – but not limited to – use in WP4 on modelling and impact assessment of WH. The database will be primarily managed by study site coordinators (i.e. separate databases per site), but partial collections will be gathered for cross-site comparative analyses (WP4-6). In addition to the database, study site descriptions were also made to provide an overview of the different sites.

2. Approach

A template for study site descriptions was prepared (see appendix …) and sent to the study site coordinators for completion. It consists primarily of: General information, bio-physical and socio-economic features, institutional and political setting and stakeholders, water resources and water use, water harvesting techniques used in the country and in the study region, past and on-going projects especially related to water harvesting, available time series data and maps. With this information an overview of the sites is obtained that provides all the background information that is necessary to understand the study sites and the problems that are experienced in these study sites, with a focus on water use and water availability.

A setup for the database was also made, and is described in section 4.

3. Summary of the study site characteristics and available databases

Below some of the main points from the study site descriptions are given for the different sites. The whole descriptions are given in Appendix 2. An overview is also given in table 1.

3.1. Burkina Faso

Located in the Northwest of the country, the watersheds of Ziga and Somyaga where around 140 000 people are living, covers an area of around 5000 km^2. The climate is sahelo-sudanian with the average annual rainfall ranging between 400 and 800 mm. The farming system is a mix of agro-pastoralism and agro-forestry. The main crops are sorghum and millet which are grown on various water harvesting systems such as: zai, half moon, bunds, etc.
In addition to the farmers and INERA, the main stakeholders include political leaders, development agencies (agriculture), farmer organizations, NGOs, other research and university teams.

Many development projects have been implemented in the region as well as research for development projects. The same site is also the study area of the project WHATER (which was funded in the same call as WAHARA).

Table 1. Overview of study site characteristics

	Burkina	**Ethiopia**	**Zambia**	**Tunisia**
Area (km2)	NE – 5000	East – 2400	South – 2300	SE – 1200
Rainfall (mm)	400-800	550-800	700-800	150-220
Bioclimate	Sahelo Sudan	Semi arid	Tropical conti	Arid
Population	140000	236000	73000	25000
Farming sys	Mixed	Mixed	Agroforestry, arable farming, dairy	Mixed
WH	Zai, ados, half moon, bund, cropping methods	Armo, diversion, spate, bunds, ponds, terraces, dams, eyebrow basins, deep trenches, cropping methods	Dams, cisterns, storage structures, quarries, cropping methods	Jessour, tabia, recharge structures, cisterns
Crops	Sorghum, millet, ..	Barely, maize, brocolli	Maize, cotton, groundnuts,	Olive, cereals
Water resources	Rain, dam, aquifer	Rain, springs, water storage,	Rain, wells, streams,	Rain, aquifer
Water use	Rainfed, irrigation, drinking	Rainfed agriculture, irrigation,	rainfed, drinking, livestock	Drinking, agriculture, industry,

3.2. Ethiopia

The study site is found in the Tekeze river basin in the Eastern zone Tigray. It concerns particularly the highlands watersheds of Suluh, Agulae and Genfel, covers an area of 2400 km^2 where around 236000 people are living primarily from farming activities. The climate is semi arid to subhumid with average annual rainfall ranging between 550 and 800 mm. The farming system is based mainly on rainfed and irrigation cropping and livestock. The main crops are barley, maize, broccoli, etc. A large variety of indigenous (armo, spate diversion, ponds, terraces, trench bunds, etc.) and introduced (gabion check dams, dams, concrete diversion dams, etc.) water harvesting and soil conservation technologies are practiced.

In addition to the farmers and the Mekelle University, the main stakeholders include local leaders, community organizations, development agencies (agriculture), farmer organizations, NGOs, international organizations, other research and university teams, etc.

Many development projects have been implemented in the region as well as research for development projects.

3.3. Zambia

Located in the southern province, the study area covers an area of 2300 km^2 where around 73000 people are living. Two major streams in Magoye and Ngwezic catchments drain into Kafue river. The climate is tropical continental high climate with dry winters and hot summers with the average annual rainfall ranging between 700 and 800 mm. The farming system is mainly agricultural based livestock including dairy and rainfed crop production. The main grown crops are sugarcane, cowpea, etc.
Magoye and Ngwezi streams have been dammed at several locations. Various WH and soil conservation techniques are practiced including individual and communal earth dams, local roof water harvesting, water collecting in roadside and quarries, in-situ water harvesting such as strip/zero-tillage, ripped furrows, planting basins, etc.

Besides the local farmers and GART, the main stakeholders include political and religious leaders, development agencies (agriculture), farmer organizations, cooperatives, NGOs, etc.

3.4. Tunisia

The watershed of wadi Hallouf, covering 1200 km^2, is located in southeastern Tunisia. With an arid climate, the rainfall is ranging between 150 and 220 mm. Around 25000 people are living in this site. The farming system is mainly based on rainfed agriculture and livestock. Various traditional/indigenous (jessour, tabia, cisterns, terraces, etc.) and newly introduced (gabion check dams, recharge wells, etc.) are encountered. They allow mainly olive and other fruit copping as well as occasional legumes and wheat.

In addition to the farmers and IRA, the main stakeholders include local authorities, development agencies (agriculture, environment), farmer organizations, NGOs, regional organizations (OSS), etc.
Many development projects have been implemented in the region as well as research for development projects. The same site is also the study are of the project AFROMAISON (which was funded in the same call as WAHARA).

4. Geo-database

4.1. Available data

The availability of data in the study sites is summarized in the table hereafter.

Time series data

Data	Burkina	Ethiopia	Zambia	Tunisia
Rainfall	☑	☑	☑	☑
Temperature	☑	☑	☑	☑
PET	☑	☑	☑	☑
Runoff		☑		☑
Flooding		☑		
Droughts	☑	☑		☑
Census of population at the regional level	☑	☑		☑
Surveys of farm structure	☑	☑	☑	☑
Household surveys (regional level)	☑	☑		☑
Prices of agriculture commodities and production factors		☑	☑	☑
Socio economic data base	☑	☑	☑	☑
Multi-sectoral data base				☑
Specific survey on livestock and animal production system	☑			☑

Spatial data

Data	Burkina	Ethiopia	Zambia	Tunisia
Boundary of study site	☑	☑	☑	☑
Topography	☑	☑	☑	☑
DEM		☑	☑	☑
Surface cover				
Soil	☑	☑	☑	☑
Vegetation cover	☑	☑		☑
Land use	☑	☑	☑	☑
WH works	☑	☑		☑
Aquifers		☑	☑	☑

4.2. Conception of the geo-database (an example from Tunisia)

The following steps are needed for the design of the database:

- *Conceptual model*
- *Logical model*
- *Physical model*
- Tables interaction (link, relation, cardinality, …)
- Data base interrogation (queries, test, questioning)
- Forms creation

4.2.1. Conceptual Model

The conceptual model is the fundamental part in the architecture of a data base system. The passage from the real model to the conceptual model (M.C.D) corresponds to a process of modeling where the objects of the real model are classified in categories and nominees by names. It consists in three elements of basis called entities (watershed, aquifers, soil, landuse, climatic stations, …), attributes (watershed name, aquifer deep, soil type, landuse system, rainfall, …) and relations between entities.

4.2.2. Dictionary of data

When the conceptual model is defined, its necessary to structure the data and the processes identified, this step permits the physical implantation of the conceptual model in the informatics corpse of the SIG (CLARAMUNT C., 1991). Thus, will be defined the files that contain the information, the attributes connected to these information, to get this one, in brief, everything that will contribute to make the system a real tool of management and analysis. The dictionary of the data contains all information on the entities of the data base (names, definition, spatial
reference, ...).

Example:
WATERSHED:. These basins separated by lines of water divides.
PEDOLOGY : It represents soil classification units

Entities	***Attributes***	***Relations***
Watershed	BV_ID: unique Identification Nom_BV: Name of the watershed Cod_BV : Number of the watershed Superficie: area of the watershed in square km Perimeter: watershed perimeter (km)	To contain : Geological Data To belong 1: infrastructural Data To belong 2: Climatic Data To belong 3: Hydrological Data To belong 4: Hydrogeological Data
Soil	Cod_unit : soil unit identification Type_sol : soil classification Text_sol : soil texture Prof_sol: soil depth Perm_soil : Soil permeability	Placed in : watershed number To belong: Administrative data

4.2.3. Logical model

The logical model is a representation of the (M.C.D) according to the possibilities of the status of the technological material. The entities and the relations described in the conceptual model of data are transformed under tables form. Identifying of the relations is gotten by concatenation of the identifying of the entities that participate in the relation.
Example: relations types
Relation one to one:
Case of a relation between the lithostratigraphy_Drilling_table and the drilling table

4.2.4. Physical model of data

The physical model corresponds to the structure of storage of the data. It permits therefore, to describe the data as they are stocked in the machine. Example:
Name of the table : watershed

By the attribute: BV_ID

Example of the physical model.

fields	Type	Larger	Decimal number
BV_Id	integer		
BV_Code	integer		
BV_Name	characters	25	

After the conception of geodatabase related to the study area we can start filling the data available and updated continuously by the newly collected data. Therefore, the geo-data base can be interrogated by query in order to obtain data in one or more tables from a question. For example, a query will be able to view the list of climatic stations in a specified area.

5. Conclusions

The study sites cover a wide spectrum of biophysical and socio-economic conditions in Africa. The bio-climates ranges from arid to subhumid as well as the average rainfall which varies from 150 mm (in Tunisia) to 800 mm in the other sites. The same trend could be also observed in terms of the size and the number of population. However, common features are also present such as the variability of climate and the associated risks of drought sand flooding. In addition, the major dominating specificity is the poor resilience of the rural populations to adverse extremes. Though the WH technologies used in the different sites appear to be different due to the local appellation, practically a lot of similarities exist which will allow comparative analyses.

The already available databases and the planned data to be collected along the implementation of the project will be first assembled in an organized in a geodatabase. In addition, it will be also of great value for the calibration and the validation of the models.

6. Appendices

6.1. Study site description template

WAHARA project
Study Site descriptions

1. **Responsible partner**
2. **General information**
   - Location (coordinates) + map / Google Earth kml-file (placemark or map overlay), Size (km^2)
   - Main reasons for selecting this site/region
   - Participating local partner institutions
   - Photos or other figures (NB: can be added anywhere in the text)
   - Main used language(s)
3. **Bio-physical description**
   - Topography / DEM
   - Climate: rainfall, temperature, ETP, etc.
   - Geology (+ map)
   - Soil (+ map)
   - Hydrology (+ map)
   - Hydrogeology (+ map)
   - Vegetation / land use (+ map)
4. **Socio-economic description**
   - Population density, as well as structure (by age, by sex ratio)
   - Changes in population (rural urban migration; population built up)
   - Level of education
   - Level and source(s) of income main stakeholder groups (income from the resource base vs. income from off-farm labor or from family members in city or abroad)
   - Major livelihood supports available from the resource base listed above
   - Agriculture. Which crops? Growing season? Irrigated/Rainfed? Average Yield?
   - Pastoralist systems – intensive, extensive grazing – water sources for livestock
5. **Institutional and political setting / Relevant end-users / stakeholder groups (at all levels)**
   - Govt. organizations (agriculture, environment, etc)
   - Research Centers and Universities
   - NGOs / Community based organizations
   - Socio-professional organizations
   - Companies/industry
   - Farmers and farmer organizations
   - Links between these organizations

6. **Water resources and water use**
   - Main sources of water, quality of water, amount of water
   - Moisture patterns throughout the year – period of stress and abundance and responses
   - Main uses and users of water – existing infrastructure
   - Insights in links between surface water sources, groundwater recharge and soil moisture
   - Any conflicts about water or moisture?
   - Upstream/downstream linkages

7. **Water harvesting techniques (used in the country/region and with focus on the study site/area)**
      - Traditional techniques (description, advantages, main problems, potential)

- Farming practices in use influencing water conservation (mulching, windbreaks, conservation agriculture, ploughing)
- Modern techniques (description, advantages, main problems, potential)
- Infrastructure having secondary effect on soil moisture and water retention – such as roads, irish bridges, embankments, sand-gravel pits
- Management practices influencing these water harvesting practices

8. **Past and on-going projects (especially related to water harvesting)**
   - Trends of land owners investing in water harvesting and land improvement
   - Government project (e.g. Extension, Watershed Management Planning etc)
   - Development projects
   - Research projects

9. **Available time series data**
   - Climate: rainfall, Temperature, ETP, Runoff, flooding, droughts, etc.
   - Land use: multiple date satellite images, etc.
   - Demography
   - Land tenure
   - Farm production

10. **Available maps (scale, date, format, etc.) – or descriptions in absence of maps**
    - Boundary of area (preferable hydrological catchment)
    - Topography (roads, towns etc)
    - DEM
    - Surface cover (permeable, impermeable
    - Soil
    - Vegetation
    - Land use
    - WH works
    - Aquifers – shallow aquifers in particular

11. **References**

6.2. Study sites full description reports

WP1: The potential for WH in an array of biophysical and human environmental settings in rainfed Africa

STUDY SITE DESCRIPTION: WATERSHED OF WADI HALLOUF, TUNISIA

by

M. Ouessar, M. Sghaier, M. Ben Zaied, M. Abdeladhim

November 2011

1. Responsible partner

Partner: 4: Institut des Régions Arides (IRA), Médenine, Tunisia

2. General information

The study site (SS) belongs to the region of south eastern Tunisia (figure 1). It is a transect which stretches out from the Great Oriental Erg and the Dahar plateau in he west, crosses the Matmata mountains between Béni Khdache and Toujane and the open Jeffara plain, then the saline depression (Sebkhat) of Oum Zessar before ending into the Gulf of Gabès (Mediterranean sea). The SS covers an area of 1226 km^2 and the approximate coordinates of the central point are 33°16’ N and 10°08’ E.

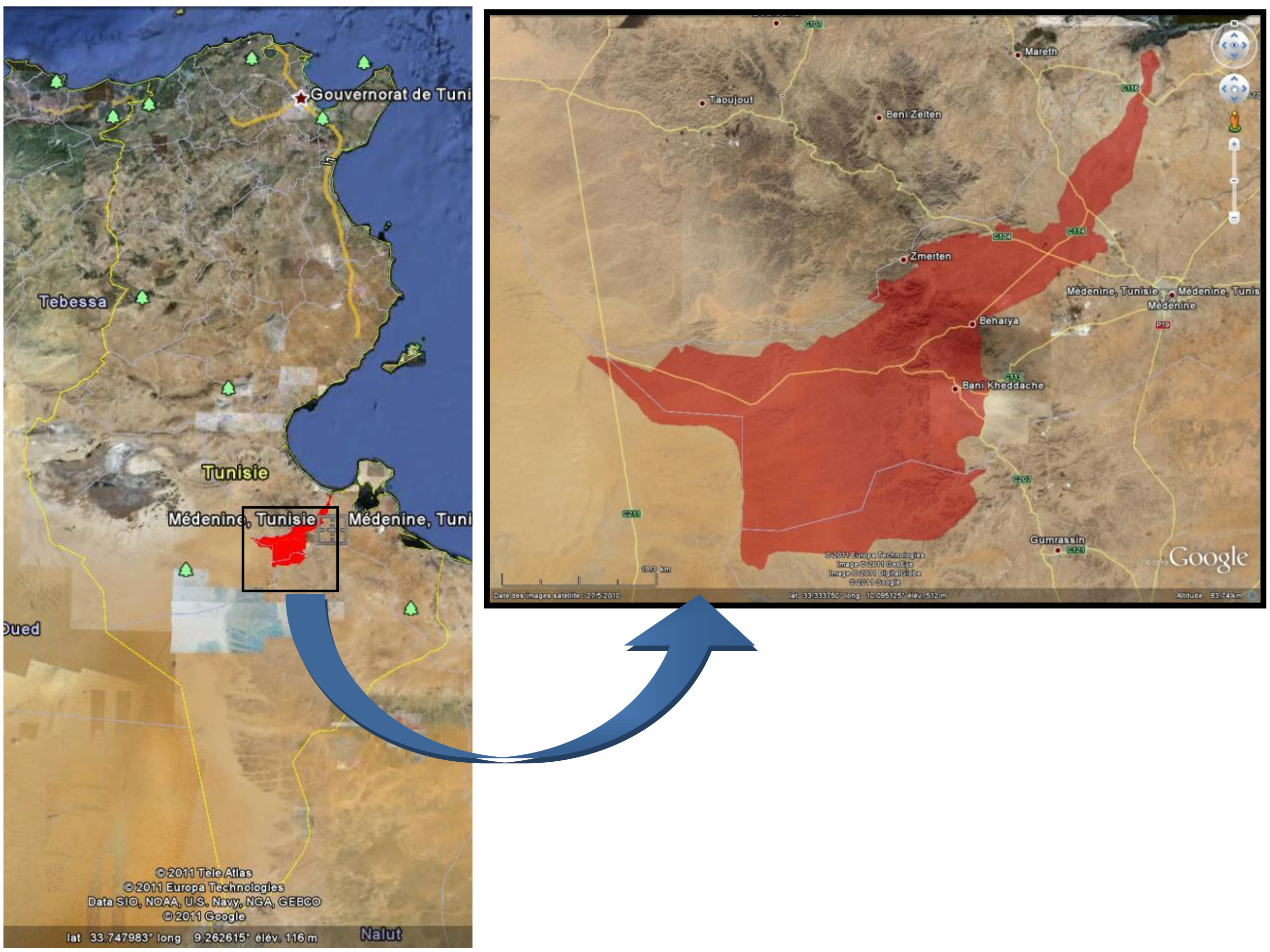

Figure 1: Study site location.

The site was selected for the following reasons:

- From the ecological and socio-economic point view it is considered representative of the region of south east Tunisia where desertification is a major concern,
- Since 1995, many integrated research projects for development cooperation (funded by the EU, CSFD, USDA, Flanders, etc.) have been undertaken in the same region such as: WAHIA (water harvesting impact assessment), MEDRATE (Evaluation of rainfed agriculture in the Mediterranean), GISTUN (GIS for watershed management), Jeffara, SUMAMAD (Sustainable management of marginal drylands), DESIRE, etc.,
- Major development projects have been carried out: soil and water conservation strategy, water resources mobilization strategy, natural resources management and livelihood improvement (World Bank); rural development programs; basic infrastructures (water, electricity, roads, etc), etc.
- IRA contributed actively in 2006 in the elaboration of the local action plan for combating desertification as part of the NAP-UNCCD in the delegation of Béni Khédache.

The main local involved partners are:

- The regional department of the Ministry of Agriculture (Commissariat Régional au Développement Agricole) (CRDA) which is in charge of all agricultural development programs and projects in the province of Médenine.
- Two local NGOs (AJZ: Association des Jeunes de Zammour à Béni Khédache; APB: Association de Sauvegarde de la Biodiversité à Béni Khédache) engaged in the preservation of the environment, combating desertification and local development.
- GDA (Groupement de Développement Agricole): the herder association which focuses mainly on the problems of grazing and livestock husbandry in the rangelands of the Dahar plateau.

Though Arabic is the official language, French is widely used too, especially for technical purposes. However, English is relatively restricted to research and university arena.

3. Bio-physical description

Theses catchments areas are drained by two principal wadis : wadi Hallouf in the west part and wadi Oum Zessar. The last one runs out since the mountainous chain of Béni Khédache crosses the Northern county of Médenine and reaches the county of Sidi Makhlouf to flow in Sebkhas Oum Zessar before reaching the sea. The highest point of the watershed reaches an altitude of 713 m on the level of Jbel Moggar (figure 2).

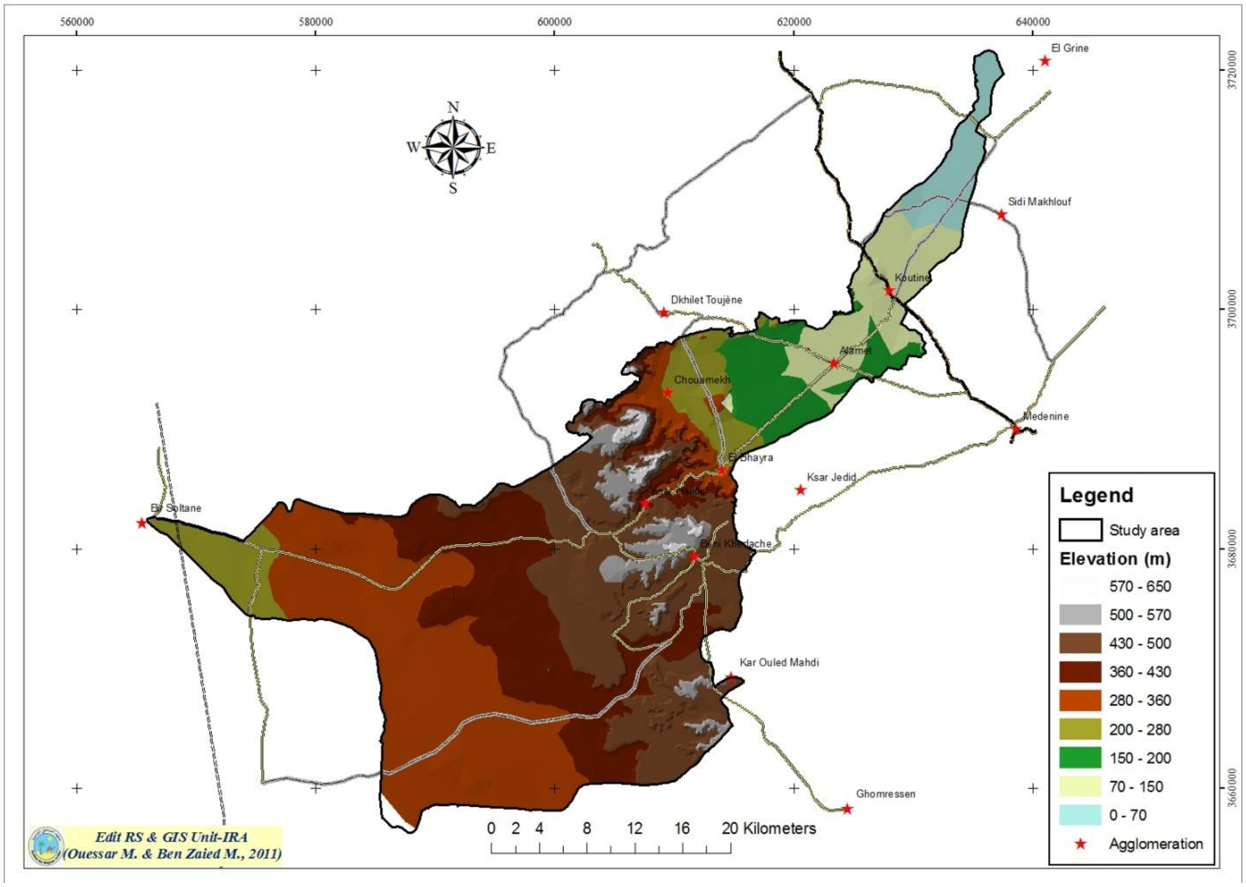

Figure 2: Digital Elevation Model (DEM)

The climate in the study site is of the Mediterranean to Saharan type (figure 3). The coldest months are December, January and February with occasional freezing (up to -3 °C). June-August is the warmest period of the year during which the temperature could reach as high as 48°C. The temperature in the SS is affected by the proximity to the sea and the altitude (figure 4).

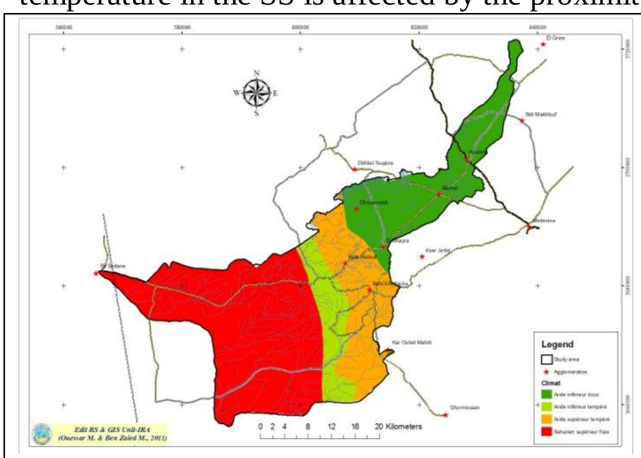

Figure 3: Bioclimatic map of wadi El Hallouf watershed

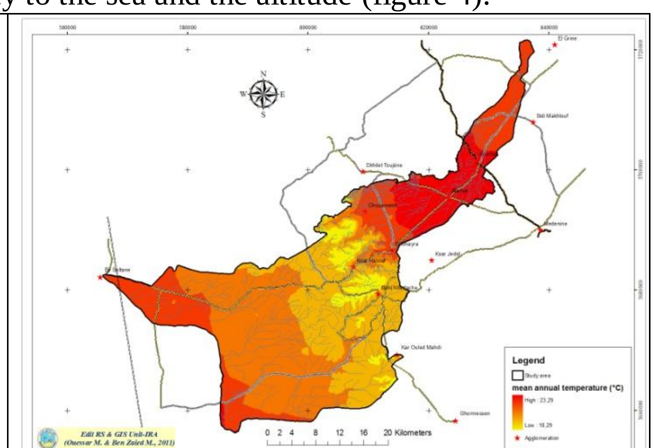

Figure 4: Temperature map (wadi El Hallouf watershed)

Having an arid climate, the rainfall in the SS is characterized by low averages, high irregularity (both in time and space) and torrential characteristics. It receives, on annual average, between 150 and 240 mm in the mountains and eastern parts but this amount decreases rapidly to less than 100 mm in the zones close to the desert (figure 5). The prevailing winds affecting the plain and the plateau are: in winter the cool and humid eastern/northeastern winds, and in summer the hot and dry southeastern winds, called *Chhili* or *Guebli*. With high temperature and low rainfall, the potential evapotranspiration (ETP) is very high (around 1321 mm/year) (figure 6) and the climatic water balance is negative almost around the year (Ouessar et al., 2006).

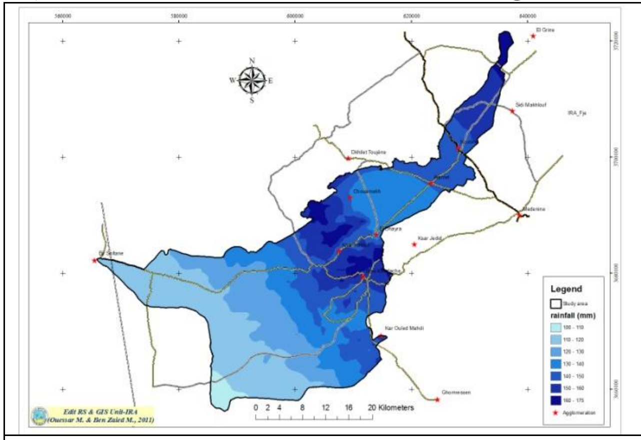

Figure 5: rainfall map of the study area

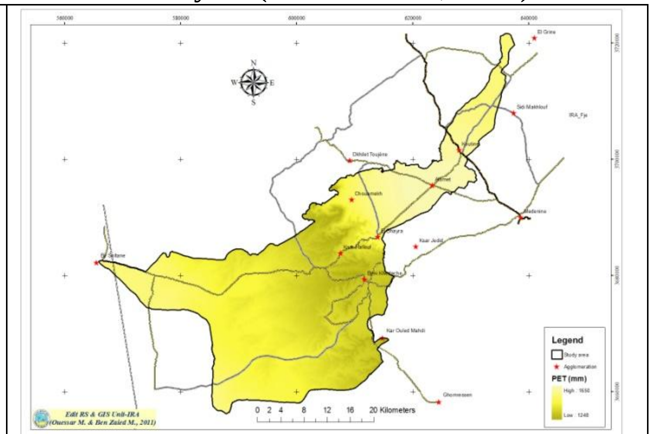

Figure 6: Potential Evapotraspiration map

The geological formations are of alternating continental and marine origin. The oldest submerging layers are represented by a marine, superior Permian, and the most recent ones are of the recent Quaternary. In between appear strata of different age, which is generally declining in northward direction.

Five main soil classes have been identified by Taamallah (2003) (figure 7):

- *Les sols minéraux bruts (d'érosion)(*lithosols*)* made up mainly of dolomites, limestone outcroppings and stony regs. They are located in the upstream area (mountains and hills). They cover 20% of the study area.
- *Les sols peu évolués* (Fluvisols) occupy a relatively reduced area and are found in the plain and the downstream parts. They represent 13%.
- *Les sols calcimagnésiques* (Calcimagnesic) represented by rendzinas on calcareous or gypsum crusting or on the miopliocene. They cover an important area on the upstream and piedmont parts (35%).
- *Les sols isohumiques bruns calcaires tronqués* (Isohumic)*:* They are not very deep soils overlaying on the dismantled calcareous crust of villafranchian and covered sometimes by a shallow (few centimetres tick) of wind deposits. They cover 20% of the region.
- *Les sols halomorphes et hydromorphes* (solonchak and solonetz) are encountered at the level of the depressions (*sebkhas* and *garaas)* on the coastal areas. They are characterized by a very high salinity (12%).

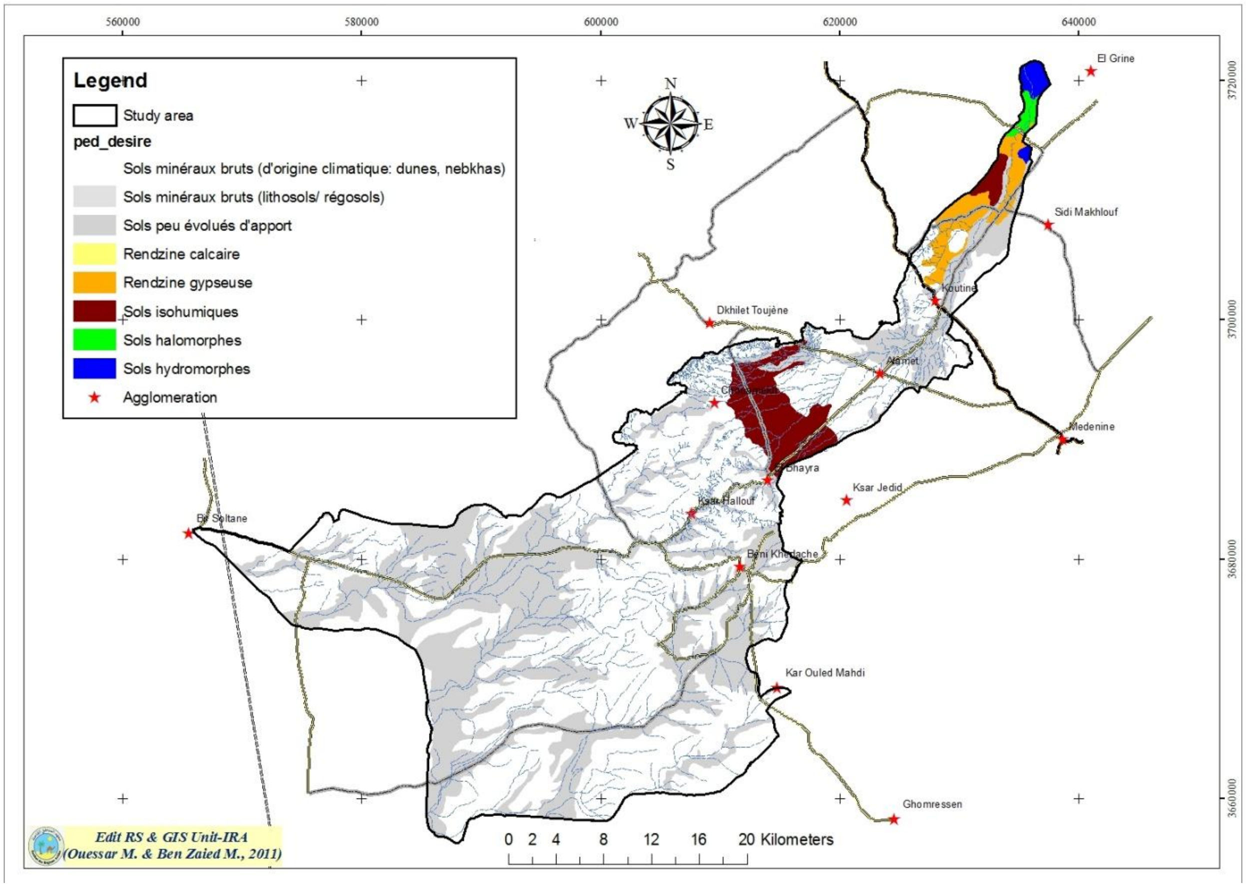

Figure 7: Soil map of the study area (source: Taamallah (2003).

The study site is drained by two main wadis (dry streams): Oum Zessar (367 km^2) facing east while the Hallouf Dahri (859 km^2) is facing west. The average runoff is estimated at 8.74 mm^3/year (Fersi, 1985).

The most important aquifer is that of Zeuss-Koutine. It is situated between the mountains in the southwest, the submerging jurassics of the Tadjeras in the south-east, and the fault of Médenine in the north east, and consists in layers of jurassic age (figure 8). It is sustained by infiltrating water from the wadis Zigzaou, Zeus, and Oum Zessar and the C.I. (*Continental Intercalaire*). Renewable resources are estimated to 350 l/s with a salinity ranging from 1.5 to 5 g/l. The depth varies between 170 and 680 m. The second one is that of *Grès du Trias***,** extending from Harboub in the south, the zone of Médenine and Metameur in the east, Wadi Hallouf in the north, and the Dahar fault in the west. Fed by the wadis of the plain of El Ababsa, it dwells in formations of the upper Trias. Salinity ranges from 0.9 g/l at El Megarine and 1.5 at Harboub. Actual exploitation is 128.2 l/s, with the renewable resources estimated at 150 l/s. The average depths is about 150 m. The characteristics of the various deep aquifers in the study were summarized by Labiadh (2003). Except, the Jurassic aquifer of Beni Khédache, the pumping rate of the various aquifers is very important. In addition, the salinity is also high. Shallow aquifers are found in the form of limited resources surface aquifers within less than 50 m depth but with high salinity in most of the cases. They are mostly generated by the subsurface underflow of the big wadis (Labiadh, 2003; Ouessar and Yahyaoui, 2006).

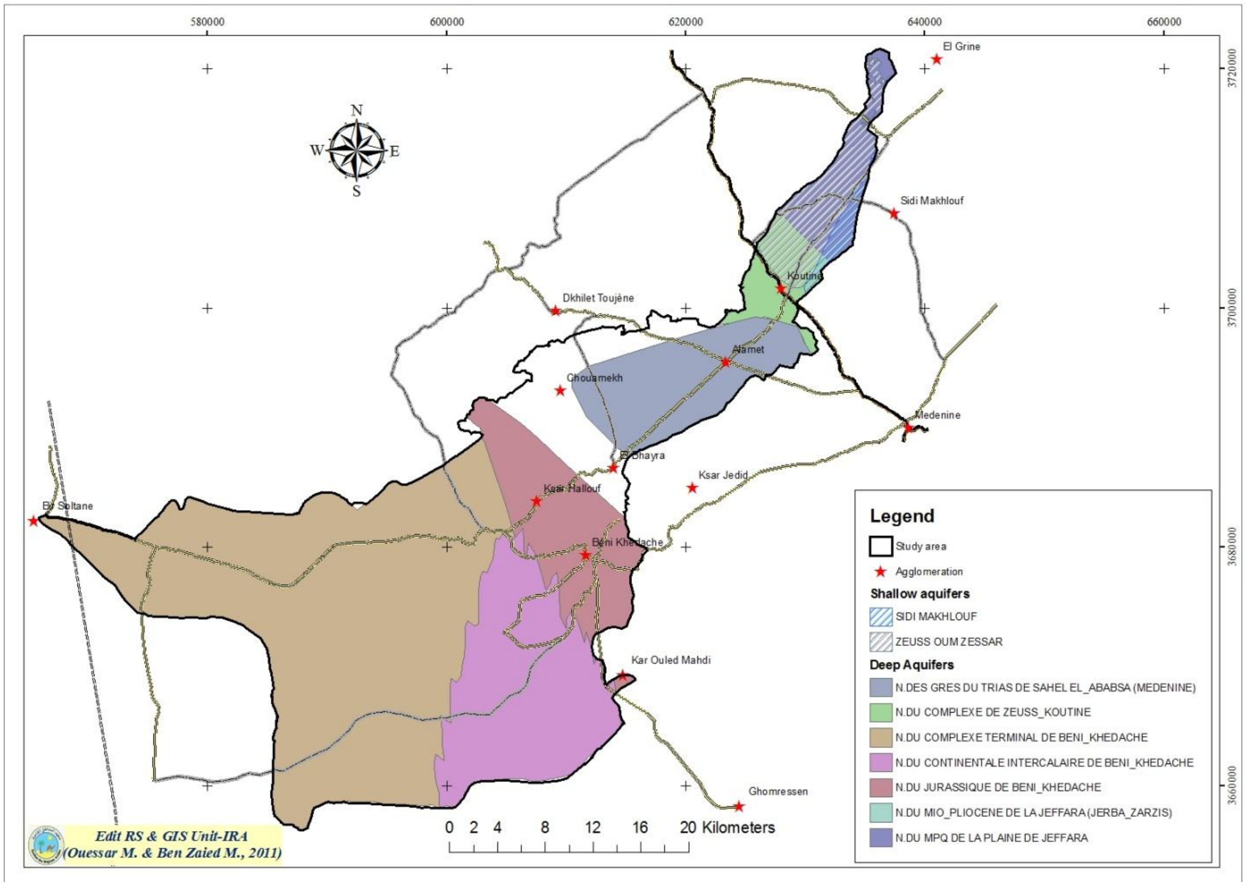

Figure 8: Aquifers map

The study area is characterized by a high diversity of vegetation types. They are linked to several ecological groups whose major part is soil groups (Ouled Belgacem et al., 2003) (Associations of *Anarrhinum brevifolium* and *Zygophyllum album*, of *Artemisia herba-alba* and *Hammada scoparia*…), but also influenced by human pressure (Association of *Pituranthos tortuosus* and *Haplophyllum vermiculare*, facies of *Pituranthos tortuosus* and *Artemisia campestris*). This could be explained by the important role of soil and man in the determination of the plant cover in these arid regions of Tunisia. This analysis allowed us not only to locate the main vegetation types which have been determined earlier but also identify new degraded facies of *Helianthemum lippii var. intricatum* of the *Anarrhinum brevifolium* and *Zygophyllum album* association. The determination of these different vegetation types and the spacialization of the field data meaning the GIS permitted the establishment of the vegetation map of 2001 (Ouled Belgacem, 2003). A high diversity of vegetation types was found due to biotic factors (soil water availability, physico-chemical characteristics of soils) as well as to abiotic factors (topography, human activities). According to the topsequence, we can distinguish relics of the *Juniperus phoenicea* and *Rosmarinus officinalis* evergreen garrigue at higher calcareous mountains followed by the *Stipa tenacissima* steppe which dominates the calcareous crust mountains. When degraded, this steppe has been replaced by the *Artemisia herba-alba* and *Hammada scoparia* steppe with its *Gymnocarpos decander* facies. In the piedmont with gypseous crusts, the *Anarrhinum brevifolium* and *Zygophyllum album* is mostly degraded and very often replaced the *Astragalus armatus*, *Atractylis serratuloides* or *Lygeum spartum* steppe. The low-lands are very often covered by steppes of *Ziziphus lotus*, but in "stream beds" the *Artemisia campestris* and *Thymus capitatus* steppe often dominated. The sandy valleys to the south-west of the study area are mainly dominated by a very degraded *Rhanterium suaveolens* steppe which has been generally replaced by different deterioration stadiums of *Astragalus armatus* or *Lygeum spartum* or its abandoned fallow lands with *Artemisia campestris* and *Pituranthos tortuosus*. Toward the downstream and in the salty closed depressions (sebkhas), the plant cover is generally dominated by halophytes such as *Nitraria retusa*, *Suaeda mollis* and *Limoniastrum guyonianum*. By comparing the dynamic of the vegetation between 1972 and 2001, Ouled Belgacem *et al.*, (2003) found: 1) an important extension of the cropping area especially in the sites where the topography is favourable for sediment and runoff collection. In fact, the data provided by the GIS showed an important decrease of the pure steppe area between 1972 and 2001 of about 13700 ha (36%) in favor of the cropping area which increased of about 200%, and 2) a high dynamics of the different vegetation types in a relatively short period (30 years). This dynamics is linked to anthropic factors (agricultural development, grazing) favored by the endogenous conditions (physico-chemical characteristics of soils, stock of seeds in the soils…). Also the important extension of crops was apparent at the expense of high range value vegetation types covering the good soils (ex: steppes of low-lands). These vegetation types are often replaced by deterioration steppe dominated by spiny species of low range values (e.g.: steppe of *Astragalus armatus* replacing steppes of *Rhanterium suaveolens*…) (Ouled Belgacem *et al.*, 2006).

A simplified land use map (figure 9) is adapted in the case of the study area:

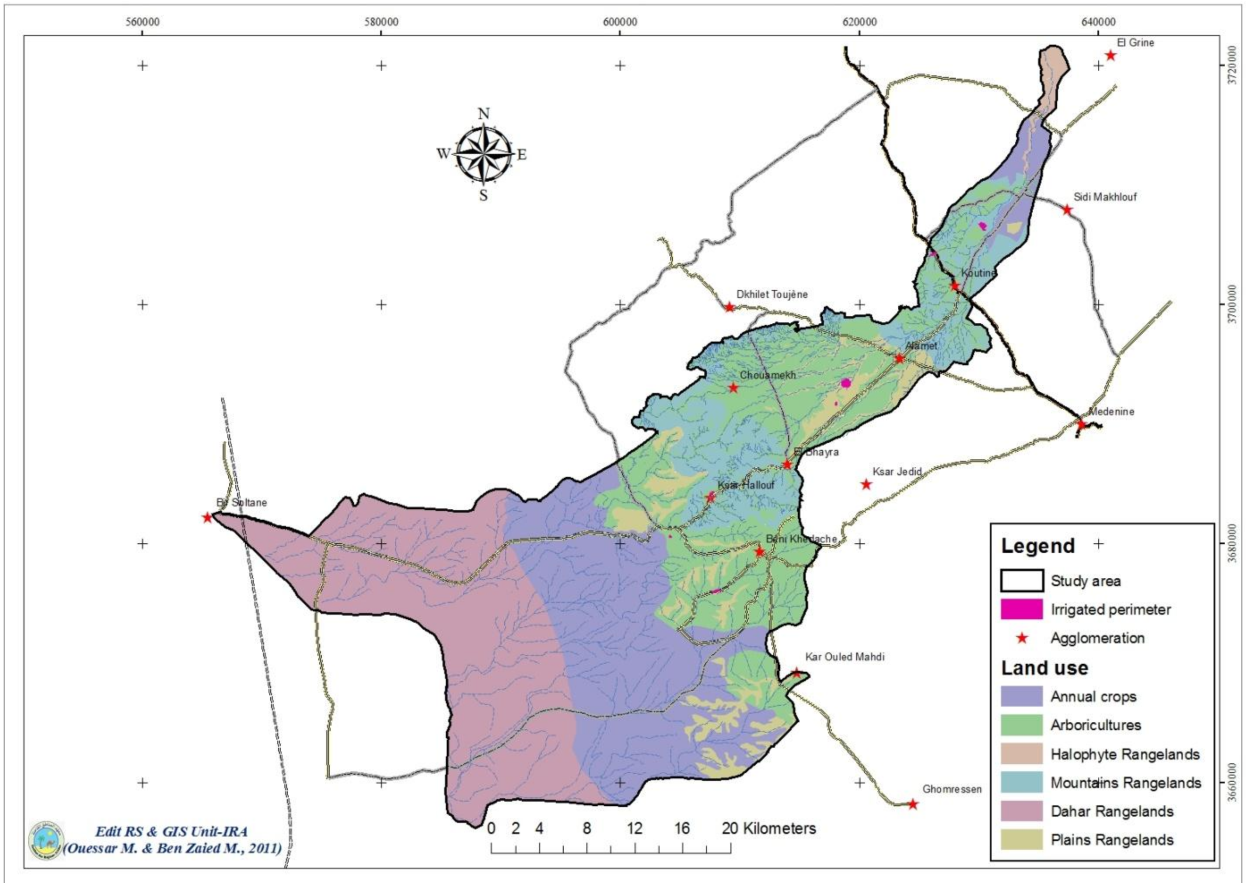

Figure 9: Simplified land use map (adapted from Ouessar, 2007).

4. Socio-economic description

The study area stretches to 10 locations belonging to three delegations such as Beni Khedache (3 locations), Medenine North (3 locations) and Sidi Makhlouf (4 locations). The population of the three delegations was estimated at 20213 habitants (INS, 2004), which were respectively distributed as follows: Beni Khedache 5538, Medenine North 9896 and Sidi Makhlouf 4779 habitants (figure 10). Approximately the population living at the study area represents 24.4 % of the total population of the three delegations.

The overall annual population growth rate in Medenine governorate was 3.3% during the decade 1972-81, this rate decrease to be 2.7% during the 1982-91 decade. Currently it is almost 1.2% (MEDD, 2006). Other, the Medenine governorate has become relatively marked by the predominance of urban population. Indeed, the urbanization rate was 61.8% in 1994 and reached 77.1% in 2004 (INS, 2004). The age structure analysis of the local population shows that in general the population is young. However, this situation is changing; the age group [0-14 years] showed a relative decline from 44.8% in 1966 to 33.9% in 2000, and is projected to be 27.2% in the year 2015 (INS, 2005); while the age group between 15 and 60 years substantially expanded, to exceed 50% in 1994, reach 57.5% in 2000, and will be almost 65% in 2015 (sghaier et al, 2006).

Apparently, the average population density is quite low with 30 inhabitants/km². The population density per land use type shows that the plain region is most populous with 60 inhabitants/km². The lowest population density is showed in the Dhahar Mountains, where the socio economic and living conditions are very harsh.

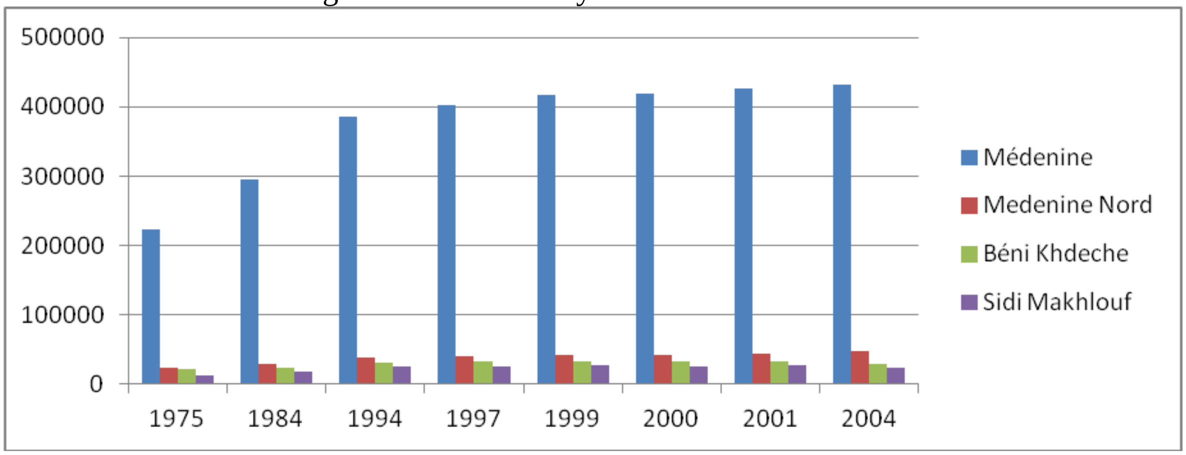

Figure10: Population growth in Medenine governorate between 1975 and 2004. (Source INS statistics)

The overall illiteracy rate in Medenine governorate exceeds 17% in 2007 (figure 11). In fact, 40% of the population finishes primary school education and 37% the secondary school, only 7% reach grade. The education level is very diverse in relation to the gender. According to Picouet et al (2003) the proportion of illiterate men is relatively low and estimated at 8 % for the age between 15 and 49 years. It is estimated at 60 % for the men with an age over 50 years. For women this proportion is higher than 35 % and 95 % respectively for women aged between 15 and 49 years and older women.

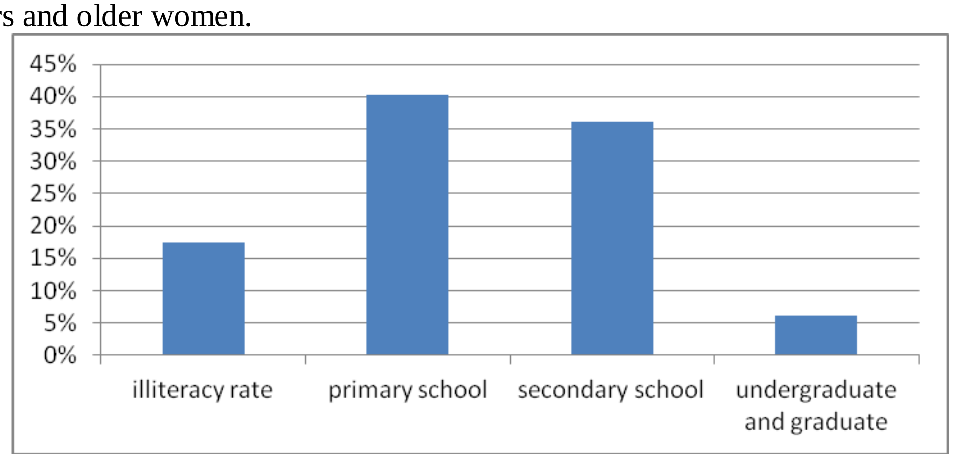

Figure 11: the education level at the Medenine governorate (INS, 2007)

The rural net migration (1999-2004) at the study area oscillates between 9 and 7%. It reaches respectively 9% in Medenine nord, 7% in Bénikdache and 7% in Sidi Makhlouf. Compared to the overall net migration rate in Medenine governorate (0.14%) the different net migration rates at the three catchments seems very high. This is can be explained by the natural resources degradation that's led to the low incomes.

Table 1. Net migration in the study area.

	Net migration between 1999-2004	Net migration rate %	immigrants	emigrants
Medenine nord	-889	9	4691	5580
Béni khédache	-384	7	599	983
Sidi Makhlouf	-348	7	599	983
Governorate of Medenine	527	0.14	27012	24316

The distribution of active population (ages between15 and 60) in the three delegations is as follows: Béni Khedache 27.2%, Sidi Makhlouf 33.7% and Northern Medenine 40% of the total population (ODS, 2006). The overall unemployment rate in the Medenine governorate is almost 10.3% and is among the lowest in the country (The unemployment rates in Tunisia as a whole was 15% in 2004).

Concerning living conditions, the infrastructure indicators show provision of drinking water of 95.4% and electricity of 96%. The road network (1,424 km of paved roads and 3,554 kilometres of unpaved roads) is also well developed (ODS, 2008).

The economic activities is mainly based on the agriculture and tourism sectors. The area has a large agricultural potential based mainly on tree cultivation, breeding and fishing activities. Farming remains a vital activity in the study area. Farm income plays a very important role in decision-making with respect to land management. Farmers tend to adopt suitable strategy to preserve the soil and the environment if farm incomes are sufficient or in surplus. Annual household incomes were estimated for the the study area at 2500 TND (Sghaier et al, 2009). Taking into account the harsh conditions in the area and compared to the minimum wage in the agricultural sector, this is quite acceptable income. However, off-farm incomes from other sectors such as artisanal activities, industries and public activities are also available. In fact, off-farm incomes contribute quite significantly to total family incomes (TFI) between 21% and 28.5%, respectively in the plain and in the mountains (Sghaier et al 2003).

Other the tourism is considred us a growing sector that employ more then 16 % of the active population. The region has over 123 hotel units with a total capacity of 45,100 beds and more than 6.5 million overnight stays per year, mainly in Djerba and Zarzis. Djerba is the main tourist destination in Tunisia, which enjoys an international reputation providing quality tourism products. Agro-ecotourism has boomed because the area is endowed with geographic units of mosaic landscapes where ecological (geology, vegetation), agricultural (pluvial agriculture, irrigated agriculture), archaeological (Roman ruins, Ksours, mosques) and cultural (matrimonial traditions, handicraft traditions, culinary traditions, etc.) traditions abound.

Since independence, the land tenure in the study area has changed with the privatization of the traditional collective lands and the evolution towards a more intensive agro-pastoral system. The promulgation of many laws since 60s has accelerated the process of privatization which encouraged the people to transform the rangelands into private cropping fields. In fact, the collective situation of the land has undergone a constant evolution during three main periods (1901-1964, 1964-1974 and 1974-1998). The area of the collective lands decreased from 99,150 ha in 1901 to 19,680 ha in 1998, i.e. a reduction of 80 %. 86 % have been attributed to private owners whereas the remaining (14%) are proclaimed as ranges within forest lands. During the period 1964-1974, the private lands doubled whereas it increased only by 19% between 1974 and 1998 due to the attribution procedures as well as the encountered difficulties at the level of some communities. The current land tenure situation of the study zone is characterized by two features: The prevalence of the small sized properties. 50 % of the farms have a maximum area of 5 ha; the property division is rather reduced (Sghaier et al., 2003).

Actually, several farming systems can be distinguished in the study area. The criteria of classification can be summarized us fellow (Ouessar et al., 2002):

- Irregular or seasonal agricultural production, which varies from year to year depending on rainfall
- Arboriculture and extension of newly cultivated fields
- Extensive livestock husbandry systems that are highly dependent on natural grazing lands, to intensive livestock system
- Irrigated agriculture which exploits both surface and deep ground water aquifers
- Olive trees (almost 90 %) and episodic cereals.

According to the classification criteria mainly five faming systems can be sited:

The jessour system: Is mainly practiced in the upstream area of Beni Khedache and Moggar. The olive is the dominant tree-crop practiced behind the jessour other small areas of fruit trees such as fig and almond, and wheat, barley and food legumes (chickpea, beans, green pea and lentil) are also practiced. The farm size for these crops expands overtime, from very small to 0.25 ha depending on rainfall.

The rainfed production system: is mainly practiced in the Jeffara plains and piedmonts. It consist of crops plantation only once in two to three years, mainly for home consumption. The main crops are cereals (wheat and barley) and legumes (faba bean, lentil, green pea). Olives are also dominant in rainfed systems with some figs, almonds, apples, etc. olive trees are often planted behind tabias with a fig and almond trees.

The irrigated perimeter system: contain the private and the public irrigated perimeters. The irrigated perimeter is on surface wells and known as a localized soil and water conservation (SWC) system, commonly practiced in upstream and downstream areas. Cash crops, greenhouses, vegetables and fruit trees are common in the upstream and downstream area. The cropping area ranges from 0.2 to 10 hectares. The Public irrigated perimeters are established through collective drilling facilitated and funded by the State. Water management is ensured by a collective interest association known as ‘AIC’. These perimeters are situated in the downstream zone such as in Kosba.

The multi-crop breeding system contains two subsystems. The first one is marginal agriculture, characterized by small areas and where most part of family incomes are derived from non agriculture sources. The second one is the agro-breeder sub-system, which is run by former breeders that transformed the system through introduction of crops, but which has also affected livestock husbandry. The system is mainly found in downstream areas on fragmented parcels of 25 to 85 hectares. The number of livestock is usually between 20 to 150 goats and sheep, and 100 camels grazing in the saline rangelands of sebkhats (saline depressions).

Photo 1: Jessour system in the mountains of Béni Khédache.

5. Institutional and political setting / Relevant end-users / stakeholder groups (at all levels)

Since the mid of 80s, a decentralization process has ben indertaken in Tunisia. As a results a dence of governmental and non governemental institutional tissue has been emerged. The institutes take on charge the natural resources managments. In fact, the management of land and collective rangelands in arid and semi arid areas of Tunisia is ensured by the Council of collective land management, which is a local institution in charge of the privatization of collective lands. The aims are to encourage the development of collective land and improve the social conditions of community members, ensure maintenance of plantations and land development in the collective territory ECT.

Water governance in Tunisia is very old, but since independence, this has undergone two major periods of change. The first period was marked by so-called ‘supply management’, wherein the governance of water is dominated by government interventions and centralized management through the national agencies. The second period was marked by the 1975 Water Code of Tunisia (Act No. 87-35), which established the legal instrument for water management. On July 6 1987, the Water Code was amended through Law No. 87-35, which creates user associations in the hydraulic domain called Collective Interest Associations (AIC). Actually the AICs were given important roles in the management of irrigation and drinking water supply. Reforms continued in 2001 through the Act of 26 November 2001. Water has thus, become an inalienable national wealth. The coordination and the supervision on the different institution is insured by the Regional Commissariat of Agriculture Development. In other hand, the institutional tissue insures the local implementation of a wide range of natural resources management policies and international conventions.

Table2: Institutional network

Institution	**Roles**
Regional department of agricultural development (CRDA of Medenine)	Planning of natural resources and agricultural development programs at the Medenine governorate level Implementation and carrying out the programs Assistance and supervision of NRM Extension activities Control Support to local actors and farmers
Regional administration of Animal production and rangeland office	Assistance and support of the animal production and private rangeland Implementation of animal production programs (animal feeds, pasture improvement in private rangeland) Extension activities
Regional department of the State domain	Land planning Control Support the local actors and farmers concerning land

	Extension activities
Regional administration of Agency of agricultural investments	Encouragement and promotion of private agricultural investment
South development Office (ODS), Ministry of regional development	Economic and development planning (all economic sectors) Monitoring and evaluation of the regional development plan Promotion of investments
Financial institutions (Banks, funds, credits and subsidies etc.)	Financial support (Credits, Subsidies) Encouragement of investment
Research institutes like IRA and University	Research activities Training and capacities building Supporting development
NGOs: AJZ (Association des Jeunes de Zammour), ADD (Association de Développement Durable), APBB (Association de la Protection de la Biodiversité à Béni Khédache), ACPPBK (Association de Conservation du Patrimoine), etc.	Assistance and support of development and research activities

Stakeholder collaboration process was adopted in several research and development projects. It consist to exchange viewpoints and search for solutions that go beyond stakeholders own vision of what is possible to done. In fact, some modern interpretations of the role of research in society require successful dialogue and cooperation between those who produce knowledge and those who use it. Stakeholders and potential end users at the local, regional and national level are:

- **The focal UNCCD point at the Ministry of Environment and sustainable development,**
- **Ministry of Agriculture and water resources and particularly the divisions of Soil and water conservation, forestry, water resources, etc.**
- **Ministry of Development,**
- **Research institutions: INRAT, INGREF, IO,**
- **National farmer union (UTAP),**
- **Grazing and livestock breeding agency (OEP),**

- **Outreach and agricultural extension agency (AVFA),**
- **Universities: IRESA, University of Tunis, University of Gabès, etc.**
- **Province council and particularly the regional commission for combating desertification,**
- **Regional directorate of the environment (south east).**
- **Schools (primary and secondary)**

6. Water resources and water use

The water resources of the study area consist of a complex hydrological system with strong complementarily between surface water and groundwater. The region includes five deep aquifers of varying quality. These aquifers are generally over-exploited. These are the Mio-Pliocene aquifer of Jeffara (fed largely by the Continental interclaire aquifers from the fault of El Hamma), the Zeuss-koutine aquifers (divided into two aquifers: Jurassic and Lower Senonian), the Triassic sandstone aquifer, and finally the Jurassic aquifers of béni-Khedache (Ouessar et al., 2003).

Table3. Deep aquifers characteristics (sources Jeffara report, 2003)

deep aquifers	Depth (m)	Salinity (g/l)	Exploitation (l/s)
Mio - Pliocène de Jeffara	**250 - 300**	**3 – 6**	**533,3**
Zeuss-Koutine Senonien	**200 – 500**	**1,5 – 5**	**292,6**
Zeuss-Koutine Jurassique	**100 – 300**	**1,5 – 5**	**292,6**
the Triassic sandstone aquifer	**100 – 300**	**1 – 3**	**128,2**
Jurassique de Béni Khédache	**200 - 300**	**1,7 – 6**	**0,31**

The groundwater is formed by the coastal aquifers (Quaternary Mio-Pliocene of Jeffara) and other less important aquifers related to watersheds in coastal areas (Ouessar et al., 2003). The chemical quality of groundwater is generally quite good. However, most of these aquifers, mainly used for irrigated agriculture, are now over-exploited, with negative consequences for the quality and level of water resources.

In addition, groundwater flows are related to rainfall and runoff, which limits their potential volumes. The complementarily between different types of water resources (surface and groundwater) has been enhanced for the last ten years by the government mobilization strategy and water and soil conservation policy; for example, more than 300 hydraulic structures contributing to the Zeuss-koutine aquifers' recharge were built on Oum Zessar, Zeuss and Om-Tamar watersheds (Yahyaoui et al., 2002). The water salinity in the Jeffara aquifers oscillates between 1g/l (Triassic sandstone) and 7g/l (Mio-Pliocene aquifer) and the exploitation rate reaches 86 per cent (Triassic sandstone).

The region has a dense river network, built around five main wadis (Zegzaou, Oum Zessar, Zeuss, Sidi Makhlouf, and El Morra) that drain rainwater to the sea in the Gulf of Gabes or to areas of sabkha (salt flats). Despite their limited volumes, the rainwater and runoff are very important for domestic use and non-irrigated agricultural production systems. Intensification of water use in the Jeffara region during the 1990s contributed to the gradual transformation of the steppic landscape. In addition to tree planting on the privatized rangeland, the irrigated area has increased around the shallow wells and boreholes. However, this development is currently facing several problems: depletion of scarce natural sources, lowering of the artesian, and the overexploitation of groundwater and deep groundwater.

7. Water harvesting techniques (used in the country/region and with focus on the study site/area)

The hydraulic history of the study area is very ancient. According to Carton (1988) a small retention dams near the village of Koutine and the abandoned terraces in the uphills of wadi Nagab in addition to numerous flood spreading based structures (henchir Zitoun, henchir rmadi, etc) are supposed to be built in the Roman era). In fact, according to ouassar et al 2002, currently wide varieties of water harvesting techniques exist in the study area that can be subdivided on traditional and modern techniques:

Traditional water harvesting technologies

Terraces

The terrace is the oldest adopted WHT in the area. The terraces are formed of small retaining walls made of rocks to slow down the flow of water and control erosion (Oweis *et al.*, 2001). Often they are, like in other regions of the country and the world, constructed on steep slopes. Actually, they are completely abandoned and only some remnants are still found in the upper extreme area of wadi *Nagab*. Nevertheless, they have been recently readopted for small scale afforestation works or olive trees plantations in the mountain ranges.

Jessour

The Jessour system is an ancient WHT widely spread in the region of the mountains of Matmata (Ben Ouezdou *et al.*, 2001). It is practiced in the inter mountain and hill water courses to intercept runoff and sediments. The *jessour* is the plural of a *jesr* which is a hydraulic unit made of three main components; the dike, the terrace and the impluvium. The impluvium is the area destined for collecting and channeling of the meteoric water. It is bounded by the natural water dividing line. The terrace is the cropped area. It is formed progressively by the decantation of the carried sediments. Generally, the fruit trees (olive, fig, almond, date palm, etc) and the legumes (pea, chickpea, lentil, broad bean, etc) are planted in the neighborhood of the dike while the remaining areas are cultivated with cereals (barley, wheat). The dike *(tabia, sed, katra)* is a barrier destined to block the sediments and run-off water. Its body is made of earth equipped with a central *(masraf)* and/or lateral *(manfes)* spillway assuring the evacuation of the excess water. The jessour are mainly found in the upstream mountain area of Béni Khdache and Moggar.

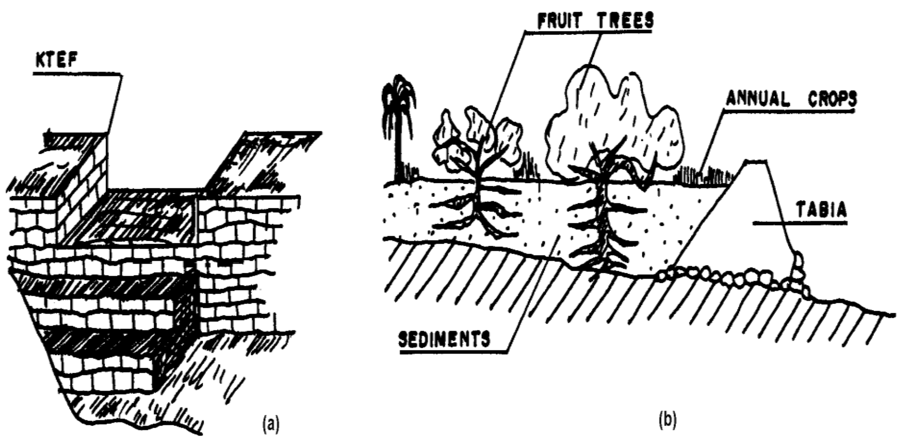

Figure 12: Scheme of the Jessour components (a: spillway, b: side view) (adapted from El Amami, 1984).

Tabias

Tabias are essentially situated in areas with profound soils with the slope that not exceeding 3%. The tabia is formed by a principal bank situated along contour lines, of 50-150 m and at the ends lateral bunds with a length of about 30 m (photo 2). Water is stored until it reaches a height of 20 to 30 cm, after which it is diverted, either by a spillway or at the upper ends of the lateral bunds. The tabia gains its water directly from its impluvium (K values between 6 and 20), or by diversion of wadi runoff by a *mgoud* (Alaya *et al.*, 1993).

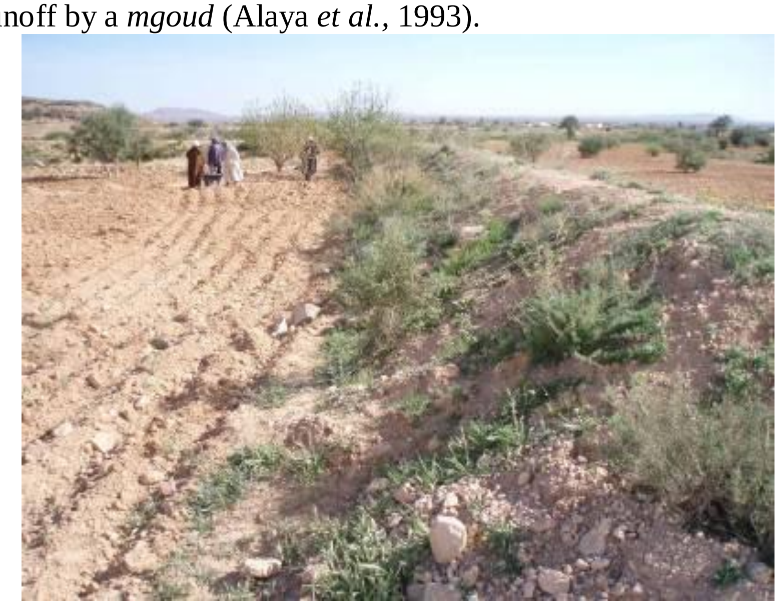

Photo 2 : Tabias in the piemond area of Bhaira (70% of farmers practice this technique in the study

Cisterns

Known by “fesquia or “majel”, the cisterns were traditionally used to collect of rain water and its storage for different purposes like domestics’ uses, irrigation and animal drinking at dry season. It consist of a hole dug in the soil with a gypsic or cement coating to avoid vertical and lateral infiltration. Generally, each unit is made of three main components; the impluvium, the decantation basin, and the storage and pumping reservoir.

Modern water harvesting technologies.

Gabion check dams units

These units are made of wire mesh cages filled with rocks. The Gabion units are built in the wadi beds (photo 3). In general, they have the form of a rectangular spillway. They are used mainly for two purposes i) slow down the runoff flow so as to increase the infiltration rate to the underground water tables ii) divert a portion of the runoff to neighboring cultivated fields

Photo 3 : Gabion units in the piemond area of Bhaira

Recharge wells

When the permeability of the underlying bedrock is judged too low, casting tubes could be drilled in the wadi beds to enhance the infiltration of runoff water to the ground aquifer. In our SWS, these recharge wells were installed behind gabion units at the level of Koutine.

Floodwater harvesting

Floodwater harvesting systems divert the total, or a portion, of the floodwater carried by *wadis* to neighbouring cultivated fields, so providing natural irrigation. The remnants of such systems, together with many units still functioning, (figure 13, Photo 4). It seems that this technique has been practiced since Roman times, and may even have been practiced in the pre-Roman period. However, El Amami (1984) believes that the arrival of the Arabs, who brought with them from Yemen immense experience of similar environments, was behind the adoption and the perfection of this technique on a large scale.

Floodwater harvesting is presently applied in regions characterized by very large watersheds, with *wadis* which can be as wide as 1000 m, and up to 100 km long and up to 4 m deep (e.g., Zeroud, Merg Ellil, Esserg). Floods generally occur during two main periods: September-October and March-May. However, they can occur at any time of the year. The yield of sediment from the *wadis* is very important for fertilizing the soil (Ennabli 1993). Mean annual rainfall ranges between 200 and 400 mm. Hénia (1993) found that this region has the most variable rainfall regime and the highest rainfall intensity of all Tunisia's regions (more than 300 mm/day recorded maximum).

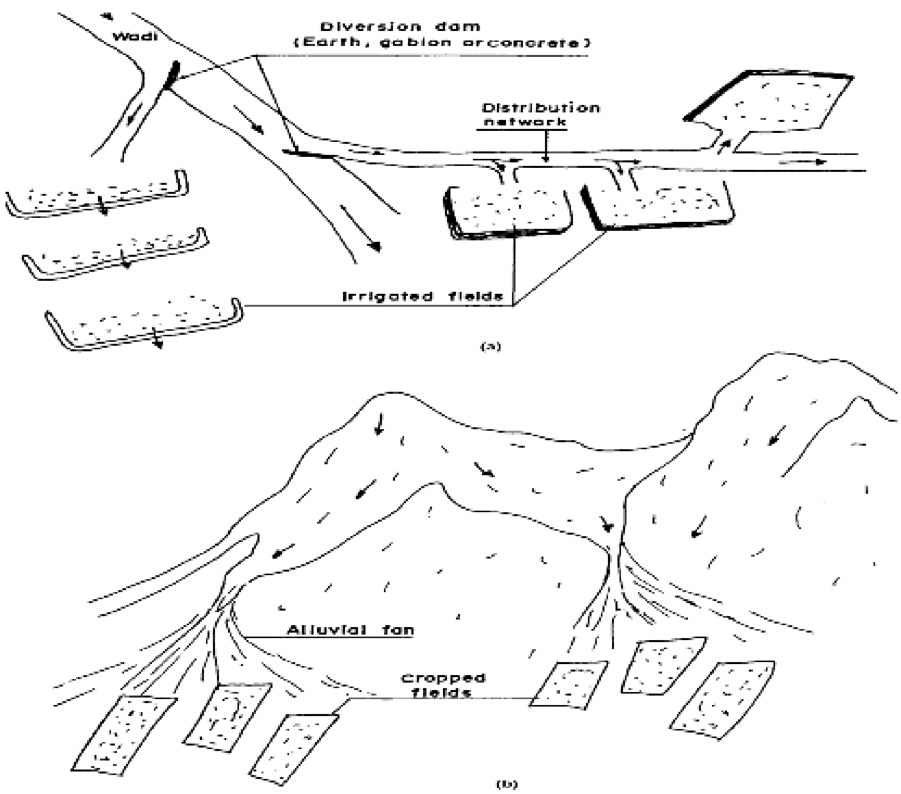

Figure 13: Scheme of flood spreading: a: artificial spreading, b: natural spreading.

Photo 4 : Floowater harvesting on Wadi Nkim(Bhaira) (*50% of farmers practice this technique).*

8. Past and on-going projects (especially related to water harvesting)

- **Development projects**

The program of integrated rural development (PDRI)

Primarily intended for the revalorization of the rural zones in particular those for agricultural use, this program is subdivided in two generations. The first generation was implemented between 1984 and 1994, and it focused on the zones: Dhahar and Fjij. The number of beneficiaries was 277. The second generation of PDRI started in 1994 and was extended to cover also small businesses.

The regional program of development

This program is annual, is conceived to improve the living conditions of the regional communities. Its budget is managed directly and completely by the regional council.

The national solidarity program (FNS 26-26)

The achievements of this program contribute to the reintegration of the remote zones in the economic sphere. It concerned between 1993 and 2001, 2438 families in19 localities.

The Ababsa II project

It is conducted mainly in the piedmont areas where it contributed to the improvement of the infrastructures (roads, water, electrification, etc) but also the agriculture sector (soil and water conservation works).

The natural resources management Project "PGRN"

The objectives of the project consist of the improvement of the natural stock management and the improvement of the standard of living of the rural populations through the implementation of participative plans of development (PDP). The intervention zone of the project concerned 18 socio-territorial units (about 3300 families) in the province of Médenine.

Agricultural development fund (FOSDA)

This fund is designed to assist the farmers in the rural areas by subsidizing small scale agricultural activities (soil and water conservation works, fruit tress plantations, etc.). It is operated by the representatives of the ministry of agriculture (CTV).

- **Research projects**

Project IRZOD

Project IRZOD (Rural Innovation in Difficult Zones) entitled "Jessour and Ksour de Béni khédivial" is implemented within the framework of an experimental program of development durable and carried out within the framework of the bilateral co-operation between the Regional Council of Médenine and the General Council of the Department of Le Hérault (France). It is a program of "research and development" initiated by the Institute of the Arid Areas of Médenine and the Mediterranean Agronomic Institute of Montpellier.

WAHIA

It is in an INCO-DC project implemented between 1998 and 2002 by IRA, Wageningen University (The Netherlands), University of Ghent (Belgium) for the impact assessment and economic evaluation of water harvesting techniques in the dry areas.

MEDRATE

It was implemented within the EC (DG.I)-CIHEAM cooperation project 'Regional Action Programme: Rainfed agriculture" between 2000 and 2002. It aimed at the evaluation of agricultural practices to improve efficiency and environment conservation in Mediterranean arid and semi-arid production systems.

SUMAMAD

This project is being implemented in joint collaboration between IRA, the UNU, UNESCO-MAB, ICARDA and the University of Gent (Belgium) with a funding from the Flemish government of Belgium (1st phase: 2003-2007; 2nd phase: 2009-2013). The project aimed at enhancing the sustainable management and conservation of marginal drylands in Northern Africa and Asia through conducting participatory research on the natural resources conservation and exploitation and exploration of alternative income generating for rural communities in the dry areas.

DeSurvey

DeSurvey is a project funded by the European Commission under the Framework Programme 6 and contributing to the implementation of the actions 'Mechanisms of desertification' and 'Assessment of the vulnerability to desertification and early warning options' within the 'Global Change & Ecosystems priority'. The ambition of the DeSurvey consortium is to deliver a compact set of integrated procedures of desertification assessment and forecasting, with application and tutorial examples at the EU and national scales. DeSurvey 39 partners representing 10 EU Member States and 6 Third Country States; integrate key research organizations and industrial companies with a wide range of skills.

LUPIS

LUPIS is an EU funded project run by 16 institutes in 13 countries. The project aim to develop integrated assessment tools for sustainable development for application by scientists in a selected number of developing countries, and the tools developed in the EU 6th framework projects of SENSOR and SEAMLESS will be used both as building blocks in and guidelines for the project.

LADA

Land Degradation Assessment in Dryland Areas (LADA) project aims to develop and validate quantitative, reproducible assessment methods, to make them widely available and to demonstrate and build capacity for their application in the dryland areas of the world.

DESIRE

Funded under the EU's Sixth Framework Programme (FP6), the DESIRE (Desertification mitigation and remediation of land) project is international, bringing together 28 research institutes, non-governmental organizations (NGOs) and policy-makers from around the world. (2007-2012). The aim of the project is to come up with alternative strategies for the use and protection of these vulnerable areas.

9. Available time series data

Available data		Time series data	observations
Climate	Rainfall	1981-2004 (daily data)	
	Temperature	1977-2010 (daily data)	
	PET	-	
	Runoff	1985 (Fersi data)	
	flooding	-	
	droughts	-	
Census of population at the regional level		1966; 1975; 1984; 1994; 2004	
Surveys of farm structure		1994-1995; 2004-2005	concern land tenure, agricultural production ; factor of production uses (land , water , labour and capital)
Household surveys (regional level)		2000; 2005	concern income distribution , labour availabilities
Prices of agriculture commodities and production factors		monthly and yearly data (CRDA)	
Socio economic data base		available in IRA (Surveys)	
Multi-sectoral data base(statistic office ODS) at the regional scale (province of Medenine)		data for tourism , fishing and industrial sectors (yearly)	
Specific survey on livestock and animal production system		2006	Available at the province of Medenine (CRDA of Medenine)

10. Available maps (scale, date, format, etc.) – or descriptions in absence of maps

Map	Availability	Scale	Date	Format	Description
Boundary of area	exist	1/100 000	2007	Shp, JPG	
Topography	exist	1/100 000	1998		
DEM	exist	1/100 000	1998	Tin, JPG	
Surface cover	-				
Soil	exist	1/100 000	2003	Shp, JPG	
Vegetation	-				
Land use	exist	1/100 000	2004	Shp, JPG	
WH works	exit	1/100 000	2004	Shp, JPG	Cover only oum Zessar watershed
Aquifers	exist	1/100 000	1998	Shp, JPG	

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BURKINA FASO

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CENTRE NATIONAL DE LA RECHERCHE SCIENTIFIQUE ET TECHNOLOGIQUE

(C.N.R.S.T.)

INSTITUT DE L'ENVIRONNEMENT ET DE RECHERCHES AGRICOLES

(IN.E.R.A.)

WAHARA SITE STUDY DESCRIPTION BURKINA FASO

Dr Hamado SAWADOGO

DAO Vincent

OUEDRAOGO Blaise

KINI Janvier

Kondombo Salam

October 2011
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1. **Responsible partner:** **INERA**

2. **General information**

- Main reasons for selecting this site/region : tradition of soil and water conservation technologies, long time collaboration with research institute, projects, large practices of soil and water conservations technologies.
- Participating local partner institutions: local farmer's organization, agricultural, Livestock and forestry extending services, PDRD, PRTD, Six S, Groupement Naam, SOS Sahel, SEMUS, AZD, Agro Forestry Project, Agro Ecology Project, 6 to 9è FED, CIRAD, IRD, Universities of Ouagadougou and Bobo Dioulasso, many universities from Europ and America
- Main used language(s): Moore, French, Fulani and dioula

3. **Bio-physical description**

The present report is a part of such a framework within which the production potential of degraded soils is assessed in the north western region of Burkina Faso, particularly in Somyaga and Ziga. It give information on bio physical and socio economic data in the north west region and the two study sites where investigation will be concentrated in the future.

Figure 1 : Carte de situation de Ziga

The overall objective is to monitor crop yields dynamic in order to recommend actions that could secure the durability of agricultural productions within an ongoing fallowless cropping system.

Specific objectives of the agronomic monitoring are to:

- Show SWC techniques and manure effects in real environment that is on-farm conditions.
- Produce data on farms and crops distribution on the topographical sequence.
- Prove the importance of using animal-drawn ploughing as agricultural equipment in cropping systems.

Study areas

The study sites are located in the north western region of Burkina Faso which corresponds to the agro-ecological zone identified by INERA, about 30 000 km² . The study area covers the provinces of Yatenga.

Climate

The study area is within the Sahelo-soudanian climate with two seasons:

- the rainy season occurs between the months of May and October
- The dry season lasts about 6 months from November to April with a short period of cold occurring between November and February.

Mean annual rainfall varies between 400mm and 800 mm and is characterized by an uneven spatial and temporal distribution. Rains are heavy at the onset of the season causing soil erosion. From 1970 to 1990 a decrease of 200 mm in the amount of rainfall has been registered. Mean annual temperature ranges from 25°C to 30°C. Minimum temperatures occur in the month of December (18°C) while maximum ones occur during the month of April (45°C).The annual potential evapotranspiration (PET) amounts to 2615 mm. The rain of Yatenga is characterized by a large variability in years and spatio temporal variation

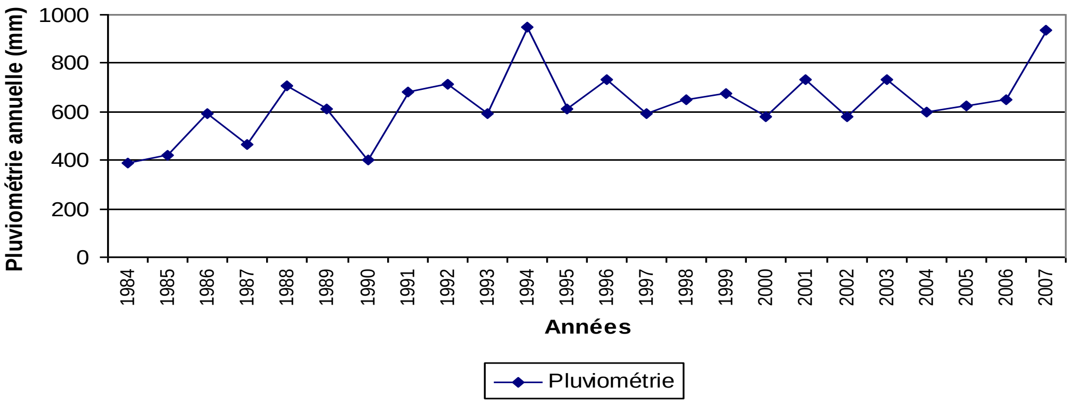


Figure 2: Annual rain of Yatenga Province (en mm) from 1984 to 2007

Geology and geomorphology

The study area is underlain by three major geologic units: the crystalline and schist basement of Antebirrimian and Birrimian; the sedimentary covers of the Gondo plain lying north and west along the border with the Republic of Mali; the sand dune covers.

The overall topography is flat with residual rocked mounds. Tectonic movements have been insignificant since the Precambrian. Therefore the bedrock is ancient, weathered and eroded, which explains the flatness of the topography.

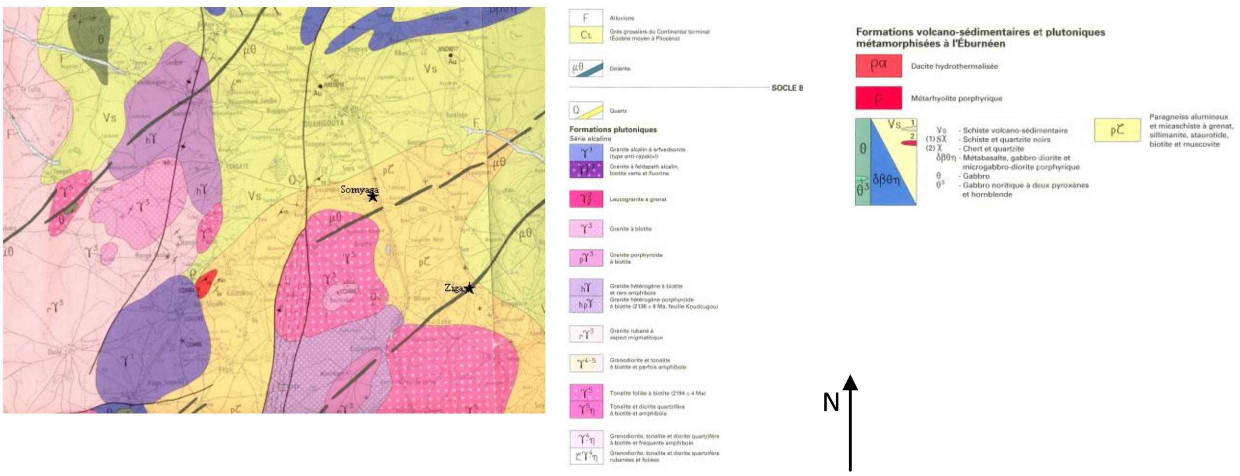


Figure 3: Carte géologique de la région de Ouahigouya (Gamsonré, 2003)

Soils

Soils are composed primarily of tropical ferruginous layers, but hydromorphic soils are found along watercourse and lithosoils lie down on rocked mounds and hills. Studies by Boulet (1968), Bunasols (1992) and INERA (1993) have identified 6 types of soils in the region:

- Crude mineral soils on lithosoils: they cover bare rocked beds and unaltered rocks. Chemical and physical properties are unsuitable (limited useful depth, low cation exchange capacity) to cropping. Therefore their agronomic interest is worthless. Runoff is high on these soils causing damages to arable soils located further down. These soils are generally used pasture lands. When possible these soils are to be reforested. They are represented in 7 provinces.

- Less developed soils: they are the outcome of the dismantling of ferruginous rockbeds. When they are located on slopes, these soils are shallow to bedrock with low water-holding capacity; in this feature herbaceous vegetation along with some trees develops. These soils are used as pasture lands. When these soils are deep-developed or developed on basic materials, they can be arable lands. These soils have high amounts of gravel on surface, which slows erosion. To improve these soils, one needs protection and recovery methods. Less developed soils are largely represented in the provinces of Yatenga, Sourou, Bam and Passoré.

- less or more washed tropical ferruginous soils developed on sandy, clay-sand or sand-clay materials. The amount of dilating-clay is lower than that of kaolin; iron oxide proportion is high and is well-crystallized leaving a reddish-brown profile. These soils can be deep with a light or moderate texture on surface and clayish in depth. Their contents in organic matter, nitrogen, phosphorous and calcium are low. They are acid soils and their water-holding capacity ranges from average to good. These types of soil are very sensitive to erosion and are well spread in the Passoré, the north of Sourou, the south and south-west of Ouahigouya, and in the Bam. These soils support sorghum, millet, peanut and other crops. Development of these soils needs adequate ploughing, additional organic matter, additional chemical fertilizers as well as biological and mechanical soil recovery techniques.

- Hydromorphic soils: they are alluvial clayey soils and are saturated on surface or through the entire profile. The saturation length depends on the rainfall regime. The chemical and physical properties of these soils are variable but the textural properties are on average on surface and heavy in depth. The high clay content increases nutrient availability and water-holding capacity but also makes cultivation difficult; rains can delay planting. These soils are suitable for water-intensive crops such as rice during the rainy season, market gardening during the dry season when hydraulic conditions are met. These soils are largely found in the provinces of Sourou and Bam, but they are also represented in Yatenga and Passoré.

- Soils developed on basic materials showing cracks and having a clayey texture on surface. Their mineral content is high and their water-holding capacity strong. However, these soils have disadvantaged morphological properties (asphyxiation, difficult to cultivate without modern equipment). In general these soils are adequate for growing cotton, maize, sorghum and other crops. The cultivation of these soils could be eased thanks to research led on their management (water, soil work, etc.). These soils are spread in the southern part of the Sourou mostly along the riversides.

- Tropical brown soils developed on neutral or basic crystalline bedrocks: these soils resemble in chemical composition the ones just described above. They are easier to work than the former soils. Thanks to their better cropping characteristics, these soils appear to be the best. They are suitable for cotton, maize, rice, sorghum, and market gardening. They are located in the Sourou, Yatenga and Bam.

The figures below present the soil map of Ziga made by Kabore (1985) and the geomorphology map by Dugue (1989)

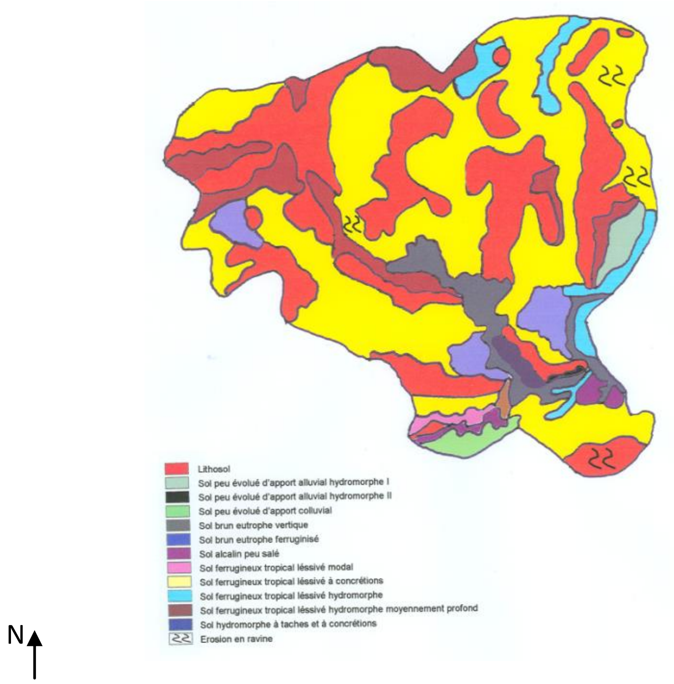


Figure 4: Esquisse ɑe carte pédologique de Ziga (Kaboré, 1985), adaptation par Sawadogo (2006)

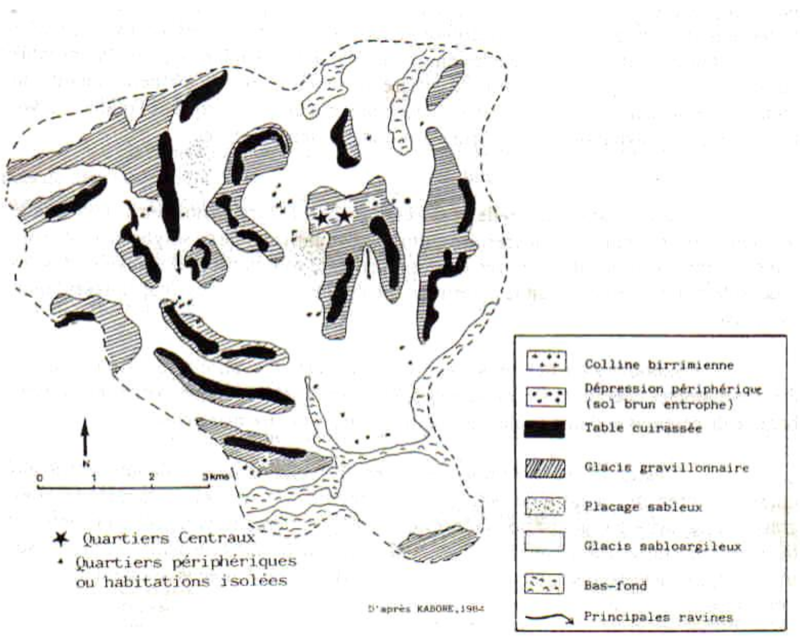


Figure 5: Map of the geomorphology of Ziga (Dugué, 1989)

Vegetation

The study region lies between two territories of natural vegetation: the sahelian and the soudanian territories.

- The sahelian territory is a sub-sahelian zone displaying a landscape of shrubs vegetation to dense woody vegetation and thickets in the north, ecosystems of striped thickets and spotted bushes, parks of trees developed on sandy soils and thin forest galleries. The landscape is less fashioned by man's activities.

- The soudanian territory is characterized by agricultural landscapes. The natural vegetation is a woody savannah composed of tree species such as *Vitellaria paradoxa (shea tree), Parkia biglobos), Tamarindus indica), Lannea microcarpa, Sclerocarya birrea, Adansonia digitata, Bombax costatum, and various acacias.*

4 socio-economic description

The population is estimated at 1 491 876 inhabitants; the average density is 50 per km² with significant disparities. The center of the region has a density of 100 per km² while the north has a density of only 20 per km². 60% of the population have less than 20 years.

Table 1: Evolution of the population of Yatenga from 1910 to 1996

Years	Population	Density
1910	200 000	16
1930	300 000	24
1960	400 000	32
1975	530 000	43
1985	537 205	44
1996	683 556	55

Source : Dugué (1989), INSD (1996).

A repartition of the population varies according to the provinces.

Table 2 : Repartition of the population in north west region (source INSD, 1997)

Provinces	Superficie (km²)	Pop. totale	Density (hbts/ km²)	Men	Women	0-20 ans	20-60 ans	+65 ans
Bam	4017	211551	53	99685	112166	127142	74869	9540
Lorum	3587	111339	31	52260	59079	67847	38863	4629
Nayala	3923	136393	35	67470	68923	82074	47338	6981
Passoré	4078	271864	67	125893	145971	165764	93008	13092
Sourou	5768	188512	33	92640	95872	112079	67340	9093
Yatenga	6987	444563	64	208247	236316	265151	156573	22839
Zondoma	1759	127654	73	56092	69562	78075	42923	6656
Région	**30119**	**1491876**	**50**	**702287**	**789589**	**898132**	**520914**	**72830**

Of the total population women represent 53% against 47% for men.

Ten principal ethnic groups live in the region: Mossi, Fulani, Dogon, Samo, Dafing, Rimaïbe, Gurunsi, Fulsé, Bella and Maransé.

The region experiences high out migration towards the provinces located west of the country as well as towards the republics of Ghana and Ivory Coast.

Farming system: The major farming systems in the watershed is mixed farming ie agropastoralism and agroforestry. Intercropping is the rule in northwest part.
Main crops: sorghum, millet, maize, bean, rice, groundnut, horticulture, sesame.
Livestock: Livestock reared include cattle, and sheep, horse, donkey, camelins, chicken etc.

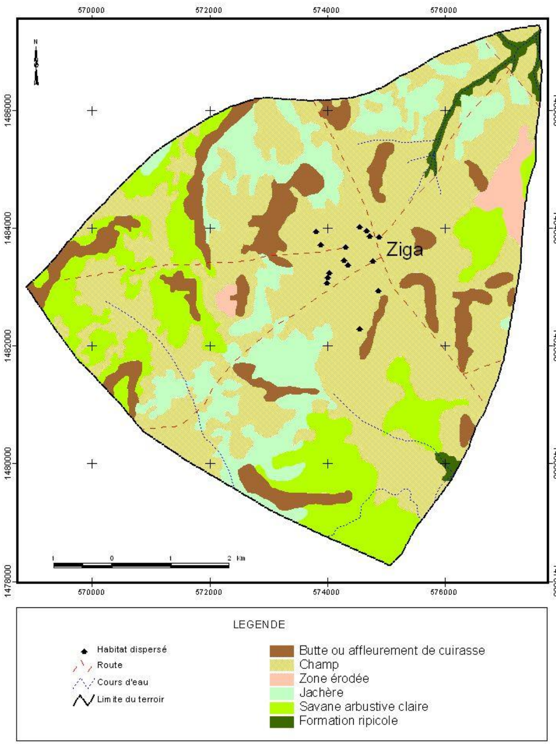


Figure 6: Land use map of Ziga in 1952

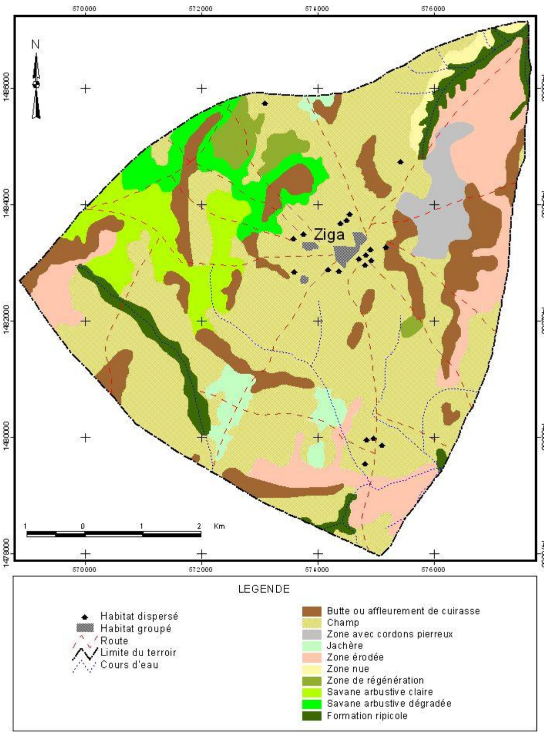


Figure 7: Land use map of Ziga in 1996

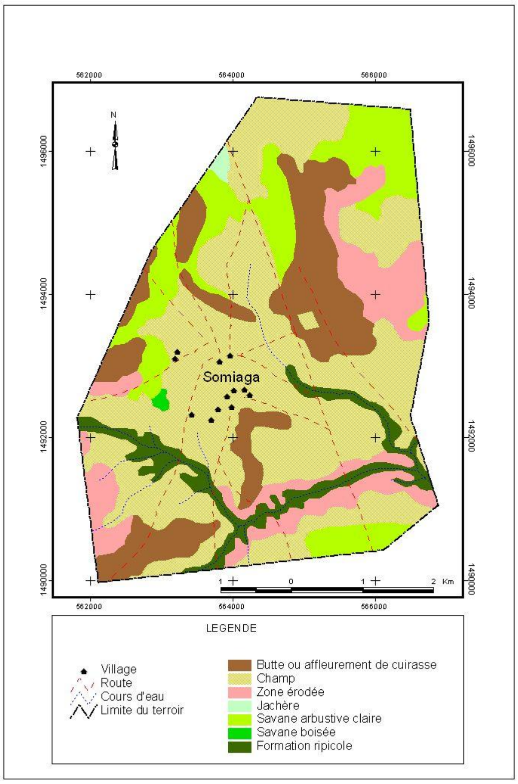


Figure 8: Land use map of Somyaga in 1952

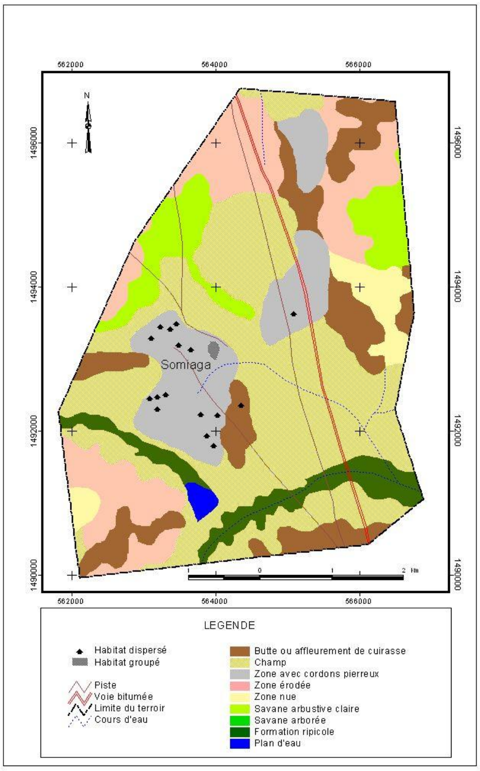


Figure 9: Land use map of Somyaga in 1996

Influence of animal-drawn ploughing equipment on farm size and crop yields

Analysis of table 3 demonstrates that farmers with modern agricultural equipment farm cultivate more land in size than those without equipment. In 2002 the size of land farmed by farmers having equipment in Somyaga was 6 ha in average against 3.79 ha for land farmed without equipment. In Ziga the size of land farmed by farmers having equipment in the same year doubled that of land farmed without equipment (5.96 ha against 2.83 ha). As a reminder the rainfall in 2002 was not good. Although 2003 received higher amounts of rainfall land under farming did not know significant variations. In fact the size of land farmed by farmers having equipment is 6.18 ha in average while that of land farmed without equipment is 3.67 in average in Somyaga. In 2002 the area of land farmed by no-equipment producers in Ziga increased in average by 0.20 ha in amount while that of land farmed by equipment producers decreased in average by 0.30 ha. Often, money lending institutions for agricultural credits require as conditions that one possess at least 5 ha extensively farmed; which leads in facto to extension of the areas under cultivation. Globally, equipment producers farm in average one and a half times as much land as do non-equipment producers. Crop yields obtained during the two years point to a trend toward intensification. Effectively, in Somyaga grain yields per ha from land farmed with equipment are about 797 kg against a grain yield of 444 kg per ha from land farmed without equipment, that is to say an increase of about 80% in 2002. In Ziga grain yields per ha from land farmed with equipment are about 619 kg against a grain yield of 435 kg per ha from land farmed without equipment, that is to say an increase of about 42%.

One could conclude that in 2002, equipment has worked as a means of soil and water conservation that has enabled plants to benefit from moisture.

Yields in 2003 were better compared to those in 2002. Equipped farms in Somyaga reached a yield of 1025 kg per ha against 644 kg per ha for non-equipped farms, that is to say an increase of 60%. The same year, in Ziga no-equipment farms obtained yields almost being equal to those obtained on equipment farms, 739 kg/ha and 817 kg/ha respectively, of course the increase in crop yields per ha for equipped farms was hardly

11%. As mentioned above 68.3% of the farms in Ziga are laid out with SWC technologies against 57.9% in Somyaga; a context that could explain the levels of yields thanks to better fertility. Straw yields knew the same trend as grain yields. In both villages the straw yields were better on equipped farms than they were on non-equipped farms.

Table 3: cereal crop yields in kg/ha and area farmed according to equipment

Years	Village	Equipment*	Grain yields			Straw yields			area/ farm (ha)
			N**	(kg/ha)	CV(%)	N	(kg/ha)	CV (%)	
2002	Somyaga	Without equipment	19	444b	38	19	1298b	35	3,79
		Equipment	14	797a	18	14	2299ab	15	5,99
		Average	33	593	40	33	1723	37	4,73
	Ziga	No Equipment	25	435b	28	25	1426b	30	2,83
		Equipment	16	619a	28	16	1925ab	29	5,96
		Average	41	507	33	41	1621	33	4,05
	Moyenne	No Equipment	44	439b	32	44	1371b	32	3,24
		Equipment	30	702b	26	30	2099a	23	5,98
		Average	74	545	37	74	1666	35	4,35
2003	Somyaga	No Equipment	19	644b	27	19	2498ab	21	3,67
		Equipment	14	1025a	14	14	3608a	14	6,18
		Average	33	829	30	33	3036	25	4,89
	Ziga	No Equipment	25	739b	15	25	2512a	15	3,02
		Equipment	16	817a	24	16	2919a	28	5,56
		Average	41	771	20	41	2680	23	4,07
	Moyenne	No Equipment	44	699b	21	44	2506a	18	3,29
		Equipment	30	918a	22	30	3253a	23	5,86
		Average	74	797	26	74	2839	25	4,43
Average over the two years	Somyaga	No Equipment	36	538	37	36	1865	42	3,73
		Equipment	30	918	20	30	2997	27	6,09
		Average	66	711	38	66	2380	41	4,81

	Ziga	No Equipment	49	584	33	49	1958b	35	2,92
		Equipment	33	721	29	22	2437ab	35	5,75
		Average	82	639	33	82	2151	37	4,06
	Moyenne	No Equipment	85	564	34	85	1919b	38	3,26
		Equipment	63	815	27	63	2704a	32	5,91
		Average	148	671	36	148	2253	39	4,39

** Is considered equipment a farm having a plough and a draught animal (ox, horse, donkey); ** Sample size*

Manure and agricultural outputs

Manure application has been for long the only mean of maintaining soil fertility and improving crop yields in the North-western region of Burkina Faso. Very little amount of external fertilizers has been used because of low financial ability of farmers and risks induced by fertilizers the years of poor rainfall.

Table 4 indicates that farmers make efforts to fertilize their farms. The proportion of farms not using manure is 31.6% in Somyaga. In Ziga the proportion of farms not using manure is higher and reaches 43.9%. For both villages, the farms not applying manure represent 38%. Nearly 70% of farms in Somyaga apply manure of which, 40% receive 1 to 5 tons/ha and 30% receive 5 to 10 tons/ha. In Ziga 42% of farms use 1 to 5 tons of manure per hectare while 20% use more than 5 tons/ha. The popularization of manure pits and compost pits has gone hand in hand with the development of SWCT in order to set up the beginnings of agricultural production intensification; that explains the great interest farmers take in the use of manure.

Table 4: Percentage of farms applying manure or not

Village	Manure application			Total
	No manure	1 à 5t/ha	5,1 à 10t/ha	
Somyaga	31,6%	39,5%	28,9%	100,0%
Ziga	43,9%	43,9%	12,2%	100,0%
Average of both villages	38,0%	41,8%	20,3%	100,0%

Table 5 gives information on crop yields according to the amount of manure applied. Manure is one of the ways for increasing crop yields in the Northern region of Burkina Faso.

In 2002 the yields of farms without manure treatment were 317 kg/ha for grains and 958 kg/ha for the straws in Somyaga. When 1 to 5 tons of manure are applied crop yields increase : average grain yield is 593 kg/ha and average straw yield is 1700 kg/ha, that is to say an increase of 87% compared to yields on farms without manure application. Farms that have received more than 5 tons of manure per ha produced an average grain yield of 839 kg/ha and an average straw yield of 2383 kg/ha. Yields on farms under manure regime increased by more than the double compared to yields on farms without manure application.

In Ziga yields on farms without manure treatment are slightly higher than those in Somyaga. Effectively, grain yields are 378 kg/ha and straw yields are 1232 kg/ha. When 1 to 5 tons of manure are applied crop yields increase : average grain yield is 563 kg/ha and average straw yield is 1791 kg/ha, that is to say an increase grain yield of 49% compared to grain yield on farms without manure application. Farms that have received more than 5 tons of manure per ha produced an average grain yield of 768 kg/ha and an average straw yield of 2405 kg/ha. Yields on farms with manure increased by more than the double compared to yields on farms without manure application. One must point out that manure allows soils to conserve their moisture at short dry periods and supplies nutrients needed for plant growth. In 2003 yields increased. Farms without manure produced an average grain yield of 527 kg/ha and an average straw yield of 2205 kg/ha in Somyaga. As in 2002 manure impact on yields is still positive. In Somyaga the application of 1 to 5 tons of manure per hectare produced an average grain yield of 825 kg/ha, that is to say an increase of 57% compared to farms without manure. Farms having received between 5 and 10 tons of manure per hectare produced an average grain yield of 1086 kg/ha and an average straw yield of 3792 kg/ha. So when the amount of manure per hectare is highest the grain yields double. In Ziga the situation is identical to that in Somyaga, that is to say an increase in or even a doubling of grain as a result of manure application.

Table 5 : cereal crop yields according to manure application

Years	Village	Use of fumure	Grain yields (kg/ha)			Straw yields (kg/ha)		
			N	Average	CV (%)	N	Average	CV (%)
2002	Somyaga	0	12	317c	45	12	958c	37
		1 to 5 t/ha	15	593b	15	15	1700b	18
		5 to 10 t/ha	11	839a	14	11	2383a	12
		Average	38	577	41	38	1664	39
	Ziga	0	18	378c	36	18	1232c	40
		1 to 5 t/ha	18	563b	14	18	1791b	12
		5 to 10 t/ha	5	768a	8	5	2405a	7
		Average	41	507	33	41	1621	33
	Mean average	0	30	353c	39	30	1122c	40
		1 to 5 t/ha	33	577b	14		1750b	15
		5 to 10 t/ha	16	817a	13	16	2392a	11
		Average	79	541	38	79	1641	36
2003	Somyaga	0	12	527c	25	12	2205b	16
		1 to 5 t/ha	15	825b	11	15	3029a	14
		5 to 10 t/ha	11	1086a	11	11	3792a	11
		Average	38	806	31	38	2990	25
	Ziga	0	18	670b	23	18	2336ab	21
		1 to 5 t/ha	18	811a	10	18	2729a	16

		5 to 10 t/ha	5	992a	3	5	3750a	6
		Average	41	771	20	41	2681	23
	Mean average	0	30	613c	26	30	2284b	19
		1 to 5 t/ha	33	817b	10	33	2865a	16
		5 to 10 t/ha	16	1057a	10	16	3779a	10
		Average	79	788	26	79	2830	25

N = Sample size

Pearson correlation coefficient shows that correlation between manure application and grain yield is significant at the threshold of 1% (table 6). Correlation is also significant between UBT category and grain yield.

Table 6: Correlations between grain yield manure application and UBT category

	Manure application	Grain yields	UBT category
Manure application	1		
Grain yields	0,702 (**)	1	
UBT category	0,375 (**)	0,352 (**)	1

Sample size N= 158 ** the correlation is significant at p= 0.01 (bilateral).

5. Institutional and political setting

There are several laws at the national level (Poverty Reduction Strategy Papers, law on land called RAF) that are relevant for soil conservation and water harvesting. There are also several groups and organizations at regional level which work on natural resources management (land, water, forest, livestock etc) and environment

6. Water resources and use

Major source of water: rainwater, dams, groundwater.

Rainfall context

Annual amounts of rainfall are shown respectively in figures 10 and 11 for Somyaga and Ziga. Annual rainfall variations have been significant from one year to the next. Taken as a whole, the rainfall context (in terms of total amounts of rainfall and number of rainy days) in 2002 can be considered as average; that of 2003 as maximum (very good) and that of 2004 as minimum (very bad). In 2004 rains took end unexpectedly in September a moment when sorghum crops ears were developing; a feature that has led to crop failure. Beyond annual amounts of rainfall, it is the temporal and spatial distribution of rainfall events that determine the quality of the cropping season, which has repercussions not only on plants growth and crops development but also and above all on crop yields.

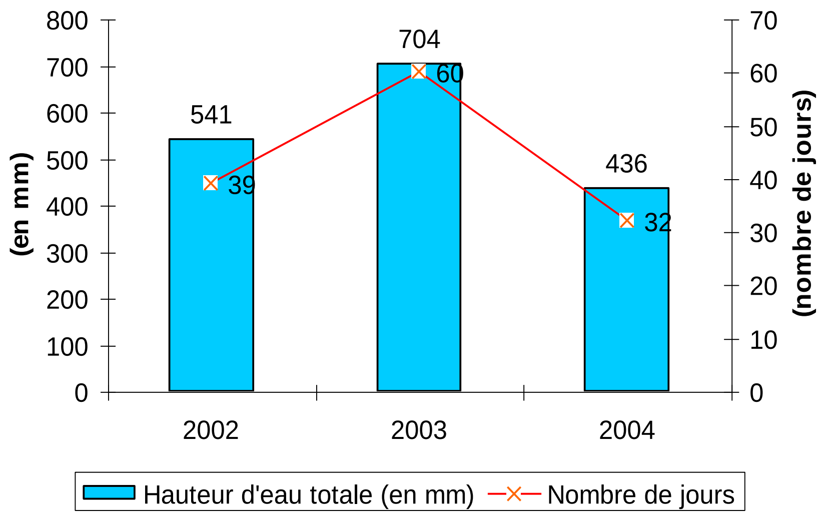


Figure 10: Annual rainfall and number of rainy days during the three seasons in Somyaga

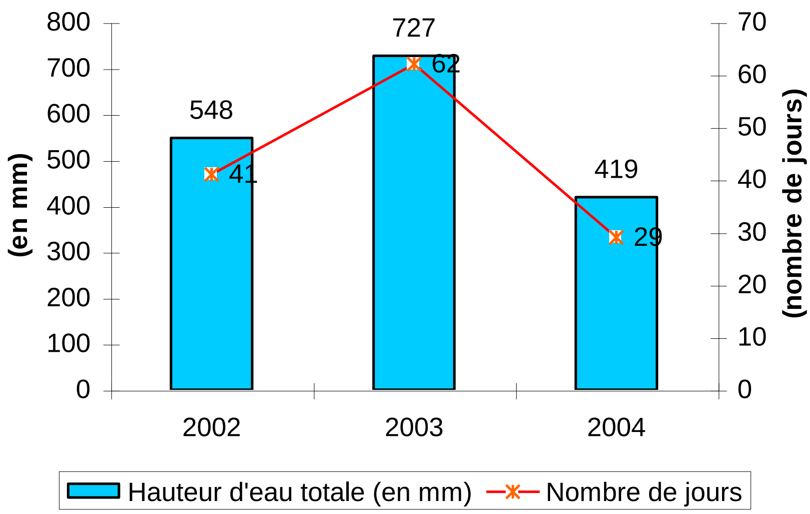


Figure 11: Annual rainfall and number of rainy day during the three seasons in Ziga

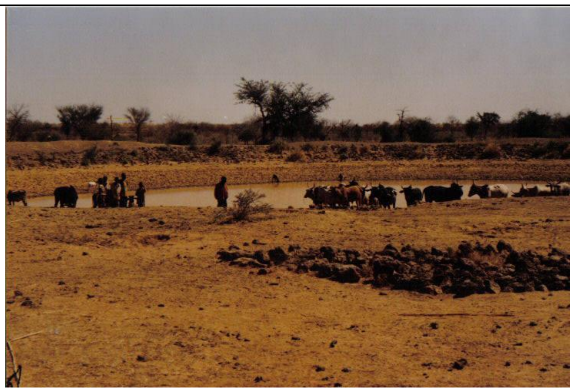
7 Water harvesting techniques

The population and the extending services have developed various water harvesting and moisture retention techniques such as:

- Ados
- ACN (ploughing contours)
- Rock bunds or lines of stones,
- Zaï, mechanized zaï, forestry zaï
- Half moons,

- Digues filtrantes,
- Mulching
- Agroforestry
- Windbreaks
- Small-dams,
- Boulis,
- Wells with big circonference, etc.

The main water harvesting technologies that are currently used are Zaï, half moons, rock bunds and bouli. Bouli is a traditional water harvesting technique. It is a big hole dug in the soil that captures runoff. It has a circumference of 30 meters and a depth of 3-4 meters.These technologies are all successful in this area, although there are also constraints and challenges. The main constrains are: labor availability, lack of stones, little availability of organic matter and compost manure, lack of chemical fertilizers. The main challenges are: mechanization, using appropriate quantity of fertilizers to improve yield, sustainability, production in quantity of compost manure

	
Sorghum growing on half moon plots	Bouli
	
Sorghum in zaï plots at Somyaga location on ferruginous soil (7 days after sowing)	Sorghum in field of rock bunds

Distribution of SWCT over plots

Table 7 illustrates the distribution and proportion of SWCT adopted by the farmers of the studied sample. In both villages, taking all SWCT into account the proportion of plots with soil and water conservation techniques is higher than that of those without SWCT; which underlines efforts made by farmers, NGO, and public development agencies to protect farms from erosion. In fact the proportion of plots without SWCT devices is 42.1% in Somyaga and 31.7% in Ziga

The SWCT taken individually, farmers give preference to zaï since 51.2% of farmers in Ziga have made zaï while 28.9% of farmers in Somyaga have made it. Plots with rock bounds count for 18.4% in Somyaga against 12.2% in Ziga.

Table 7: Percentage of SWCT devices of the sample per village

Village	SWCT devices					Total
	Without SWCT devices	zaï	Rock bounds	Rock bounds +zaï	Half-moons	
Somyaga	42,1%	28,9%	18,4%	7,9%	2,6%	100,0%
Ziga	31,7%	51,2%	12,2%	2,4%	2,4%	100,0%
Average	36,7%	40,5%	15,2%	5,1%	2,5%	100,0%

Plots with both rock bounds and zaï count for 7.9% in Somyaga against 2.4% in Ziga. Half-moons techniques are still at the experimental stage in the region as plots farmed with this last type of SWCT device count only for 2.6% in Somyaga against 2.4% in Ziga, which is in average 2.5%. The high proportion of plots with SWCT devices observed in the two villages indicates all interests the farmers have in securing maximum production and in preserving soil fertility of their farms.

Soil and water conservation technologies impact on crop yields

Table 8 contains cereal crop yields (kg/ha) according to the different SWCT devices. In 2002 average yields are 577 kg/ha in Somyaga and 507 kg/ha in Ziga. The first observation that can be made is that the effect of SWCT on crop yields is positive irrespectively of the village. However the scale of increase in crop yield varies depending on the type of SWCT. In 2002 zaï technique application to plots had resulted in doubling yields comparatively to plots that had no SWCT treatment in Somyaga. The same year yields on farms under zaï regime increased by 63% in Ziga.

Table 8: cereal crop yields (kg/ha) according to SWCT use

Years	Village	SWCT	Grain yields			Straw yields			*Return (%)
			N	kg/ha	VC(%)	N	kg/ha	VC (%)	
2002	Somyaga	No SWCT	16	381c	46	16	1128c	41	0
		Rock bounds	11	663ab	16	11	1901b	14	100
		Zaï	7	763a	18	7	2179a	23	74
		Rock bounds + zaï	3	754a	43	3	2115a	40	98

		½ moons	1	534b	-	1	1550c	-	40
		Average	38	577	41	38	1664	39	51
	Ziga	No SWCT	13	364c	47	13	1192	52	0
		Zaï	21	593b	21	21	1869	20	63
		Rock bounds	5	531b	21	5	1728	16	46
		Rock bounds + zaï	1	499b	-	1	1702	-	37
		½ moons	1	439	-	1	1369	-	21
		Average	41	507	33	41	1621	33	39
	Average of both villages	No SWCT	29	374c	46	29	1157	46	0
		Zaï	32	651ab	22	32	1975	19	74
		Rock bounds	12	608ab	21	12	1829	20	63
		Rock bounds + zaï	4	690b	42	4	2012	36	84
		½ moons	2	486bc	14	2	1460	9	30
		Average	79	541	38	79	1641	36	45
2003	Somyaga	No SWCT	16	604	30	16	2394	19	0
		Zaï	11	1006a	12	11	3605	9	67
		Rock bounds	7	882b	25	7	3252	25	46
		Rock bounds + zaï	3	978a	24	3	3301	24	62
		½ moons	1	809b	-	1	2981	-	34
		Average	38	806	31	38	2990	25	33
	Ziga	No SWCT	13	637	27	13	2263	-26	0
		Zaï	21	839	13	21	2936	20	32
		Rock bounds	5	842	9	5	2827	15	32
		Rock bounds + zaï	1	744	-	1	2287	-	17
		½ moons	1	760	-	1	2428	-	19
		Average	41	771	20	41	2681	23	21
	Average of both villages	No SWCT	29	619	28	29	2336	22	0
		Zaï	32	896	15	32	3166	19	45
		Rock bounds	12	865	19	12	3075	22	40

		Rock bounds + zaï	4	920	25	4	3047	27	49
		½ moons	2	784	4	2	2704	14	27
		Average	79	788	26	79	2830	25	27

N=Sample size *Return in grain yields in comparison with the situation with no SWCT device

Farms that had received rock bounds treatment produced significant yields with an increase rate ranging from 74% in Somyaga to 46% in Ziga. Farms under half-moon treatment produced yields with an increase rate of 40% in Somyaga and 21% in Ziga.

Rock bounds and zaï addition impact on yields was a bit lower than that of zaï, that is to say 98% in Somyaga and 37% in Ziga. The fact that in our sample there were fewer farms under rock bounds and zaï addition and their location down slope could explain the lack of synergic effect that had been noticed. However, when all of the yields of both villages are considered, the crock bounds and zaï addition had produced the best mean yield with 690 kg/ha against 651 kg/ha for zaï and 608 kg/ha for rock bounds in 2002.

The first observation that can be done is that in 2003 the overall yields are higher than those in 2002 undoubtedly thanks to the good rainfall. The second observation that can be done is that SWCT effect although positive on yields in 2003 has decreased significantly in 2002. This seems logical as SWCT are more efficient in years of average rainfall at the time that they compensate for the lack of moisture. At the opposite in case of good rainfall, hydromorphies often occur on farms on soil of heavy texture. When the SWCT performance in grain yields are compared one to each other, one notices that zaï is at all times the most efficient technique with a grain yield of 67% and 32% respectively in Somyaga and Ziga. The zaï technique is followed by the rock bounds techniques with increases in yield of 46% and 32% respectively in Somyaga and Ziga. Half-moon techniques efficiency was lesser with increases in grain yield of 34% in Somyaga and 19% in Ziga.

The rock bounds and zaï addition had an erratic effect on yields with increases of 67% in Somyaga and 17% in Ziga.

The third observation that can be done is that the impacts of all SWCT on yields are more significant in Somyaga than they are in Ziga. Generally, soils in Ziga are considered to be more fertile than those in Somyaga; that explains the difference in response to SWCT. Globally, the effect of the different SWCT is positive no matters the year. It has been reported also that the age of the SWCT has an impact on their efficiency. Table 9 displays crop yields under a few SWCT according to their age.

Many comments can be made from the examination of table 9:

- The first comment is that all SWCT have contributed to increasing sorghum crop yields. Yields gained on farms that had received rock bounds treatment are the double or the triple of those gained on farms that received no SWCT treatment in Somyaga (367 kg/ha against 176 kg/ha). In Ziga there is a significant increase in sorghum yields.
- The second comment is that the age of the rock bounds has an influence on sorghum yields. In fact five year rock bounds regime produce a yield higher than that produced by ten year rock bounds treatment. What emerges from that result is that the maintenance of the rock bounds is essential for their durability as well as for their efficiency as SWCT. Effectively, rock bounds that are over ten years suffer from many breaches, which reduce their efficiency. Moreover, some farms that formerly had received SWCT treatments act as *zipella* (bare soils in Mossi language); a situation that leads farmers to remove the rocks and rebuild the bounds in order to avoid filling in. Rock bounds cannot operate properly when the rocks are buried under the sand and fine particle deposits.
- The third comment is that manure application improves yield levels.

In 2002 zaï treatment produced the best result in yields in Somyaga. Grain yields under zaï regime were 826 kg/ha and 792 kg/ha respectively in Somyaga and Ziga. In the latter village, five year rock bounds and manure addition produced the highest yields (814 kg/ha). Runoff collection has made possible the conservation of soil moisture on farms under rock bounds and zaï regimes during the dry periods. Soil fertility improvement that zaï offered has resulted in positive levels of yields.

Table 9: Sorghum grain and straw yields (in kg/ha) on farms under SWCT treatments according to age.

Type of farms	**Somyaga**				**Ziga**			
	2002		2003		2002		2003	
	Grain	Straw	Grain	Straw	Grain	Straw	Grain	Straw
Show farm with no SWCT device nor manure	176	560	452	1856	327	1024	629	2046
A five year rock bounds	435	1239	817	2502	522	1744	902	3766
A ten year rock bounds	367	1192	582	2038	486	1802	799	3582
A five year rock bounds + manure*	779	2045	1018	3635	814	3478	1133	3950
A ten year rock bounds + manure*	508	1956	877	3408	659	2834	936	3848
Zaï	826	3364	1322	4025	792	3172	1207	4006

* The amount of manure per ha is five tons for all SWCT

The difference in yields between farms under zaï and the show farms is very significant in Somyaga, an estimate of 650 kg/ha. In Ziga the difference in yields is 465 kg/ha.

In 2003 the zaï produced the highest grain yields in both villages with 1322 kg/ha and 1207 kg/ha respectively in Somyaga and Ziga. Under zaï treatment of under five year rock bounds and manure addition yields exceed 1000 kg/ha in good season; a figure that explains producers' wide temporary enthusiasm for these techniques.

Straw production is significant on farms that have received manure application; an estimate of 2000 kg/ha to 4000 kg/ha depending on the type of treatment and the village.

Regarding soil fertility and being concerned about understanding the contribution of SWCT to soil fertility levels on farmers' plots, soil samples have been analyzed and table 10 shows the outcome. The observation that can be made is that soil fertility is clearly improved on farms under SWCT treatments compared to that of show farms. Effectively, agronomic parameters such as carbon and nitrogen display higher contents with C/N ratios that are lowest. The soil contents in calcium and magnesium on farms under zaï regime and under the combination of rock bounds and zaï are higher even thought grain yields on farms under the combination of rock bounds and zaï are lower than those on farms under zaï treatment alone. The levels of saturation in bases are 52% on farms with no SWCT device in Somyaga while they are 69% on farms with rock bounds and 66% on farms with zaï treatment. The same trend is observed in Ziga. Phosphorus contents are especially more significant on farms with SWC technique treatments than they are on show farms. Absorbable phosphorus content has nearly doubled on farms under zaï treatment and on those under the combination of zaï and rock bounds regime. Despite limits due to the fact that soil sampling was done from a same topographic unit instead of being done from the same farm, in that case there could be differences in soil texture, in runoff etc., it can be pointed out that the soil fertility improvement is remarkable on farms under SWCT treatments.

Table 10 : Chemical natures of soils with or without SWC techniques

Locality	SWCT devices	Acidity		Agronomic parameters (%)			Nutritional parameters (meq/100g TS)					Phosphorus (in ppm)	
		pH_{H2O}	pH_{KCl}	C	N	C/N	CEC	Ca	Mg	Na	K	Pto	Pdis
Somyaga	No SWCT device	4,7	4,3	0,9	0,05	18	6,4	1,52	1,19	0,16	0,46	45,0	4,0
	Rock bunds	5,2	4,1	1,0	0,07	14	6,6	1,93	1,77	0,15	0,69	69	14
	Zaï	6,3	5,4	1,1	0,09	12	9,7	3,24	2,12	0,17	0,86	92	19
	Zaï+ Rock bunds	6,4	5,4	1,3	0,10	12	10,3	3,61	2,28	0,24	0,81	99	21
Ziga	No SWCT device	5,8	4,8	0,9	0,06	15	7,9	1,66	1,06	0,15	0,69	56	12
	Rock bunds	6,2	5,3	1,1	0,09	12	8,8	2,80	1,97	0,22	0,63	64	18
	Zaï	6,3	5,3	1,2	0,10	12	9,4	2,90	2,01	0,15	0,73	81	25
	Zaï+ Rock bunds	6,7	5,7	1,3	0,10	13	10,2	3,09	2,06	0,22	0,86	83	29

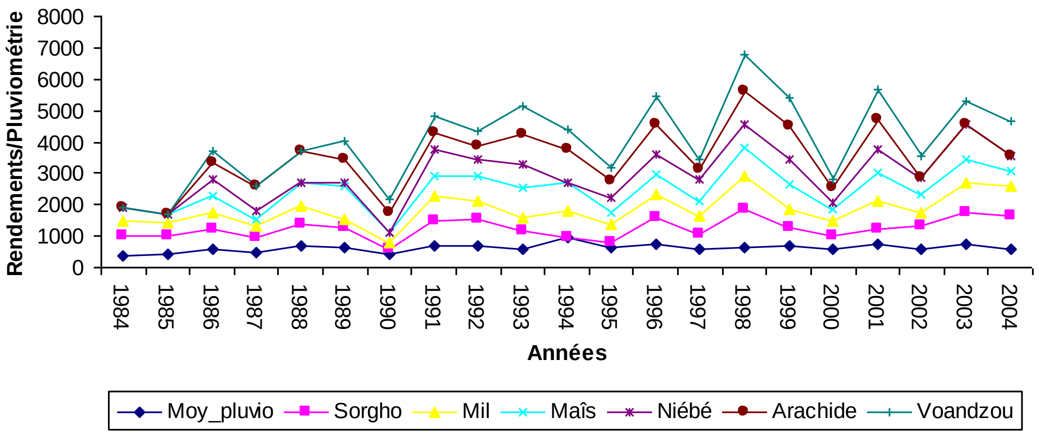


Figure 12: Evolution of crop yield and rain from 1984 to 2004 according to statistical services in the Yatenga

Table 11: Crop yield from 1984 to 2004 according to statistical services in the Yatenga

Year	Sorghum	Millet	Maize	beans	peanut	Voandzou
1984	594	473	438	-	-	-
1985	577	413	284	-	-	-
1986	623	543	517	518	533	400
1987	483	381	222	236	817	-
1988	694	556	728	-	1030	-
1989	662	281	1036	100	731	628
1990	165	234	322	-	643	409
1991	807	786	617	880	548	520
1992	824	596	806	490	436	468
1993	554	463	922	780	933	914
1994	-	858	908	-	1034	655
1995	199	555	401	480	533	379
1996	858	728	663	617	950	905
1997	452	608	457	720	293	333
1998	1230	1022	889	760	1087	1126
1999	587	620	773	812	1026	908
2000	432	466	368	208	513	249
2001	474	887	924	760	947	921
2002	746	428	575	528		672
2003	1020	937	742	1143		752
2004	1026	962	499	491		1104

Table 12 : Socio economic data sur les unités de production dans les sites d'études du projet.

Village	Members/ UP	Actifs	Enfant scolarisé	Maisons	Motos	Vélos	Charrette	Charrue
Somiaga	10,42	5,46	1,62	1,73	0,35	1,77	0,62	0,62
Ziga	12,93	7,28	3,17	1,69	0,55	1,97	0,93	1,34

Source : Données étude Sahel, CILSS 2008

Table 13 : data on livestock by household

Villages	Cattle	sheep	goat	donkey	chicken	Residu cereals (kg)
Somiaga	1,88	3,62	3,35	0,69	10,73	2272
Ziga	2,21	5,48	8,48	1,24	18,38	2625

Source : Données étude Sahel, CILSS 2008

8. Past and on-going projects (especially related to water harvesting)

Relevant past projects include GERES, CES/AGF, CES II, PAF, PAE

The most relevant ongoing projects are : Projet de Développement Rural Durable, Projet de Récupération des Terres Dégradées, Projet de Développement Local/Sécurité Alimentaire dans le Zondoma, Services techniques de l'agriculture, de l'élevage et de l'environnement

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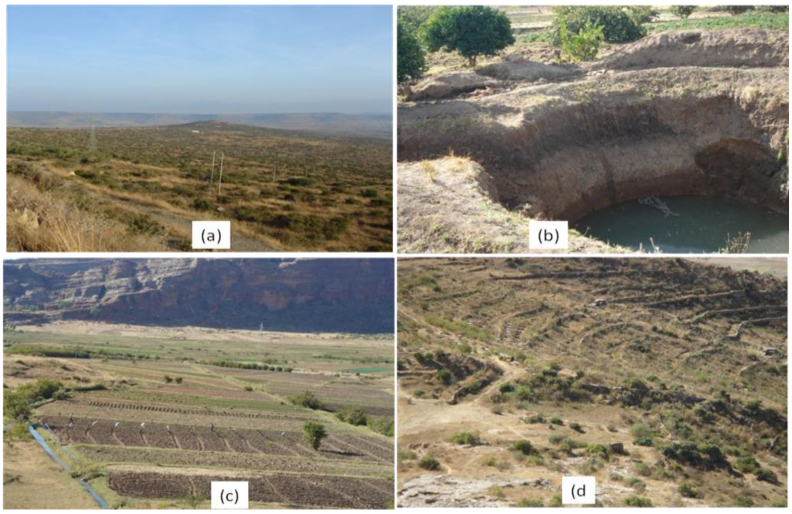
Watershed Inventory

WAHARA Study Site in Ethiopia

(Study Site 3)



Watersheds: Suluh, Genfel and Agulae

1. Responsible partner: Mekelle University

2. General information

Location

The study area is found in the Eastern Zone of Tigray and includes Suluh, Genfel and Agulae watersheds. It is geographically located between 39°18’E and 39°48’E longitude and between 13°32’N and 14°15’N latitude and cover a total area of about 2,400 Km^2 (Figure 2). It is on the head waters of the Tekeze basin and is characterized by dendritic drainage pattern. Most of the rivers in Ethiopia including Suluh, Genfel and Agulae have high seasonal variability and about 70% of the total runoff occurs during the main rainy season in the period from June to August. Dry season flow originates from springs, which provide base flows for small-scale irrigation (FAO, 2005).

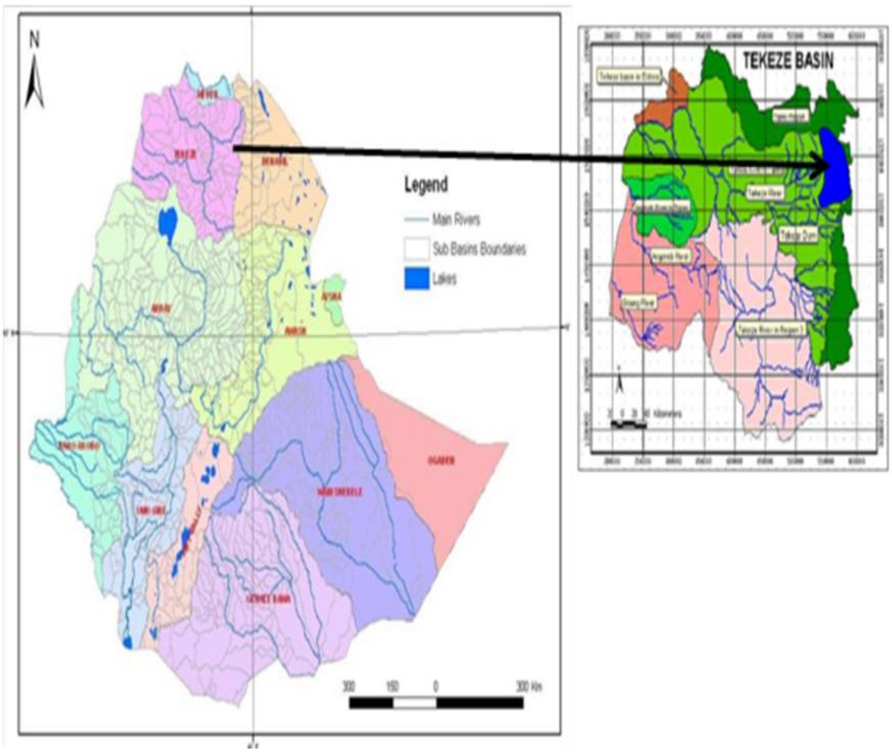


Figure 1 Location of the study area

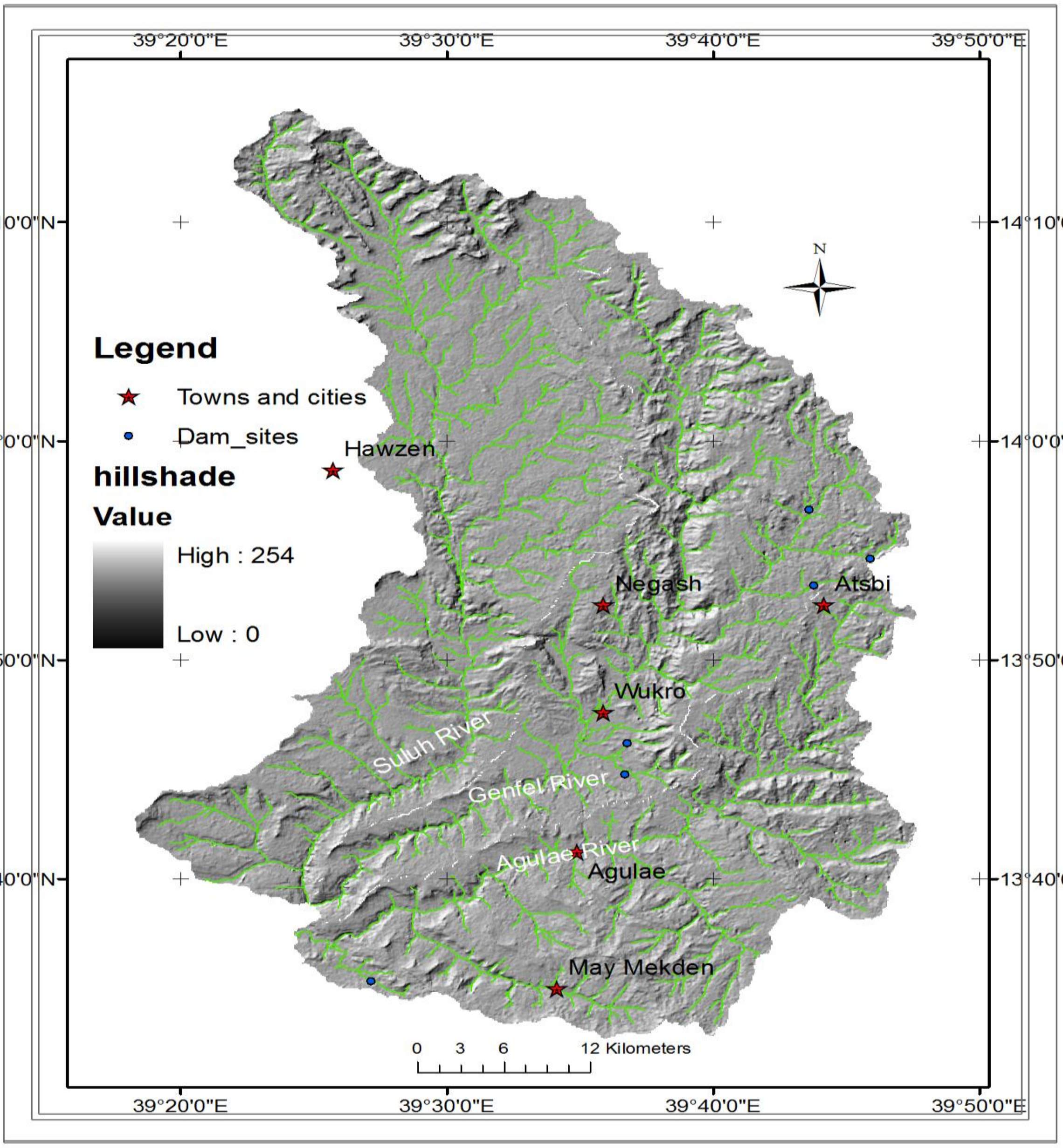


Figure 2 Major rivers, towns and DEM of the study area

The selected watersheds are prone to recurrent drought. Since the economic condition of the majority of the people in the area is generally low, even slight rainfall changes have been causing great disaster. The communities in the watersheds have been food insecure for several reasons: (a) land degradation mainly erosion and reduction in soil fertility, (b) short rainy season coupled with high rainfall variability between seasons, (c) small land size that rarely exceeds 0.5 ha per family, and (d) limited irrigation practices.

Suluh, Genfel and Agulae rivers are tributaries of the Geba river (that originates from the Mugulat Mountain with elevation of 3,298 m.a.s.l) which joins the Tekeze River.

The Suluh-Genfel-Agulae watersheds were selected for this study due to three main reasons:

- They cover the three major agro-ecological zones of Ethiopia, i.e. Dega (highland), Weyna Dega (midland) and Kolla (lowland);
- There is an extensive and rich experience of water harvesting technology on the one hand and poor practices on the other which makes the area an ideal location for comparative study;
- The proximity of the watersheds to Mekelle University.

Population and demographic issues

Suluh, Genfel and Agulae watersheds have a total of 49,574 household heads and an estimated total population of 236,486 of which 51.7% are female and 48.3% male. From the total population of the watersheds, about 76.4% live in rural areas. From the total rural dwellers, 63.4% are female while male accounts about 36.6%. The average family size per household of the study area is about 5 persons. The aggregate dependency ratio of the valley is 1.09, with relatively higher ratio in rural area. The calculated dependency ratio in rural area indicates that on average two persons are dependent on one economically active family member (Mekelle University, 2011).

3. Bio-physical description

Physiography and climate

The landscape of the project area is associated with wide ranges of landforms which include plateaus, mountains, rolling hills, steep hill slopes and deeply incised valleys. The slope gradients range from flat plains to over 40% (Figure 3). The slope range renders itself very conveniently to both on-farm and off-farm water harvesting practices.

The catchment encompasses a wide range of altitude starting from 1,500 to 3,300 m.a.s.l with diverse rock types (e.g., sedimentary, metamorphic and igneous origin) and various cover types and land use. The mean annual rainfall and temperature of the Geba catchment varies from 552 mm – 767 mm, and 16 – 20° C respectively. The major soils are Leptosols, Cambisols, Luvisols and Fluvisols.

The climate of the project area is classified as semi-arid, with erratic and torrential rainfall that often lasts for not more than 3 months (end of June to beginning of September). Actual and potential evapotranspiration are about 540 mm and 1,390 mm respectively.

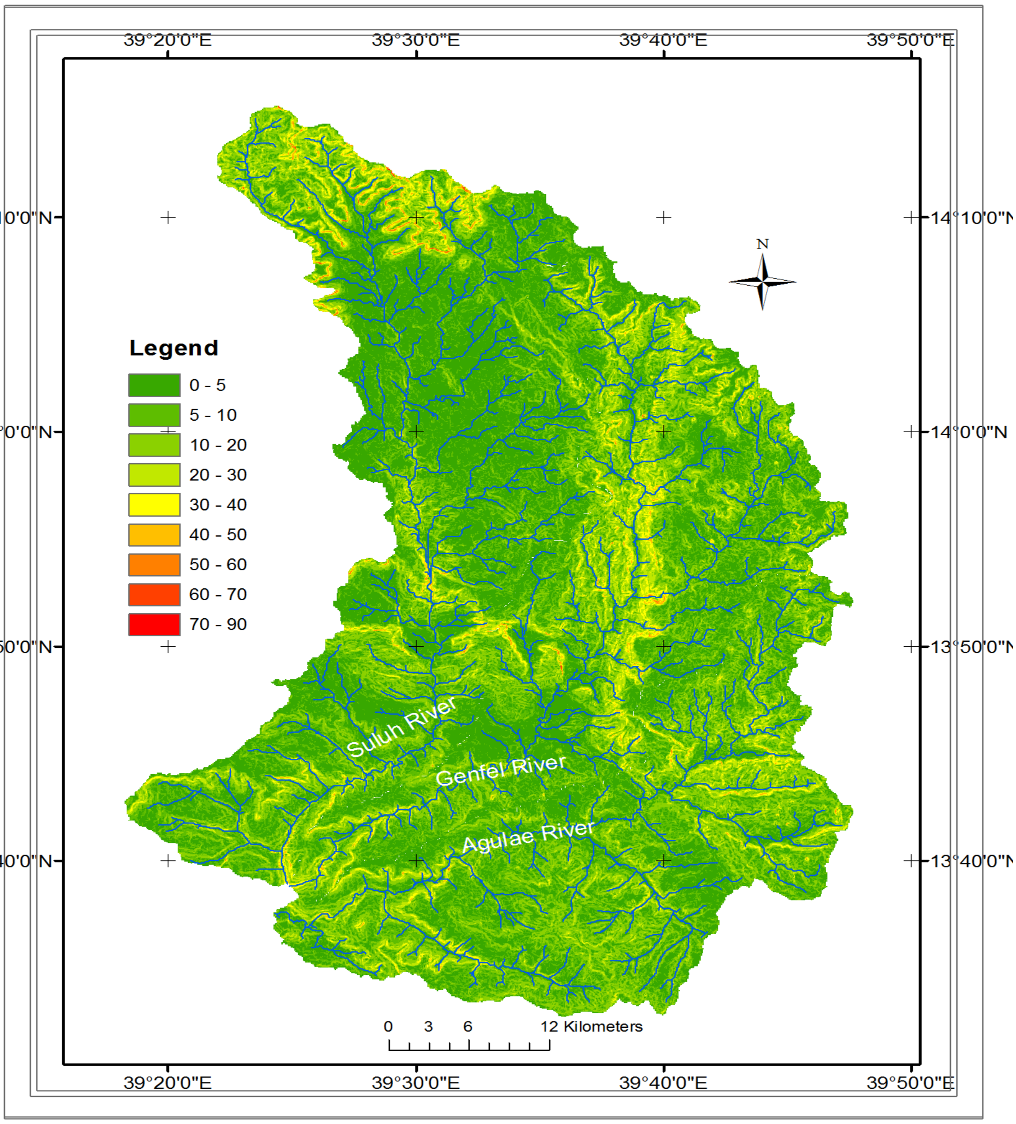


Figure 3 Slope map of the study site

Erosion processes

Various authors (e.g. Hurni and Perich, 1992; Beraki and Brancaccio, 1993; Beraki et al., 1997; Bull, 1997; Nyssen et al, 2004; Billi and Dramis, 2003) have reported on the prevalence of sheet erosion as well as stream/river incisions and gully erosion in the highlands of Ethiopia. Two main types of gully erosion are common (Billi and Dramis, 2003): (a) discontinuous gullies which generally develop on low slope gradients, and (b) stream gullies which are formed by deep erosion processes typically migrating up-slopes. Erosion processes have produced steep valleys (Mekelle University, 2011).

Land use and land cover

According to HTS (1976), the natural woodland vegetation in most of Tigray has been largely destroyed or severely modified by human activities. The original Olea Juniperus-Acacia woodlands of the central plateau survive only in inaccessible and remote areas on the main mountain ranges, on the main escarpments and locally around churches. Elsewhere, the present vegetation comprises a sparse cover of low and thorny Acacia bush and shrub interspersed between cultivated areas. Edaphic grassland occurs on non-cultivated lands in depressions of the central plateau.

The major land use and cover types of the catchments used for classification are: cultivated land, bare land, forest and bush land, grass land, built up area and water body. Based on the land cover classification scheme of the South Africa National Land Cover Data base project (Thompson, 1999), the land cover categories for catchments were defined as follows:

- Cultivated land- areas of land prepared for growing rain fed or irrigated crops. This category includes areas currently under crop, fallow, and land under preparation.
- Forest land- areas covered with a natural forest community with a closed, deep and complex canopy often consisting of several crown layers. Many species are ever green and their floor is incompletely covered with herbs, shrubs, and grasses.
- Bush land- areas covered with scattered and/or patches of bushes and shrubs in combination of grasses.
- Grass land- all areas of grassland with less than 10% tree and/or shrub canopy cover and greater than 0.1% total vegetation cover.
- Water body- areas of (generally permanent) open water. The category includes natural and man-made water bodies, which are static or flowing, and fresh, brackish and salt water condition.
- Bare land- non-vegetated areas, or areas, very little vegetation cover (excluding agricultural fields with no crop cover), where the substrate or soil exposure is clearly apparent.

A majority of the catchments are dominated by cultivated land, followed by bush land and forest and plantation. Water body accounts for the smallest proportion in all the catchments followed by built up area. The map depicting the land use/cover classes of each catchment of the study area is given in Figure 4. The area coverage of each land use and land cover of the various watersheds of the study site is presented in

Table 1.

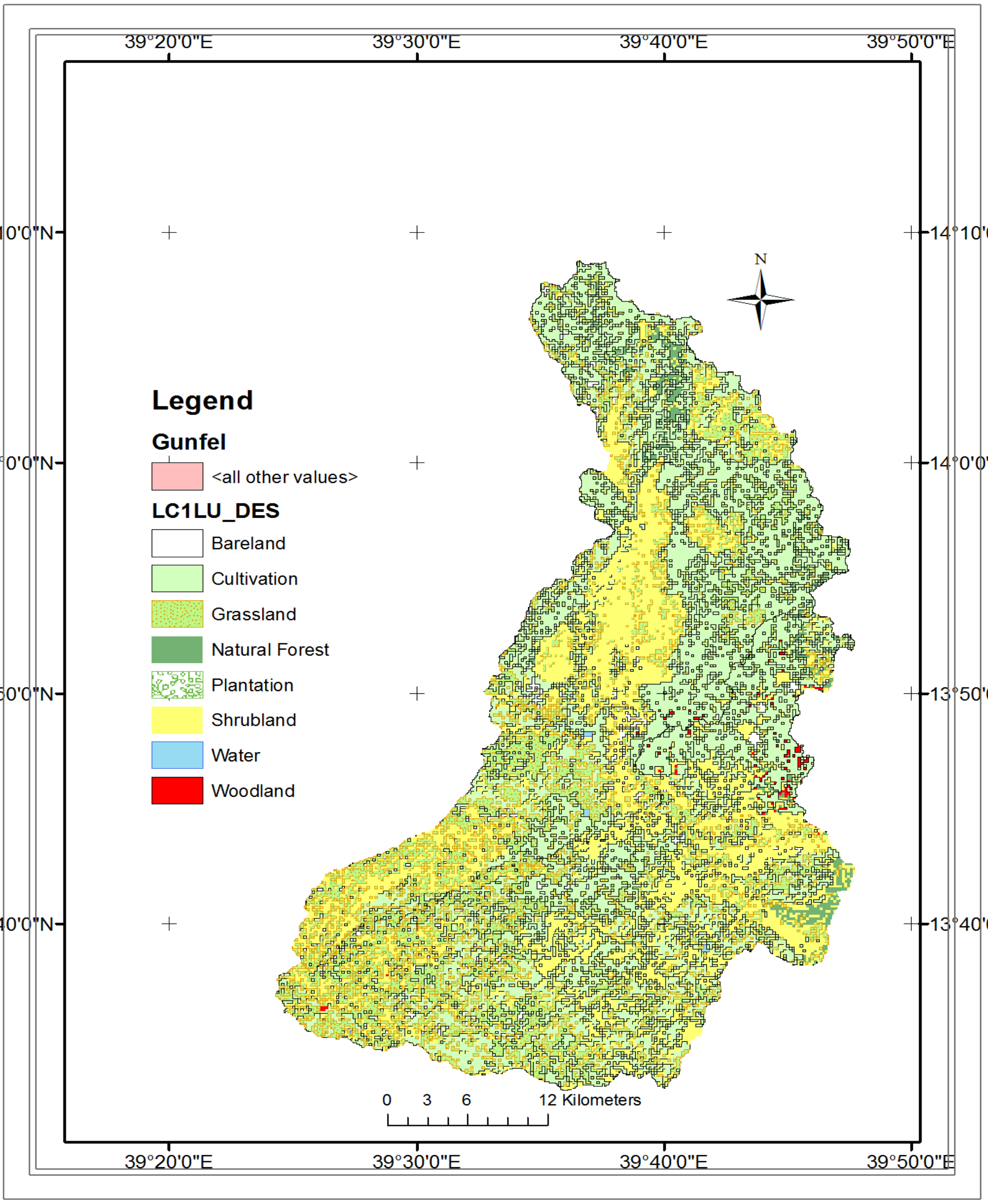


Figure 4 Land use/cover map of the study area

Table 1 Area coverage of each land use/cover of the various watersheds of the study area

Land use/cover	**Agulae**		**Genfel**		**Suluh**	
	Hectare	***%***	***Hectare***	***%***	***Hectare***	***%***
Open water	90	0.13	125	0.17	45	0.05
Cultivated land	33723	48.79	30951	41.94	46678	48.48
Forest and plantation	8877	12.84	9222	12.49	11615	12.06
Bush land (and Bare)	19796	28.64	23074	31.26	19186	19.93
Built up area	1364	1.97	6509	8.82	9667	10.04
Grass land	5270	7.63	3923	5.32	9093	9.44
Total	**69119**	**100**	**73804**	**100**	**96284**	**100**

Soils

Several authors (e.g. Mitiku et al., 2002) have studied the soil types in the study area. Most soils in Tigray have been under cultivation for many centuries without proper management and maintenance. These soils have decreased their fertility status mainly due to the removal of vegetative cover (Tsegay and Kahsa, 2000). Four major groups of soils are found in the project area, namely, Cambisols, Leptosols, Luvisols and Fluvisols (Figure 5).

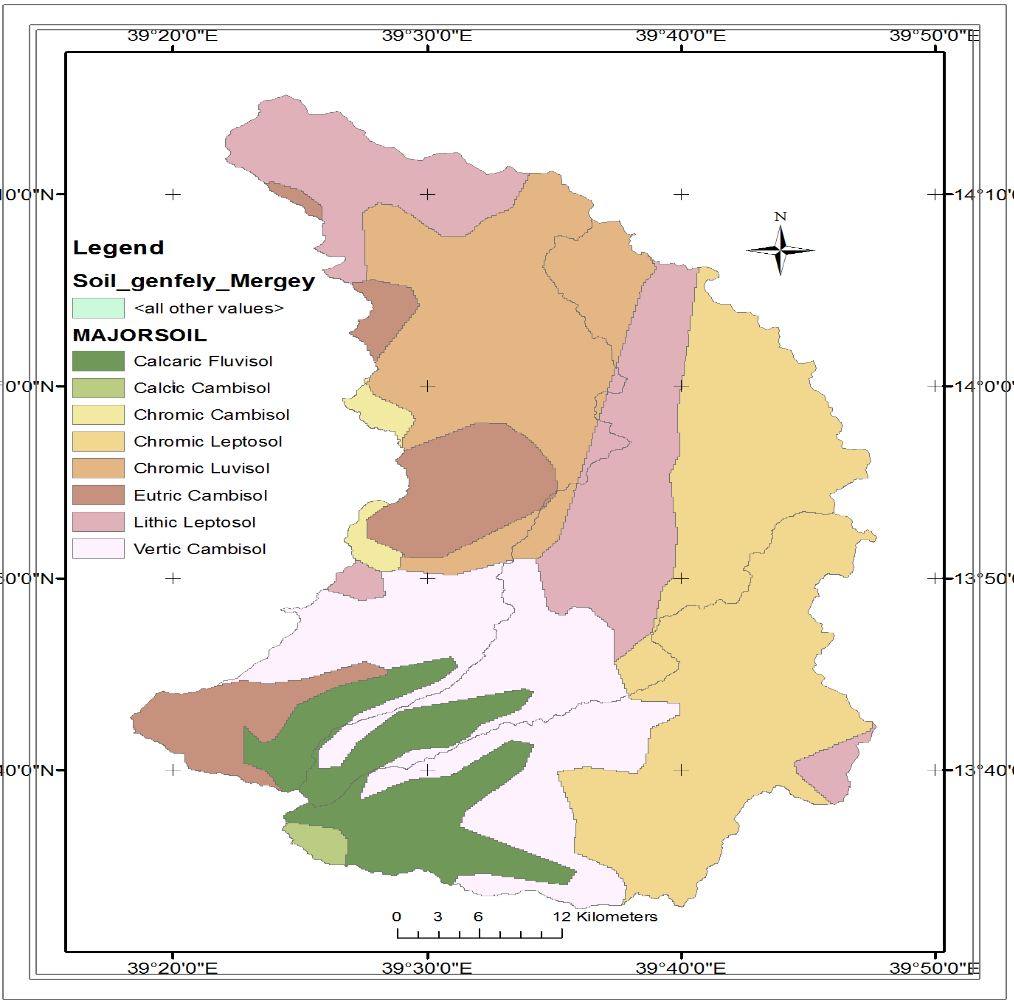


Figure 5 Major soils of the project area (Produced based on Geomorphology and Soils of Ethiopia, Scale 1:1,000,000 (UNDP, FAO, MOA, 1984).

Cambisol

Cambisols are moderately developed soils characterized by slight or moderate weathering of the parent material and by absence of appreciable quantities of illuviated clay, organic matter, aluminium or iron compounds. These soils are largest soil group in the project area. Cambisols are highly important soils used for a wide variety of crops unless climatic condition, topography, shallowness/stoniness, or low base status are prohibiting.

Leptosols

These are shallow soils, limited in depth by continuous hard rock or a continuous cemented layer within 20 cm of the surface or highly calcareous materials (>40% $CaCO_3$ equivalent). These soils are second largest soil group in the project area. These soils are dominantly found in mountainous parts of Genfel and Agulae.

Luvisols

Luvisols are soils in which clay is leached down from the surface soil to an accumulation horizon at some depth. In view of their moderate stage of weathering and high base saturation and a good drainage status, they are suitable for a wide range of agricultural uses. These soils are found in Suluh and Genfel sub-catchment.

Fluvisols

Fluvisols are soils developed in alluvial deposits. They are developed from recent, medium and fine-textured fluviatile, lacustrine or marine deposits. These soils are found on valley bottom and cover part of (not more than 6%) of Agula, Genfel and Suluh sub-catchments. These soils may also be found on other valley bottom parts of the sub-catchments, although the areas are too small to be portrayed on this map.

Land degradation and management issues

Soil erosion is one of the most serious limiting factors for crop production in Ethiopia. Erosion due to water is one of the most important land degradation processes. It is common to observe erosion features such as sheet, rill, gully and stream bank erosion in the project area. NEDECO (1997) has confirmed that soil erosion by water is more significant (in terms of extent and degree) than any other forms of soil degradation processes in Tekeze basin where the project area is found. Consequently, most of the soils are believed to have become less fertile due to soil degradation caused by intense rainfall, steep slopes and sparse vegetation cover, population pressure and poverty, overstocking and overgrazing, deforestation and inappropriate crop management.

However, like many parts of Tigray, the project area is not only known for its erosion and land degradation processes, but also for its efforts to reduce runoff and soil erosion and maintain fertility of the soil. A number of management practices (indigenous and introduced soil and water conservation) are widely practiced on cultivated and uncultivated lands in the study area. Soil and water conservation measures such as stone/soil bunds, check dams, hillside terraces and trench bunds are constructed to reduce runoff and to harvest moisture (Figure 6).

Soil fertility management practices in the project areas include the use of artificial (Urea and DAP) and natural (manure and compost) fertilizer, contour ploughing/tillage, crop rotation and, to some extent, fallowing. However, the fertilizer application rate in the area is very low: 18 – 28 Kg/ha of DAP and 10 – 18 Kg/ha of Urea.

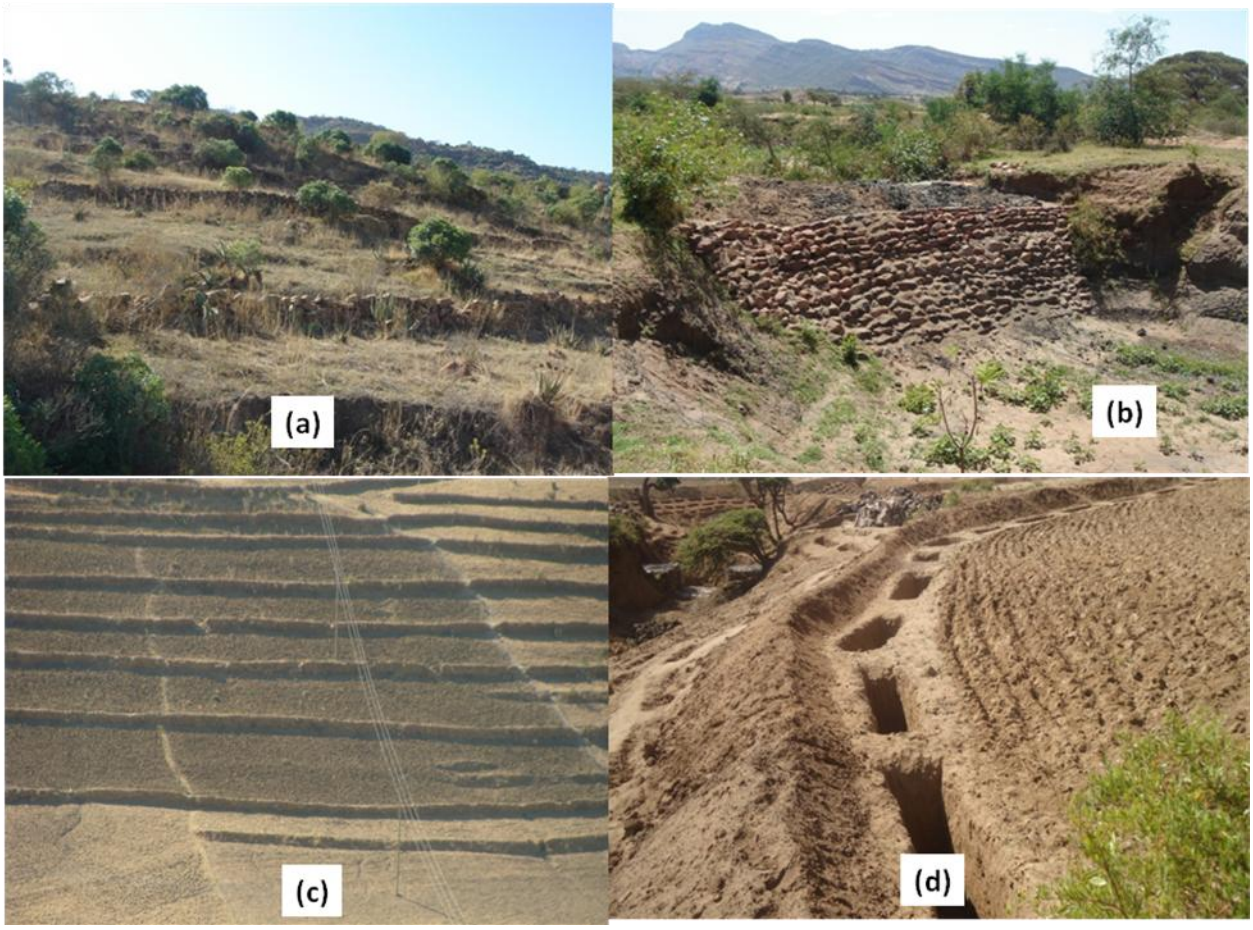


Figure 6 Some of the soil and water conservation measures in the study area: Hillside terraces (a), Checkdams (b), Stone bunds (c) and trench bunds (d)

4. Socio-economic description

General

With little access to irrigation, most of the smallholding farmers in the study area depend on rainfed agricultural practices. The selected watersheds are prone to recurrent drought. Since the economic condition of the majority of the people in the area is generally low, even slight rainfall change has been causing great disaster.

The communities in the watersheds have been food insecure for a number of reasons, among which are: (a) land degradation mainly erosion and reduction in soil fertility, (b) due to short rainy season coupled with high rainfall variability between seasons, (c) the small land size that rarely exceeds 0.5 ha per family and (d) absence of irrigation practices. In order to ensure food security, over the years, a number of programs have been implemented to harvest water (surface and subsurface), control soil erosion and promote afforestation. In this line, several micro-dams, diversion weirs, ponds and groundwater wells have been developed by different organizations. Extensive soil and water conservation activities have been also carried out in the last 15 years. This effort has particularly been intensified in the last 3 years. Currently, the government has introduced a new plan whereby every farmer is required to have at least one “water bank” for irrigation.

The dominant mode of livelihood of the population is mixed crop and livestock agriculture (Figure 7 and Figure 9). The predominant agricultural practice in the study area is traditional crop-livestock mixed farming. The major rainfed crops grown is dominated by cereals and legumes such as Barely, Wheat, Beans, Vetch, Peas, Faba Beans, Lentils, Teff, Maize while the irrigated crops include Maize, Tomato, Onion, Pepper, Carrot, Cabbage and fruit trees. Other income sources include quarrying (stone gathering), wages, pity trade, etc. In general, livelihood diversification of the study area increases with market proximity.

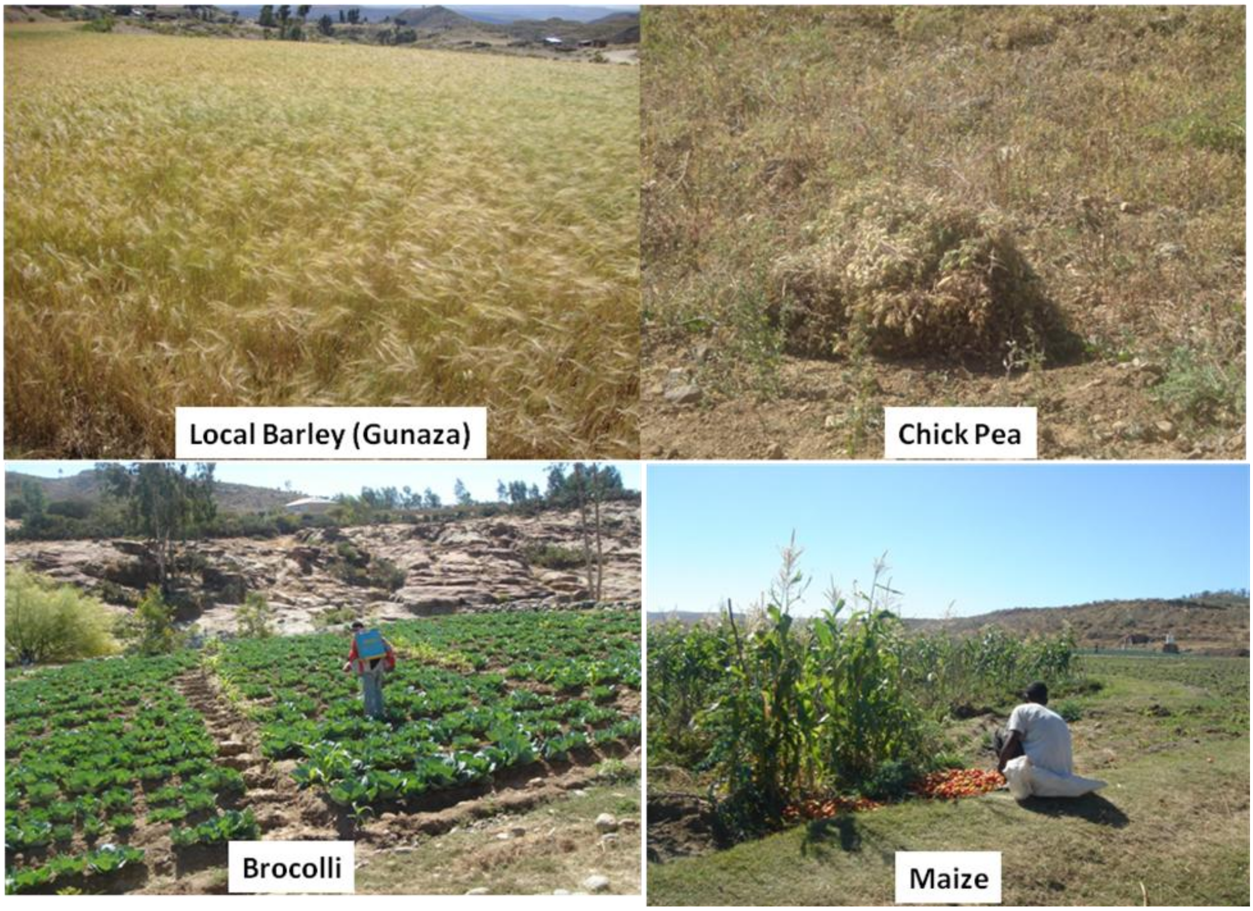


Figure 7 Some of the rainfed and irrigated crops in the study area

Rainfed agriculture

The total cultivated land in the area in 2009/2010 production year was 34,911.1 hectare while the corresponding total yield was 793,540.2 quintal. It was found out that, with an average of 13.1 quintal/ha, the average annual yield in Suluh, Genfel, and Agulae Valley varied from 7.9 quintal/ha to 22.7 quintal/ha. The major factor contributing to the variability is the unreliability of rainfall both in amount and distribution.

The other factors causing low productivity include poor soil fertility, poor agricultural inputs including improved seeds and fertilizer, poor tillage practices and weed problems. As a result, farmers do not produce sufficient food and are exposed to year round food aid.

The population of the study area which is similar to the other parts of the country grows by 2.5% which requires parallel growth in the agricultural commodity sector. However, recurrent drought and low yields have caused the growth rate of food production to lag behind the rate of population growth.

Irrigated agriculture

Various water harvesting technologies ranging from individual farm household to community level are used in the study area for irrigation. Some of these include earth dams, river diversions, ponds (Horoye) and hand-dug wells (Figure 8).

Figure 8 Some of the water harvesting technologies used for irrigation in the study area

In the year 2009/2010, the total irrigated land in the study area was 6,916.03 hectare, with a total yield of 744,832.35 quintal. The average yield was 107.70 quintal/hectare. Irrigation crop choices vary with market proximity as it determines price, demand, shelf life, transportation and access to information. As one approaches market center (town), the availability of vegetables increases while that of cereal like maize decrease and vice versa.

More interestingly, in areas with longer history of irrigation practices, the productivity of crops is reported decreasing as farmers are continuously cultivating similar crops continuously without allowing rotation. This in turn harbors soil born disease and pests. As a result, farm profitability is reported minimal in some cases.

Moreover, surplus production of similar commodities with a given production season was also reported as common trend along the irrigation users. As a result price of perishable commodities like onion, tomato, carrot and cabbage becomes low and in extreme case some farmers leave the product in the farm as it fail to cover harvesting and transaction costs. In seasons with good market conditions, wholesalers were also blamed in distorting the true value of farm products in a coordinated manner. As a result, individual farmers are forced to sell their product at lower prices to these wholesalers (Mekelle University, 2011).

Equally important, with increasing expansion of irrigation land, water use conflict was also reported common between up and down stream users despite the existence of Water Users Association (WUA) in some areas. Most of the Water Users Associations have limited members and little capital. As a result, in most cases, the WUAs were found weak in mobilizing the users for maintenances of the irrigation systems.

Livestock

Livestock are the second most important source of farm livelihood to the communities in the study area. According to the TBoFED (2010), the livestock population in the study area is 207,167 Cattle, 234,787 Sheep, 69,580 Goats, 205 Camels, 189,576 Poultry, 2,599 Mules, 103,307 Donkeys and 457 Horse.

Figure 9 Cattle rearing is one of the most important livelihood mechanism in the study area

Livestock productivity is very low; the average daily milk production of the local cattle is between 0.5 to 1 litters. Livestock are left to freely graze during the dry season, but are restricted during the main rain season because of crops. During the wet season where livestock movement is restricted because of crop production, cut and carry is practiced to supplement oxen and dairy cows. This is especially common in Atsibi and villages around urban area. However, feed is a major limiting factor of livestock production in the area. There are important livestock diseases in the area that also contribute to the poor productivity. Currently, there is good effort in promoting high yielding local (eg. Begaite) and hybrid dairy cows but are still suffering from feed and management problems.

Non-farm and off-farm livelihoods

Following the agricultural sector, productive safety net is the most important livelihood strategy throughout the study area. The program is serving in addressing food gaps for those who are below poverty line (1 US Dollar). Especially the old aged and disabled (the so called "Direct Support") group consider this program as their primary means of survival.

Pity trade and daily labor are also important livelihood strategies in the valley especially in areas around the main road.

<u>5 Institutional and political setting / Relevant end-users / stakeholder groups (at all levels)</u>

The valley floors of the watersheds are very fertile. If the available water resource is properly harvested and utilized, there is a possibility to ensure food security in this very fragile environment. There is, therefore, a need to create a knowledge base on water harvesting technologies that harvest more water, that are cost-effective and sustainable (operational sustainability). Small holder farmers, especially the young and literate ones of the area will be the most relevant users. The government is exerting efforts to scale-up best practices to other parts of the region. This would give a good opportunity to share the best techniques to other areas.

Figure 10 Some older land owners work as daily labourers by leasing their land to the younger and relatively educated generation

Institutional and political setting

The study area is found in Tigray National Regional State. The institutional arrangement is favourable for applying the knowledge gained on water harvesting. The watershed has its own administrative organ with several development sector offices (governmental and non-governmental), including Agriculture and Rural

Development, Water Resources Development, Education and Health Offices. Moreover, several NGOs are operating in the area, mainly Relief Society of Tigray. The Ethiopian Water Policy follows cost-recovery principles for any water related project. It is being implemented even on multimillion projects developed for small holder farmers. As part of the current Growth and Transformation Plan, the Government is also working very hard to ensure the ownership of at least one "Water Bank" per farm household to avoid risks and guarantee sustainable agricultural productivity.

6. Water resources and water use

The major source of water for agriculture and livestock is rainwater. Due to the erratic nature of rains, the community and the government have developed various water harvesting and moisture retention techniques such as trenches, terraces, soil bunds, ponds, dams, diversion weirs and shallow wells

7. Water harvesting techniques (used in the country/region and with focus on the study site/area)

To ensure food security and conserve the natural environment, a number of efforts have been made in Tigray region in general and in the study area in particular. There exist indigenous as well as introduced technologies.

Indigenous technologies

Some of the indigenous technologies that communities and farmers have been using as tools for moisture conservation, water harvesting and watershed management include the following:

- Construction of demarcation bunds (Armo) between farm holdings or within a farm to reduce slope length and gradient;
- Plantation of indigenous drought tolerant plants such as "ERE" to stabilize bunds;
- Application of manure to farms;
- Fallowing of farm lands;
- Crop rotation between cereals and legumes;
- Construction of diversion channels to protect farm lands from damage by upstream runoff and drainage channels to safely remove excess runoff from the farm lands;
- Construction of traditional spate diversion systems to divert seasonal flood from highlands to low lying alluvial valleys;
- Construction of earth bunds to harvest moisture and reduce erosion;
- Application of ash to farms to increase the fertility of the soil;
- Planting indigenous trees that can fix nitrogen in the soil;
- Construction of hand-dug wells for household and irrigation purposes;
- Construction of community ponds (Horoye) especially for livestock watering;
- Spring development;

- Incorporating crop residue to farms.

Introduced technologies

A number of technologies have been introduced not only conserve soil and water but also harvest water and preserve the natural environment. The government and non-governmental organizations (mainly REST) have been at the forefront in introducing these technologies.

The moisture conservation, water harvesting and watershed management techniques that have been introduced in the study area include the following:

- Area closures along with plantation of indigenous and introduced grasses, bushes and trees;
- Application of compost to farms;
- Use of organic and stone mulching to minimize evaporation loss;
- Application of inorganic fertilizers;
- Contour ploughing;
- Contour soil and stone bunds;
- Stone faced soil bunds;
- Stone/soil/stone faced soil bund with trenches;
- Hillside stone terraces;
- Bench terraces;
- Stone faced deep trenches;
- Percolation ponds;
- Eyebrow basins;
- Negarim micro-catchments;
- Check dam ponds: concrete, masonry, or mixed;
- Gully rehabilitation check dams: gabion, masonry, concrete or mixed. In many cases gully rehabilitation check-dams are coupled with planting trees (e.g. elephant grass);
- Semi-circular bunds;
- Modern spate systems;
- Drip irrigation systems: conventional and family kits;
- Perennial river diversion weirs;
- Small-scale dams (with size from less than 10m to over 25m heights): for water storage as well for sediment trap;
- Protected spring development;
- Motor pumps;
- Groundwater wells: deep, shallow, hand-dug wells;
- Cisterns;
- Ponds;
- Roof water harvesting;
- Hillside conduits are tried in limited cases and need to be scaled-up.

Figure 11 – Figure 14 present some of the water harvesting and natural resources management practices in the study area.

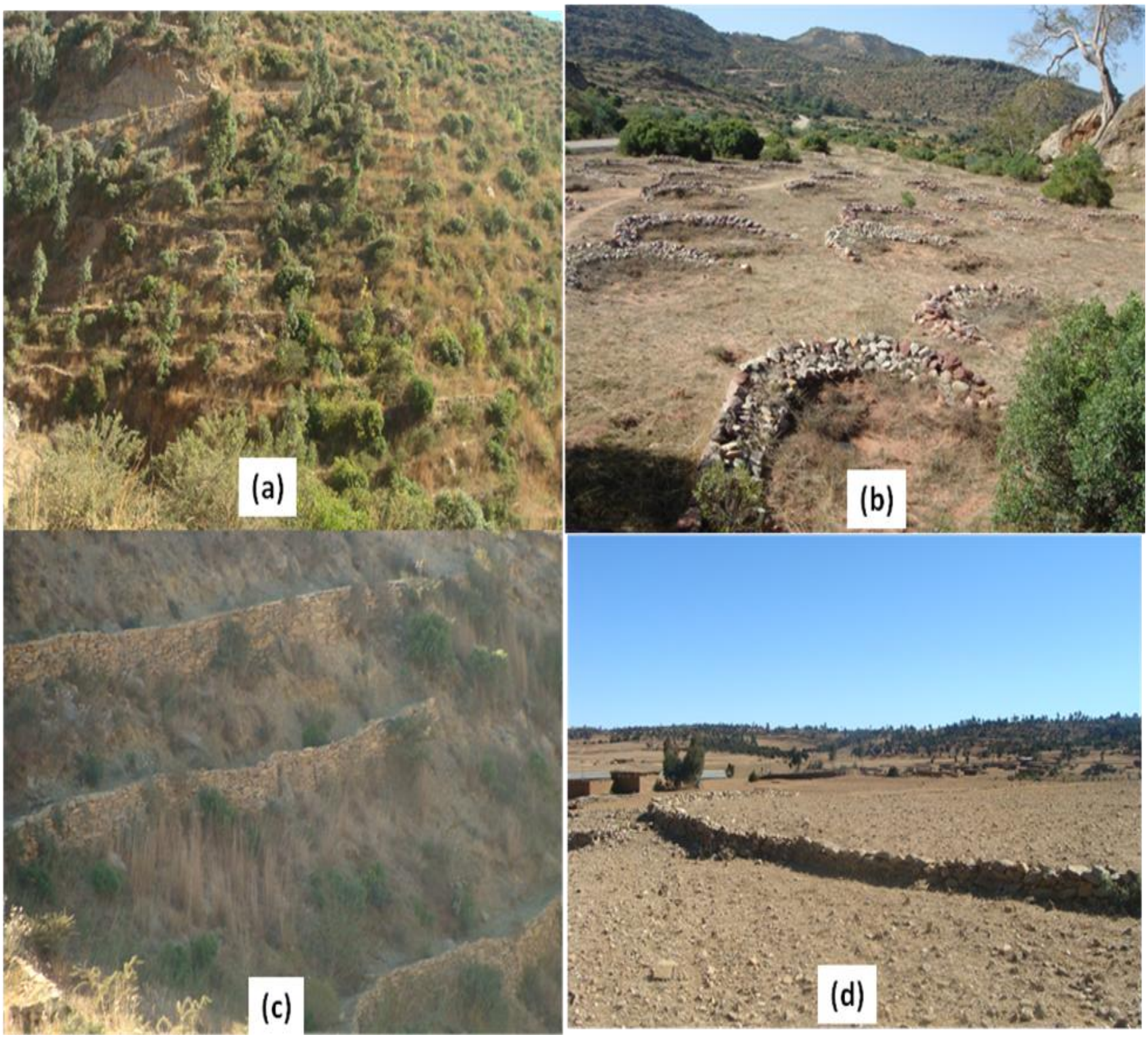


Figure 11 Integrated watershed management (a), Eyebrow basin (b), Hillside stone bund (c) and Stone bunds (d)

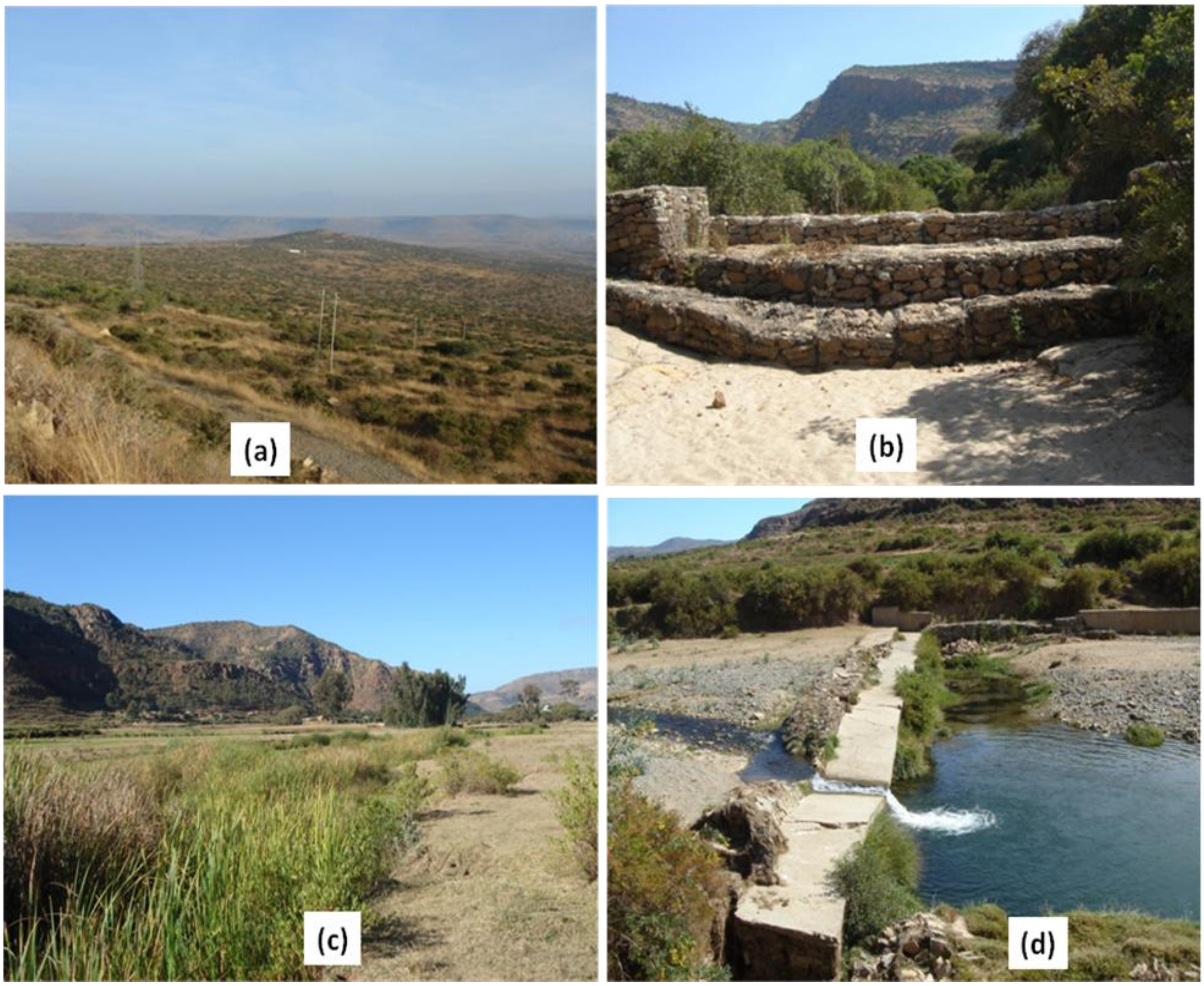


Figure 12 (a) Area closure, Check-dams (gabions) (b), Gully treatment with vegetation (elephant grass) (c) and River diversion weir (d)

Figure 13 Micro-dam (a) and pumping from rivers (b)

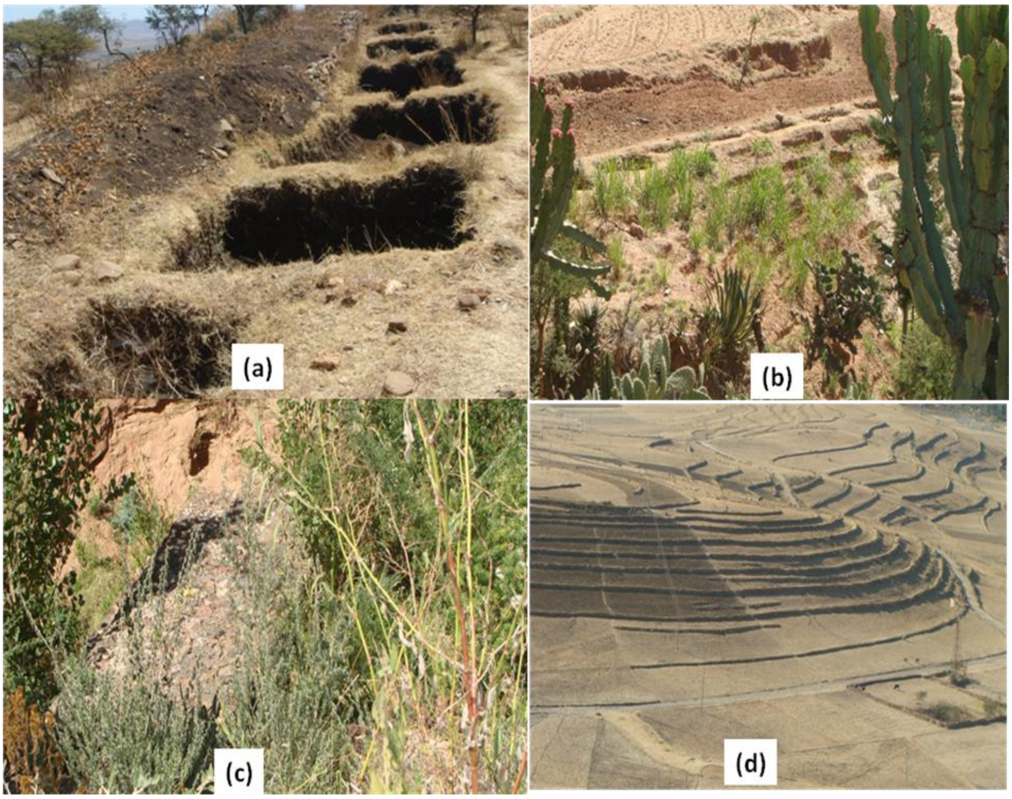


Figure 14 Deep trenches (a), Contour ploughing and pits (b), Gully treatment (c) and terraces (d)

The various water harvesting schemes such as dams, diversion weirs and shallow wells that has been constructed during the last 15 years to ensure food security have significantly improved the livelihood of farmers (Figure 15 and Figure 16). Recent data from BoARD (2010) indicate that more than 70% of the watersheds are covered by different soil and water conservation activities. A number of positive effects have been recorded as a result of such interventions which include improvement in agricultural yield, improvement in the micro-climate of the areas and increase in both groundwater recharge and spring discharge. The communities in the study area are well aware of the importance of water harvesting and soil/water conservation activities. Farmers and local communities are able to recognize the following positive effects of natural resources management and water harvesting:

- There is a change and improvement in SWC, natural resources management and irrigation practices.
- Best practices are coming and being scaled-up though not at the required level.
- There is change in the awareness and attitude towards natural resources management and irrigation.
- Watersheds are improving in all aspects: moisture, productivity, etc.
- Gully treatment is leading to improved economic and social conditions of the communities and for improved environment.
- The advancement of gullies was halted, the gullied area was reclaimed and moisture stored behind the check dams used for growing fruit trees;
- Farmland is safe from inundation by flood and silt deposition;

- Groundwater is adequately recharged and is being used for irrigation, livestock and domestic water supply;
- Hillsides are currently covered with indigenous and introduced grasses, bushes and trees;
- Increase in yield and subsequent income:
  - improved harvest of fodder grass from marginal lands has increased the productivity of livestock;
  - production of honey has increased due to the enhanced biomass availability;
  - cereal productivity has increased and vegetable and fruit production introduced.

On the other hand, the following weaknesses have also been identified and needs due attention.

- Lack of proper management and maintenance of interventions especially on communal sites such as letting livestock into closure areas and maintenance negligence of physical structures.
- Occasional drawbacks of community participation in the selection and implementation of technologies.
- Technical limitations in the design, construction, monitoring, evaluation and implementation of desired modification.
- Hosting of destructive rodents such as mice by some structures such as stone bunds in cultivated lands.
- Lack of proper prioritization of intervention sites which can be explained by the implementation of water harvesting technologies at lower catchment before treating the upper catchments. This approach has been the cause of flood and subsequent damage of downstream water harvesting structures.
- Lack of contour alignment during the construction of water harvesting structures by farmers which could easily have been done by locally made, easy to operate by farmers and no-cost instruments such as A-frame and line-level;
- Water logging problems downstream of dams in some areas.

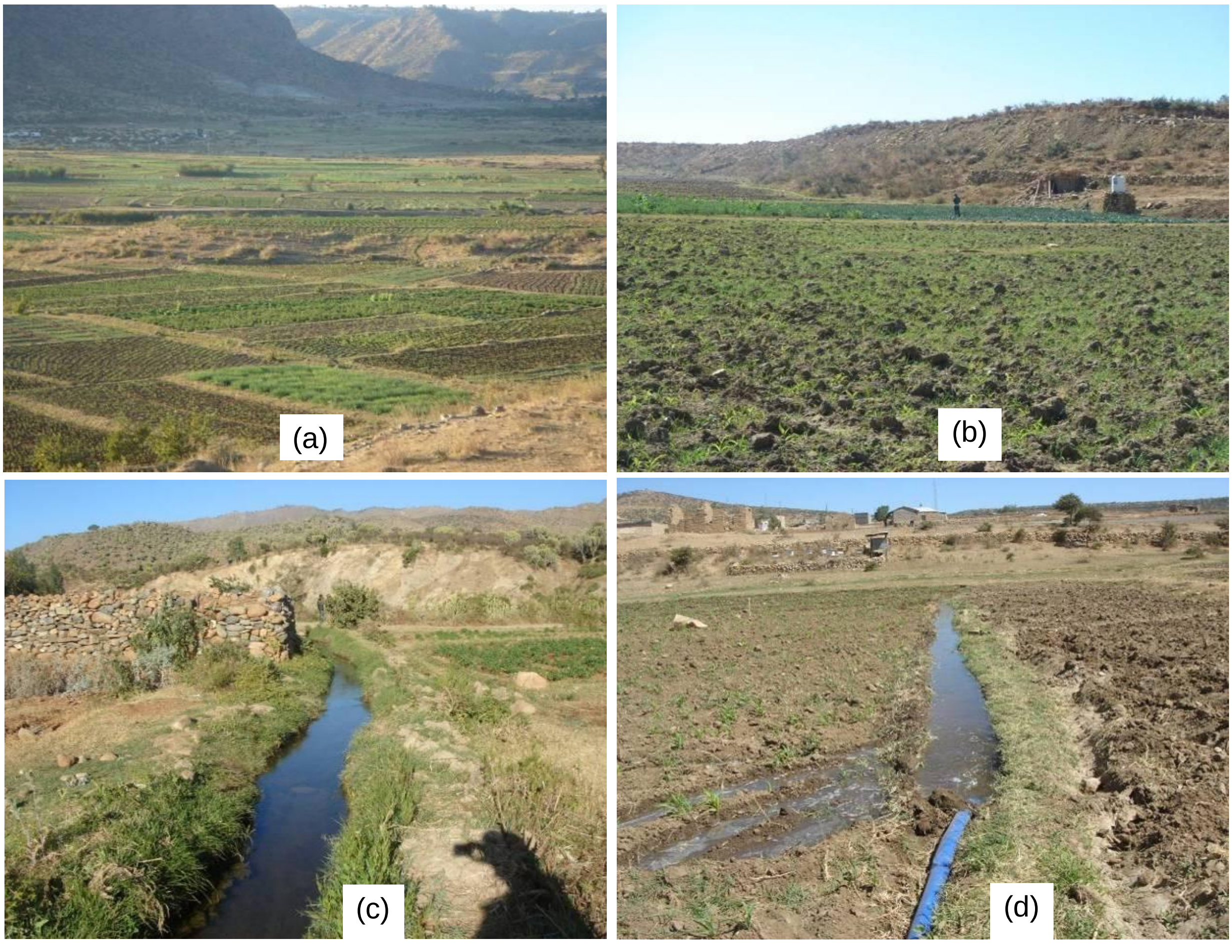


Figure 15 Irrigation practices in the study area

Figure 16 Economic benefits as a result of small-scale irrigation

8. Past and on-going projects (especially related to water harvesting)

Mainly government-organised projects for watershed management and irrigation

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WAHARA PROJECT

Study Site Descriptions

Responsible Partner : 7 (GART)

Study Site : Magoye

Contents

- General Information
- Bio-physical description

Date:31 January, 2012

1. **Responsible partner:** **Partner 7 (GART)**

2. **General information**

Figure 1. Location of Magoye Study area

2.1 Location

Magoye is located about 140 km South of Lusaka (Latitude: 16.133S; Longitude: 27.633e; altitude: 1018 m). The size of Magoye catchment area is 2,281 km^2.

Sparsely populated and largely traditional agricultural area within Mazabuka district of Southern Province, Zambia. The population density is about 20 people per km^2. The predominately rural community mostly sustain their liveslihoods on smallholder farming, mainly arable and dairy farming under rainfed conditions. Remarkably the farmers are marked oriented, particularly those in the settlements. Public services (health, education, banking etc.) are to a certain extent adequate.

In terms of industrial development in the area, Mazabuka district (in which Magoye lies) hosts the largest Sugar Company in Zambia. Zambia in the last 5 years, has witnessed unprecedented maize (staple food) bumper harvest and the majority of households in Magoye are food secure nearly throughout the year

2.2 Main Reasons for Selecting this Site/Region

a. The Study Site Coordinator/Leader is based at Magoye in Mazabuka district. Magoye used to be a Government Regional Agricultural Research Station. The premises are now shared between Cotton Development Trust (CDT) and GART.

On the side of GART it is a Tillage and Mechanization Centre. It has got essential research facilities, including a well established meteorological station and irrigation system.

b. The research centre lies on the frontage of two microcatchment areas, Magoye river and Ngwezi stream. At the confluence of these two is a dam (macrocatchment) constructed with funding from the World Bank. It is this dam which provides water for irrigation.

The dam at confluence of Magoye river and Ngwezi stream (13.01.2012)

c. Within a radius of 20 km (from the station) lie three settlement schems for smallholder farmers, and these are Dumba, Njeleka and Ngwezi. Ngwezi stream traverses Ngwezi settlement scheme. These smallholder farmers have been our pivot in the development and promotion of conservation agricultural technologies. Included are water harvesting technologies, mainly In-Situ (or in-field) moisture conservation and retention. These water harvesting techniques (eg. pits, ripping, mulching) were introduced and practiced by farmers between 2000 and 2006 under the Dutch funded *"Conservation tillage, development and promotion project"* IMAG (WUR) was a key player in this project.

Farmer's field with Faidherbia albida trees in Njeleka Settlement (13.01.2012)

2.3 Participating Local Partner Institutions

Apart from the Cotton Development Trust, we have yet to identify others.

2.4 Main Used Languages

The languages used within the Study Site are (a) English as the official language and (b) Tonga being the local language. It is Tonga which is aired on Mazabuka Community Radio Station and covers Magoye as well.

3. Bio-physical description

a. The topography is visualized in figure 2 using a Digital Elevation Model (DEM) for Southern Province.

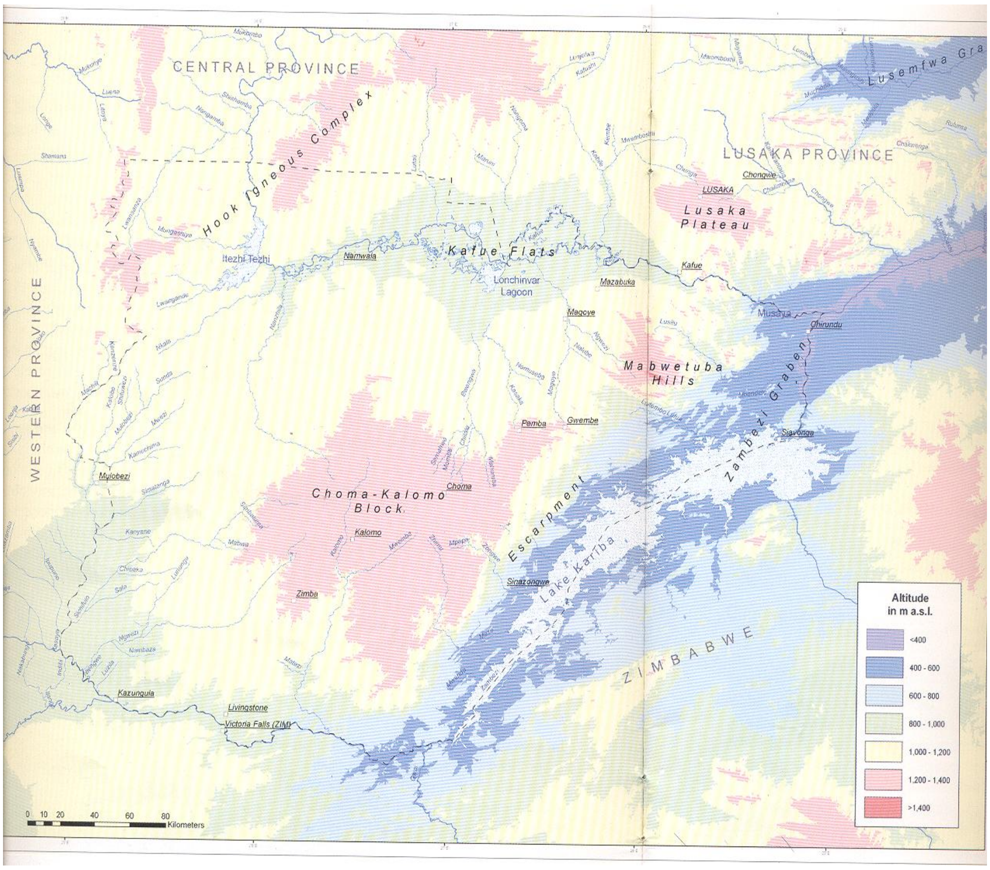


Figure 2: Digital Elevation Model (DEM) with elevation zones at 200 m-intervals.

The terrain for Magoye is gently undulating with slopes up to 10 % particularly towards the Magoye river and Ngwezi stream.

A gully heading towards Ngwezi stream. (13/1/2012)

A typical gully (donga) (13/1/2013)

The natural vegetation is mostly *miombo woodland* dominated by semi-evergreen trees 15-21 m high with a well-developed grass cover. Most miombo is a secondary re-growth as a result of extensive tree falling for crop cultivation and charcoal production. But there is no *chitemene system* (slush and burn) as what happens in Northern Zambia. Open grassland is predominantly occurring in wetlands (dambos) and along streams.

Dambo surrounded by woodland.

The area has a tropical continental high climate with dry winters and hot summers, corresponding to class Cwa according to the Koppen-Geiger classification. Commonly three seasons are distinguished.

1. Rainy season – a warm wet season from November to April.
2. Cold season – a mild to cool, dry season from April to August.
3. Hot season – a hot and dry season from September to November.

The mean monthly temperatures during the months of October/November are hot (22.5 – 26^{O}c). The cold season is mild with mean monthly temperatures between 13.5 and 16.5^{o}C.

Climatic parameters at stations in Southern Province and for Zambia (Source):, after data from Meteorological Department).

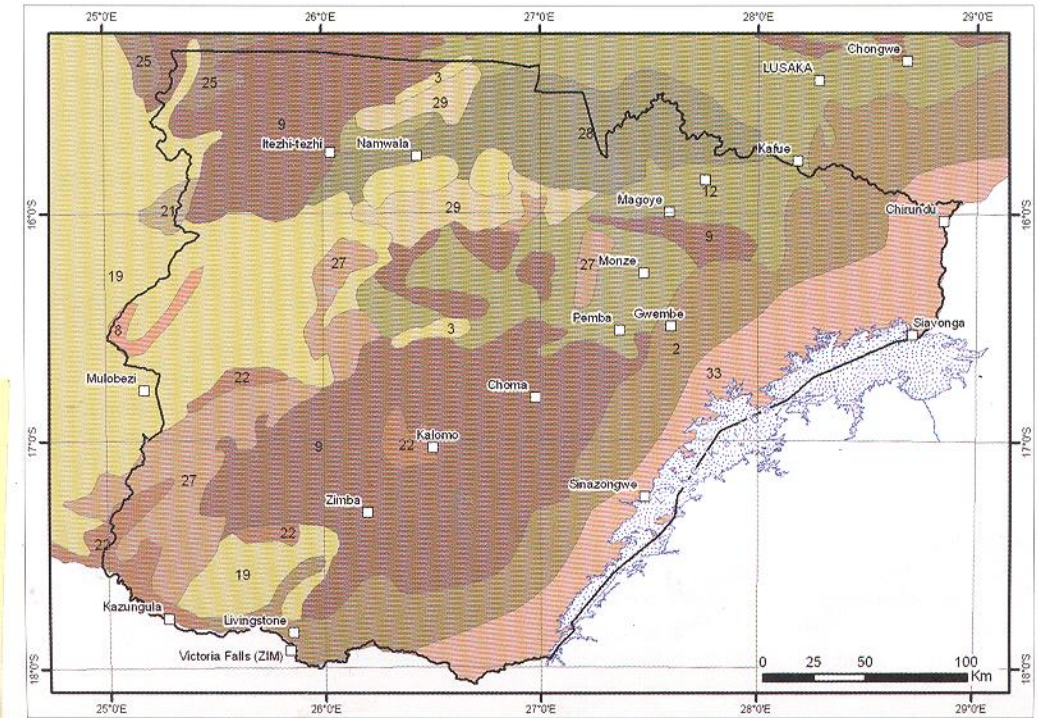
Station	Latitude	Longitude	Altitude	Temp	Sunshine
	S	E	m asl	^{o}C	hrs/day
Choma	16.850	26.067	1267	19.3	8.2
Kafue Polder	15.767	27.917	978	21.6	8.4
L/stone	17.867	25.883	989	22.1	8.6
Magoye	16.133	27.633	1018	21.3	n/a
Zambia				21.0	7.8

Long-term rainfall and evaporation at stations in Southern Province and for Zambia (Sources: MET, (29).

Station	Rainfall	Rainfall Days	Pan Evaporation 100%/75%	Actual Evaporation 1	PET 2	Net Evaporation 3	Runoff Coefficient 4
	°mm	Day	Mm	mm	mm	mm	%
Choma	796	83	1902/1427	667	1122	-726	17
Kafue Polder	767	68	2122/1592	677	1176	-1009	12
L/Stone	697	76	2166/1625	637	1745	-1048	9
Magoye	720	67	1991/1493	674	1634	-914	6
Zambia	1001	97	2061/1546	816	1574	-573	18

1) Calculated using Turc (1961) equation
2) Potential Evapotrasnpiration, calculated using (revised) Penman (1948) equation
3) Net evaporation = Rainfall – Potential Evaporation
4) Runoff Coefficient = 1 – (Actual Evaporation/Rainfall)

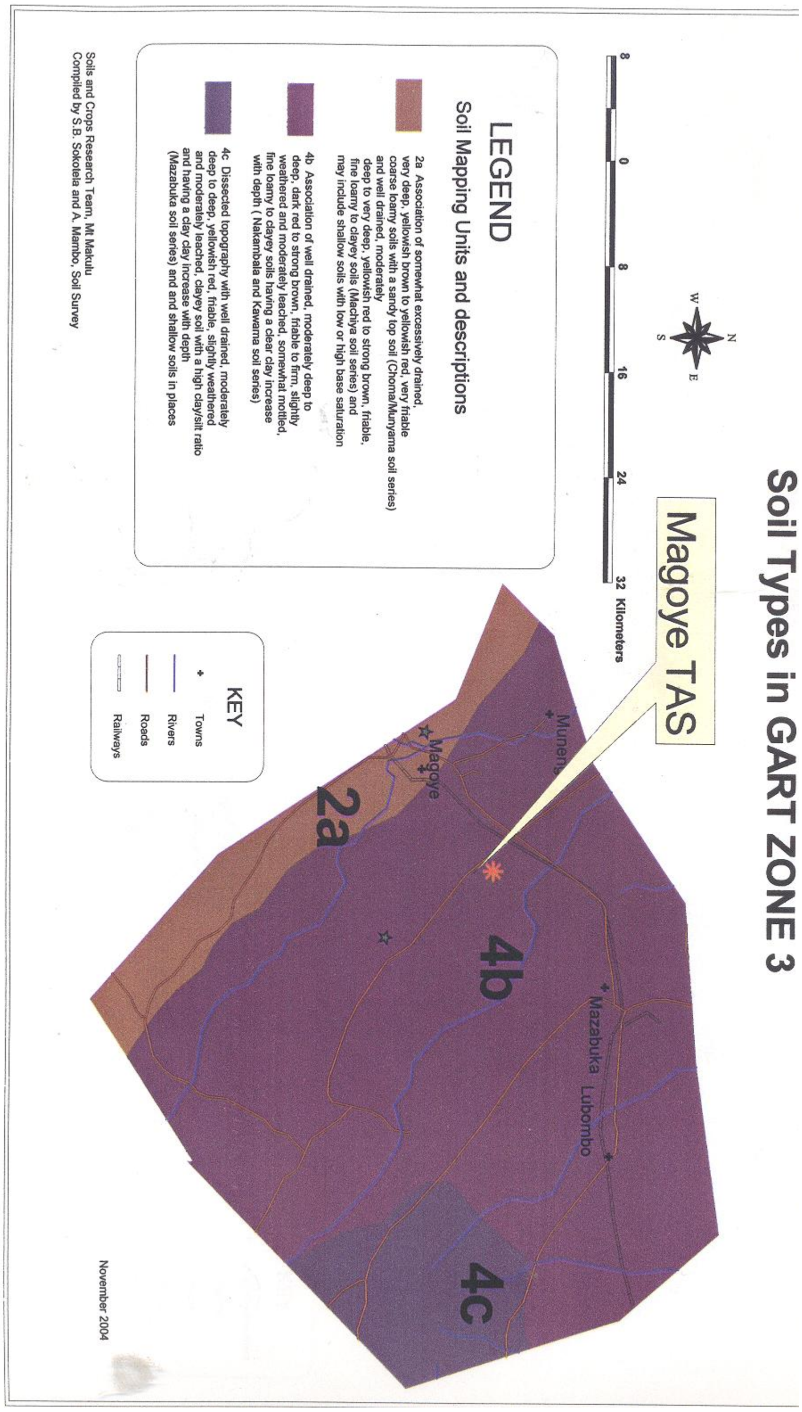
The soils are inherently infertile and vulnerable to degradation when opened for cultivation, low in organic water content, pH_2, nutrient and water retention.



Soils of the Southern Province and adjacent areas in Zambia. Numbers represent individual soil units. Explanations to the soil codes are given in Tab below:

Soils in the Southern Province and the associated geology as well as the characteristic vegetation (in brackets). The soil code corresponds to the labels in the map above. Soil units according FAO/UNESCO classification.

Soil Code	Soil Unit	Description	Associated geology	Area (%)
9 (Magoye)	Ferric Acrisol, Ferric Luvisol	Moderately leached reddish to brownish clayey to loamy soils, derived from acid rocks (Miombo)	Common soils on mag-matic and metamorphic rocks of the Hook Igneous and Basement Complex.	24.9



Magoye, Pit 014

			Exchangeable Bases (m.e)							
Lab No	Depth (cm)	pH	Ca	Mg	K	Na	CEC	Org.C	P	Texture
261	0-10	4.4	0.8	0.4	0.43	0.08	12.45	0.56	5	
262	28 Oct	4	1	0.5	0.26	0.17	13.8	0.46	3	
263	28-50	4.2	1.2	0.7	0.1	0.04	13.38		6	
264	0.20	4.8	1.5	0.6	0.51	0.08	12.57	0.79	3	

Geology

The geology of Southern Province encompasses rocks of large variety which were formed over a long time range.

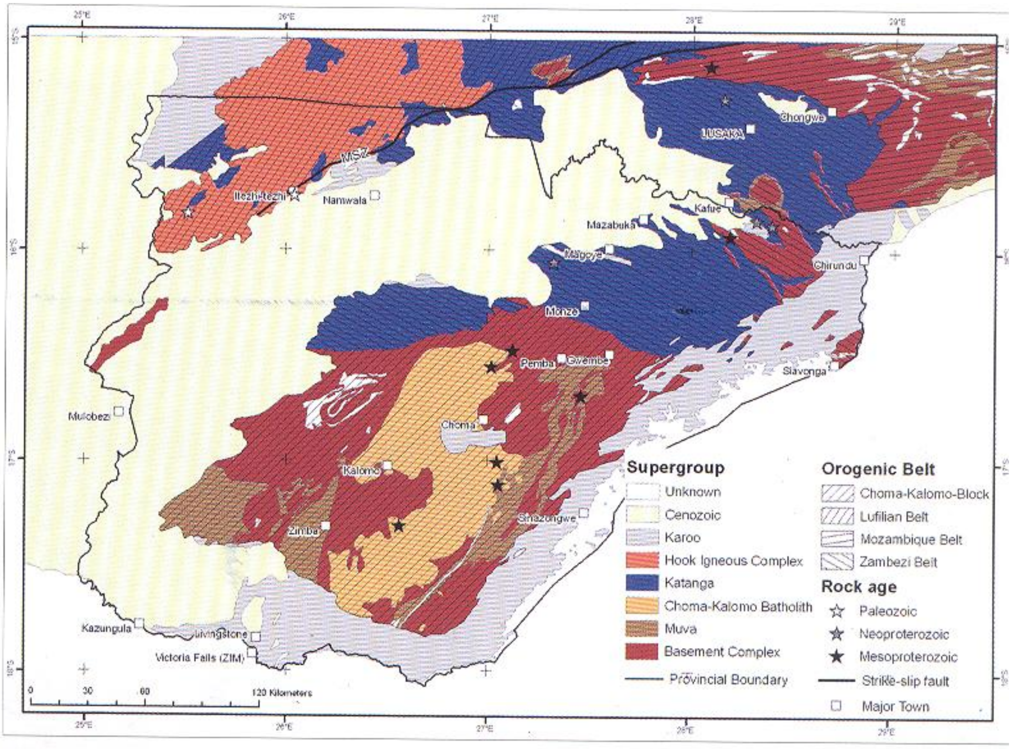
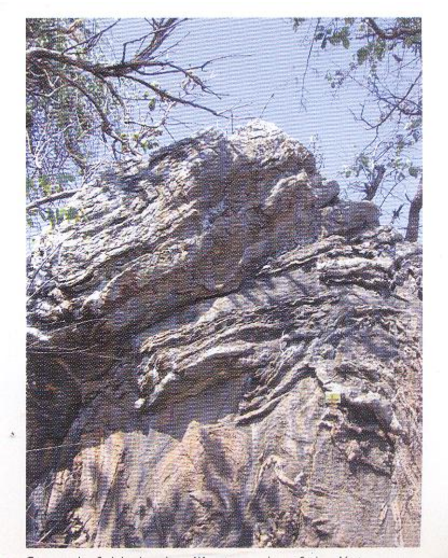


Figure 13: Geological map of the Southern Province with the main Orogenic Belts.

The Magoye Study Site area falls under the Katanga Super group.



A simplified version of this rock was identified at Magoye dam (13/1/2012)

Strongly folded calc-silicate rocks of the Katanga Supergroup.

These are metasedimentary rocks of various compositions: marble and calcsilicate rocks alternating with regions of amphibolites-facies, kyanite, staurolith and locally sillimanite and garnet bearing schists and gneisses.

4. Socio-economic description

The WAHARA project will have a positive impact on farmers' livelihoods as it will mitigate the effects of temporary shortages of rain to cover both household needs as well as productive use. Magoye is quite densely populated with 12,705 households and a total population of 72,951 inhabitants. According to the 2010 Census of Population and Housing Preliminary Report, 51% are female and the remaining 49% are male, with 42% of the population being 18 years and above. This implies that the majority of the population is below the age of 18 which poses a challenge to labour availability.

Although the majority of farmers in the area have received some formal education, there are others who have not received any education at all. Majority of the farmers depend on agriculture- both crop farming and rearing livestock- for their livelihoods. The farmers grow maize, which is the major staple food and most valued crop in Zambia. It is therefore not surprising that the Zambian government devotes about 70% of the Ministry of Agriculture's budget to fertilizer subsidies and maize marketing, as the FAO reveals. Other crops include groundnuts, soya beans, sunflower, tobacco and cassava. Farmers produce an average of 2.5 tonnes/hectare which translates into 50 x 50 kg bags. But with proper management, this can be raised to 4.5 tonnes and more. However, they face many constraints such as erratic rainfall which leads to poor yields and ultimately low productivity. Water harvesting therefore has the potential to improve agricultural production and thereby contribute to poverty alleviation; improve access to water and sanitation for the local community as well as address floods and droughts by storing excess water.

The WAHARA project will have a positive impact on farmers' livelihoods as it will mitigate the effects of temporary shortages of rain to cover both household needs as well as productive use especially that farming is an important economic activity for them.

Magoye Smallholder Dairy Farmers Cooperative

Farmers Training at Milk Collection Centre (MCC)

Crossbred Dairy Cow

Transporting milk to MCC on ox-drawn sctochcart

5. Institutional and political setting / Relevant end-users / stakeholder groups (at all levels)

The main government institutions are the Ministry of Energy and Water Development and the Ministry of Agriculture and Cooperatives. In the water sector the emphasis has been more on water supply and sanitation than on integrated water resource management, but plans has been drawn up to address this issue. The Water Resources Action Programme in 2001 developed a Water Resources Management Bill, a new Water Resources Institutional Framework, an improved Water Resources Management Information System and a draft action plan on addressing challenges related to water resources. Moreover, the Fifth National Development Plan (FNDP, 2006–2010) is specifically geared towards applying integrated water resource management nationwide.

Endusers are virtually entirely small-scale farming households.

6. Water resources and water use

Hydrology

Rivers and Streams

The two major river systems, the Zambezi and the Kafue rivers form together with the three Kafue tributaries; Nanzhila , Kaleya and Magoye the only perennial water courses within Southern Province. The smaller rivers and streams eg. Ngwezi are generally dry during the dry season (April to October). During the rainy season the flow of these minor rivers is generally intermittent or driven by rainfall events.

The largest sub-catchments of the lower Kafue are the Nanzhila catchment (7,134 Km^2) followed by Bweengwa (2,510 Km^2), Magoye (2,281 Km^2) and Munyeke (2,271 Km^2) catchments.

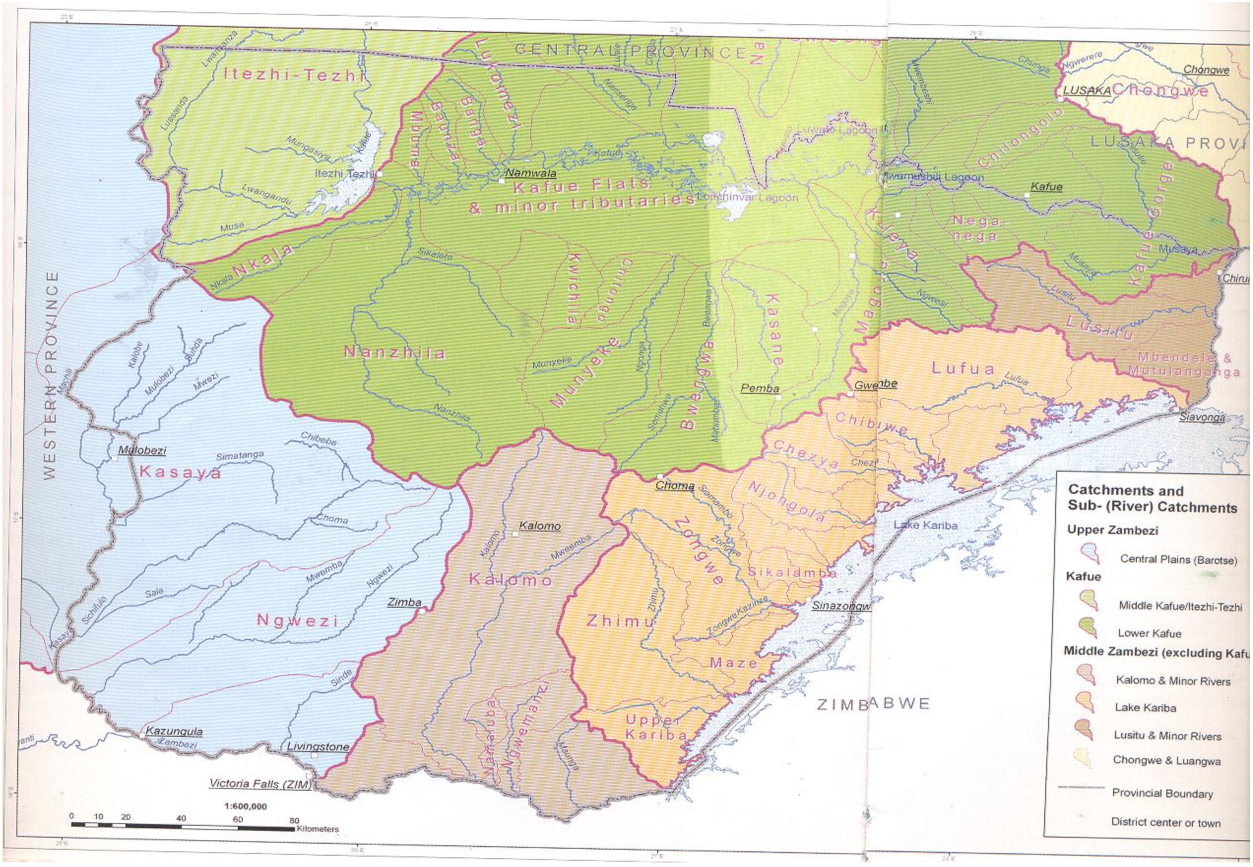


Fig 8 : Major river systems and catchment

Dam at confluence of Magoye river and Ngwezi stream (13.01.2012)

Hydrogeology

We were able to get hard copies of the hydgrogeological maps of Zambia, Southern Province.

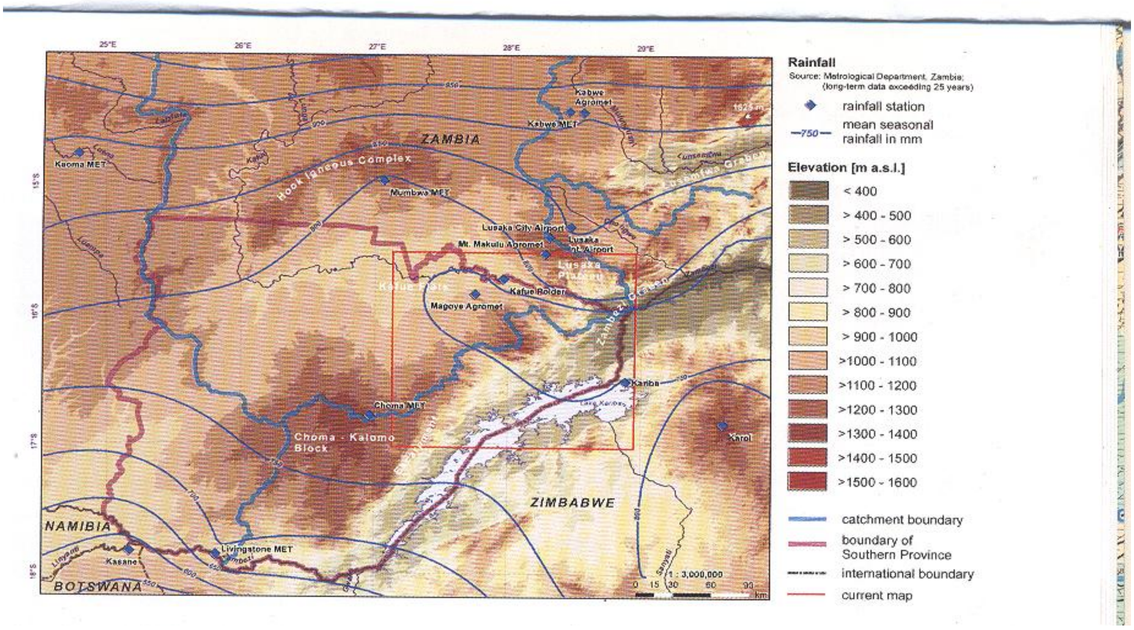
a. Lusitu catchment 1: 100,000

b. Southern Kariba Lake and Kalomo 1: 250,000
c. Northern Kariba Lake and Kafue Gorge 1: 250,000
d. Northern Kariba Lake and Kafue Gorge 1: 250,000

These comprise of:

- Topography including roads, villages, towns, health centres and schools.
- Hydrography including rivers and wetlands.
- Surface elevation.
- Surface catchment and sub-catchment boundaries.
- Water points such as boreholes and wells including unsuccessful drilling sites, and themal springs.
- Lithology and geological structures (faults, etc).
- Boundaries and potential of groundwater systems, so-callec aquifers.
- Groundwater elevation contours and direction of groundwater flow.
- Rainfall distribution (insert map)

These were prepared by Ministy of Energy and Water Development and BGR (Federal Institute for Geosciences and Natural Resources in 2007. We failed to download from internet particularly the map for Lusitu catchment which covers Magoye as well. I just managed to get inset map, showing topography and overall rainfall.



Insert map included in the hydrogeological maps 1:250,000 showing topography and overall rainfall

Should need arise to have these maps, particularly the Lusitu catchment, I can make arrangements to reproduce it and send it by DHL.

7. Water harvesting techniques (used in the country/region and with focus on the study site/area)

There is a dam at the confluence of Magoye river and Ngwezi stream; the water is used for irrigation. The dam was constructed with funding from the World Bank.

There are also some other water harvesting technologies, mainly In-Situ (or in-field) moisture conservation and retention. These water harvesting techniques (eg. pits, ripping, mulching) were introduced and practiced by farmers between 2000 and 2006 under the Dutch funded *"Conservation tillage, development* *and promotion project"* IMAG (WUR) was a key player in this project. Roof water harvesting is also practiced, often at schools.

8. Past and on-going projects (especially related to water harvesting)

The major past and ongoing work on water related aspects are respectively various projects by government and NGOs on household water supply and sanitation. Among the few known water harvesting projects are the conservation farming projects by GART, MACO and various NGO's. In recent years, the Zambia Rainwater Harvesting Association (ZARHA) has been promoting water harvesting technologies at community schools.

9. References

Baumle R, Nkoma J., Silembe O. and Neukum C: Groundwater Resources for Southern Province. A brief description of physiography, climate, Hydrology, Geology and Groundwater Systems of the Southern Province. Prepared as a technical co-operation project between the Governments of Zambia and the Federal Republic of Germany. Lusaka-Hannover, October, 2007.

Nkoma J. and Baumle: Groundwater Resources for Southern Province. A manual with explanations for the use of the Hygrogeological Maps. Ministry of Energy and Water Development and BGR-Federal Institute for Geosciences and Natural Resources. Lusaka-Hannover, October, 2007.