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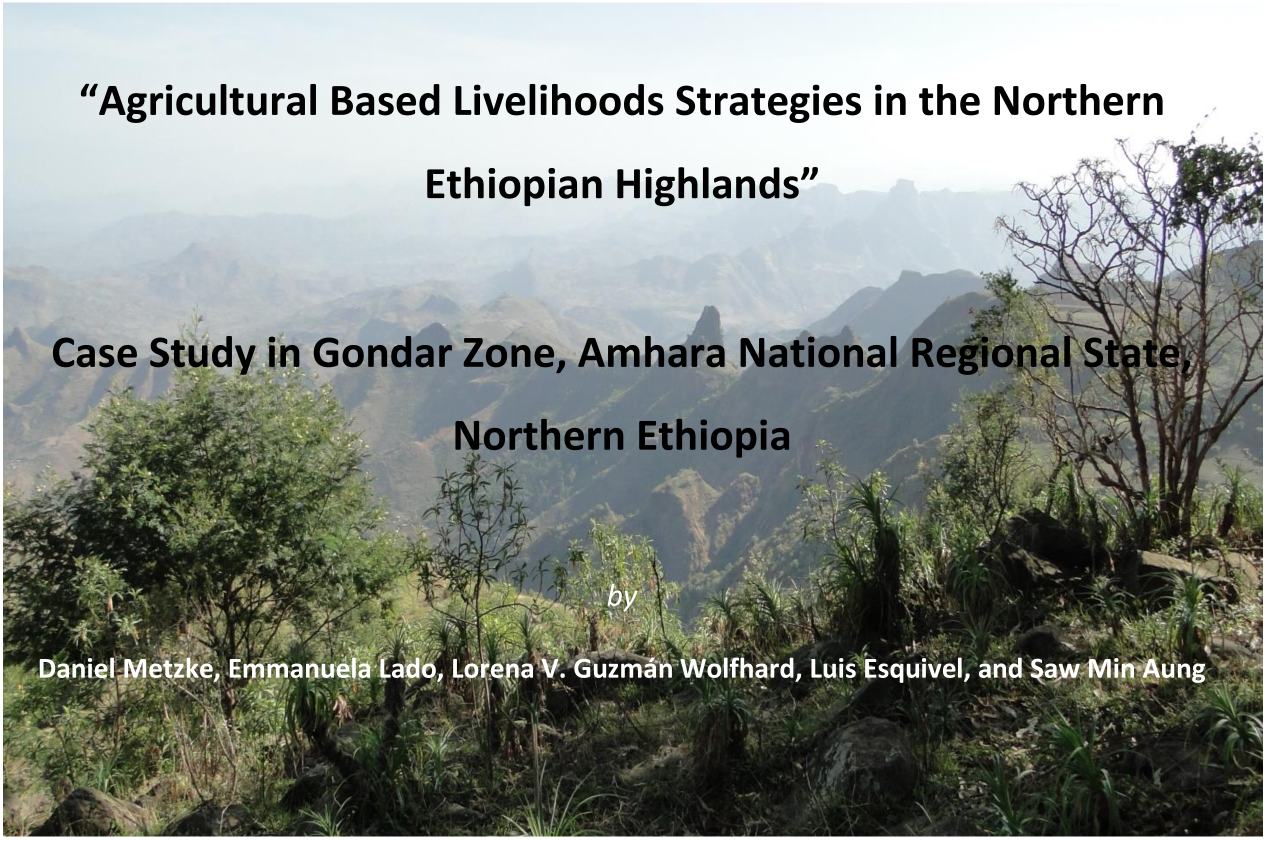

"Agricultural Based Livelihoods Strategies in the Northern Ethiopian Highlands"

Case Study in Gondar Zone, Amhara National Regional State, Northern Ethiopia

by

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1. Introduction

The Amhara region, from Lake Tana to the Simien Mountains, is an area of great importance to Ethiopia due to ecologically and economically aspects. This region is home to unique ecosystems in the world, which had been managed throughout centuries by its inhabitants whose lives depends on small scaled rain-fed agriculture and livestock farming. It is a place with highly valuable natural resources that is now being threatened by severe challenges. These are attributed to low agricultural productivity and food insecurity due to climatic, demographic and economic causes. Today, over 87% of the population depends on agriculture productivity to sustain their livelihoods.

One of the main issues is the small-scaled rain-fed agriculture systems, which is characterized by having a low amount of external inputs and having a dependency on the availability of natural resources. Its low adaptive capacity qualities to cope with changes in rainfall patterns and other natural aspects, makes this system highly vulnerable to livelihoods. Also, rapid population growth has led to crop expansion and deforestation in the region. This excessive natural exploitation of land has severe impacts on soil fertility and on the crop yield productivity.

Due to these problems, there is a necessity to develop long term sustainable solutions that can assure socio economic development in the region, as well as nature conservation. Strategies that can integrate an efficient allocation of resources, such as water, land, forests and especially knowledge transfer to the farmers are crucial. These components require to be supported by strong sustainable policies and institutions in order to reach sustainable development in the future.

1.1 EBL- Nexus Project

EBL- Nexus project (Enquiry-Based Learning in the Curricula of Master-Level Courses in Land and Water Nexus) is a DAAD (German Academic Exchange Service) funded international master-level, joint research project in the field of integrated land and water management (ITT, 2014). The project aims at promoting higher education cooperation between the universities from Germany, Jordan, Ethiopia and Sudan. In this sense, it will identify examples of the interactions of land-water use problems in Jordan (Azraq aquifers), Sudan (Gezira irrigation scheme) and Ethiopia (Gondar-Dembeia-Koladiba rain-fed scheme) and use them to develop case studies for enquiry-based learning in the master programs in resources management of the participating universities. The project includes small scale case studies, jointly participated by university professors, students, researchers, and different stakeholders from participant countries during field trips to yearly selected countries.

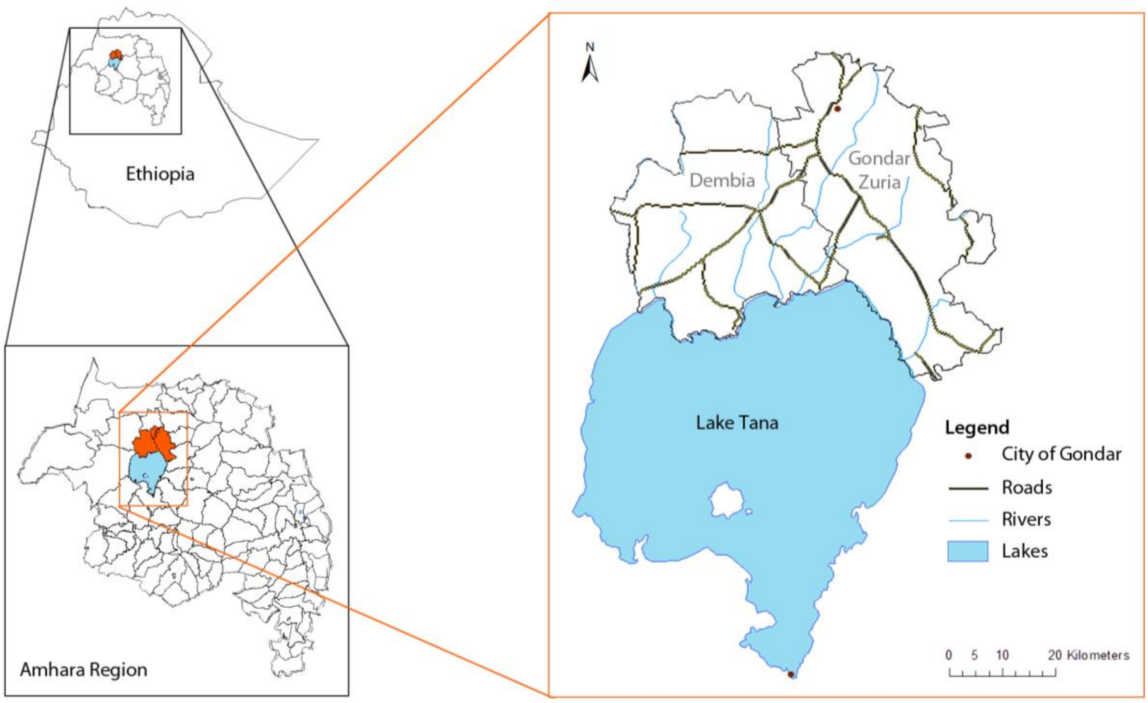
In 2013, the EBL-Nexus project was started in Azraq wetland, Jordan; and in 2014 in Gondar-zone from Ethiopia. The area was selected for the case study on the vulnerability of rain-fed agriculture in the global climate change context and to develop the mitigation and adaptation strategies for better livelihood security. In 2015, the project will go into Sudan for Gezira irrigation scheme. In such regional and basin wide investigations in terms of natural and socioeconomic impacts, the participating researchers and students will be able to understand and analyze interactions in a larger geographic and conceptual scale.

2. Case Study Area: North Gondar, Amhara State, Northern Ethiopia

2.1 Location

The Amhara National Regional State (ANRS) is one of the nine regional states of the Federal Democratic Republic of Ethiopia (FDRE). In geographic terms, the ANRS is located between 9° 21' to 14° 0' N and 36° 20' to 40° 20' E. With a total area of 170,752 km^2, the state is divided into 10 administrative zones (kabelas), one special zone (the capital city of the State- Bahir Dar), and 105 woredas (districts) and 78 urban centers (FDRE, 2014). For the remote sensing analysis we focus on the two woredas north of Lake Tana, Dembia and Gondar Zuria. Gondar Zuria has a size of 142 km^2. Dembia has a size of 130 km^2 (see FIGURE 1).

Figure 1. Map of Ethiopia, the Amhara Region, Dembia and Gondar Zuria



Source: Own Compilation

2.1 Climate, Land Use Changes, and State of Environment

The state consists of diverse agro-ecological zones with altitudes ranging from 500 to 4620 meters above sea level (m a.s.l.), including highlands of mountain ecosystems with altitudes higher than 1,500 m a.s.l., lowlands with drier climate at altitudes below 1,500 m a.s.l., and wetlands near lake Tana. The highlands of more than 1,500 m a.s.l. comprise the largest part of the northern and eastern parts of the region. The highlands are also characterized by chains of mountains and plateaus. Ras Dejen (4620 m), the highest peak in Ethiopia, Guna (4236 m), Choke (4184m) and Abune-Yousef (4190m) are among the mountain peaks located in the highland parts of the region (FDRE, 2014). According to Ethiopian traditional climate classification system, which is based on altitude and temperature (Araya, et al., 2010), the ANRS has three main climatic zones. Areas beyond 2,300 m a.s.l. fall within the "*Dega*" climatic zone; areas between the 1,500-2,300 m a.s.l. belong to the "*Woina Dega*" climatic zone; and areas below 1,500 m a.s.l. are classified as the "*Kolla*" or hot climatic zones. The Dega, Woina Dega, and Kolla zones constitute 25%, 44%, and 31% respectively of the total area of the region. In the center of Amhara region is Lake Tana, Ethiopia's largest fresh water body covering an area of 36,000 km^2 and the source of the Blue Nile River. From here the Blue Nile flows for more than 5000 km through Sudan and Egypt to the Mediterranean Sea.

2.2 Socioeconomic conditions

The Amhara region has a population of more than 17,000,000, which represents one of the most populous regions of Ethiopia. Like the rest of Ethiopia, Amhara region is dominated by subsistence agriculture, mainly small scale mixed crop-livestock systems. Depending on the topography, the dominant crops are: cereals (teff, rice, sorghum, and barley), pulses (beans, chickpea and field pea), oil seeds and horticultural crops. Crop production primarily varies depending on the amount and distribution of rainfall as well as the average temperature. Two main cropping seasons can be defined: meher (big) rainy season with kiremt rains, beginning in mid-June and ending in mid-September, and belg (short) rainy season using belg rains, occurring February-April.

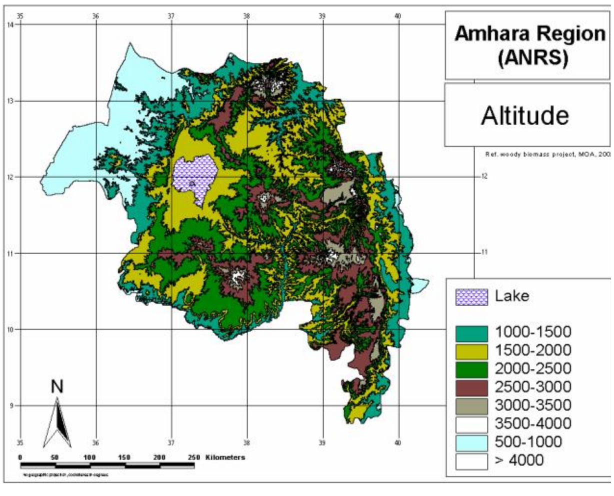


Figure 2. Altitude Map of Amhara State (in meters above sea level)

Source: Tesfahun, 2008

3 Problem Statement

Ethiopia's heavy dependency on rain-fed and subsistence agriculture increases its vulnerability to the impacts of climate change. Regardless of the presence of surface and groundwater resources, the failure of seasonal rains seriously affects the region's agricultural activities that lead to food insecurity and other hardships. The most important factor leading to low productivity is the increasing of population which resulted in extensive forest clearing; for agricultural use, overgrazing, and exploitation of existing forests, for fuel wood, fodder, and construction materials (Bishaw 2001). Moreover, inappropriate land-use systems and land-tenure policies enhance desertification and loss of agro biodiversity. Utilization of dung and crop residues for fuel and other uses disturbs the sustainability of land resources.

The general components of the problem are shown in the figure below:

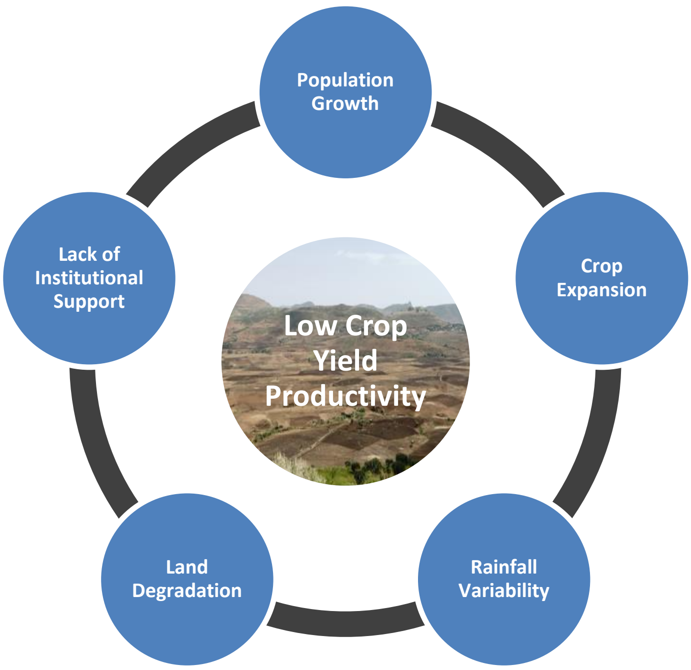


Figure 3. Core Problem

Source: own compilation

According to the figure above we can observe that the population growth is the main trigger of an increase of the demand of resources use such as food, fuel wood to cook meals and build houses. Because of this condition, agriculture intensification takes place, leading farmers to expand their crops causing extended deforestation and overgrazing in important natural areas. From the natural perspective, there is a high loss of ecosystem services which have significant influence in climate changes of the local area. This is reflected by changes in rainfall patterns and recurrent droughts. Today, farmers follow their traditional rain-fed agricultural practices without knowing exactly when to plant or which strategies to use in order to secure their crop yield productivity.

We also have to consider that there is not enough institutional support through the extension services and development agents. This is a cause due to lack of institutional capacity to attend all farmers and weak sustainable policies to support the cause. The result of this specific problem is a deficient knowledge transfer to the farmers and farm resources such as fertilizers, seeds and strategies.

Even though each of these factors has impacts that can vary in time and space, a categorization of the main cause-effect relationships is necessary. Only by recognizing the complexity of interdependence among them, decision making processes concerning livelihood strategies and activities can be undertaken.

4. Objectives

Main Objectives

I. **Natural and Physical Climatic Conditions**

- Vegetation dynamics due to climate variability using GIS for calculation of (VCI) & (NDVI)

II. **Socio Economic conditions**

- Socio economic background (farmers)
- Assessment of land and water management

III. **Institutional Framework**

Sub Objectives

i. To study the response of vegetation dynamic to rainfall patterns.

ii. Investigate the main problems of the farmers and the main factors influencing their decisions.

iii. Identify adaptation strategies on land and water management.

iv. To explore institutional efforts to develop and promote soil and forest conservation strategies to enhance food security.

5. Literature Review

Agriculture is the main activity in Ethiopia and some of the problems regarding this subject are the extreme weather events, especially rainfall variability. (Annual Report "Climate Change Adaptation in Africa Program", 2011) The intensification of climate variability might accelerate soil degradation, deforestation, the loss of biodiversity and may cause more floods and droughts. (The World Bank group, 2011).

Understanding vegetation dynamics and how they respond to climate change is a fundamental requirement for predicting future ecosystem dynamics. Satellite remote sensing is an effective tool for monitoring vegetation at the regional and global scales (Anderson L. O. et al). It provides full coverage of large and remote areas on a regular basis over extended periods of time as well as spatial data and associated information to deepen our understanding of ecological systems (Boyd D. S., Foody G. M.). Of the many remote sensing techniques for analyzing vegetation dynamics, time-series analysis of vegetation indices has become the most common approach for phonology and drought assessment **(**Anderson L. O. et al). Among the numerous vegetation indices, the normalized difference vegetation index (NDVI), which is defined as the difference between near-infrared and red reflectance divided by their sum (Rouse J. W. et al.), is most commonly used to measure vegetation changes. Recently, moderate-resolution imaging spectroradiometer (MODIS) NDVI data have been widely used in vegetation studies and related drought monitoring. Many studies using the NDVI, derived from NOAA⁄AVHRR (advanced very high-resolution radiometer) satellites or MODIS, indicate that in the Sahel zone (including Ethiopia), rainfall, vegetation cover and biomass have direct relationship to each other. However, the relation may vary in terms of their prediction strength and amount of error (standard error or standard deviation), slope and y-axis intercept (Elhag and Walker, 2009). Since vegetation does not respond immediately to precipitation there is a NDVI lag after the occurrence of rainfall that may be up to 3 months. The lag time depending on the climatic zone (being shorter in dry regions than in humid regions) and environmental factors; such as soil type, soil water holding capacity, vegetation type, among others (Chikoore 2005)**.** The correlation between NDVI and above-ground biomass is well established (Justice *et al.,* 1985; Tucker *et al*, 1985; Tucker & Sellers, 1986). Temporal and spatial correlations between NDVI and climatic factors are investigated in many research works. Particularly good Correlation in the arid regions, both spatial and temporal, show NDVI and rainfall (Richard &Poccard, 1998; Tateishi & Ebata, 2004; Li *et al*, 2004), the relationship between NDVI and temperature are reported to be weaker but also significant (Kowabata *et al*, 2001;

Schultz & Halpert, 1995; Wang *et al,* 2001; Wang *et al.,* 2003). Some scientists derived also high correlation between NDVI and potential evapotranspiration (Yang *et al*, 1998), between NDVI and soil moisture (Farrar *et al*, 1994). However, there were studies indicated opposite results: the studies conducted by Li *et al*. (2002) and Xiao & Moody (2004) for China found a leading role of temperature by controlling vegetation patterns, and Eklundh (1998) reported to find no significant correlation between NDVI and rainfall in East Africa. Many studies proved a high sensitivity of NDVI to inter-annual rainfall anomalies. Thus, NDVI can be used as a good proxy for the study of inter-annual climate variability on regional and global scales or for identification of climatic signal by evaluation of land degradation (Richard & Poccard, 1998, Kuwabata *et al*, 2001; Evans & Geerken, 2004). However, there are limits of rainfall amounts under which only a weak NDVI sensitivity to inter-annual rainfall anomalies can be found. This rainfall limits vary by geographical region, but generally, a minimum of 200-300 mm/yr seems necessary to induce the NDVI sensitivity to rainfall anomalies (Nicholson *et al*, 1990). Temperature deviation from average reported to have no correlation with NDVI deviation from average (Wang *et al.*, 2001). In summary, many studies have been carried out for identifying the relationships that could exist among different climatic variables and the vegetation characteristics. These relationships could vary at different regions across the world. However, the findings of the past studies for establishing relationships between vegetation parameters and climatic variables have shown a considerable degree of variability over different temporal and spatial scales. Therefore, it is necessary to establish these relationships locally or regionally depending on their levels of spatial and temporal variability.

In Ethiopia, agricultural intensification is taken place through many different adoptions of technology and traditional practices, using the ox-plow to economize the labor, and trying to maximize the value per ha especially for external market. However, the current situation show that many of these technologies may not be the adequate ones and more attention has to be focus especially in the policy making due to the high growth of the population. Some efforts are been done to increase the small farmer's productivity by introducing chemical fertilizers, irrigation systems and making some small investments in construction of roads and agricultural extension services. (Headey et al., 2009) Hence the productivity of agricultural economy of Ethiopia is being seriously affected by unsustainable land management practices both in areas of food crops and in grazing lands (Berry, 2003 cited in Adgo, et al., 2014). In the land-water interaction of Ethiopian agriculture, ***soil erosion*** mainly by water is a major constraint to agricultural production and food security (Bewket, 2007) citing Hurni, 1993; Bekele, 1997; Shiferaw, 1998; Zeleke, 2000; Tadesse, 2001; Sonneveld, 2002; Beshah, 2003; Bewket, 2003). According to (Bewket, 2007) with reference to (FDRE, 1997; Bekele, 2003), the problem is more severe in the highlands (> 1500m and covering about 45% of total land area) where roughly 88% of the population lives and 95% of the regularly cultivated lands are found. Through previous studies it is known that farmers prefer to use ox plows for the cultivation and sickles for harvesting instead of using spade, shovel, sprayer, axe, or other implements, which they rarely use. Most farmers in the highlands cultivate small grain cereals such as teff, sorghum and wheat. For and during the land preparation farmers use different seedbed techniques such as flatbeds, broad bed, and ridge and furrow. The farmers mostly take the weed out with their own hands and a few of them use some herbicides. Only some of them use improved wheat varieties, and even less use improve varieties of lentils, barley and rough peas. The decision the farmers take in their choice of crops depends mostly on profitability and the food they normally are used to eat. (Steven J. Humphrey, Arjan Verschoor, 2004) Thus many farmers also plant some crops according to the type of soil together with their use as food like chickpeas, lentils and peas. (Headey et al., 2009) Rain-fed agriculture is the most common practice in the Ethiopian highlands, but in some areas irrigation is been used as a land quality improver especially in the off-seasons. Chemical fertilizers are used by all the farmers in these regions and sometimes some insecticides. Even though, many farmers aren't aware of this technique. Another reason why they don't use this is because of the lack of money and the lack of effectiveness of the insecticide. (Tiruneh et at., 2001). A national level study carried out by the mid-1980s estimated that soil erosion was putting out of use some 20,000–30,000 ha of croplands annually and projected that around 10 million highland farmers would have their lands totally destroyed by the year 2010 (FAO, 1986). The update scientific investigation for that projection is still needed. Measurements from experimental plots and micro-watersheds showed that the highest rate of soil loss occurs from cultivated fields, which is 42 t/ ha/ yr on average (Hurni, 1993). According to (Sonneveld, 2002), (Bewket, 2007) mentioned that the cost of soil erosion to the national economy is around US$ 1.0 billion/ year. Soil erosion is thus a contributory factor to the country's structural food insecurity problem. (Bewket, 2007) described that soil erosion, and the resulted land degradation, has been recognized to be a serious natural-resource based problem in Ethiopia since the early 1970s, subsequent to the devastating famine of the time. Considerable efforts have been made since then to rehabilitate degraded environments and stop further degradation. The managerial emphasis has been on construction of *physical soil and water conservation (SWC) measures* in cultivated fields and afforestation of hillsides, which are common property resources in Ethiopia. The largest conservation activities in the country are those implemented during the 1970s and 1980s in which the farmers were mobilized through their **Peasant Associations**, the lowest levels in the agricultural administrative structure, for campaign work. The international donor community made significant contributions to those land resource conservation efforts by supplying food grains and edible oil that were used as **food-for-work payments** for the 'participating' farmers. According to the past experiences, these top-down conservation practices cannot be expected to be effective and sustainable since most of the farmers are not willing to contribute their labor. There are therefore no longer such payments, but instead the farmers have to be paid for any of their labor utilization by any organizations.

Small-scale farmers normally work under precarious conditions and their decision making cannot take many risks because they are not well protected against price fluctuations and livestock or human diseases. (Humphrey and Verschoor, 2004) In relation with the livestock production most farmers own animals such as cows, goats, mules, donkeys and sheep. Several factors influence farmers' decisions to *adopt* such SWC measures, *modify* or *reject* new SWC technologies, and these are often classified as personal, physical, socioeconomic, institutional and technological Gebremedhin and Swinton, 2003; Paudel and Thapa, 2004; Kessler, 2006a). The most commonly cited individual level or personal factors are age and educational status, which have implications on the farmers' level of perception of the erosion problem and its productivity consequences (Bewket, 2007).factors in the adoption literature (Bewket, 2007) referring to Napier et al., 1991; Shiferaw and Holden, 1998; Lapar and Pandey, 1999; Semgalawe and Folmer, 2000; Bekele and Drake, 2003; Beshah, 2003.

On the other hand farmers don't own the land. In Ethiopia all land is state-own. From 1975 land came under the ownership of the state but the farmers could use it as usufruct basis and also commercial large-scale farms turned into state farms. Migration was also restricted with the "use it or lose it" policy. Even after many efforts only some re-distributions have been done but nowadays the land still is owned by the government and the same restrictions as before are still being used in Ethiopia. Land can be inheriting in the family including some donations when parents are still living. However in practice some land tenure arrangements can be done, but still the land tenure could solve many of the farmers problems by reducing the fear to risk. (Ethiopian Development Research Institute, 2013) But due to the high population growth the younger generations inherit smaller size lands. Many villages cannot even meet the basic requirements for the younger generations. (Headey et al. 2009) The small farms are majority in Ethiopia, and even though they have small land areas they are still often fragmented and are only used for self-consumption generating sometimes a small surplus. (Headey et al. 2009) One important factor to improve the productivity is the access to the credit service because it increases the risk-taking capacity and the ability to invest. Together, the high prices of the many inputs such as fertilizers, seeds, machines and other and the difficult access to loans from the bank and other credit sources lead to crop failures in Ethiopia. In order to have access to a credit farmers have to agree to buy the fertilizers and other inputs that are already included in the extension service program. (Ethiopian Development Research Institute, 2013) The Ministry of Agriculture (MoA) is the main institution in charge of improving the agricultural situation in Ethiopia. This ministry is in charge of conservation and use of forest and wildlife resources, food security, water use and small-scale irrigation, monitoring events affecting agricultural development and early warning system, promoting agricultural development, and establishing and providing agriculture and rural technology training. It is important to mention that the Ethiopian agricultural sector has been a priority in the development agenda for the government over the last 15 years mainly through an economic development policy known as Agricultural Development Led Industrialization (ADLI)). The major challenges to food security experienced in Ethiopia are: Low farm productivity (owing to subsistence farming systems in crops and livestock production), poor market linkages and little value addition, land degradation and poor infrastructure (Mogues, 2009). At a local level, the extension service works by assigning development agents to the kebeles in the areas, so that they can deliver assistance to the farmers regarding their agricultural activities. The major activities of the DA are to give advisory service and provide training for farmers at farmers' training centers. (Tesfahun, 2008).

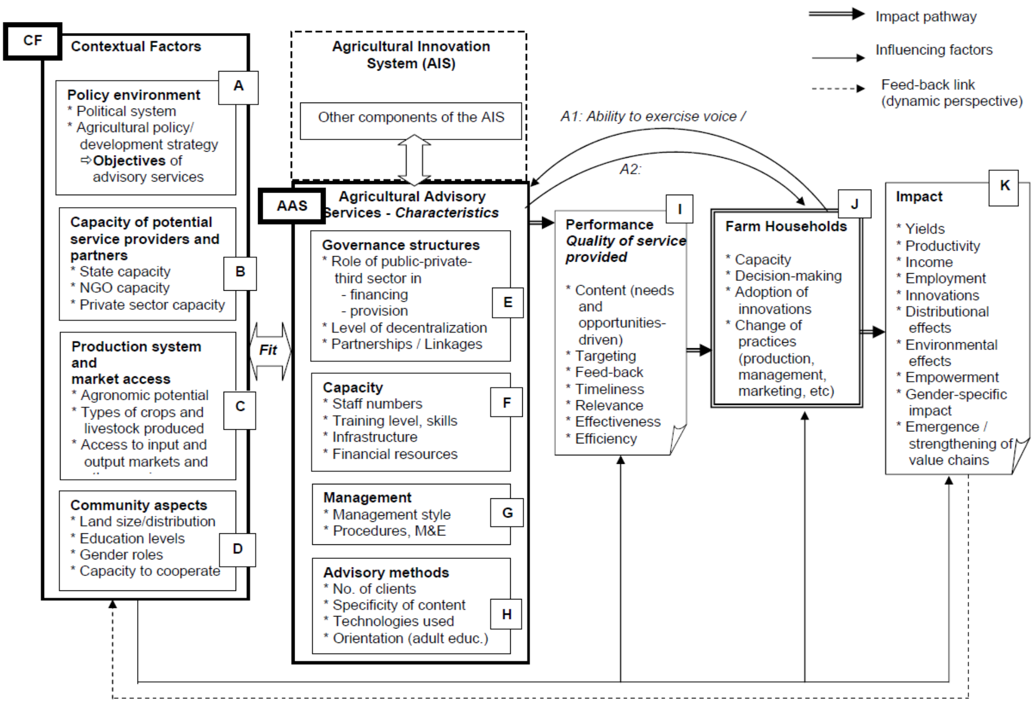


Figure 4. Conceptual Framework of the Agricultural Extension Service

Source: Brinner, 2009

The agricultural extension service has an agricultural office in each woreda. Basically, development Aaents are based in the kebeles and rotate to new communities every few years and remain accountable to the agricultural office. The extension team leader in the kebele serves as the agriculture portfolio holder in the kebele cabinet. The team deploys in the kebele on a watershed basis, with each member taking responsibility for all agricultural advice within her or his territory, and drawing on the technical expertise of colleagues as needed. The team members work closely with contact and model farmers in their respective territories and facilitate the development of kebele-level agricultural planning (Mogues 2009).

The specific objectives of the current extension are:

- Production of good quality products which compete on the international market
- Promoting different technologies which suit farmers' conditions
- Enhancing food processing technologies in areas where surplus production is available
- Enhancing natural resource development, conservation and efficient use of these resources.

Previous studies of agricultural extension in Ethiopia emphasize a top-down approach to service provision. Agents have received relatively hard quotas for enrolling farmers in technology packages and have been evaluated on this basis. Extension also works through "model" or "progressive" farmers, who tend to be better with their crop productivity. Communication is mostly one way, with extension agents transferring knowledge to farmers (Mogues, 2009). In the Amhara region, the stakeholders of the rural development efforts are supposed to work in integration with the farmers. The experience so far is very poor collaboration and understanding among the different institutions. Specifically, the poor functional linkage and lack integration between the agricultural research component and the agricultural extension part of the agricultural development interest of the country has contributed to the lack of impact at the farming community level (Tesfahun, 2008). Some constraints of the current extension system are low level of data and information flow, low capacity of the woreda to lead development activities, poor communication among actors, duplication of activities among actors and inefficient managerial capacity of cooperatives to facilitate input and credits supply (Tesfahun, 2008). It is critical to improve communication between the stakeholders so that development agents from the extension services can be able to deploy accurate land and water strategies based on scientific information and supported by research and non-governmental organizations.

6. Methodology

We used the following methods to understand and analyze the rain-fed agriculture system in Northern Ethiopian highlands, and develop the most feasible solutions for the current livelihood challenges of the system:

6.1 Normalize Difference Vegetation Index (NDVI)

The NDVI is used to analyse vegetation dynamics. It is calculated from the reflectance in the visible red (R_{RED}) and near infrared (R_{NIR}) portion of the electromagnetic spectrum:

$$NDVI = \frac{R_{NIR} - R_{RED}}{R_{NIR} + R_{RED}} \quad (1)$$

Consequently, the range of possible NDVI values varies between plus one and minus one. Reflectance is expressed as the ratio of energy reflected from an object to the energy absorbed from an object (Verhulst & Govaerts 2010). Healthy plants absorb a great fraction of the visible light and reflect a large fraction of the near infrared light, leading to high positive NDVI values. On the contrary, unhealthy plants reflect most of the visible light and absorb a great portion of the near infrared light, leading to low positive NDVI values (NASA Earth Observatory 2014). Clouds, water and snow have negative values since they show greater reflections in the visible range than in the near-infrared range (ESRI 2014).

Decadal NDVI datasets for East Africa were downloaded from the Famine Early Warning System Network (FEWS Net) for the time period of 2001 to 2013. Since the largest vegetation dynamics are expected to occur during the main rain season, only the monsoon months (June, July, August, September and October) were considered. Hence, each year entails 30 images, 15 for each study region. In total, 390 maps have been produced to display decadal NDVI data for Dembia and Gondar Zuria region.

The satellite images are based on the Moderate Resolution Imaging Spectroradiometer (MODIS) considering a 250-meter spatial resolution (Swets et al. 1999). Each image contains stretched raster data with values ranging from zero to 255.

The datasets were processed with the geographic information system ArcGIS. In order to reduce the amount of data, each image has been clipped to the spatial extend of the two respective study regions. Since the available datasets contained stretched values, they had to be reclassified to fit the NDVI scale. Therefore, spatial analyst tools such as *Reclassify*, *Float* and *Division* were applied using model builder. Invalid values range from 201 to 255 and could therefore by excluded (Swets et al. 1999). The reclassification is expressed by the equation:

$$Rec_{NDVI} = \frac{NDVI\ -\ 100}{100} \qquad (2)$$

Afterwards, the average monsoon NDVI of each pixel was calculated for the period 2001-2013 using the tool *Cell Statistics*. The results visualize the spatial distribution of higher and lower photosynthetic activity and were set into relation with land cover, slope inclination and digital elevation maps.

In another step, integrated NDVI (iNDVI) values were generated for both study regions by summing up decadal values for each year. Thereby, annual differences in plant growth can be identified. The results are obtained by using the ArcGIS tools *Cell Statistics* and *Zonal Statistics*.

Vegetation Condition Index (VCI)

The VCI serves as a measurement tool to assess drought conditions for a pre-defined time series. It compares the observed NDVI value of one pixel with the range of values in the entire time period (European Earth monitoring program 2013). The VCI is expressed by the equation:

$$VCI = \left(\frac{NDVI - NDVI_{Min}}{NDVI_{Max} - NDVI_{Min}}\right) \times\ 100 \qquad (3)$$

The calculation of maximum and minimum NDVI values over several years allows for the assessment of the potential of geographical areas (Kogan 1995). Optimal weather conditions stimulate a maximum of photosynthetic activity, while extremely unfavourable weather conditions withhold plant growth, leading to a minimum of photosynthetic activity (Gebrehiwot et al 2011). The VCI ranges from 0 to 100 per cent. Drought conditions are considered to occur with values equal or less than 35 per cent. Fair vegetation conditions are reached between 35 and 50 per cent. All values equal or above 50 per cent are considered as optimal vegetation conditions.

In a first step, the mean NDVI of each pixel for every monsoon season was calculated. Afterwards, the respective $NDVI_{MAX}$ and $NDVI_{MIN}$ of each pixel were obtained for the entire time period. Both steps are accomplished by using the tool *Cell Statistics*. At the end, the VCI equation is applied for each of the 13 mean annual NDVI maps using *Raster Calculator*.

6.2 Stakeholder Power Analysis (SPA- Power Tool)

Stakeholder power analysis is a tool which helps understanding of how people affect policies and institutions, and how policies and institutions affect people (Mayers, 2005). Mayers mentioned SPA as “an approach for understanding a system by identifying the key actors or stakeholders in the system, and assessing their respective interests in, or influence on, that system”. The main focus is on improving livelihood strategies then this generally requires an increase in the capability or empowerment of the person pursuing it - the ‘primary stakeholder’.

We carried out the following six-step process to develop stakeholder power analysis.

1) Develop purpose and procedures of analysis and initial understanding of the system;
2) Identify key stakeholders;
3) Investigate stakeholders’ interests, characteristics and circumstances by means of field observations, interviews, and discussions;
4) Identify patterns and contexts of interaction between stakeholders;
5) Assess stakeholders’ power and potential roles;
6) Assess options and use the findings to develop feasible recommendations.

6.3 Observation

The research work in Ethiopia was done by visiting many locations of the Amhara region, mainly in Gondar city. Due to the big size of the group and the many field visits, observation was the most suitable methodology in order to obtain information about the land situation, the water management, the common practices, the improvements of the implemented strategies and the relation between the stakeholders.

Observation provides direct access to the social aspect that is been studied. It allows observing the real behavior and gives the chance to further analysis and compare crosswise time and location. Observation can complement other approaches such as interviews, for example, and thus enhance the quality of evidence available to the researcher. However, observer bias (record of things the researcher wants or expects more to see or thought they saw) and observer effect (effect on the observed society could sometimes influence their behavior) had to be well managed in order to avoid changes in the results. (University of Strathclyde, 2012)

The focus of the observation is based on the formulated questions that were developed in order to accomplish the objectives. Mainly focus on the farmer's behavior, the land situation, the adaptation strategies, the relations between the stakeholders and the improvements in the area. The system that has been developed for the data collection includes mainly field notes and recording sheets that comprise some preset questions. (Evaluation Research Team (ERT); 2008)

According to the University of Playmouth, 2006, there are different characteristics of observations. During the data collection in the Amhara region the observation was: 1) non participant, which means from an "outside" approach, where the observers weren't directly participating in the activities of the farmers or of the extension service but still watching from outside the behaviors; 2) semi-structured, which means that the observations were mainly done according to already fixed objectives and trying to answer the formulated questions in the beginning; 3) overt, which means that both the observed groups were aware that were being observe and at some level also why they were being observed; 4) descriptive, that helped to describe while observing the behavior of the stakeholders and the environment without influencing it in any way.

6.4 Interviews

Another important methodology for the data collection was the carrying out of interviews (Ivonne Küsters; 2009). Interviews were made as qualitative analysis in order to obtain information from the different stakeholders (farmers, NGO's, extension service and government), mainly cause and effect relations. First structured interviews have been developed for the farmers. The objective was to find out face to face their most common type of land use and water management, how they cope and perceive the climate stresses and adaptation, their conservation methods and their relation with the extension service. The questions were formulated more openly to let the farmers express their sincerely thoughts and try to avoid influencing their responses. However some of the questions were formulated of more way in order to save time. For example, questions about the common crops and practices, which are thought to be similarly answered by the farmers in order to the information previously researched. The advantages of this methodology are the statistic data collection and the high comparability among them. Unfortunately, due to time restriction and the big size of the group of students not many structured interviews could have been done. Also due to the language constrains much more time was needed for each interview and some problems were faced due to the lack of time and of translators for longer interviews. However, more informal interviews were conducted during the whole research time. Many fields of agriculture have been visited and questions have been done to the farmers, trying to be always related to the already structured questions in order to maintain the focus area. Farmers were very open and contribute with information about their problems and common practices, which help the data collection.

Furthermore, expert interviews (Jochen Gläser, Grit Laudel; 2009) have been made to the extension service members in order to understand how their work is been done and the results of their efforts. These interviews were conducted to find out natural efforts from the extension service perspective to improve land from deforestation and overgrazing. Most of the questions were answered during a formal meeting in the University of Gondar. The questions were openly asked but they were also related to the structured interview formulated in the beginning.

Also expert interviews have been conducted, filmed and transcripted for the better understanding and analysis of the problems in the region.

6.5 SWOT Analysis and Problem Tree method

We tried to scientifically understand the opportunities and challenges, and problem statement of the case study areas by the application of SWOT (Strength-Weakness-Opportunities-Threats) Analysis, and Problem Tree method.

Problem Tree Analysis

The problem tree analysis is one participatory tool of mapping out main problems, along with their causes and effects, supporting project planners to identify clear and manageable goals and the *strategy* of how to achieve them. There are three stages in this analytic process:

1. The identification of the negative aspects of an existing situation with their “causes and effects” in a problem tree
2. The inversion of the problems into objectives leading into an *objective tree*.
3. The decision of the scope of the project in an analysis of strategies. The value of this type of assessment is greatest if it is carried out in a workshop with the *stakeholders*, giving the opportunity to establish a shared view of the situation.

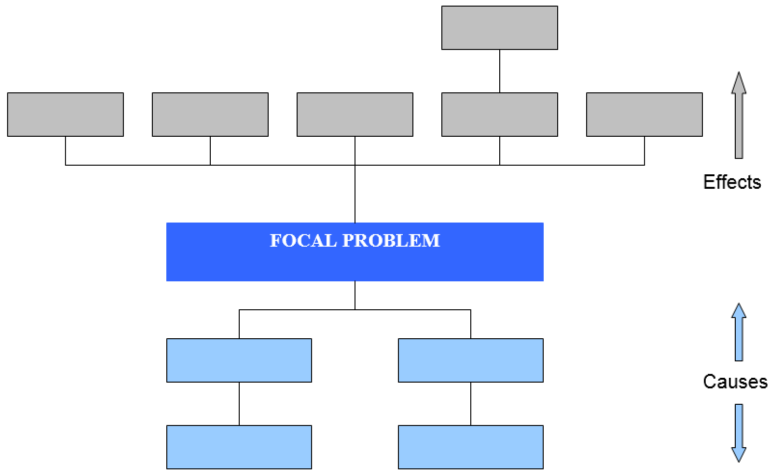


Figure 5. Problem Tree Scheme

Source: Wilson, 2003

It is used to link together the various issues or factors which may contribute to a problem. Also, it helps to identify the underlying or root causes of a problem. The major assumption underlying the problem tree is the hierarchical relationship between cause and effect.

7. Results

7.1 Climate Variability

7.1.1 Average Monsoon NDVI

Figure 6 visualizes the Average Monsoon NDVI for the period 2001 – 2013. The values range from minus 0.05 to plus 0.69. Five intervals were chosen to display the range of values with different colours. The classification is orientated to the scale provided by NASA (NASA Earth Observatory 2014).

It can be denoted that the bulk of Average Monsoon NDVI values ranges between 0.3 and 0.6. According to NASA, such values correspond to vegetation cover less than rainforest but higher than shrubs and grasslands (NASA Earth Observatory 2014). Significantly low values (0.1 or less) are only found at the southern borders of both woredas. Values close to below zero are identified as fresh water from Lake Tana. In Dembia, the highest area-wide NDVI values are achieved in the northern part (0.5-0.7), while the southeast is marked with the lowest area-wide NDVI values (0.3-0.4). The west and the central region of the woreda more scattered with alternating values of higher (0.69) and lower (0.2) intensity. In Gondar Zuria, the lowest area-wide values are present in the west (0.3-0.4), while the highest area-wide values are achieved in the southeast and the northern central region (0.5-0.7). Scattering values of higher (0.69) and lower (0.2) intensity are found in the north. However, in both woredas there are only a few areas marked with bare soil or bare rock during the growing period. Areas of low vegetation cover are mostly found around greater settlements and cities, such as the city of Gondar in the northern part of the Gondar Zuria woreda.

The correlation of the Average Monsoon NDVI with the slope map (see Figure 6) reveals that areas with a slope inclination equal or higher than 40 degrees are continuously marked by NDVI values greater than 0.55. Such patterns are visible for the far north and south of Dembia as well as for the east of Gondar Zuria. The height map (see Figure 6) shows that the areas with the largest slope inclinations are found at higher altitudes between 2000 and 3000 metres above sea level. On the contrary, areas with low slope inclinations and homogenous height patterns are marked by a greater fraction of low NDVI values in the range of 0.3 to 0.4.

The land use map (see Figure 6) reveals that the forest cover throughout the area is relatively low. Forests are dispersed in patches with greater shares in the plane areas. At higher altitudes, forests are almost unrepresented. This is one of the reasons why NDVI values higher than 0.7 are not represented in both woredas. Acoording to NASA, high NDVI values above 0.7 are only found in areas with temperate and tropical rainforests (NASA Earth Observatory 2014). On the other hand, it can be seen that the lower values in the southeast of Dembia, respectively southwest of Gondar Zuria, are due to a high concentration of shrubland and grassland. However, rain-fed croplands and mosaic croplands are generally marked by higher Average Monsoon NDVI values (0.4-0.6). A clear correlation can be identified for various widespread areas, such as the north of Dembia, the north of Gondar Zuria as well as the east and southeast of Gondar Zuria.

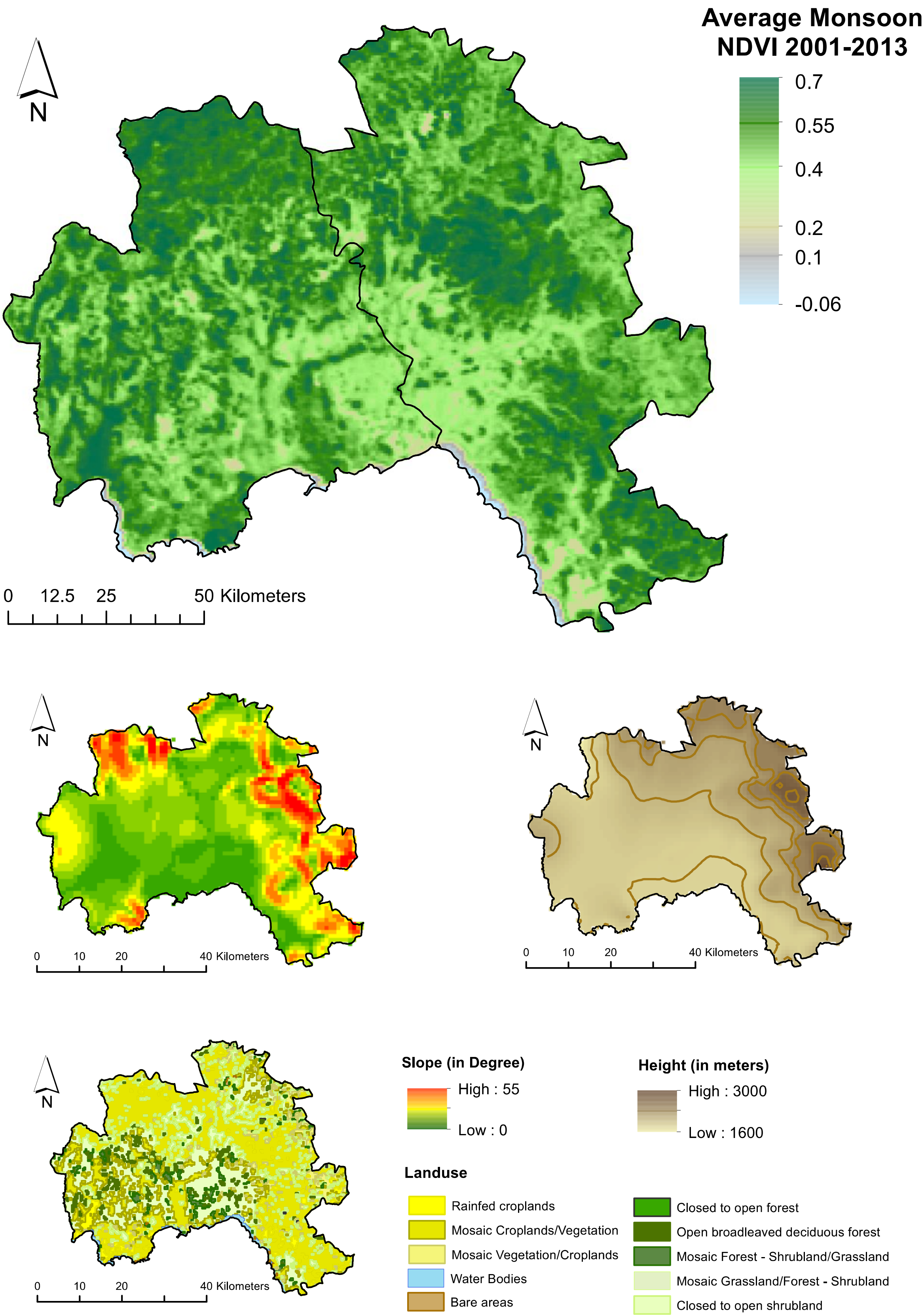


Figure 6. Average Monsoon NDVI (2001-2013) and the maps showing slopes, altitude, and land use

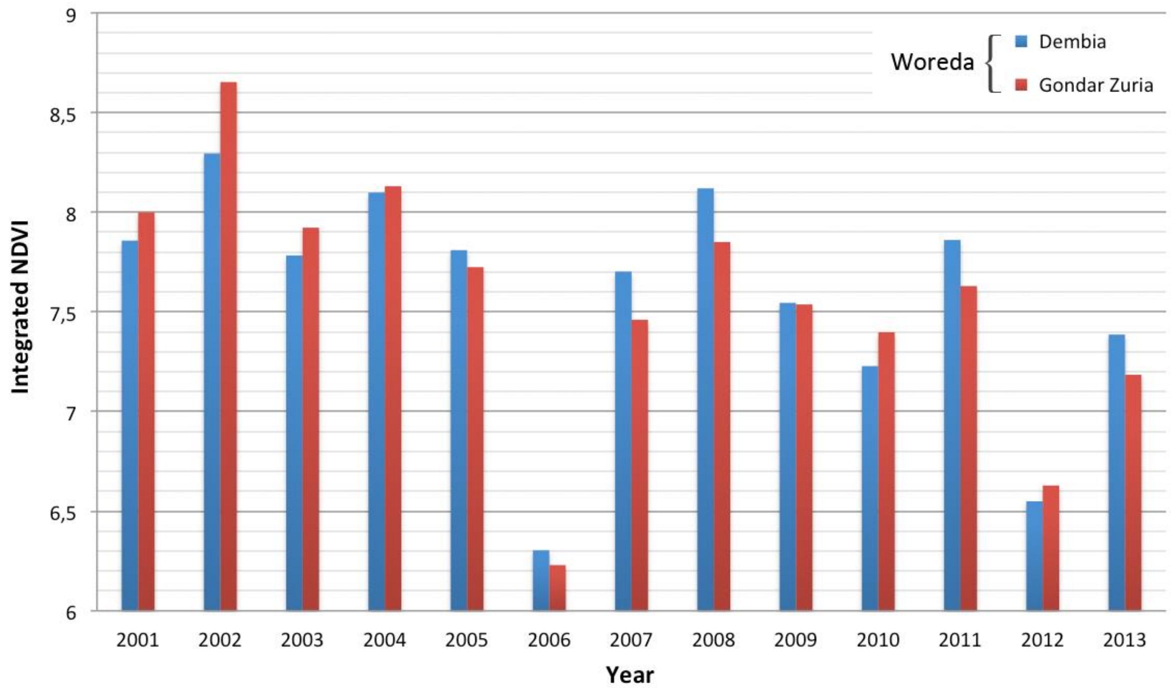
(Source: own compilation)

7.2 Integrated NDVI

The iNDVI reveals differences in live green vegetation for each year. Higher iNDVI values correspond to higher photosynthetic activity. The results for the two study areas are shown in Table 1.

The iNDVI values range from 6 to 9, with a bulk concentration between 7.4 and 8.1.Generally, annual values between both Woredas show similar patterns. A high iNDVI in Dembia goes along with a high iNDVI in Gondar Zuria. However, none of the woredas continuously possesses superior iNDVI values compared to the other district. At some years Dembia holds a higher iNDVI, while at other years Gondar Zuria has a higher iNDVI. Of main importance is the fact that both woredas show similar plant growth patterns for each of the respective years. In 2002, both study areas reach the highest iNDVI with values between 8.3 and 8.7. On the contrary, both woredas are denoted by a relatively low iNDVI in 2006 (6.2 to 6.3) and 2012 (6.5 to 6.7).

Table 1: Results for the two study areas



7.3 VCI

Figure 7 illustrates whether the annual state of the vegetation corresponds to drought conditions, fair vegetation conditions or optimal vegetation conditions.

Starting chronologically, optimal vegetation conditions are reached for the majority of pixels in both regions from 2001 to 2006. However, in 2001, 2003, 2005 and 2006 greater patches of drought conditions can be identified in certain areas.

The spatial distribution and concentration of droughts changes from year to year. However, in most cases drought conditions are not small-scale events but can rather be designated to larger areas. For example, a larger concentration of drought conditions can be identified for the west of Dembia and the east of Gondar Zuria in 2001. In 2007, drought conditions are for the first time predominant in Dembia. Only the northern region and the southern tip, which are marked by high slope inclinations, remain with optimal vegetation conditions. On the contrary, the areas with highest slope inclination reveal intensive drought conditions for Dembia in 2009.

In 2002, 2004 and 2008 both districts are almost entirely characterized by optimal vegetation conditions. Only a few pixels show drought or fair vegetation conditions.

However, in 2010, 2012 and 2013 drought conditions are predominant in both woredas. The highest severity was found in 2012. As opposed to the years with optimal vegetation conditions, Dembia is marked with drought conditions throughout the whole region. The patterns are similar for Gondar Zuria, where only a little fraction along the eastern boarder shows optimal vegetation conditions.

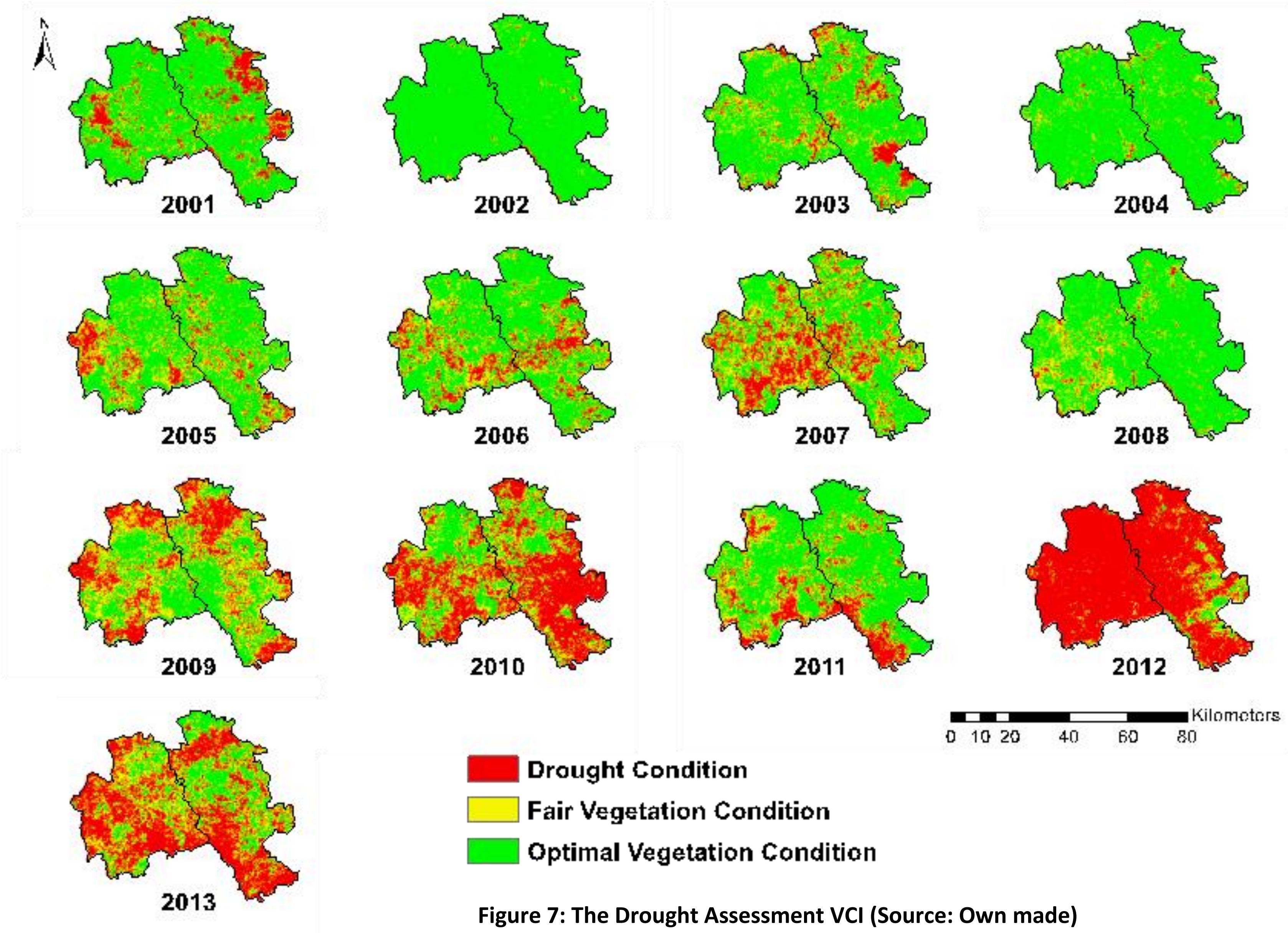


Figure 7: The Drought Assessment VCI (Source: Own made)

7.4 Main problems of farmers and main factors influencing their decisions

The accelerate increase of the population in the highlands is rising the demand of natural resources such as fuel, wood and of course, of the food. And together with the effects of climate variability the negative impacts to the environment and crop yield are even worsen. Especially in the highlands they depend mainly on their own crops not only for their daily food supply but also for their income. Therefore the main challenges for farmers are on the one hand the natural resource base in terms of water management and rainfall variability, land use, energy and climate variability and land degradation and on the other hand socio-economic factors mainly induced by population growth.

a. Water management and rainfall variability

The field observations and the interviews with the farmers showed that they mainly sow teff (July with harvest in December) and sorghum (Mai and harvest in December) because for them these are the most productive crops, but they also sow barley and wheat. The sowing is been done annually and depends highly on the rain-fed agriculture. For the farmers it is crucial that an adequate quantity of rain is falling during the growing season. They just wait for the rain to come; most of them don't have other methods. So, if there is a drought or a variation on the rainfall they simply lose their crops that season and face with droughts and hunger. Furthermore, it is not only the absence of rain that leads to crop failures, but also a high quantity of rain falling within a short time period. Too much rain within a few days may also cause crop failures, for example caused by floods and water logging.
According to farmers one of the major challenges is the water availability especially in Mai and also the high risk to droughts in the area. Some of the farmers use irrigation methods for their crops, mainly the ones that live close to rivers. Irrigation is a useful technique to reduce the dependence on rainfall. Actually, in the dry season, rivers and especially small tributaries are often not containing enough water to allow for constant flow through the whole riverbed. However, the small fraction of water that continues flowing downward is being utilized for irrigation purposes. Farmers concentrate the water within the riverbed and divert it through small handmade channels out of it towards their irrigation fields. Irrigation schemes contribute to food security through higher production and yields, as well as lower risks for crop failure. Through irrigation techniques they are now able to further diversify their cropping patterns. For example, they plant potatoes on their small-scale fields. But still many farmers are pushed to do a rotation-irrigation in some areas for example in Gumera watershed. That means there are groups of 6 or 7 farmers and their crops are irrigated one time and then have to wait until the others are supplied to then again irrigate their crops. The main risk with this method is

the high probability of crop failure due to the lack of water supply in many days. Another problem for the farmers is water storage for future use.

There are many farmers that don't storage the water at all, and the ones that are doing it have some other problems. In many cases the water storage ponds are actually too small to really secure the harvest in the dry spells. Furthermore, the ponds evolved as major breeding areas for mosquitoes and have siltation problems. So, they are not very effective. Plus, in order to avoid the water infiltrating into the ground plastic sheets are needed to cover the surface of the pond. For that sheet farmers need to borrow money mainly from credit services. And this represents another big cost for them reducing their income.

b. Land use

The land in Ethiopia is owned by the government. Farmers can use it as usufruct basis but are generally vaguely motivated to improve their land and do investments due to this fact. According to the informal interviews farmers work in around 1.33 ha (EBL Nexus Project, 2014).
Many years ago the amount of ha per family was bigger but now it reduced due to the growth of population. The intensification and expansion of the agriculture that is needed in order to satisfy the necessity of the people is causing many problems mainly deforestation, overgrazing, loss of biodiversity and loss of ecosystem services. Farmers use normally use 0.5 ha for each crop and they do crop rotation year to year because according to them it increases fertility and avoids high amount of nutrients leaching. They mostly do tillage practices and ploughing. Some even do mulch tillage. They consider a fertile soil when it is easy to tillage and when it is fractured they consider it less fertile or infertile. Approximately they get 450 kg of teff and sorghum as crop yield in the area. So, for many of the small-scale farmers this source of income just serves as a subsistence source because it doesn't satisfy entirely their needs. Also due to the small land scale most of the farmers cannot do fallow like in the past and many of them do not do it at all. (Interview with farmers and own observations, 2014)
One of the main problems in the crop production is the use of fertilizers. Farmers sometimes use the roots of the crops from previous seasons as organic fertilizer but use mainly the basal fertilizer. This last fertilizer is used the whole time and most of the farmers do not know exactly how to use it properly. Farmers have then two problems, on the one hand they have to buy the basal fertilizer from the extension service and since they mostly have not enough money they have to take a loan from the credit service. On the other hand the use of the fertilizer is mostly done wrongly and production

reduces due to infertility of soil and soil degradation. So it is more difficult for the farmers to pay the loan and their income reduces even more. Also if they want to fight against the pests they mainly use pesticides which they also need to buy from the extension services. This can make the 15 weight of the loan so high that the farmers dedicate their crops mainly to pay back to the credit service and not for their own income.

Moreover, farmers still conserve many of their traditional practices like for example they organize themselves in groups of 4 to 6 people to support each other with manpower as well as money in order to be more productive. So, they sow one field together and plough one field together and if they have the possibility of irrigation they do it together before moving ahead to the next field.

c. Energy

The mainly energy source of the farmers is the animal dung. So, instead of using the dung as organic fertilizer they use it as fuel for energy. Most of them are not conscious of the advantages of animal dung or rests of crops as organic fertilizers. Besides they get the energy from the forest by cutting trees which is also increasing the deforestation in the area.

d. Climate variability and land degradation

As results from the observations and the questions answered buy some of the farmers in the area, it is clear that they are aware of the climate variability and the reasons for crop failure and soil degradation. They argued that the temperature has increased in the last years and the rainfall changed completely from what there were used to. Also they are aware that the deforestation is increasing the land erosion and degradation and that both are causing high negative impacts in their productivity.

Normally, the farmers depend only on agriculture. But if the conditions are not favorable and there are some extreme climatic events (droughts or floods) or soil infertility, farmers have to search for some other income sources in order to survive. Most of them sell their cattle to compensate the lost but according to them it is not enough and in many cases it doesn't support their needs. Therefore some farmers are doing other activities for their income sources, such as bee keeping and selling fire wood from Eucalyptus tree. Less have some paying jobs in constructions, but most of them are not trained well for any other activity that is not agriculture. (Figure 8)

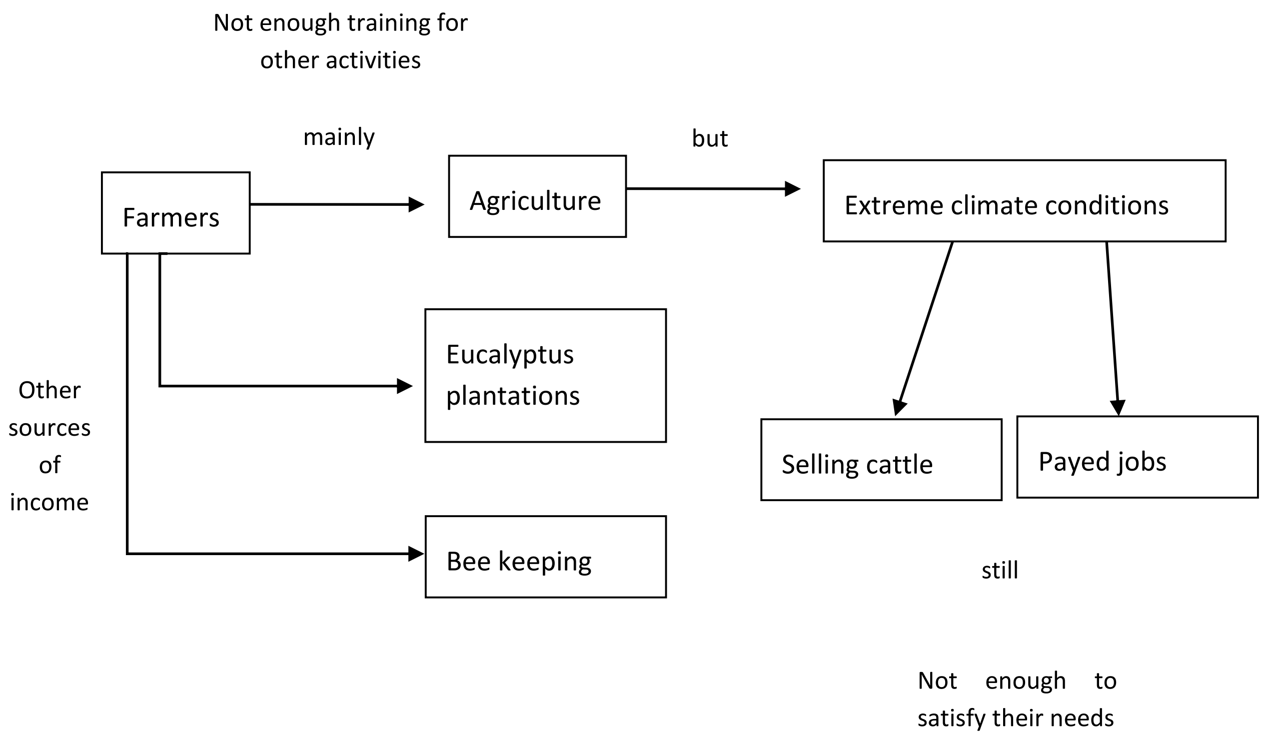


Figure 8. Behavior of farmers to cope the low yield productivity

Source: Own compilation

7.5 Land & Water Management

The productivity of agricultural economy of Ethiopia is being seriously affected by unsustainable land management practices both in areas of food crops and in grazing lands (Berry, 2003 cited in Adgo, et al., 2014). Land degradation is one of the major causes of low and, in many places, declining agricultural productivity and continuing food insecurity in rural Ethiopia, in general, and in Amhara Region.

7.5.1 Land Management

According to the Harmonized World Soil Database[1] (HWSD), the major soil types in our case study areas are Leptosols, Vertisols, and Luvisols in their dominance order and some minor soil types are Nitisols.

[1] FAO/ IIASA/ ISRIC/ ISS-CAS/ JRC, 2009: *Harmonized World Soil Database (version 1.2)*. FAO, Rome, Italy and IIASA, Laxenburg, Austria

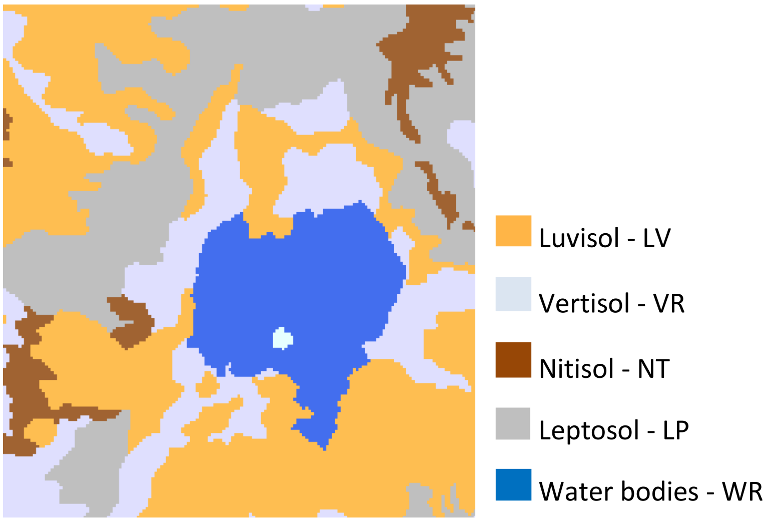


Figure 9. Soil Type

7.5.2 Water Management

(a)

(b)

Image 1. Examples of on-farm retention ponds (a) Structures of trapezoid-shaped, stone-walled (upper left) and plastic-covered (upper right) ponds (b) Smaller on-farm pond with terraces as catchment area. Source: (Tesfay, 2011)

(a) (b)

Image 2. Examples of household ponds developed as vegetable gardens, (a) Owned by a model farmer, Dargie Teka, in *Raya Azebo* district, *Genetia* Tabia (sub-district) and *Waekel* Kushet (village); and (b) a second example of household pond. Source: (Tesfay, 2011)

Image 3. A typical pond and a pond user from kelte Aelelo woreda harvesting pepper from her plot [Photo: REST Public Relation Unit] Source: (Tesfay, 2007)

7.5.3 Natural & Forest Conservation

Deforestation and forest degradation is one of the main environmental challenges of Ethiopia, and also one of the major causes for declining agricultural productivity. Because of rapid population growth, large forests and crop areas are required to satisfy the needs of the region.

The steadily growing population pressure and agricultural expansion in the region and in all Ethiopia, will inevitably increase the forest resources utilization such as construction and fuel wood as well as agricultural areas for crops. About 20,000 ha of forests are harvested annually in the Amhara region for fuel, logging and construction purposes. Since harvested trees are not replaced and, thus, expose the soil, about 1.9 to 3.5 billion tonnes of fertile topsoil are washed away annually into rivers and lakes due to deforestation alone (UNECA, 1996).

Below we describe how deforestation takes place as a continuous cycle:

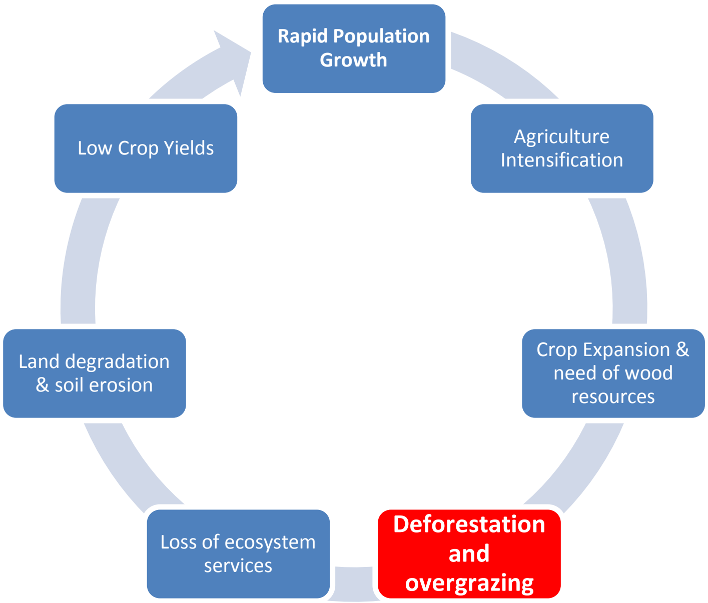


Figure 10. Deforestation Cycle

Source: own compilation

This situation causes different forms of unsustainable forest utilization such as (fires, logging, cultivation, urbanization). This destruction of forests has made the land more susceptible to wind and water erosion which degrades the fertility of the soils and lowers crop yield productivity. The destruction of forests for fuel is already proceeding at a rapid rate. In the last 50 years, the amount of closed forest resources has fallen from 34% of the total landmass of the country to less than 3% (FAWCDA 1982).

Factors such as government policies on infrastructure and market development, input and credit supplies, land tenure, agricultural research and extension, conservation programmes, land use regulation, local governance and collective action are important to revise and improve in order to revert the situation and contribute to a better crop yield productivity. Also, an important aspect to consider is there is lack of information and knowledge transfer to the farmers about appropriate alternative technologies and farming strategies.

Image 4: Natural Landscape of the Region

Photo: Lorena V. Guzmán Wolfhard, 2014

Today, we can observe in the image that the agricultural landscape is highly overused with very few forest cover left. During a farmer's interview in our fieldwork, we could understand that farmers are actually aware that the rains are not coming because there is few forest cover left. A farmer stated; "….ten years ago we had forests up in the hills, but now forests are gone and that is affecting our farms…."

Presently, the extension services have reforestation and afforestation initiatives present in the case study area, but the assurance and compliance of expected achievements control is questionable. According to expert interviews, it is said that *"there would be a 35% to a 40% of forest coverage in the next 15 years".* (Belete Birhanu - Expert Interview).

"*So, because of that the Ethiopian Government is already now introduced that are – afforestation program, every region every district already plan to reforest some area annually increasing and increasing. Now some of the researchers just evaluated that now it's increasing. Our forest coverage is increasing 6 to 7% now in these 6 months practice*". (Belete Birhanu - Expert Interview)

Table 2: Policy and Investment Framework (PIF) 2010 - 2020

Manage, conserve and utilise natural resources sustainably. (FYGTP, CAADP Pillar I and MDG 7). Major investment projects: SLMP, CINRMA	SO 3: To reduce degradation and improve productivity of natural resources.	• Area under irrigation increased.	• 8% annual increase of arable land irrigated.	• Review and effectively implement appropriate NRM policies and instruments. • Establish and effectively implement Good Agricultural Practice (GAP) policies.
		• Water conservation and water use efficiency improved.	• 5% annual increase of total precipitation conserved. • 5% annual increase in crop yield per unit of water used.	
		• Arable, rangeland and forest degradation reduced.	• 8% annual increase in area under improved land management, including forest coverage. • 3% of degraded land rehabilitated per annum. • 5% annual increase in normalised difference vegetation index (NDVI).	
		• Agricultural biodiversity maintained.	• 3% change in agro-biodiversity index.	
		• Soil health in key agricultural landscapes improved.	• 3% increase in soil organic carbon level.	
		• Security of private sector access to land resources improved.	• 80% of rural households issued with first and second level certificates.	• Implementation capacity for improving security of access to natural resources.
		• Farmers' ability to respond to climate change challenges strengthened.	• Mechanisms in place to support climate change adaptation and mitigation.	• Develop and effectively implement policies and instruments for climate change adaptation and mitigation.

Source: Ethiopia's Agricultural Sector Policy and Investment Framework (PIF) 2010 - 2020

In the table above, we observe the ambitious PIF Plan from the Ministry of Agriculture and Rural Development, which basically intends to direct Ethiopia towards a middle income country in 2020. To achieve this, they have developed a sequence of objectives with indicators that are related in one area, to reduce degradation and improve the productivity of natural resources. Even though there is a plan to revert the forest coverage situation in Ethiopia, its ambitious characteristics makes it difficult to steer in such a difficult scenario.

According to the Ethiopian Institute of Agricultural Research (2004), the destruction of the natural forests of Ethiopia results directly in the loss of unaccounted plant and animal species as well as in a shortage of fuel wood, timber and other forest products. It also indirectly leads to more aggravated soil erosion, deterioration of the water quality, further drought and flooding, reduction of agricultural productivity, and to an ever-increasing poverty of the rural population. It is obvious that the depletion of forest resources contributes significantly to the climatic and physical environment change. To worsen the matter, the reforestation effort is not, by any means matching with the rate of deforestation (Derero, 2004). This institution also states that the Agriculture offices at regional, zonal and woreda levels revealed some factors that have negatively influenced the forestry development such as lack of appropriate institutional arrangements, unknown contribution of forestry to the GDP, inadequate budget, skill gaps in forestry, absence of a clear strategy, insufficient land use planning and development, deforestation, inaccurate information, less technical support, inadequate and poor quality tree seeds, insufficient research extension linkage and a weak coordination.

Source: Derero, 2004

7.6 Institutional Framework

The institutions play an important role in the agricultural landscape of Ethiopia, and especially in the northern highlands of the Amhara region which is one of the most populous rural crop areas of the country. The Ministry of Agriculture and Rural Development (MoARD) deploys the so called "Extension Service" to help farmers with their agriculture. The extension service is a branch of the Agricultural Office at Woreda (District) level, which basically works by deploying professional assistance to the farmers. In each Woreda there is one Agricultural Office, which has the responsibility to manage the agricultural assistance in all their corresponding Kebeles (Municipalities). The extension service works by providing assistance to farmers through development agents, which are professional that are established in each Kebele and delivers agricultural "know how" and best practices on how to manage crops to improve their agricultural yields.

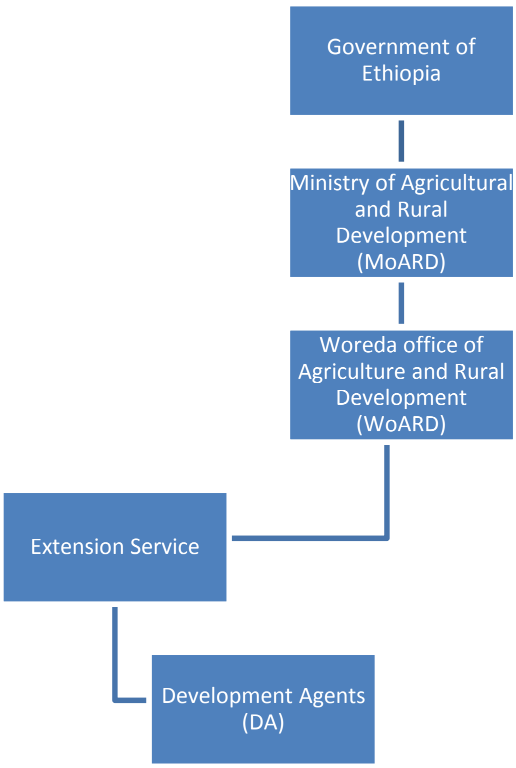


Figure 11: Organizational Structure of Institutional Agricultural Assistance

Source: own compilation

In the figure above we can observe that the organizational structure of the agricultural assistance provided to the farmers, follows a top-down approach, by which the government provides farmers strategies on how to use the resources efficiently, such as fertilizers, pesticides and seeds. In each

Kebele, there are 3 development agents assigned to attend the area; one crop specialist, one natural resource specialist and one livestock specialist. These development agents have the capacity to attend 5 farm groups each day. It is important to mention that a Kebele is conformed approximately by 300 persons which are organized in farm groups in order to cooperate one to another. There are also development groups which are 6 farm groups joined together to work in cooperation.

7.6.1 On-site extension service activities

The extension service provides assessment and evaluation of the farms, by which they monitor the progress of their crops and their land management practices. These evaluations are manually collected and transferred to the agricultural office in the Woreda. Development agents use this information from all Kebeles so that they can exchange ideas on how to assist technically each farm. The development agents in each Kebele have the capacity to attend four to five farm groups per day. In each Kebele there are 60 farm groups (the farm group is integrated by 5 households). In this regard, the extension service plays a leading role to increase agricultural productivity in the area. In the table below we describe the activities that the extension service perform in site farmlands in the Amhara region:

Table 3: Extension Service Activities

Main Challenges	Assistance
Poor land management (High nutrient depletion, slope farming, soil erosion, deforestation and overgrazing).	• Soil Conservation techniques (terracing, gabionsand trenching). • Using fertilizers efficiently and planting Acacia trees to improve soil fertility and increase crop yields. • Best practices by planting grass cover around croplands. • Reforestation and afforestation initiatives. • Relocation of farmers to improve crop areas when farmers are facing cropland pressures. • Slope farming strategies such horizontal land plough instead of vertical plough.
Water management problems (The existing water harvesting	• Water harvesting schemes (ponds, check dams). • Developing small scaled irrigation practices. The development agents provides weirs to divert water from the river.

systems are few, traditional irrigation systems which brings waterlogging problems.	• BBM (Broad Bed Maker) system that is used to drain water from excessive water in croplands. • Constructing trench or drainage canals for plain farmlands in order to protect them from water logging problems.
Patterns and distribution rainfall	• Inform farmers about the annual rainfall distribution so that they can cultivate the correct type of crops.
Low income to purchase fertilizers, pesticides and seeds.	• Providing loans to farmers to purchase fertilizers, pesticides and seeds from the nearby agricultural office or through the credit service. It is important to remark that farmers are supposed to pay the loan after the harvesting period.
Rapid population growth and agricultural intensification	• Provide assistance to the farmers to be more productive with their crops. This way farmers can an efficient crop yield avoiding the necessity to expand their crops. Provide awareness and education to the farmers about rapid population growth and its consequences on food security.
Problem of communication with other stakeholders: NGOs, farmers, research and government	• The extension service makes efforts to communicate with all the stakeholders in order to provide assistance to the farmers in topics such as introduction of new varieties in their crops (tomatoes, potatoes, etc). Also they make efforts to provide information about rainfall patterns. *Note: there is a need of communication improvement between all stakeholders.*
Resistance to change: farmers are unable to accept new technologies so they follow their traditions.	• Development agents have a very close communication with the farmers in order to understand their needs (farm practices, pesticides, fertilizers, seeds). • Provide awareness and education about the benefits of new technologies. *Note: it is not easy to talk with the farmers, and developing agents express that they need to become friends with the farmers.*

Source: own compilation

According to the table above we can observe that the extension service has many solutions to increase agricultural productivity and overcome all these challenges. This seems like an active effective plan, but the reality is somewhat different. According to interviewed farmers, the extension service fails to deliver a proper assistance in many ways.

7.6.2 Farmers Opinion on Extension Service

The farmers need support, this is usually provided by extension services. The development agents also need support from the research but most of the times these three groups are not very well connected. The relationship between farmers and extension services is by far not ideal. The extension service follows a top-down approach, where farmers are simply told what to do. But they do not have the chance to actively participate, to contribute with their own precious traditional knowledge and to speak out their real needs. So, it is very much a supply driven approach. Also according to some farmers there is a lack of help from the extension services. Even though most of them they affirm the extension service helped with some conservation mechanism such as the construction of terraces and irrigations schemes, there are many farmers that do not receive any help. What they mostly want is a technical knowledge to apply the fertilizer and pesticides and also in the availability of improved seeds.

8. Discussion

According to our results and observations on the field, we found out that the challenges are actually interrelated with each other; therefore these should be tackled with a holistic approach. Based on this perspective we gained a better understanding of the root causes and effects of the low crop yield productivity problem in the Amhara region. Important aspects such as vegetation dynamics, farmer's perspectives of the situation, land management and water conservation practices and the role of institutional support were key aspects analyzed to develop sustainable solutions. We could also determine that a strong relationship between stakeholder's interactions is necessary to combat low crop yield productivity.

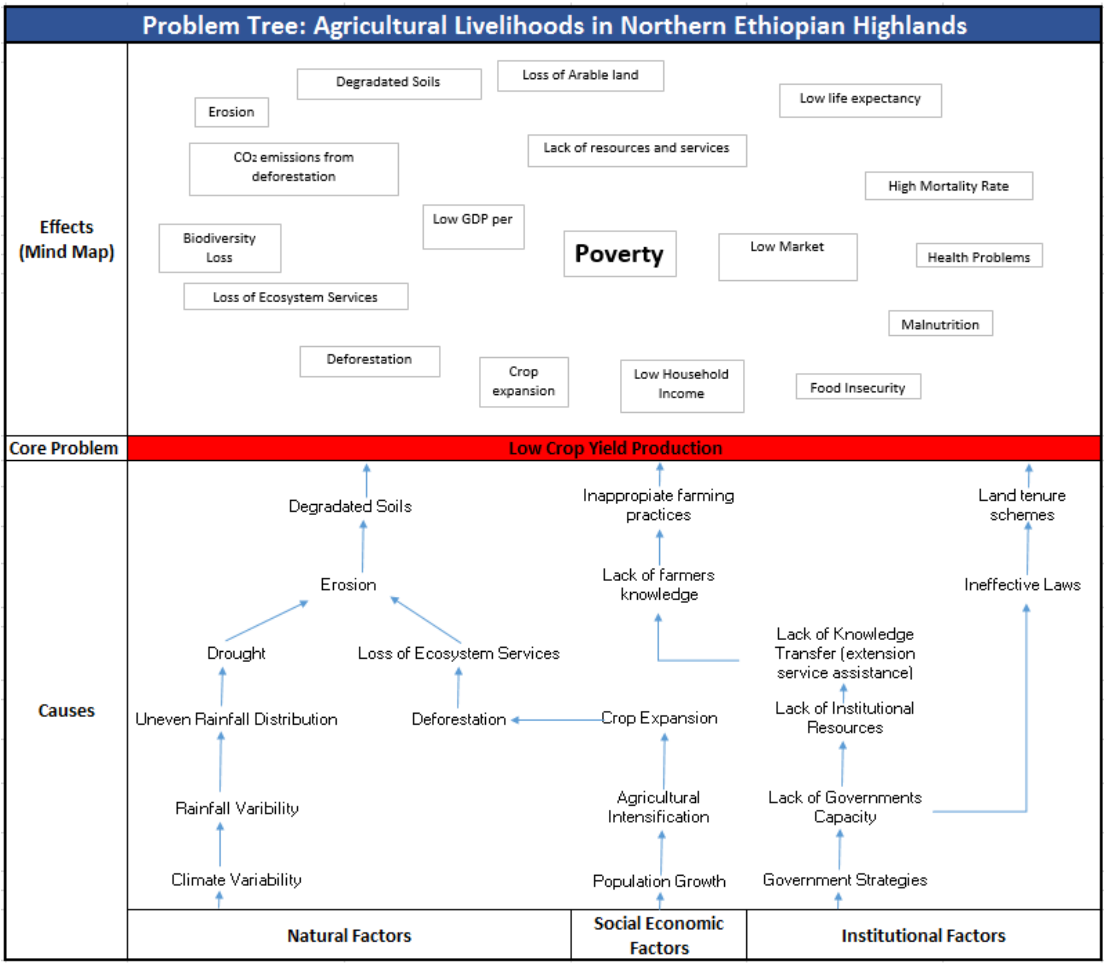


Figure 12. Problem Tree

Source: own compilation

The figure 12 shows how different components such as natural, social and economic are related to each other and are root causes of the main problem: low crop yield productivity.

On one hand the communication between researchers and the extension service officers is not effective, causing failure to obtain scientific data when deploying assistance to the farmers. Some development agents don't have enough preparation and knowledge on important information such as rainfall variability, soil structure, vegetation or temperature. Therefore, development agents don't have clear ideas of which are the suitable inputs and strategies to provide in a specific farm area. Because of this situation, fertilizers, seeds or strategies do not match to the farmer's needs. This situation makes the farmers unaware about forecast information that can help them to cultivate efficiently.

Another important point to consider is the lack of institutional human resources. Currently there are not enough development agents to attend farm groups. The development agent which is assign to each kebele can only attend 4 to 5 farm groups per day and as we mentioned before, Amhara region is one of the most densely populated rural area of Ethiopia.

Farmers within kebeles should be more encouraged and better organized to attend to workshops seminars that enable them to be certify with the best farming practices. This can motive them as well to become leaders of their farm groups and involve actively with other farmer groups. This is a key aspect to consider when talking about education, employment and professional formation in small rural areas.

An additional problem is the one regarding enforcement of agricultural policies. First of all, there is a need of policies on effective slope limits to avoid erosion and land degradation from agricultural production in steep areas. Also, an important aspect to consider is the land tenure policy system. The government owns the land and the farmers are being constantly relocated when having insufficient crop yields and that is why farmers mostly don't feel motivated to invest much effort and resources in the land. Transforming the landownership to individual farmers could encourage them to get more involved into the proposed practices of the extension service.

On the other hand, improvements in the research area have to be done in order to increase the soil quality and the water management. For example, according to the observed research papers from reliable sources such as the FAO and Ethiopian Agricultural Research Organization (EARO), potassium, cation exchange capacity (CEC) and organic matter contents of most Ethiopian highland soils are generally high by international standards. Ethiopian soils are generally low in available nitrogen and phosphorus and cannot produce high crop yields unless these are supplied (Mengistu, 2006). Eventough farmers are awre of the problems they are not aware of how to cope with it.

Furthermore, the farmers expressed the very low or unsatisfactory fertilizer responses in their fields. This is mainly because of the combination of the nutrient retention properties of Vertisols, which is rich in swelling clays and forms alternate swelling and shrinking of expanding clays resulting deep cracks in the dry season under the scenario of erratic rainfall and drought incidences in our studied areas. These soils are on extensive basalt plateaus of Ethiopian highlands (FAO, WRB 2006). Thus these soils have considerable agricultural potential, but adapted management is a precondition for sustainable production and again most of the farmers are not aware of it. The susceptibility of Vertisols to waterlogging is also the single most important factor that reduces the actual growing period. Excess water in the rainy season must be stored for post-rainy season use (water harvesting) on Vertisols as they have very slow infiltration rates. Management practices for crop production should be directed primarily at water control in combination with conservation or improvement of soil fertility by following the Good Agricultural Practices (GAPs).

Also, research is currently not able to provide extensive and adequate data to other stakeholders. Remote sensing may be an effective tool to measure past and present physiogeographic dynamics. For example, satellite images may contribute to monitor changes in vegetation cover, such as forests, shrub lands or croplands. NDVI and VCI are possible tools to assess such changes. However, both indexes are not free of criticism. In order to apply the VCI formula a mean value for the 15 images of each year had to be formed. Hence, the VCI results are only showing smoothened values but not real values. Furthermore, the VCI assumes that the highest value of one pixel over the given time series corresponds to high vegetation cover, while the lowest value corresponds to sparse vegetation coverage. However, if the lowest value is still characterized by a relatively high NDVI value (far from any drought condition), it will still be marked as drought condition. Hence, the method implies that drought conditions will exist. There is no option that there are no drought conditions over the whole time series due to the build up of the formula. Furthermore, the iNDVI does not consider spatial differences in NDVI in each year. The iNDVI for one year might be at average compared to other years, but the spatial distribution can be highly distinctive. Further in-depth investigations are necessary to understand the reasons for the annual iNDVI. Also, climate data are missing to correlate iNDVI or Average Monsoon NDVI values with rainfall patterns to generate datasets with higher representativeness. With the above-described deliberations we are only able to give estimations and assumptions where drought conditions exist but we do not have climate data to verify their existence.

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Framework for Integrated CGRES Approach to improve Rainfed Agriculture-based Economy of Northern Ethiopia Highlands

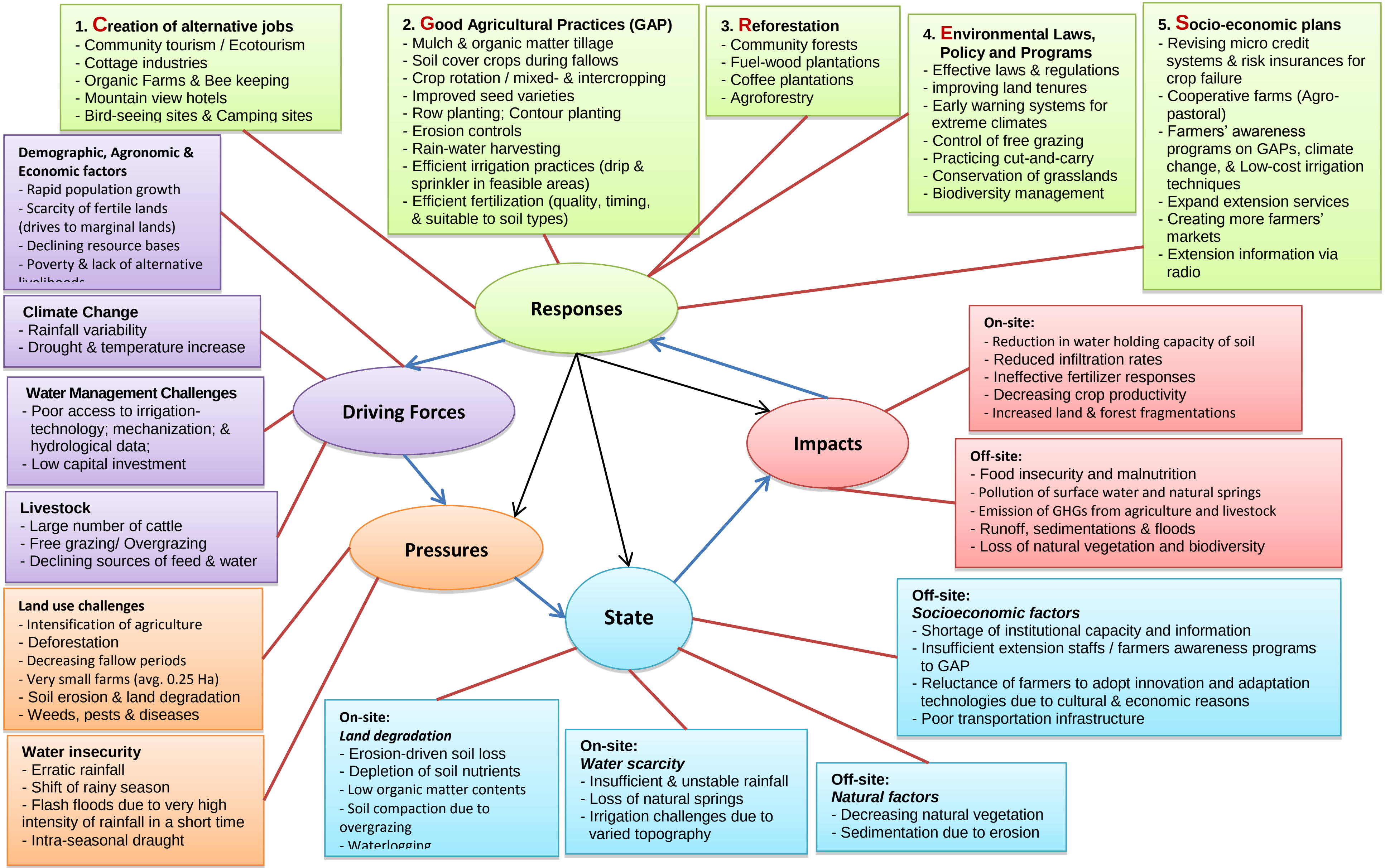

Figure 14. Developed by Aung, Abugazleh, & Barsi. 2014. EBL Project, Ethiopia. "**D**riving force-**P**ressure-**S**tate-**I**mpact-**R**esponse (**DPSIR**) model" based on **Invalid source specified.**

9. Conclusion and Recommendations

The Ethiopian government attempts to improve the situation with efforts that are not sustainable in the future. Their efforts are based in short term solutions such as supplying fertilizers and seeds to the farmers, but without sufficient knowledge transfer. Also, the farmers are receiving inefficient support from the extension service due to a lack of institutional capacity and ineffective communication between the stakeholders. In order to improve crop yield productivity in the Amhara region, we recommend to implement long-term sustainable strategies to reduce land degradation and increase crop yields in order to assure a proper nutrition and income generation for the farmers in the region. This long term solutions have to be sustainable and requires integrate the following aspects:

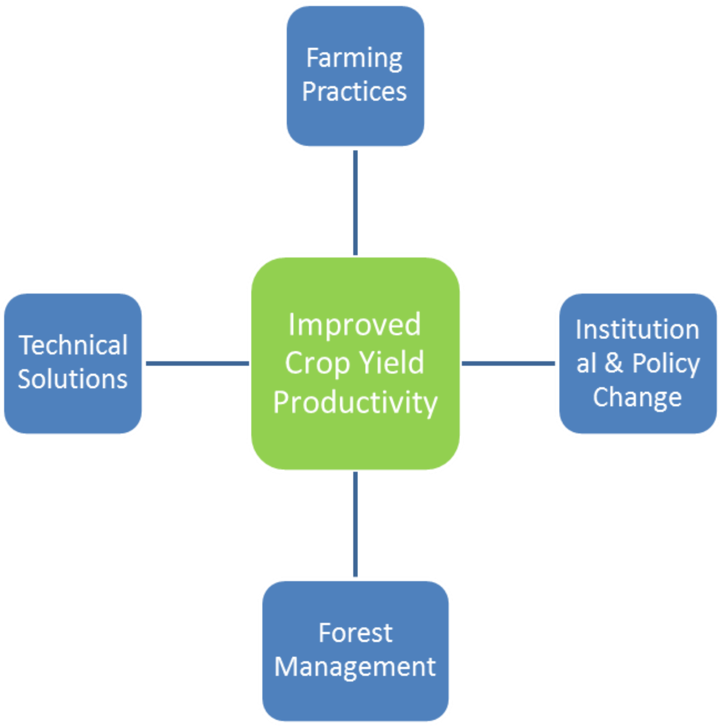

Figure 15. Recommendation Components

Source: own compilation

Specifically, we recommend a holistic integration of the following recommendations:

Table 4. Recommendations to Improve Crop Yield Productivity

Farming Practices	**Technical**	**Institutional & Policy**	**Forest Management**
Control fertilizer content which alters water quality of rivers and water reservoirs.	Build small earth dams and large water reservoirs to irrigate crops in the drier periods of the year.	Define slope limits for crop production.	Close degraded areas and let vegetation cover to reestablish.
Increase soil moisture by: using crop residues and mulches, tied ridges (furrow dams), tillage to reduce runoff and evaporation.	Introduce efficient water harvesting system.	Change land ownership policies by law	Protect important natural areas from overgrazing and deforestation.
Use animal manure and combine agroforestry with agricultural crops to increase soil fertility and crop diversity.	Study the applicability of improved seed varieties.	Improve institutional communication between stakeholders	Increase vegetation cover with effective reforestation programs.
Introduce nitrogen fixing agents such as Acacia species in order to improve crop yields.	Use mechanization in suitable flat areas.	Increase institutional capacity of extension service to support farmers	Measure deforestation with a monitoring system
	Use mechanization in suitable flat areas.	Redesign the farmers credit system	
		Include alternative jobs in the area (ecotourism)	

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