Land, water, people and landscapes in north Ethiopia's grabens

Jan Nyssen, Biadgilgn Demissie, Tesfaalem Ghebreyohannes
(eds.)

Front cover: Headwaters of Gobu River near Dingur (Photo Sofie Annys)

Back cover: Delesa village (Photo Sofie Annys)

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Executive summary: Land, water, people and landscapes in north Ethiopia's grabens

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I. Introduction

In the twenty-one chapters of this book, we highlight the main findings of the Graben project. The word "Graben" is of German origin. It means "long trench", and it is used to indicate long flat valley bottoms that exist at the edge between highlands and Rift Valley. The "Graben" TEAM project description is given in Chapter 1, whereas characteristics of the grabens are presented in chapter 2.

Chapter 1: The "Graben" TEAM project

The "Graben" TEAM project (2013-2018) focused on a major development corridor of Ethiopia, the closed basins at the interface between the Highlands and the Rift Valley. Such basins are sensitive to environmental changes on the surrounding escarpments as well as to climate variability. The landscapes are subject to rapid changes, from (agro-) pastoralism through cereal-based cropping systems to semi-intensive irrigated agriculture. Cooperation and conflicts exist between pastoralist Afar lowlanders and Tigray and Amhara crop farmers. We have performed an integrated geographical study on land use, settlement and agricultural systems, in order to contribute to planning and management of land and water. The project involved the Department of Geography and Environmental Studies of Mekelle University and the Universities of Gent, and K.U. Leuven in Belgium.

Chapter 2: At the edge between Ethiopian plateau and Rift Valley

To acquire a better understanding of the grabens, we selected a representative research area including the Aba'ala, Kalla, Raya and Ashenge grabens. All the marginal grabens are semi-surrounded by escarpments. As a result, their soil and water resources are continuously replenished by the floods and sediments that flow from the escarpments.

The main characteristics of the study area, as detailed in Chapter 2, are the following:

- **Geology:** A graben is a block of land bounded by parallel faults in which the block has been downthrown, producing a narrow valley that, in this case, runs parallel to the margin of the Ethiopian plateau. Antalo Limestone dominates the Aba'ala graben, and basalts and other volcanic rocks the Raya graben. Alluvial deposits fill the graben bottoms.
- The marginal grabens have generally an arid and semi-arid **climate**, with a main rainy season in summer. The *belg* rains are clearly present in the Raya graben, allowing for a second crop in the uplands, whereas they are absent in Aba'ala.
- Many **rivers** drain the escarpments and flow from the foot of the escarpment to the centre of the basin, mostly forming terminal distributary systems. The majority of the floods of

these rivers sink before reaching the outlets. Outlets are deeply incised gorges across the eastern horst, towards the main Rift Valley.

- **Soils:** The Raya and Ashenge graben bottoms are dominated by Vertisols, and the Aba'ala and Kalla graben bottoms by Cambisols. Overall, on the escarpment, soil associations are dominated by Leptosols.
- **Population:** An approximate 650,000 people live in the studied grabens. Most densely populated are the Raya and Ashenge graben bottoms. The population comprises Amhara, Tigraians, largely assimilated Oromo and Afar. Amhara, Tigraians and Oromo are engaged in smallholder agriculture; Afar are pastoralists, on the way of sedentarisation in the grabens.
- **Land cover:** Grassland and shrubs are the dominant land cover in the western escarpments and eastern horsts, whereas cropland is the dominant land cover in the graben bottoms. On the western escarpment, reforestation has occurred and it has a better tree cover than the graben bottom.

II. At the edge of the north Ethiopian highlands

This section concerns the escarpment and also the edge of the Ethiopian plateau from where the water drains to the graben bottoms. At the total top of the escarpments, mountains rise very high, among the highest of Ethiopia. Chapter three presents the afro-alpine envrionment at the top of the escarpment in some mountain ranges of the northern Ethiopian highlands, including along the Raya graben

Chapter 3: On top of the escarpment: the afro-alpine environment

The Ethiopian highlands comprise about 50 percent of the mountains of Africa above 2000 m. These highlands form a good context to study the afro-alpine environment. Therefore, three mountain ranges in the North Ethiopian highlands were studied, the Simen Mts (4550 m above sea level), the Abune Yosef Mts (4277 metres) and Ferrah Amba Mt (3939 metres). All these mountain areas bare evidence of past glaciations and periglacial processes. Small avalanche-fed glaciers existed in the upper north-facing slopes of the Abuna Yosef range. Evidence of such Pleistocene avalanche-fed glaciers in Ethiopia has not been produced earlier. With these observations, a temperature drop of 6 °C was calculated for the Late Glacial Maximum in the study area. Under the current environmental conditions, frost action in these mountains is limited to frost cracks and small-scale patterned ground phenomena. The afro-alpine mountain forests formed by the ericaceous belt is (at present) found between 3200-3700 metres. Despite recent temperature increase, the *Erica arborea* treeline did not rise to higher altitudes in the tropical African highlands. The treeline position in the tropical afro-alpine mountains of North Ethiopia is primarily anthropo-zoogenic driven. However, air temperature is the dominant treeline limit under protected conditions. Thus, management interventions are vital to restore the important ecosystem services of mountain forests.

Also, high up along the escarpment, level lands exist, which are in fact also small grabens. Think about Korem, Ashenge or Maychew. In Chapter 4, the soil erosion that exists in those areas of the escarpment is analysed.

Chapter 4: Soil erosion around Lake Ashenge in historical times

The analysis of sediments deposited by flash floods give information on processes of land degradation in the upstream catchment. For this reason, we monitored a representative segment of the Menkere gully that leads to Lake Ashenge. We have investigated a sequence of alluvial debris fans downstream of the gully segment; we also analysed the texture and dated the sediment that was deposited in the lake. In this way we could see the periods when more sediment was deposited; that means, when there was more erosion in the Lake Ashenge catchment. We could reconstruct the evolution of the gully over the past half century and validate it with aerial photographs and semi-structured interviews. The findings related to gully filling through time are in line with the dating of sediments in the Lake. There was increased sediment supply starting from the 1970s, when lots of sand was deposited in the lake. In most recent years, due to restoration of vegetation on the steeper slopes, proportionally, less sand (hence more clay) was deposited in the upper layers of the lake bottom sediments.

Chapter 5 analyses the cropping system in the upper part of the escarpment, from Korem to Kwiha and beyond.

Chapter 5: Cropping systems in the Raya uplands

In the Northern Ethiopian Highlands ca. 33% of the land is used as cropland. This land is mainly cultivated by smallholders who use their indigenous knowledge to plan their cropping system. By mapping the occurrence of cropping systems, and establish the relationship with annual rainfall, we could improve our understanding of how cropping systems are applied in the Northern Ethiopian Highlands. Five cropping systems were identified, each having a distinct cropping season length and crop association: short crop cycle (four months), short normal crop cycle (five months), long normal crop cycle (six months), long crop cycle (nine months) and long two crop cycle (ten months). Cropping systems with shorter cropping seasons were generally found on the valley sides whereas longer cycles occurred in the valley bottoms. The length of cropping season also increased from north-northeast to south-southwest. Crop associations within cropping systems also varied with altitude. Cropping systems changed in responses to variation in annual rainfall. This resulted in shifts of cropping systems at catchment and regional scales, with cropping systems having longer cropping seasons where there was greater annual precipitation.

People have been living up on the edge of the grabens since many centuries. In Chapter 6, we present a study of the rural society near Lake Ashenge, and the changes in land tenure.

Chapter 6: From unequal access to land to equity: impacts on land degradation around Lake Ashenge

We investigated the land tenure in the uplands around Lake Ashenge over more than 100 years, and particularly how land distribution impacted land degradation. We used aerial photographs, interviews, and mapped the land tenure over time. At the feudal times, there were very unequal areas of land holding. For instance, in the village of Menkere, one Dejazmatch had 14 hectare, and other feudals held large lands also. But more than 50 families had no land at all. When the Derg government came to power, they did a first land reform, which was hastily and not equally done. One farmer said that “it depended whether you came by foot or by hand”. Indeed, the previous feudals managed to keep larger land holdings. The TPLF fighters organised another land reform around 1990; the aim was to have the same land area to every farmer (men and women), with some land readjustments later on. Informally there is a land market; people are renting, but not selling land. All in all, nowadays, 90% of the farmers in Menkere cultivate two or three plots. In Ethiopia, over the last 20 years, cereal production has strongly increased. This is related to the efforts for land management, the feeling of ownership of the land, and investments done in agriculture. The land fragmentation, to a large extent, allows also the farmers to apply very intensified and diversified agriculture, that comes close to "precision agriculture". In Menkere, there is a complex interaction between biophysical and social system. Equal land sharing is attempted. Land holdings are small, and this leads to removal of the matrix vegetation. Many farmers need off-farm income (part- or full-time). Crop production and soil conservation have strongly increased.

III. The escarpment, a source of water and sediment

Several chapters address the escarpment itself that drains directly to the graben bottoms. Our researchers have been walking up and down this escarpment to study its environment and human impacts. Obviously, humans bring changes to woody vegetation cover there, but to what extent could increase or decrease of vegetation also be due to climate variability? In Chapter 7 the woody vegetation cover of the Raya graben is presented.

Chapter 7: Land cover and woody vegetation cover changes along the Raya escarpment (1972 – 2014)

We analysed the land cover changes along the Raya escarpment using ground reference data and multi-temporal Landsat satellite images for the period 1972 to 2014. As a re-greening of the study area was expected, special attention was given to the woody vegetation species in the area. The main species were identified in the field and their spatial distribution was studied. Observed land cover changes were a strong decline in farmland (from 60% to 35%) and an important increase in woody vegetation (from 33% to 53%) between 1972 and 2014. Despite this re-greening, the woody vegetation cover in the area is dominated by pioneer species (e.g. *Dodonea angustifolia*, *Carissa edulis* and *Euclea racemosa*) and indicator species for disturbance (e.g. *Cadia purpurea*, *Opuntia ficus-indica* and *Aloe sp*). Late-successional species that once dominated the escarpment (e.g. *J. procera* and *O. europaea*), almost completely disappeared from the open-access forests, and only can be found in protected (church) forests. Hence, it is recommended to focus on bushland and forest protection and restoration (establishment of new exclosures), especially in the southern part of the escarpment (west of Alamata to Robit). The last page of this book holds also a translation of scientific tree names to local tree names.

After understanding changes to vegetation cover, Chapter 8 addresses some evidence of this improved vegetation cover.

Chapter 8: Successful land rehabilitation on the escarpment

The catchments in the western rift valley escarpment of Ethiopia were severely degraded by the first half of the 1980s.The severity of the land degradation was mostly evidenced by development of dense gullies and scar networks in the steep slopes transporting huge volumes of floods and very big boulders down to the Raya graben. To reverse this problem, rehabilitation interventions that included establishment of exclosures were initiated in the mid-1980s. Consequently, the vegetation cover of many catchments has increased substantially. In order to study the role of the rehabilitation interventions on minimizing land degradation, (i) scar networks in 20 catchments were mapped in Google Earth Imagery and their density was correlated with greenness of vegetation cover in each catchment as represented by (Normalized Difference Vegetation Index and slope gradient), and (ii) changes in the geomorphology of stream channels were observed in the field. This study has shown that catchment rehabilitation interventions in northern Ethiopia have led to a remarkable improvement in vegetation cover and stabilization of the slopes in short time (less than 30 years). Particularly, the improvement in vegetation cover significantly reduced (i) scar density in all catchments except in the catchments with very steep slopes (with slope gradient >60%) and the size and amount of sediment supply to streams. Consequently, stream channels have been stabilized, incised, narrowed and many of the previously braided stream channels were abandoned in favour of single thread streams. Therefore, it is recommended that intensive rehabilitation interventions should continue on the relatively less rehabilitated catchments and the existing protection system of the catchments should be strengthened.

As shown in Chapter 9, such improved vegetation cover has led to decreased flooding, though floods remain strong.

Chapter 9: The floods from the escarpment

Owing to severe deforestation, the catchments in the western Rift Valley escarpment of Northern Ethiopia were highly degraded in the first half of the 1980s. Consequently, the high intensity of precipitation in such catchments led to extreme foods that usually produced environmental, economic and human losses in the marginal graben. As a result of the reforestation interventions that were initiated in the second half of the 1980s; the vegetation cover of the catchments has improved. In this research, we a studied the impact of vegetation cover change on instantaneous floods in 11 steep mountains which are under way of forest restoration. We monitored a total of 332 flood events in three rainy seasons (2012–2014). The result demonstrates that the reforestation interventions and the establishment of exclosures in the highly degraded catchments in particular have significantly minimized flood generation from the catchments. Based on this we recommend sustaining the reforestation efforts and establishment of further exclosures in the sloping catchments.

In small, steep escarpments, the floods cannot evacuate most of the sediment and it stays behind as rock deposits, also called "debris cones" (Chapter 10).

Chapter 10: Rocky deposits on the foot of the escarpment

Debris cones are widespread terrestrial landforms in semiarid regions. Therefore, the objectives of this study were to investigate the distribution and livelihood effects of debris cone in the marginal grabens. GoogleEarth Pro, Landsat images and questionnaire were employed address distribution and livelihood effects of debris cone in the grabens. The study points out that many debris cones are formed at the juncture of steeper hillslopes and the flatter graben bottoms along the Rift Valley. The study shows that the areal extent of the debris cones showed a linear association with the area of headwaters. Moreover, the average volumes of debris cones were larger (0.75 million m^3) in the basalt graben than in the limestone graben (0.08 million m^3). Furthermore, the expansion of debris cones inundated the graben bottom croplands. By contrast, debris cones absorb floodwater, build fertile soils and recharge the underlying aquifers that enriching the on-site blue and green water storages. Therefore, an integrated catchment rehabilitation should be implemented to reduce the expansion of debris cones in the grabens along the Rift Valley.

The large rivers are also carrying large volumes of sediment towards the graben bottoms. In Chapter 11, the thick river bridge sedimentation of the Raya graben is presented.

Chapter 11: River sedimentation at bridges in the Raya graben

The Raya graben is located along the margins of the Rift Valley in northern Ethiopia. Its ephemeral rivers are among its endowments that attract attention. The rivers flow from the high mountain range in the west to the graben bottom. During the rainy season the rivers transport large size of sediment. When they descend, they drop sediments under the bridges found at the foot of the escarpment. As a result, due to sediment fill up, it is a common practice to excavate the sediment from the bridges at least two times after the end of the rainy season. There are also times when the excavation takes place during the rainy season. Since there were no evidences of the miracles of the thick sediment deposits under the bridges, this study was conducted to understand the main controls of the bridge sedimentation. The study indicates that the hydraulic process around the bridge reaches is the main cause for the tick sediment deposition under the bridges. Since the width of the bridges is twice less than the channel width in upstream reaches, the flash floods flowing into the bridges are forced to sheer stress and decrease in velocity due to bridge narrowing. This process forces the flood to drop sediments under the bridge. Low vegetation cover in the upper catchment is also an important reason. Thus, the study suggests (1) width of the bridges should be at least as wide as the upstream channel reaches (but at a lower cost), (2) increase vegetation cover in the head waters in order to reduce the sediment input in the graben bottom, and (3) better results can be achieved if rivers are allowed to follow their natural process, there are flood protection measures in place which make the flooding impact worse.

IV. The Aba'ala, Kalla and Raya graben bottoms

The next seven chapters all concern water and land in the graben bottoms. Chapter 12 addresses the temporal broad meandering rivers in the graben bottoms.

Chapter 12: Temporal meandering rivers in the Raya graben bottom

The rivers in the Raya graben have a steep escarpment in their headwaters and flow to the flat graben bottom. As a result, they have a large land holding the graben bottom, particularly related to their expansive tributary systems. Related to their drainage behavior they show changes in length, area and direction. This tudy investigated the link between the upper catchment characteristics and the morph-dynamics of the rivers in the graben bottom (length and area). The study shows that area of the upper catchments is the most important controlling factor for the dynamics in the length (57%) and area (66%) of the rivers in the graben bottom. The study also shows that there is an increase in vegetation cover in the upper catchments starting from 1986. Hence, vegetation cover has a profound effect on the length and area of the rives. Measures geared towards reducing the impacts of river dynamics on agricultural activities and thereby the livelihood of the society in dryland areas with ephemeral rivers needs to focus on rehabilitation activities (soil and water conservation) in both the river reaches and upper catchments

Thanks to a lot of measurements, we are able, in Chapter 13, to share our understanding on the water in Aba'ala graben.

Chapter 13: The water of the Aba'ala graben

Grabens are major development corridors in Ethiopia, which needs to be understood for proper hydrological budget. However, the sustainability of water resources in the grabens of northern Ethiopia's Rift Valley are insufficiently understood to support planning and management of land and water resources. The objective of this study was to examine water balance of the Aba'ala limestone graben under the challenge of data scarcity. We measured the rainfall and river discharge in order to analyze the graben's runoff components. The rainfall volume in the Aba'ala graben has an erratic behaviour, and led to a rapid flood runoff of the major river into the graben bottom. However, the flood runoff and evapotranspiration affected the water availability in Aba'ala graben. Generally, the storage takes a share of 36% of the water inflow into the graben bottom. Therefore, a sustainable water management could reduce the temporal variation of the water storage in Aba'ala graben.

People in the Aba'ala graben have always been dependent on the floods from the highlands. Yet, in current years the landscapes have been changing (Chapter 14).

Chapter 14: Changing landscapes in the Aba'ala graben

This study analysed land use and land cover changes (LULC) in the Aba'ala graben between 1984 and 2018 and the impact of LULC changes on landscape structure of Aba'ala graben. The findings of the study show that farmland and settlement have increased at the expense of shrubland and bare land in the Aba'ala graben between 1984 and 2018. Consequently, shrubland and bare land have decreased from 51% and 27% in 1984 to 39% and 22% in 2018 respectively. On the contrary, settlement dramatically increased from 3% in 1984 to 12% in 2018, mainly due to the rapid population growth and sedentarization program of the government in the pastoral areas of the country in general and in the Aba'ala graben in particular. The increment in settlement and farmland in the Aba'ala graben has led to the increment of the number of patches, suggesting landscape fragmentation in the graben. The study calls up on regional and local governments to consider the expansion of agriculture and settlement and their adverse impacts on the landscape in their planning. In this case, the policy makers should give attention to the sedentarization program of the Afar pastoralists and should implement it in a well-organized manner.

Moving south, in Kalla graben (Chapter 15) we studied the competition for water and grazing grounds.

Chapter 15: Conflicts for water and grazing land in the Kalla graben

The study examined the process of transhumance and the linkages between the social and biophysical aspects of the landscapes in the grabens of northern Ethiopia. The study found that transhumance in the Kalla graben and its environs has led to conflicts between the highland agro-pastoralists and low pastoralists due to competition over scarce resources in the transhumance zones. The conflicts have also led to the displacement of communities from their original homeland, which abandoned a village. The Vegetation Index values measured in the abandoned village and on the escarpment showed an increasing trend due to the decrease of human and livestock pressure on the landscape in the Kalla graben and application of exclosures and soil water conservation interventions on the escarpments. The study recommends that policy makers and local governments should carefully consider the conditions of transhumance and its associated consequences. This can be done by ensuring sustainable management of landscapes through the establishment of strong environmental protection institutions, conflict resolution strategies and bylaws. Moreover, conflict resolution strategies need to be localized and the participation of elders and religious institutions need to be undertaken.

Similarly to Aba'ala, Chapter 16 address the water balance of the Raya graben.

Chapter 16: The waters of the Raya graben

Matching agricultural water demand and supply is a growing policy challenge in drylands. We investigated the water balance components in Raya (3507 km^2) and Ashenge (80.5 km^2) grabens. The rainfall depth, river discharge, abstraction, climate and soil data were used to address the research question. In addition, the average annual runoff depth of the Raya escarpment was substential than its graben bottom due to the contributing area and headwater elevation. About 40% of the runoff discharges reaching the Raya graben bottom were flushed out at its outlet. About 77 % of the annual rainfall left through evapotranspiration from the basalt grabens. As a result, 16% and 33% of the average annual inflows recharged in the Raya graben and Ashenge graben, respectively. Therefore, proper mobilization of water resources into agricultural development could be "a window of opportunity" to drift the region into better off economic base. These findings can be used to help achieve sustainable agricultural development.

Besides supplying a large share of the water available to the grabens, Chapter 17 shows that these rivers are also very dynamic and affect the landscape in the graben bottoms.

Chapter 17: Land cover in relation to stream dynamics in Raya graben

Land cover change remains a priority research need as it translates various aspects of human activities and earth surface processes. Rivers are important elements a landscape that need attention in land cover studies. This study focuses on the influence of rivers in the Raya graben on land cover change in the graben bottom. The study considered the Warsu river in the Kobo basin which was believed to represent the other rivers in Raya. The study shows that the land coverage that are related to the river dynamics are cyclic; the transitions are from farmland to stream channel/flood plain/bar, stream channel/flood plain/bar to grassland/bushland/forest, from grassland/bushland again to farmland. This is because the rivers turn the farmlands into a river channel/flood plain/bar and after some time this land is abandoned by the rivers and is transformed to grassland/shrubland. After a while, the farmers start to plow again after the soil gets its fertility back. In general, the changes in land cover due to the river morpho-dynamics have implications on the livelihoods of the farmers and land management in the study area. The land cover changes are not only related to a distributary river system but also that human intervention and natural vegetation regeneration are important. Land management interventions should consider the behaviour and impact of river systems. Allowing rivers to follow their natural bed can make rivers easily manageable.

Water availability is positive, yet Chapter 18 addresses the problem of salinity.

Chapter 18: Salinity conditions in the Raya graben

Rising salinity is a sever problem of sustainable agricultural development in arid and semi-arid regions. This study seeks to understand the spatio-temporal patterns of water salinity and their implication on the downstream water availability in the grabens of northern Ethiopia. We measured the electrical conductivity (EC) of flash floods, baseflows, springs, wells and lakes. The study indicates that significant difference in the EC values of the water points between rainy and dry seasons was found in the grabens. Additionally, the average annual water EC increased from the mountains towards the outlets of the graben basins. With this striking contrast, water salinity “hotspots” imply that the graben basins were in a “closing” state. As a consequence, an increasing water salinity may endanger agricultural production, especially when agricultural intensification will be fully underway in the graben landscapes. Thus, we suggest that integrated catchment management is needed to tackle the degrading water quality and quantity in the grabens along the northern Ethiopia Rift Valley.

V. Land management in the graben bottoms

Over the last years, changes of different nature have occurred in the Raya graben bottom. Chapter 19 discusses the effects of agricultural investments on land use change.

Chapter 19: Agricultural investments and land use change in the Raya graben

The study investigated the impact of agricultural investment on land use and land cover changes in the Raya graben. The study found that the expansion of agricultural investment has resulted in land use and land cover changes in Raya graben. Forest coverage in the investment areas of Kobo sub-basin decreased by 62%. In Mehoni sub-basin, shrubland in the selected investment areas decreased by 60%. Besides, settlements in the investments sites of Mehoni have been demolished. Conversely, the findings also indicate that irrigable land in Kobo sub-basin has increased by 74% and it also increased by 73% in Mehoni sub-basin. In conclusion, agricultural intensification and extensification of agriculture in the marginal grabens have resulted in land use and cover changes which in turn affected landscape services in the Raya graben. Hence, the study recommends that due considerations should be given to the landscapes by applying landscape-based environmental impact assessments on the agricultural investment areas.

Environmental changes and different use of the land jointly lead to landscape changes that are analysed in Chapter 20.

Chapter 20: Landscape dynamics and major drivers in the Raya graben

This study examined landscape composition and configuration in the Raya graben over a period of three decades. Farmland is the predominant landscape element in the study area. It has shown significant increase in size and fragmentation in the last three decades. Proportion of shurbland in the landscape has decreased and high fragmentation of shrubland is observed. Forest cover decreased progressively throughout the study period. The number of patches for forestland did not increase significantly. For villages both the mean patch size and number of patches have increased significantly, hence a progressive expansion of settlement. Built-up patches are consolidated around the cultivated land, shrubland, and at the edge of forestland. In the study area, changes are mainly human driven due to an increasing demand for food and settlement. Extinction of villages due to pooling up of scattered villages is also another cause. The increase in commercial agriculture is also a strong cause of landscape changes in the study area. Hence, we understood that the settlement pattern in the study area needs a serious attention and planning as the development of villages is in a scattered way and also that their expansion is towards farmland, shrubland and forestland.

Finally, Chapter 21 addresses very recent issues.

Chapter 21: The fertiliser excess crisis in the Raya graben and beyond (2012-2016)

As fertiliser sales have exponentially grown in Ethiopia, and evidence exists of a supply that was beyond the demand in the drier northern parts of the country, we investigated the inorganic fertiliser sales and its black-market resale prices in north Ethiopia. The research was conducted in 2016 in the Raya graben, and contrasted to other districts. Quantitative data on fertiliser provision, official prices and black-market prices in 2016 were obtained from official statistics and from key informants in each of the 35 studied districts and in all municipalities of the Raya area. To promote inorganic fertiliser, agricultural experts used incentives, and also bartered the purchase of fertiliser by a farmer against food aid or other advantages from the authorities. In 2016, the average official price at which the fertiliser was sold to the farmers was 1407 Birr per quintal, with variations for type of fertiliser and distance to Addis Ababa. The average price on the black market in the whole study area was 731 Birr per Qt, but only 463 Birr per Qt in the three graben woredas. In the Raya graben, only farmers with dry season irrigation state that they need fertiliser, others will sell it off. The farmers claimed that, first of all, the graben is a very hot area with moisture deficit, and secondly the land is fertile, in relation to the yearly deposition of a thin layer of alluvium originating from the escarpment. Most of the inorganic fertiliser on the black market was purchased by external users, with the help of local merchants or relatives who acted as brokers. By accepting to sell excess fertiliser to agricultural companies and traders, smallholders saved themselves from greater losses. Inorganic fertilisers are one of the elements that have allowed to boost agricultural production in Ethiopia, but the fertiliser policy needs to be much more fine-tuned so that it is led by agronomic needs, rather than by statistics of sold volumes of inorganic fertiliser. Pressurising smallholder farmers to purchase fertiliser against their will is a bad service to agricultural development.

የሰሜን ኢትዮጵያ ገራበኖች (Grabens) መሬት፣ ውሃ፣ ህዝብና ገፀ-ምድር

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[2] የጂኦግራፊ ት/ት ክፍል፣ ጌንት ዩኒቨርሲቲ፣ ቤልጅየም

I. መግብያ

የዚህ መፅሃፍ ሃያ አንድ ምእራፎች ውስጥ በ ግራበን ቲም (Graben TEAM) ፕሮጀክት የተገኙ የምርምር ውጤቶችን አስቀምጠናል፡፡ ግራበን (Graben) ማለት መሰረቱ የጀርመንኛ ቋንቋ ሲሆን በዳገታማ ከፍተኛ ቦታዎች የተከበበና በስምጥ ሸለቆና በኢትዮጵያ ከፍተኛ ቦታዎች ጠርዝ ላይ የሚገኝ ረጅም ሸለቆ (ሜዳ) ማለት ነው፡፡ የመፃሃፉ እዚህ ክፍል ስለፕሮጀክቱ አጭር ዝርዝር ምእራፍ አንድ የተቀመጠ ሲሆን ምዕራፍ ሁለት ላይ ስለ የጥናት ቦታዎቹ በህሪያት ተቀምጧል፡፡ እዚህ መፅሃፍ ላይ ያሉት አመታት በ ግሪጎሪያን አቆጣጠር ናቸው፡፡

ምዕራፍ 1፡ የግራበን ቲም (Graben TEAM) ፕሮጀክት

የ ግራበን ቲም (Graben" TEAM) ፕሮጀክት (2013-2018) በሰሜናዊ ኢትዮጵያ ከፍተኛ ቦታዎችና በስምጥ ሸለቆ መካከል የሚገኘውን የኢትዮጵያ የእድገት መተላለፊያ/መገናኛ ቦታ ላይ ትኩረት አድርጎ የተሰራ ነበር፡፡ እነዚህ ቦታዎች በአካባቢው በሚገኙ ከፍተኛ ቦታዎች የከባቢያዊ ለውጥና የአየር ንብረት ተለዋዋጭነት ምክንያት በቀላሉ ተጋላጭ ናቸው፡፡ ይህ ገፀ ምድር፣ ከአርብቶ አደርነት ጀምሮ የእህል ሰብሎችን መሰረት ያደረገ የሰብል ግብአት ስርአት እስከ ከፊል መስኖ ተኮር ግብርና ድረስ ለፈጣን ለውጥ የተጋለጠ ነው፡፡ በዚሁ አካባቢ በአፋር ዝቅተኛ ቦታ የሚኖሩ አርብቶ አደሮችና በትግራይና አማራ አርሶ አደሮች መካከል የመተባበርና የመጋጩት ሁኔታዎች ይታያሉ፡፡ በመሬትና ውሃ እቅድና አስተዳደር ለማበርከት የተቀናጀ የመሬት አጠቃቀም፣ የሰው አሰፋፈርና፣ የግብርና ስርአት ላይ ያተኮረ መልከአ ምድራዊ ጥናት ተደርጓል፡፡ ጥናቱ መቐለ ዩኒቨርሲቲንና በቤልጅየም የሚገኙ ጌንት ዩኒቨርሲቲና ሉቨን ካቶሊክ ዩኒቨርሲቲን ያካተተ ነበር፡፡

ምዕራፍ 2: በኢትዮጵያ አንባዎች እና በስምጥ ሸለቆ መካከል ባሉት ቦታዎች

ስለግራበኖች (grabens) የተሻለ ግንዛቤ ለማግኘት የአብዓላ፣ የካላ፣ ራያ እና አሸንጌ አካባቢዎችን እንደ ወካይ የምርምር ቦታዎች መርጠናል፡፡ እነዚህ ቦታዎች በከፊል ዳገታማ በሆኑ ከፍተኛ ቦታዎች የተከበቡ ናቸው፡፡ በዚህም ምክንያት አፈራቸውና ወሀቸው ከላይ በሚወርደው ጎርፍና ደለል እንደገና ይሞላል፡፡
በምዕራፍ ሁለት ውስጥ እንደተገለጸው የጥናት ቦታዎቹ ዋና ዋና ባህሪያት የሚከተሉት ናቸው፡፡

• **ስነ ምድራዊ ይዞታ፣** ግራበን (Graben)ማለት ልክ እንደ ገንዳ ትይዩ በሆኑ ዝንፈት መስመሮች የተከበበና ወደታች የወረደ ጥምረ መሬት ነው፡፡ ይህ የወረደ ጥምረ መሬት ሸለቆ በመፍጠር ተዳፋት በሆኑት የኢትዮጵያ ከፍተኛ ቦታዎቸ ጠርዝ ትይዩ ይሄዳል፡፡ በአማርኘኛው ትርጓሜ ወደታች የወረደው ጥምረ መሬት ሜዳ ብለን ልንጠራው እንችላለን፡፡ በአብዓላ አካባቢ የአንታሎ በሀ ድንጋይ (ኖራ)፣ በራያ አካባቢ ደግሞ ኮተቤ (ጥቁር ድንጋይ) የበላይነቱን ይይዛሉ፡፡ የሜዳዎቹ ወለል በደለል አፈር የተሸፈነ ነው፡፡

• በስምጥ ሸለዎ አዋሳኝ የሆኑት ሸለቆዎች በዋናነት ከፊል በረሃማ የአየር ንብረት አላቸው፡፡ ዋናው የዝናብ ወቅታቸው ክረምት ሲሆን የራያ አካባቢ ግን የበልግ ዝናብ ጭምር ያገኛል፡፡

• ወንዞቹ ዳገታማ ከሆኑ ከፍተኛ ቦታዎች ተነስተው ወደ ዝቅተኛው ሜዳማ አካባቢ በመፍሰስ የራሳቸው ከፋይ ይፈጥራሉ፡፡ ብዙዎቹ ወንዞች መውጫቸው ከመድረሳቸው በፊት ሜዳው ላይ ያልቃሉ፡፡ ከሜዳ የሚወጡባቸው በሮች በመሸርሸራቸው ምክንያት በጣም የጎደጎዱ ናቸው፡፡

• **አፈር**፣ በዋናነት የራያና የአሸንጌ አካባቢ አፈር መረሬ (ጥቁር) አፈር ሲሆን የአብዓላና የካላ ሜዳዎች አፈር ቡናማ አፈር (Cambisols**)** ነው፡፡ በአጠቃላይ ዳገታማ በሆኑት ከፍተኛ ቦታዎች ያለውን የአፈር ጥምረት ድንጋያማ/ጭንጫ አፈር (Leptosols**)** የበላይነቱን ይይዛል፡፡

• **የሕዝብ ብዛት**፣ በጥናት ቦታዎቹ በግምት 650000 ሰዎች ይኖራሉ፡፡ የራያና የአሸንጌ ኣካባቢዎች ጥቅጥቅ ያለ አሰፋፈር አላቸው፡፡ በነዚህ አካባቢዎች በዋናነት አማርኛና ትግርኛ ተናጋሪዎች እናም የተቀላቀሉ የኦሮምኛና አፋርኛ ተናጋሪዎች

ይገኙበታል፡፡ የአማርኛ፣ ትግርኛና ኦሮምኛ ተናጋሪዎች በአነስተኛ የግብርና ስራ ሲኖሩ አፋርኛ ተናጋሪዎቹ ደግሞ በአርብቶ አደርነት ይኖራሉ፡፡

• **የመሬት ሽፋን፣** የሸለቆዎቹ የምእራባዊና የምስራቃዊ ከፍተኛ ቦታዎች በዋናነት በሳርና ቁጥቋጦ ሽፋን የተሸፈኑ ሲሆን ሜዳዎቹ በአብዛኛው የእርሻ ቦታዎች ናቸው፡፡ በምዕራባዊ ከፍተኛ ቦታዎቹ የመሬት ማዳን ስራዎች ስለተሰራባቸው የተሻለ የደን (የእፅዋት) ሽፋን አላቸው፡፡

II. በሰሜን ኢትዮጵያ ዳገታማና ከፍተኛ ቦታዎች ጠርዝ ላይ (የምርምር ወጤቶች)

ይህ ክፍል ዳገታማና ከፍተኛ እንዲሁም አምባዎች (ሜዳማ የደጋ ቦታዎች) ላይ መሰረት አድርገው የተሰሩ ጥናቶች ውጤት ላይ ትኩረት ያደረገ ነው፡፡ እነዚህ የጥናት ቦታዎች በኢትዮጵያ ውስጥ ትላልቅ ከሚባሉ ተራሮች ውስጥ የሚገኙባቸው ናቸው፡፡ እነዚህ ከፍተኛ ቦታዎች ለሜዳማ ቦታዎቹ ዋና የውሃ ምንጭ ሆነው ያገለግላሉ፡፡ በዳገታማ ከፍተኛ ቦታዎች ጫፍ ላይ ደጋማ የአካባቢ ሁኔታ በምእራፍ ሶስት ቀርቧል፡፡

ምዕራፍ 3፡ በዳገታማ ከፍተኛ ቦታዎች ጫፍ ላይ ደጋማ የአካባቢ ሁኔታ

የኢትዮጵያ ከፍተኛ ቦታዎች የምስራቅ አፍሪካ ከ2000 ሜትር ከባህር ጠለል በላይ ከፍታ በላይ ያላቸውን 50 በመቶ የሚሆኑትን ቦታዎችን ይይዛል፡፡ እነዚህ አካባቢዎች የደጋማ ቦታ አካባቢያዊ ሁኔታ ለማጥናት አመች ናቸው፡፡ በዚህም ምክንያት በሰሜናዊው የአገሪቱ ክፍል የሚገኞ ሶስት የተራራ ሰንሰለቶች ላይ ጥናት ተደርጓል፡፡ እነሱም ሰሜን ተራሮች (4550 ሜትር ከባህር ጠለል በላይ)፣ አቡነ ዮሴፍ ተራራ (4277 ሜትር)ና ፈራሕ አምባ ተራራ (3939 ሜትር) ናቸው፡፡ እነዚህ ተራሮች የቀድሞ በረዷማነት መረጃዎችን የያዙ ናቸው፡፡ ወደ ሰሜን በሚያየው የላይኛው የአቡነ ዮሴፍ የተራራ ሰነሰለት ክፍል በትንንሽ የበረዶ ናዳዎች የሚመገቡ የበረዶ ክምችቶች እነደነበሩ ያሳያል፡፡ እስካሁን በኢትዮጵያ ተራራማ ቦታዎች በትንንሽ የበረዶ ናዳዎች የሚመገቡ የ ፕሌሰቶሴኔ (Pleistocene) በረዶ ክምችቶችን እንደነበሩ ያረጋገጠ ጥናት አልነበረም፡፡ በጥናቱ ቦታ የመጨረሻው የበረዶ ግግር ከነበረበር ጊዜ ጀምሮ 6 °C የሚሆን የሙቀት መጠን መቀነስ ተሰልቷል፡፡ አሁን ባለው ሁኔታ የውርጭ/አመዳይ ሂደት ተግባር በአመዳይ ስንጥቆችና ትናንሽ መዳሪዎች ላይ ተወስኖ ይገኛል፡፡ የደጋማና ውርጫማ ቦታዎች ደን ከ3200-3700 ሜትር ከፍታ ባላቸው ቦታዎች ይገኛል፡፡ ምንም እንኳን የሙቀት መጠን ቢጨምርም የአስታ/ውጨና ዛፍ ማብቂያ መስመር ከፍታ አልጨመረም፡፡ በምድር ወገብ አካባቢ በሚገኙ (tropical) የኢትዮጵያ ተራራዎች የዛፍ ማብቂያ መስመር ከፍታ በሰዎች ጣልቃ ገብነት (anthropo-zoogenic) የተመሰረተ ነው፡፡ ሆኖም ግን በተጠበቁ ከልከል ቦታዎች የሙቀት መጠን ለዛፍ ማብቂያ መስመር ዋናው ወሳኝ ምክንያት ነው፡፡ ስለዚህ የተራራማ ደኖች ስርአተ ምህዳር ጥቅማጥቅሞችን ወደነበሩበት ለመመለስ የመሬት አጠባበቅ ስራዎች ጠቃሚ ናቸው፡፡

ከፍተኛ ቦታዎቹ ውስጥም ትናንሽ ግራበኖች (Grabens) ይገኛሉ፡፡ ለምሳሌ ኮረም፣ አሸንጌና፣ ማይጨው በጥቂቱ ከሚጠቀሱት ናቸው፡፡ ምዕራፍ አራት ላይ በአሸንጌ ሐይቅ የረጅም ጊዜ የአፈር መሸርሸር ሁኔታን ያስቀምጣል፡፡

ምዕራፍ 4፡ በአሸንጌ ሐይቅ የረጅም ጊዜ የአፈር መሸርሸር

በደራሽ ውሃ/ጎርፍ የተከማቸ ደለልን በማጥናት ተፋሰሶች ላይ ለረጅም ጊዜ የነበረውን የመሬት መራቆት ሂደት እንድንረዳ ያደርጋል፡፡ ይሄንን በመረዳት ይወከላል ያልነውን ወደ አሸንጌ ሐይቅ የሚገባውን የመንከረ ጎረጎር ከፊል አካል ላይ ለተወሰነ ጊዜ የነበረውን የአፈር መሸርሸር ሁኔታ ላይ ክትትል በማድረግ ጥናት አካሂደናል፡፡ በጎረጎሩ ዎስጥ ወደ ሐይቁ አቅጣጫ ቅደም ተከተል ያላቸው የደለል ክምችቶች ላይ ምርምር አካሂደናል፡፡ በተጨማሪም ሐይቁ ውስት ያለው ደለል ላይ የስራትና የእድሜ ትንተና አካሂደናል፡፡ በዚሁም መሰረት በሐይቁ ውስጥ ከፍተኛ የደለል ክምችት የነበረበት ጊዜ ለማወቅ ችለናል፡፡ ይህ ደግሞ በአሸንጌ ተፋሰስ ከፍተኛ የሆነ የአፈር መሸረሸር መቼ እንደተከሰተ እንድናውቅ አድርጎናል፡፡ ባለፈው ግማሽ ምዕተ ዓመት የጎረጎሩ ዝግመተ ለውጥ እንደገና መዋጀት/ማነፅ ችለናል፡፡ ይሄንንንም የአየር ፎቶዎችና ቃለመጠይቅ ተጠቅመን አረጋግጠናል፡፡ የጎረጎሩ በጊዜ ሂደት በደለል መሙላት የትንተና ውጤትና በሐይቁ ላይ የተደረገው የደለል የእድሜ ትንተና ውጤት ይጣጣማሉ፡፡ ከ1970ዎቹ ጀምሮ የደለል መጨመር ታይቷል፡፡ በዚህ ጊዜ ከፍተኛ የሆነ የአሸዋ ደለል በሐይቁ ውስጥ ተከማችቶ ነበር፡፡ ሆኖም ግን በቅርብ ጊዜ በተፋሰሶች የደን (የእፅዋት) ሽፋን በመጨመሩ ምክንያት በሐይቁ ውስጥ ያለው የላይኛው ደለል ጥቂት አሸዋ ወይንም ከፍተኛ የለም አፈር/ሸክላ ይዘት ያለው ነው፡፡

ምእራፍ አምስት ከራያ ከፍተኛ ቦታዎች እስከ ኩሓ የሰብል ግብዓት ስርዓትን ያስቀምጣል፡፡

ምዕራፍ 5፡ በራያ ከፍተኛ ቦታዎች የሰብል ግብዓት ስርዓት

በሰሜናዊ የኢትዮጵያ ከፍተኛ ቦታዎች 33% የሚሆነው መሬት ለሰብል እርሻነት እያገለገለ ይገኛል፡፡. ይህ መሬት በዋናነት የሰብል ግብአት ስርአት እቅዳቸውን የአገር በቀል እውቀት በመጠቀም በሚሰሩ አነስተኛ አርሶ አደሮች የተታዘ ነው፡፡ ያለውን የሰብል ግብዓት ስርዓት በካርታ ለማስቀመጥና ከአመታዊ የዝናብ መጠን ጋር ያለውን ግንኙነት በመረዳት በሰሜን ኢትዮጵያ ከፍተኛ ቦታዎች የሰብል ግብአት ስርአት እንዴት እንደሚተገበሩ ያለንን ግንዛቤ ከፍ ማድረግ እንችላለን፡፡. ይሄንን ለመረዳት የራሳቸው የምርት ወቅት ርዝማኔና የግብአት ጥምረት ያላቸው አምስት ሰብሎችን አውጥተናል፡፡ እነሱም አጭር የሰብል ዑደት (አራት ወራት)፣ መደበኛ አጭር የሰብል ዑደት (አምስት ወራት)፣ መደበኛ ረዥም የሰብል ዑደት (ስድስት ወራት)፣ ረጅም የሰብል ዑደት (ዘጠኝ ወር) እና ረዥም ሁለት የሰብል ዑደት (አሥር ወራት) ናቸው፡፡ በአብዛኛው አጭር ኡደት ያላቸው ሰብሎች በሸለቆ ጥግ ላይ ሲገኙ ረዥም ዑደት ያላቸው ሰብሎች በሸለቆ ወለል ውስጥ የገኛሉ፡፡ የምርት ወቅት ርዝመትም ከሰሜናዊ ምእራብ ወደ ደቡባዊ ምእራብ አየጨመረ ይሄዳል፡፡ በአንድ የሰብል ግብአት ስርአት ውስጥ የምርት ጥምረት በከፍታ ልዩነት ይለዋወጣል፡፡ በተጨማሪም የሰብል ግብአት ስርአት ከአመታዊ የዝናብ መጠን ለውጥ ጋር ይለዋወጣል፡፡ ይህ በመሆኑ ምክንያት በተፋሰስና በክልል/አካባቢ ደረጃ የሰብል ግብአት ስርአት ለውጥ ያሳያል፣ ከፍተኛ አመታዊ የዝናብ መጠን ሲኖር የምርት ወቅት ረጅም እንዲሆን ያደርገዋል፡፡

በግራበኖቹ ጠርዝ ላይ ሰዎች ከረጅም አመታት ጀምሮ ይኖራሉ፡፡ ከዚህም ጋር ተያይዞ ምዕራፍ ስድስት በአሸንጌ ሃይቅ የሰዎች አሰፋፈርና የመሬት ይዞታ ሁኔታን ያስቀምጣል፡፡

ምዕራፍ 6፡ እኩል ካልሆነ የመሬት ይዞታ ወደ እኩልነት፣ በአሸንጌ ሐይቅ ኣካባቢ በመሬት መራቆት ላይ ያለው ተጽእኖ

በአሸንጌ ሃይቅ አካባቢ ላለፉት 100 አመታት የመሬት ሽንሽና በተለይም የመሬት ስርጭት በአፈር መሸርሸር ላይ እንዴት ተፅዕኖ እንደሚያሳድር ተመልክተናል፡፡ የአየር ፎቶዎችንና ቃለመጠይቆችን ተጠቅመን በጊዜ ሂደት ያለውን የመሬትን ይዞታ በካርታዎች አስቀምጠናል፡፡ በነበሩት የፊውዳል ዘመናት በጣም ያልተለመዱ የመሬት ይዞታዎች ነበሩ፡፡ ለምሳሌ መንከረ መንደር ውስጥ አንድ ደጃዝማች 14 ሄክታር እና ሌሎች ፊውዳሎችም ከዛ በላይ ትልቅ መሬት ነበራቸው፡፡ ነገር ግን ከ 50 በላይ ቤተሰቦች ምንም መሬት አልነበራቸውም፡፡ የደርግ መንግስት ስልጣን ከያዘ በኋላ ለመጀመሪያ ጊዜ የመሬት ይዞታ ክፍፍል አድርጓል፡፡ ሆኖም ግን ግልፅ ያልሆነና እኩል የመሬት ክፍፍል ያላደረገ ነበር፡፡ አንድ ገበሬ "ወሳኙ ነገር በእግርህ ነው የመጣኸው ወይስ በእጅህ’’ ሲል ተናገሯል፡፡ በእርግጥም በዚህ ወቅትም ቢሆን የቀድሞው ፊውዳሎች ትልቅ የመሬት ይዞታዎችን መያዝ ችለዋል፡፡ ህወሓት በ1990 አካባቢ ሌላ የመሬት ይዞታ ማሻሻያ አድረጓል፡፡ ዓላማው ለእያንዳንዱ ገበሬ (ወንድና ሴት) ተመሳሳይ መሬት እንዲኖረው ማድረግ ነበር፡፡ ኋላም አንዳንድ የመሬት ይዞታ ማስተካከያ ተደርገዋል፡፡ በመደበኛነት የመሬት ገበያም ነበር፡፡. ሰዎች መሬታቸውን ያከራዩ ነበር፡፡ ነገር ግን መሬት አይሸጡም ነበር፡፡ በአሁኑ ጊዜ በመንከረ መንደር 90% የሚሆኑት ገበሬዎች ሁለት ሶስት እርሻዎችን ያርሳሉ፡፡ በኢትዮጵያ ባለፉት 20 ዓመታት ውስጥ የሰብል ምርት በከፍተኛ ሁኔታ እያደገ መጥቷል፡፡ ይህም የመሬትን አስተዳደር መሻሻል፣ የመሬት ባለቤትነት ስሜት ማደግ እና በግብርና ላይ የተደረጉ ኢንቨስትመንቶች ጋር የተያያዘ ነው፡፡ በተጨማሪም የመሬት መበታተን ለአብዛኛው አርሶ አደር የተጠናከረና የተለያየ ከ "ዝንፍ የማይል ግብርና" ጋር ተቀራራቢ የሆነ የግብርና ስርአት እንዲከተሉ እድሉን ሰጥቷቸዋል፡፡ በመንከረ በስነሂወት-አካላዊ እና በማህበራዊ ስርዓቶች መካከል ውስብስብ የሆነ ግንኙነት አለ፡፡ እኩል የመሬት መጋራት ሙከራ ተደርጓል፡፡ የመሬት ይዞታ በጣም ትንሽ ነው፡፡ ይህ ሁኔታ ደግሞ የድምበር እፅዋት (matrix vegetation) እንዲወገዱ ያደርጋል፡፡ ብዙ አርሶ አደሮች ከእርሻ ውጭ ገቢ (በከፊል ወይም ሙሉ ጊዜ) ያስፈልጋቸዋል፡፡ የሰብል ምርት እና የአፈር ጥበቃም በከፍተኛ ደረጃ አድጓል፡፡

III. የውሃና የአፈር/አሸዋ ደለል ምንጭ የሆኑት ዳገታማ ከፍተኛ ቦታዎች

አስፈላጊውን መረጃ ለማግኘት ተመራማሪዎቹ በጥናት ቦታዎቹ ዳገታማ ቦታዎች ላይና ታች ብለዋል፡፡ እንደሚታወቀው የሰው ልጅ ጣልቃ ገብነት የደን (የእፅዋት) ሽፋን ለውጥን ያመጣል፡፡ የአየር ንብረት ለውጥ ያለው ተፅእኖስ ምን የመስላል? ለዚህ ጠያቄ መልስ ይሆን ዘንድ ምዕራፍ ሰባት በዝርዝር ያስቀምጣል፡፡

ምዕራፍ 7፡ በራያ ከፍተኛ ቦታዎች የመሬትና የእንጨት እፅዋት ሽፋን ለውጥ (ከ1972 እስከ 2014 ዓ/ም)

ከ1972 እስከ 2014 ዓ/ም ባለው ጊዜ ውስጥ ከመስክ የተሰበሰበ መረጃና የብዙ ጊዜ የላንድሳት የሳተላይት ፎቶዎችን በመጠቀም በራያ ከፍተኛ ቦታዎች ላይ ያለውን የመሬት ሽፋን ለውጥ ገምግመናል፡፡ የጥናቱ አካባቢ መሬትን የማዳንና ዳግም ማለምለም ይጠበቅ ስለነበር ለእንጨት እፅዋቶች ማደግና መለምለም ልዩ ትኩረት ተሰጥቶት ነበር፡፡ በአካባቢው ዋነኞቹ የእንጨት እፅዋት ዝርያዎችም በመስክ ላይ ተለይተው ተገኝተዋል፡፡ ከ1972 እስከ 2014 ዓ/ም ባለው ጊዜ ውስጥ ከተመዘገበው የመሬት ሽፋን ለውጥ የእርሻ መሬት በከፍተኛ ሁኔታ ሲቀንስ (ከ 60% ወደ 35%) የእንጨት እፅዋት ሽፋን (ከ 33% ወደ 53%) ጨምሯል፡፡ የዳግም መለምለም ሁኔታ ቢታይም በአካባቢው በብዛት በሚታወቁ የእፅዋት ዝርያዎች (ለምሳሌ ክትክታ፣ ኢጋምና ደደሆ)እና የእፅዋት መረበሽ አመላካች የሆኑ ዝርያዎች (ለምሳሌ ሽለን፣ አሸዋ ቁለቋልና እሬት) የበላይነትን ወስደዋል፡፡ በከፍተኛ ቦታዎቹ ላይ የበላይነትን ይዘው የነበሩ ዘግይተው የሚመጡ/የሚለመልሙ ዝርያዎች (ለምሳሌ ጽድና ወይራ) ከገላጣው ደን ሙሉሙሉ ጠፍተዋል፡፡ በቤተክርስቲያን ደኖች ብቻ ተወስነው ይገኛሉ፡፡ ስለዚህ የጫካዎች እና የደን ጥበቃ እና መልሶ ማዳን (አዳዲስ ክልክሎች በማቋቋም) በተለይም በራያ ከፍተኛ ቦታ ደቡባዊውአካል (ከአላማጣ በስተ ምእራብ እስከ ሮቢት) ላይ ትኩረት ማድረግ ያስፈልጋል፡፡ በዚህ መፅሃፍ መጨረሻ ገፅ ላይ የተክሎች ትርጓሜ ተሰጥቷል፡፡

ያለውን የደን ሽፋን ከተረዳን ለውጦች እንደነበሩና መኖራቸው ላማሳየት ማስረጃዎች የሚሆኑ የጥናት ወጤቶች ምዕራፍ ስምንት ላይ ተቀምጠዋል፡፡

ምእራፍ 8፡ በሰሜን ኢትዮጵያ ከሚገኙ ዳገታማ ተዳፋት ተፋሰሶች የተከናወኑ ስኬታማ የተፈጥሮ ሃብት እንክብካቤ ስራዎች

በሰሜን ኢትዮጵያ ከሚገኙ ዳገታማ ተዳፋት ተፋሰሶች እስከ 1970ዎቹ ለከፍተኛ የደን መጨፍጨፍ እና የመሬት መሸርሸር አደጋ ተጋልጠው የነበሩ ሲሆን በዚህ ምክንያት ከተፋሰሶቹ የሚፈሱ ድንገተኛ ጎርፎች በራያ በሚገኙ መንደሮች እና ከተሞች በሂወት እና ንብረት ላይ ትልቅ ጉዳት ሲያደርሱ ነበር፡፡ይህንን ችግር ለመፍታት ከ1975 ኢ.ም እንደ ኤውሮጳውያን አቆጣጠር ጀምሮ የተለያዩ የተፈጥሮ ሃብት እንክብካቤ ስራዎች በተለይ ደግሞ በጣም የተጎዱ ተፋሰሶችን ከሰው እና እንስሳት ንክኪ ነጻ የማድረግ ስራዎች ሲከናወኑ ቆይተዋል፡፡ ይህ ጥናት በነዚህ ተፋሰሶች ሲከናወኑ የቆዩ የተፈጥሮ ሃብት እንክብካቤ ስራዎች ያመጡት ለውጥ ለመረዳት የተከናወነ ጥናት ሲሆን ጥናቱ 20 የተለያየ የደን መጠን ያላቸው ተፋሰሶች በመምረጥ በእያንዳነዱ ተፋሰስ የነበሩት ጥልቅ ቦረቦሮች (scars) በእያንዳንዱ ተፋሰስ በሚገኘው የደን አረንጓዴነት(Normalized Difference Vegetation Index) በማወዳደር እና የደን ለውጡን ተከትለው በተከሰቱት የጎርፍ ለውጥ ምክንያት በእያነዳንዱ ወንዝ፣ የተፈጠሩት የስፋት፣ የጥልቀት ፣ እንዲሁም የቅርጽ ለውጦች በማጥናት የተከናወነ ነው ፡፡ የጥናቱ ውጤት እንደሚያሳየው በተፋሰሶቹ የተከናወኑት የተፈጥሮ ሃብት እንክብካቤ ስራዎች ከሌሎች ባከባቢው የተካሄዱ ተመሳሳይ ስራዎች ሲወዳደር ባጭር ጊዜ (30 አመት) የተፋሰሶቹ የደን መጠን በከፍተኛ ደረጃ እንዲጨምር ያደረጉ ሲሆን ከዚህ በተጨማሪ እስከ 1975 እ.ም ሲከሰቱ የነበሩ ጥልቅ ቦረቦሮች (Scars) ከተወሰኑ ከፍተኛ ተዳፋት ያለባቸው ተፋሰሶች (with slope gradient >60%) ውጭ በሁሉም ተፋሰሶች በጣም እንዲቀንስ አድርገዋል፡፡ በተጨማሪም የተፋሰሶቹን ደን መጨመር ተከትሎ ከነዚህ ተፋሰሶች ሲፈሱ የነበሩ ጎርፎች በመቀነሳቸው በነዚህ ተፋሰሶች የሚገኙ ወንዞች እየጠበቡ እና ጥልቀታቸው እየጨመረ መምጣቱ እነዲሁም ለሁልት ና ከዛ በላይ ተከፋፍለው የነበሩት ወንዞች ወደ አንድ ተቀይረዋል፡፡ ስልዚህ ተመራማሪዎቹ የተፈጥሮ ሃብት እንክብካቤ ስራዎች ተጠናክረው እንዲቀጥሉ ይመክራሉ ፡፡

የታዩት የደን ሽፋን ለውጦች የጎርፍ መጠንና ክስተት መቀነስን ያስከትላሉ፤ጎርፎቹ አሁንም ጠንካራ ቢሆኑም፡፡ ይሄንን ጉዳይ አስመልክቶ መዕራፍ ዘጠኝ አስቀምጧል፡፡

ምእራፍ 9፡ በሰሜን ኢትዮጵያ ከሚገኙ ዳገታማ ተዳፋት ተፋሰሶች የሚፈሱ ጎርፎች መቀነስ

ይሄ ጥናት በሰሜን ኢትዮጵያ ከሚገኙ ዳገታማ ተዳፋት ተፋሰሶች ከ1975 ኢ.ም እንደ ኤውሮጳውያን አቆጣጠር ጀምሮ ሲከናወኑ የቆዩት የተፈጥሮ ሃብት እንክብካቤ ስራዎች በተፋሰሶቹ የተፈጥሮ ሀብት መሸርሸርን ለመቀነስ በተለይ ድግሞ የደን መጠን ለማሻሻል እንዲሁም ከነዚህ ተፋሰሶች ሲፈሱ የነበሩት ጎርፎች ለመቀነስ ያበረከቱት አስተዋጽኦ ለመረዳት የተካሄደ ጥናት ነው፡፡በመሆኑም ለዚህ ጥናት በተመረጡ 11 ተፋሰሶች በሶስት ተከታታይ አመታት (2012–2014) 332 ጎርፎችን በመለካት የተካሄደ ሲሆን ከእያንዳነዱ ተፋሰስ የተለካው የጎርፍ መጠን ልዩነት በእያነዳነዱ ተፋስስ በተለካው የዝናብ መጠን፣ የደን መጠን እንዲሁም የእያነዳነዱ ተፋሰስ የመልክኣምድር ባሕርይ ልዩነት መሰረት በማድረግ ተተነትነዋል፡፡ የጥናቱ ውጤት እንደሚያሳየው በተፋሰሶቹ የተከናወኑት የተፈጥሮ ሃብት እንክብካቤ ስራዎች የተፋሰሶቹ የደን መጠን እንዲጨምር ከማድረጋቸውም ባሻገር ከነዚህ ተፋሰሶች ሲፈሱ የነበሩት ጎርፎች በእጅጉ እነዲቀንስ እና እነዚህ ጎረፎች በራያ

በሚገኙ መንደሮች እና ከተሞች ሲያስከትሉተ የነበረው የማህበረ ኢኮኖሚያዊ እና ሰብአዊ ጉዳቶች መቀነሳቸው ያሳያል፡፡ በዚህ መሰረት በተፋሰሶቹ የሚከናወኑ የተፈትሮ ሃብት እንክብካቤ ስራዎች ተጠናክረው እንዲቀጥሉ እንመክራለን፡፡

በትናንሽ ዳገታማ ቦታዎች ጎርፉ ያለውን ደለል ሁሉ አጥቦ አይወስድም፡፡ ድንጋያማ የሀኑትን ደሎሎች ተራሮቹ እግር ላይ ያስቀምጣል፡፡ ምእራፍ አስር የሄንን መሰረት አድርጎ የተሰራን የምርምር ውጤት ያቀርባል፡፡

ምዕራፍ 10፡ ዳገታማ በሆኑ ተራሮች ስር የተቀመጠ የድንጋይ ደለል

ብዛት ያላቸው የደለል ክምር በደረቃማ መሬት ይገኛሉ፡፡ የጥናቱ ዓላማ በረባዳ መሬት (ግራበን) ቦታዎች ያለው ኣለት የበዛበት የደለል ክምር ዝርጋታው እና በንሮ ላይ የሚያሳድረው ተፅዕኖ መመርመር፡፡ በግራበኖች የሚገኘው ኮረት የበዛበት ደለል ክምር ዝርጋታ እና ይህንን በንሮ ላይ የሚያሳድረው ተፅዕኖ ለማየት ጉጎል አርዝ፣ የሳትላይት ምስሎችና ፅሑፋዊ ተጠይኾል። ይህ ጥናት ኮረት የበዛበት የደለል ክምር ገደላማ ቦታዎች በሚገጣጠሙበት እና ስምጥ ሸለቆ ባለው የግራበኖች ታቸኛው ክፍል እንደሚፈጠሩ ያመለክታል። ኮረት በበዛባቸው የደለል ክምር ያላቸው የኤርያል መጠን ከወንዙ ከሚነሳበት ምንጭ ቀጥተኛ የሆነ ዝምድና እንዳላቸውም ያሳያል። በተጨማሪ፣ ኣማካይ ይዘት መጠን ኮረት የበዛባቸው የደለል ክምር ከኖራ ድንጋይ ግራበኖች (0.08 ሚልዮን ሜ^3) የጥቁር ድንጋይ ግራበኖች (0.75 ሚልዮን ሜ^3) እንደሚበልጥ ያስረዳል። ብተመሳሳይ፣ የኮረት የበዘባቸው የደለል ክምር መስፋፋት ወይ መጨመር በታቸኛው ክፍል ግራበኖች የሚገኝ የእርሻ ቦታ በውሃ እንዲጥለቀለቅ እንደሚያደርግም ያስገነዝባል። በንፅፅር፣ ኮረት የበዛባቸው የደለል ክምር ውሃ ወደ ውስጢ እንዲዘለቅ መጠው ያስቀራሉ፣ ለም አፈር ይፈጥራሉ ብዛት ያለው የከርሰ ምድር ውሃ እንዲኖርም ያግዛሉ። ስለዚህ በስምጥ ሸለቆ በሚገኙ በሚገኙ በጥቅም ላይ ያልዋሉ ግራበኖች አስተማማኝ የሆነ የእርሻ ምርቶች ለማፍራት የተቀናጀ የገፀ ምድር እና የከርሰ ምድር ውሃ አጠቃቀም አስፈላጊ ነው።

ወንዞቹ ትልቅ ደለል ወደ ሜዳማ ቦታዎቹ ይዘው ይወርዳሉ፡፡ በምዕራፍ አስራ አንድ በራያ ወነዞች ድልድዮች የአሸዋ ደለል መሙላት ሁኔታን እናያለን፡፡

ምዕራፍ 11፡ በራያ ወነዞች ድልድዮች የአሸዋ ደለል መሙላት

የራያ አካባቢ በሰሜን ኢትዮጵያ በስምጥ ሸለቆ አዋሳኝ ቦታዎች ውስጥ የሚገኝ ሲሆን ትላልቅ ወንዞቹ ተፈጥሮ ካደለችው ነገሮች ውስጥ ትኩረት የሚስቡ ናቸው፡፡ እነዚህ ወንዞች ከራያ ሜዳ በስተምእራብ በኩል ባለው ከፍተኛ ተራራማ ቦታ ተነስተው ወደ ሜዳ የሚፈሱ ሲሆን ዝናባማ በሆነ ወቅት ትልቅ ደለል ይዘው ይወርዳሉ፡፡ በሚወርዱበት ጊዜ የወንዞቹ መግቢያ ላይ በሚገኙት ድልድዮች ላይ ደለላቸውን ጥለው ያልፋሉ፡፡ በዚሁም ምክንያት ድልድዮች እንዳይዘጉ የዝናባማ ወቅቶች አንዳለፉ ቢያንስ በአመት ሁለት ጊዜ በዝናባማ ወቅቶች ጭምር ከ 2 ጊዜ በላይ ደለል ማንሳት የሁልጊዜ ስራ ነው፡፡ ሆኖም ግን በድልድዮቹ ስር የሚጣልው የደለል መጠን ሙብዛት ምክንያቶቹ ምን እንደሆኑ በቂ የሆነ ጥናት ባለመኖሩ በዚህ ጥናት ለማየት ተሞክሯል፡፡ ጥናቱ እንደሚያሳየው በዋናነት በድልድዮቹ ዙርያ ባለው ግፊተ ውሃ ድርጊት (hydraulic process) ምክንያት እንደሆነ ያመላክታል፡፡ በዋናነት የድልድዮቹ መጥበብ ትልቅ ምክንያት ሆኖ ተገኝቷል፡፡ የድልፍዮቹ ስፋት ከወነዞቹ ስፋት ሁለት አጅ ያነሰ በመሆኑ ምክንያት ወደ ድልድዮቹ የሚፈሰው ውሃ መጨናነቅ ይፈጠርበትና ይዞት የመጣውን ደለል ድልድዮቹ ስር እንዲጥላቸው ይገደዳል፡፡ ጠንከር ባላ የቀመር ውጤት ባይደገፍም የተፋሰሶቹ የደን/እፅዋት ሽፋንም የራሱ የሆነ የማይናቅ ሚና አለው፡፡ ስለዚህ ጥናቱ እንደሚያሳየው (1) የድልድዮቹ ስፋት በተቻለ መጠን (ወጪን በቆጠበ መልኩ) ቢያንስ የወንዞቹን ስፋት ያክል ሆኖ ቢገነባ፣ (2) የተፋሰሶቹ የደን/እፅዋት ሽፋን እነዲጨምር በማድረግ ከላይ ታጥቦ የሚመጣውን የደለል መጠን መቀነስ ይቻላል እና፣ (3) ወንዞቹ የተፈጥሮ ሂደታቸውን እንዳይከተሉ በሚደረጉት የጎርፍ መከላከል ስራዎች ምክንያት የበለጠ አጥፊ እንዲሆኑ እየተደረገ ስለሆነ የተፈጥሮ ሂደታቸውን ጠብቀው እንዲሄዱ ቢደረግና ተፋሰሳቸው ላይ የአፈርና ውሃ ግደባ ስራዎች በሰፊው ቢሰራ የተሻለ ውጤት ይገኛል፡፡

IV. የአብዓላ፣ ካላና፣ ራያ ሜዳዎች

ቀጣዮቹ ሰባት ምዕራፎች ሜዳማ ቦታዎች ውስጥ ያሉ የውሃና የመሬት ሃብቶችን ያስቃኙናል፡፡ ምዕራፍ አስራ ሁለት ከጊዜ ጋር የሚለዋወጡት የራያ ጠመዝማዛ ወንዞች ዙርያ ያለውን የጥናት ውጤት ያሳያል፡፡

ምዕራፍ 12፡ ከጊዜ ጋር የሚለዋወጡት የራያ ጠመዝማዛ ወንዞች

የራያ ወንዞች ከራያ ሜዳ በስተምእራብ በኩል ባለው ከፍተኛና ተራራማ ቦታ ተነስተው ፈጣን በሆነ ፍሰት ወደ በተቃራኒው ዝቅተኛ የሆነው የራያ ሜዳ ይገባሉ፡፡ በዚህም ምክንያት በራያ ሜዳ ውስጥ ከፍተኛ የሆነ የመሬት ይዞታ አላቸው፡፡ ከዚህም ጋር ተያይዞ ባላቸው የተፋሰስ ባህሪ በየጊዜው የስፋት፣የርዝመትና የአቅጣጫ ለውጥ ያሳያሉ፡፡ ላላቸው ርዝመትና ለያዙት የቦታ ስፋት ዋና ምክንያቶች ምን እንደሆኑ በግልፅ ስለማይታወቅ ይህ ጥናት ይሄንን ትኩረት አድርጎ ተሰርቷል፡፡ ጥናቱ እንደሚያሳየው የላይኛው ተፋሰሳቸው ስፋት ዋና ወሳኝ ምክንያት እንደሆነ ታይቷል፤ ለምሳሌ ወደ 57% የሚሆነው የወንዞቹ ርዝመትና 66% የሚሆነው የያዙት ቦታ ስፋት ለውጥ በተፋሰሳቸው ስፋት እንደሚወሰን ያሳያል፡፡ በተጨማሪም በተደረገው ጥናት ከ1978 ዓ/ም ጀምሮ የደን/እፅዋት ሽፋን እየጨመረ እንደሆነ ያሳያል፣ በመሃል የመጨመርም የመቀነስም አዝማሚያም አለው፡፡ ስለዚህ የደን ሽፋንም በወንዞች ርዝመትና ስፋት ላይ የማይናቅ ተፅእኖ እንዳለው ያሳያል፡፡ ስለዚህ ማንኛውም ወንዞች በእርሻ ስራውች ላይ ያላቸውን ተፅእኖ ለመቀነስ ብሎም የማህበረሰቡን የኑሮ ሁኔታ ለማሻሻል የሚደረጉ የመሬት ማዳን ስራውች በተፋሰሶቹና ወነዞቹ ዙርያ ትኩረት ያደረገ ቢሆን የወንዞቹን ይዞታና የማጥፋት ሃይል መቀነስ እንደሚቻል ጥናቱ ያመላክታል፡፡

መረጃ ለማግኘት ለተደረገው ጥረት ሊያመሰገንን ምዕራፍ አስራ ሶስት የአብዓላ የውሃ ሃብትን ያስቀምጣል፡፡

ምዕራፍ 13፡ የአብዓላ ግራበን (Graben) የውሃ ሐብት

በረባዳ መሬት (ግራበን) የተሸፈኑ የኢትዮጵ ስምጥ ሸሎቆ ውስጥ በሚገኙ እንደ ውሃ የመሳሰሉት የተፈጥሮ ሃብቶች በአስተማማኝነት የመጠቀም ዕቅድና አያያዝ ያለው ግንዛበ አንስተኛ ነው። ስለሆነም የጥናቱ ዓላማ የመረጃ እጦት ባለበት ሁኔታም ቢሆን፣ አብዓላ በሚገኘው የኖራ ድንጋይ ግራበን ያለውን የውሃ መጠን ለመዳሰስ፡፡ የዝናብ መጠን የሚገልፅ መረጃ ለመሰብሰብ ለሦስት ዓመታት (2015-2017) የዝናብ መጠን መለከያ መሳርያዎች (ሬንጌጆች) ተከለናል። በተጨማሪ፣ ከወንዝ የሚፈሰውን የውሃ መጠን ብቁጥር ለክቶ ለማስቀመጥ ወንዞች ጌጆች ጥቅም ላይ ውለዋል። የዝናብ መጠን ተለዋዋጭ ባህርያት አሉት። ይህንን የባህሪ ተለዋዋጭነት ፈጣን የውሃ ፍሰት እና ወይ ማጥለቅለቅ በዋናው ወራጅ ውሃ አድርጎ ወደ ታቾኛው ክፍል የአብዓላ ግራበን እንዲያመራ ያደርጋል። ብተጨማሪ ከመሬት ወደ አየር የምያመለጥ ዉሃ ብዙ ነዉ፡፡ በኣጠቃላይ፣ በኖራ ድንጋይ ግራበን ከሚፈሰው ውሃ 36% ወደታቸኛ የግራበኑ ክፍል ዘልቆ ይገባል። ይህ በመሆኑ የእርሻ ምርቶች ለማፍራት የተቀናጀ ውሃ አጠቃቀም እና ተገቢ የመሬት አያያዝ እና ለተለያዩ ጉዳዮች የሚያስፈልግ ጥሩ የውሃ አመዳደብ አስፈላጊ ነው።

ከቅርብ ጊዜ ወዲህ በአብዓላ ሜዳ ላይ የገፁ ምድር ለውጦች እየታዩ ነው፡፡ ይሄንን አስመልክቶ የተደረገው የጥናት ውጤት ምዕራፍ አስራ አራት ላይ ተቀምጧል፡፡

ምዕራፍ 14፡ በአብዓላ ረባዳ ምድር የምድር ገፅታ ተለዋዋጭነት

ይህ ጥናት በአብዓላ ረባዳ ምድር የምድር ገፅታ የመሬት አጠቃቀምና የመሬት ሽፋን ለውጥና በመሬት አቀማመጥ መዋቅር ላይ ያመጡትን ለውጥ ላይ ያደረገ ነበር፡፡ በጥናቱ መሰረት በአብዓላ ከ1984-2018 ባለው ጊዜ ረባዳ ቦታዎች በቁትቋጦ በመሸፈንና ገላጣ በመሆን ፈንታ የሚታረስ መሬትና የመኖሪያ መንደሮች በከፍተኛ ደረጃ እያደጉ መምጣታቸውን አሳይተዋል። ከዚህ የተነሳ በቁትቋጦ የተሸፈኑ እና ሰው ያልሰፈረባቸው ገላጣ ቦታዎች በ1984 ከነበረው 51%፣ እና 27%፤ በ2018፣ ወደ 38.9% እና 22.3% በቅደም ተከተል ቀንሰዋል። በተቃራኒው የመኖሪያ መንደር በ1984 ከነበረው የ3.3% በ2018 ወደ 12.4% አሻቅቧል። በተለይ የህዝብ ቁጥር ዕድገትና በመንግስት በአገሪቱ ባጠቃላይ በተለይም ደግሞ በአብዓላ በመካሔድ ላየ ያለው አርብቶ አደሮችን በመንደር የማሰባሰብ መርሃግብር ምክንያት ዕድገቱ ከፍተኛ ሆኗል። የመኖሪያ መንደሮችና የሚታረስ መረት መጨመር የምድር ገፅታ መበታተን አስከትላል፡፡ስለሆነም ይህ ጥናት ክልላዊና ከባቢያዊ መንግስታት የእርሻና የመኖሪያ መንደሮች መስፋፋት በትኩረት ማየት እንዳለባቸው ያሳስባል፡፡ በተጨመሪም ጥናቱ ሰዎችን በመንደር የማሰባሰብ መርሃግብር በታቀደና በተቀናጀ መልክ መተግበር እንዳለባቸው ያሳያል።

በካላ አካባቢ ለውሃና ለግጦሽ መሬት ያለውን ፉክክር በተመለከተ ምዕራፍ አስራ አምስት ላይ ኢይተናል፡፡

ምዕራፍ 15፡ በካላ ረባዳ ምድር ለውሃና ለግጦሽ መሬት የሚደረገው ግጭት

ይህ ጥናት በሰሜን ኢትዮድያ የምድር በሚገኙ የኻላ ረባዳ ቦታዎች እና አካባቢው ላይ የሰውና የእንስሳት ወቅታዊ እንቅስቃሴ (Transhumance) ሂደትና ከ ማህበራዊና ስነ አከባቢያዊ ያለው ቁርኝት ላይ የተደረገ ነው፡፡ ጥናቱ በኻላ ረባዳ

ቦታዎች የሰውና የእንሰሳት ወቅታዊ እንቅስቃሴ በደጋማና ቆላማ ነዋሪዎች መካከል የጥቅም ግጭት መኖሩ አሳይተዋል፡፡ የተከሰቱ ግጭቶች ደግሞ የሰዎች ከቀያቸው መፈናቀልና የመንደር ውድመት አስከትለዋል፡፡ የእፅዋት ሽፋን መለኪያ ውጤት እንደሚያሳየው በወደመው መንደርና በተዳፋቶች ላይ የእፅዋት ሽፋን ጭዋማሪ አሳይተዋል፡፡ የእፅዋት ሽፋን መጨመር ዋና ምክንየቶች ደግሞ በኻላ ረባዳ ቦታዎች ላይ የነበረው የሰዎችና የእንሰሳት ተጽእኖ መቀነስና በተዳፋቶች ላይ የተደረጉ የአጥር፣ የውሃና የአፈር ጥበቃ ስራዎች ናቸው፡፡ ስለሆነም ጥናቱ ፖሊሲ አውጭዎችና የክልል መንግስታት ከሰውና ከእንሰሳት ጊዜያዊ እንቅስቃሴ ጋር ተያይዘው የሚመጡ ችግሮችን ግምት ውስጥ ማስገባትና ትኩረት መስጠት እንደሚኖርባቸው ይጠቁማል። ይህም ዘላቂነት ያለው የምድር ገፅታ አቀማመጦች አስተዳደርን ማረጋገጥም፣ ጠንካራ የአከባቢ ጥበቃ ተቋማትን መመስረት፣ የግጭት መፍቻ ስልቶችና ህጎችን በመፍጠርና የግጭት አፈታት ስልቶችን ከአከባቢው ማህበረሰብ ጋር የተጣጣመ ማድረግ እና የአገር ሽማግሌዎችንና የሀይማኖት ተቋማትን ማካተት ያስፈልጋል።

የራያ የውሃ ሐብት በተመለከተ ምዕራፍ 16 ላይ ተቀምጧል፡፡

ምዕራፍ 16፡ የራያ ግራበን (Graben) የውሃ ሐብት

በበረባዳ መሬት (ግራበን) የተሸፈኑ የኢትዮጵ ስምጥ ሸሎቆ ውስጥ በሚገኙ የውሃ የተፈጥሮ ሃብት በአስተማማኝነት የመጠቀም ዕቅድና አያያዝ ያለው ግንዛበ አንስተኛ ነው። ስለሆነም የጥናቱ ዓላማ በራያ እና ሃሸንገ ጥቁር ድንጋይ ግራበኖች የሚገኙ የውሃ መጠን ኣካላት ብቁጥር ለማስቀመጥ፡፡የዝናብ መጠን የሚገልፅ መረጃ ለመሰብሰብ ለሦስት ዓመታት (2015-2017) የዝናብ መጠን መለክያ መሳርያዎች (ሬንጌጆች) ተክለናል። በተጨማሪ፣ ከወንዝ የሚፈሰውን የውሃ መጠን ብቁጥር ለክቶ ለማስቀመጥ የወንዞች ጌጆች ተጠቅመናል። በተመሳሳይ፣ በአካባቢው ያሉ ቦታዎች ያላቸው የውሃ መጠን ለማስላት የውሃ ፍሰት፣ የአፈር ባህርያት፣ የአየር ሁኔታ መለክያ እና የመሬት ኣጠቃቀም የሚገልፁ መረጃዎች እንደማጠናከርያ አገልግለዋል። ጥናቱ እንደሚያሳየዉ የዝናብ መጠን ተለዋዋጭ ባህርያት አሉት። ይህንን የባህሪ ተለዋዋጭነት ፈጣን የውሃ ፍሰት እና ወይ ማጥለቅለቅ በዋናው ወራጅ ውሃ አድርጎ ወደ ታቸኛው ክፍል ግራበኖች ዘልቆ ይፈሳል። ብተጨማሪ፣ ዓመታዊ ኣማካይ የፍሰት መጠን በአከባቢ ከሚኖረው አስተዋፅኦ የፍሰቱ ምንጭ ከሆነ የውሃ ከፍታ የራያ ገደላማ ቦታዎች ከታቸኛው የግራበኑ ክፍል ($p<0.001$) የበለጠ ፍሰት አለው። ወደ ታቸኛው የራያ ግራበን ክፍል ከሚፈሰው 40% በመተላለፍያ በኩል ኣድርጎ ፈሶ ይቀራል። በጥቁር ድንጋይ ግራበን ከዝናብ ከሚጠራቀመው ዓመታዊ የውሃ መጠን 77% ለትነት ይጋለጣል። በዚህ ምክንያት፣ የራያ ግራበን እና የሃሸንገ ኃብየን ዓመታዊ አማካይ የውሃ ፍሰት በቀደም ተከተል 16% እና 33% ነው። በአጠቃላይ፣ ስለሆነም፣ በግራበኖች ያለው ውሃ በአግባቡ በመጠቀም የተሻለ ኢኮኖምያዊ ለማምጣት ተገቢ የሆነ ማነሳሳት ወይ ማናቃቃት ማድረግ ያስፈልጋል። የተቀናጀ ውሃ አጠቃቀም እና ተገቢ የመሬት አያያዝ ለየተሻለ ኢኮኖምያዊ ለማምጣት አስፈላጊ ነው።

ውሃ ከማቅረብ በተጨማሪ እነዚህ ወንዞች በሜዳማ ቦታዎች ገፀ-ምድር ለውጥ ላይ አስተወፅኦ አላቸው፡፡ ምዕራፍ አስራ ሰባት የራያ ወንዞች ስኑ-ቅርፅ መለዋወጥና በራያ ሜዳ ላይ ያመጣውን የመሬት ሽፋን ለውጥ ያሳያል፡፡

ምዕራፍ 17፡ የራያ ወንዞች ስነ-ቅርፅ መለዋወጥና የመሬት ሽፋን ለውጥ

የመሬት አጠቃቀም/ሽፋን ጥናት በአሁኑ ጊዜ አንገብጋቢ የጥናት መስክ ነው፡፡ በመሬት ሽፋን ዙርያ ወንዞች ትኩረትን የሚሹ አካላት ናቸው፡፡ ይህ ጥናት የራያ ወንዞች ከምእራብ በኩል ካለው ተራራማ ተፋሰሳቸው ወደ ሜዳው በሚገቡበት ጊዜ ሜዳው ውስጥ በመሬት አጠቃቀም/ሽፋን ላይ ያላቸው ተፅእኖ ትኩረት አድርጎ የተሰራ ነው፡፡ ለዚህም በቆቦ ሜዳ ላይ የሚገኘውን ሌሎቹን የራያ ወንዞችን ይወክላል ተብሎ የታመነበት የዋርሱ ወንዝ ላይ ትኩረት ያደርጋል፡፡ ጥናቱ እንደሚያሳየው ወንዞቹ በተስፋፉበት ቦታ የመሬት አጠቃቀም/ሽፋን ለውጥ ኡደት እንዳለው ያሳያል፡፡ ከእርሻ ወደ ወንዝ/ጎርፍ ሰታቶ/ደለል፣ ከወንዝ/ጎርፍ ሰታቶ/ደለል ወደ ሳር/ቁጥቋጦ/ጫካ፣ ከሳር/ቁጥቋጦ/ጫካ እንደገና ወደ እርሻ የመቀየር ሁኔታ ይታያል፡፡ ይህ የሚሆንበት ምክንያት ወነዞቹ የእርሻ መሬቱን ወደ ወንዝነት/ጎርፍ ሰታቶ/ደለል ቀይረው ከተወሰነ ጊዜ በኋላ ይተዉትና ወደ ሳር/ቁጠቈጦ/ጫካ/ ይቀየራል፡፡ የተወሰነ ጊዜ ቆይቶ አፈሩ ከለማ በኋላ እንደገና ባለ እርሾቹ ይሄንን መሬት ማረስ ይጀምራሉ፡፡ በአጠቃላይ ወንዞቹና መለዋወጥና በመሬት አጠቃቀም/ሽፋን የሚመጣው ለውጥ በገበሬዎቹ የአኗኗር ሁኔታና በመሬት አስተዳደር ላይ ከፍተኛ የሆነ አነደምታ አላቸው፡፡ የመሬት ሽፋን ለውጦቹ ከወንዞቹ የስነ-ቅርፅ ለውጥ ብቻ ሳይሆን ከሰው ልጅ ጣለቃ ገብነትና ከተፈተሯዊ የእፅዋት እንደገና መወለድ/ማደግመ ጭምር ነው፡፡ ስለዚህ የመሬት አያያዝ ስራዎች ላይ የወንዞቹን ባህሪ መገንዘብ ጥሩ እንደሆነ ያሳያል፡፡ በተጨማሪም ወንዞቹን ለመቆጣጠር በምንሰራቸው ስራዎች የወንዞቹን ተፈጥሯዊ ባህሪና ነፃነት መጠበቅ የተሻለ አማራጭ ነው፡፡

የውሃ መኖር ጥሩ ነገር ቢሆንም በራያ አካባቢ በጨዋማነት ላይ የተደረገው ጥናት በምእራፍ አስራ ስምንት ተቀምጧል፡፡

ምዕራፍ 18፡ በራያ ግራበን (Graben) የውሃ ጨዋማ ሁኔታ

የውሃ ጨዋማነት በደረቃማ አከባቢ ለእርሻ ትልቅ ማነቆ እየሆነ መጥተዋል። በኤለክትሪክ ኮንዳክቲቪቲ በመታገዝ የውሃው ጨዋማነት ቦታና ጊዜ ግምት በማስገባት መግለፅ የሚሉ ናቸው። ቀስ በቀስም በቦታው ለሚገኘው የውሃ ጨዋማነት ስርዓቶች በቦታ እና ጊዜ በኩል ለማየት በኤለትሪካዊ ኮንዳክቲቪቲ በሚባል መሳርያ ወንዞች፣ ምንጮች፣ የጓድጓድ ውሃዎች እና ሓይቆች ለመሳሰሉ የውሃ አካላት እንዲለኩ ኣድርገናል።ይህ ጥናት ግራበኖች ያሉ የኤለክትሪካዊ ኮንዳክቲቪቲ ይዘቶች በክረምት እና በበጋ የጎላ ልዩነት እንዳላቸው ይጠቁማል። ከዚህ በተጨማሪም፣ ዓመታዊ አማካይ የውሃ ኤለትሪካዊ ኮንዳክቲቪቲ በተራራዎች ካለው መጠን በሸለቆው በሚገኙ ግራበኖች እንደሚጨምር ያስረዳል። በሚገርም መልኩ፣ በሸለቆው ባሉ ግራበኖች የሚገኝ የውሃ ጨዋማነት በአሳሳቢ ሁኔታ ይገኛል። የዚህ ውጤት ማሳያ ደግሞ እየጨመረ በመምጣት ላይ ባለው የውሃ ጨዋማነት ፣በተለየ በጋቢኖች ገፀ ምድር የእርሻ እንቅስቃሴዎች በሙሉ ዓቅም ሲሰራበት በእርሻ ምርቶች አደጋ ሊያደርስ ይችላል። ስለሆነም፣ በኢትዮጵ ስምጥ ሸሎቆ ውስጥ የሚገኙ ግራበኖች ያላቸው የዉሃ ሃብት በአግባቡ በመጠቀም የተሻለ ኢኮኖምያዊ መምጣት ይÒላል።

V. በሜዳዎቹ ላይ የመሬት አስተዳደር ጉዳይ

በባለፉት አመታት በራያ አካባቢ ከውሃ፣ ከመሬትና ከህዝብ ጋር የተያያዙ የተለያዩ አይነት ለውጦች ታይተዋል፡፡ ከዚህም ጋር ተያይዞ ምዕራፍ አስራ ዘጠኝ የግብርና ኢነቨስትመንት የመሬት ለውጥ ላይ ያለው ተፅእኖ ተመልክቷል፡፡

ምዕራፍ 19፡ በራያ ረባዳ ምድር የግብርና ኢንቨስትመንት በመሬት አጠቃቀምና በመሬት ሽፋን ላይ ያለው ተጽእኖ

ይህ ጥናት በራያ ረባዳ ምድር ላይ ያለው የግብርና ኢንቨስትመንት መስፋፋት በመሬት አጠቃቀምና በመሬት ሽፋን ላይ ያለው ተጽእኖ ለማወቅ የተደረገ ጥናት ነው፡፡ በጥናቱ መሰረት በራያ ረባዳ ምድር ላይ ያለው የግብርና ኢንቨስትመንት መስፋፋት ከፍተኛ የመሬት አጠቃቀምና የመሬት ሽፋን ለውጥ አስከትለዋል፡፡ በተጨማሪ ጥናቱ የራያ ረባዳ ቦታዎች የግብርና ኢንቨስትመንት በተለይ የቆቦ ንዑስ ተፋሰስ ፈጣን የደን መመናመን እንዳስከተለ ያመለክታል። ይኸውም የደን ሽፋን ከ2007-2014 ዓ.ም በ62% ቀንሷል። በተመሳሳይ በመኮኒ ኢንቨስትመንት ቦታዎች ላይ በቁትቋጥ የተሸፈኑ ቦታዎች በ60% ቀንሷል፡፡ በተጨማሪም በመኮኒ ኢንቨስትመነንት ቦታዎች ላይ የነበሩ የመኖርያ መንደሮች ወድመዋል፡፡ በተቃራኒው ጥናቱ በቆቦና በ መኮኒ ንዑስ ተፋሰሶች ላይ ያሉት ለመስኖ እርሻ የሚሆኑ ቦታዎች በ 74% እና በ 73% በቅደም ተከተል ጭማሪ አሳይቷል፡፡ ሲጠቃለል በራያ ረባዳ ቦታዎች ላይ የግብርና መስፋፋት ተጠናክሮ በመቀጠሉ በመሬት አጠቃቀምና በመሬት ሽፋን ላይ ለውጦች እንዲታዩ አድርጓል። ይህም በበኩሉ በራያ ረባዳ ቦታዎች የምድር ገፅታ አገልግሎቶች ላይ ተጽእኖ እንዲፈጠር ምክንያት ሆኗል። ስለሆነም የግብርና ኢንቨስትመንት በሚስፋፋባቸው ቦታዎች ኢንቨስትመንቶቹ በምድር ገፅታ ላይ ያላቸው ተጽእኖ ለማወቅ መንግሰት የምድር ገፅታ መሰረት ያደረገ ጥናት ማድረግ እንዳለበት ጥናቱ ያሳስባል፡፡

የከባቢያዊ ለውጥና የተለያዩ የመሬት አጠቃቀም ለውጦች አንድ ላይ የገፁ-ምድር ለውጥ ያመጣሉ፡፡ ምዕራፍ ሃያ ይሄንን ጉዳይ አስመልክቶ የጥናት ውጤት አስቀምጧል፡፡

ምዕራፍ 20፡ በራያ ሜዳ የገፀ-ምድር ተለዋዋጭነትና ዋና ምክንያቶች

ይህ ጥናት በራያ ሜዳ በሶስት ዘመናት የተከሰተ የገፀ-ምድር ቅንብርና ውቅረት ላይ ምርምር አድርጓል፡፡ በጥናቱ መሰረት እርሻ መሬት ጎልቶ የሚታይ የገፀ-ምድር አካል ነው፡፡ ላለፉት ሶስት አስርት አመታት ትርጉም ያለው የመጠንና መበታተን የመጨመር ለውጦችን አሳይቷል፡፡ የቁትቋጦ መሬት የመጠን መቀነስ ያሳየ ሲሆን ከፍተኛ ሁኔታ የመበታተን ለውጥ ታይቶበታል፡፡ የደን ሽፋን እንዲሁ በተከታታይነት እየቀነሰ የመጣ ሲሆን ትርጉም ያለው የመበታተን ጭማሪ ግን አላሳየም፡፡ የመኖሪያ መንደሮች በመጠን እየጨመሩ እንዳሉ ጥናቱ ያሳያል፡፡ ለሰው መስፈሪያ የሚሆኑ የተገነቡ ትንንሽ ቦታዎች በእርሻ ቦታ፣ ቁጥቋጦ ቦታና፣ ደኖች አካባቢ ታጭቀው ይገኛሉ፡፡ በዚህ ጥናት የተጠቀሱት ለውጦች በዋናነት ከሰው የምግብና የመኖሪያ ቤት ፍላጎት መጨመር ጋር ተያይዘው የመጡ ናቸው፡፡ የገጠር መንደሮችን ወደአንድ አካባቢ የማሰባሰብ እንቅስቃሴም አንደኛው ምክንያት ሆኖ ተገኝቷል፡፡ በተጨማሪም የንግድ እርሻ ስራዎች መስፋፋት ለገፀ-ምድር ለውጥ ጠንካራ ምክንያት ነው፡፡ በአጠቃላይ በራያ ሜዳ ላይ ያለው የሰዎች የአሰፋፈር ሁኔታ ትልቅ ትኩረትና አቅድ የሚሻ ጉዳይ

ነው፡፡ ምክንያቱም የመኖሪያ መንደሮች በዋናነት የታረሰ መሬት፣ የለሙ የቁጥቋጦ ቦታዎችና፣ የደን ቦታዎች ላይ በከፍተኛ ሁኔታ እየተስፋፉ ይገኛሉ፡፡

በመጨረሻም ምዕራፍ ሃያ አንድ የቅርብ ጊዜ አጠቃላይ ሁኔታዎችን ያስቀምጣል፡፡

ምዕራፍ 21፡ በራያና አካባቢው የማዳበርያ መጠን ኪሳራ (2012-2016)

የማዳበርያ ኦፊሴላዊ ገበያ ሽያጭና የጥቁር ገበያ ሽያጭ ዋጋ ላይ ጥናት አድርገናል፡፡ የማዳበሪያ ሽያጭ በኢትዮጵያ ውስጥ በብዛት መጨመሩን እና በሰሜናዊው የሀገሪቱ ክፍል ያለው አቅርቦት ከፍላጎት በላይ መሆኑን መረጃዎች ያሳያሉ፡፡ ጥናቱ የተካሄደው በ 2016 ዓ.ም በራያ አካባቢ ሲሆን የማዳበርያው የዋጋ ሁኔታ ከሌሎች ወረዳዎች ጋር ይቃረናል፡፡ የማዳበርያ አቅርቦትና የ 2016 ዓ.ም የማዳበሪያ ኦፊሴላዊ እና ጥቁር ገበያ ዋጋዎች አሃዛዊ መረጃዎች ከ35 ወረዳዎችና፣ ራያ አካባቢ ከሚገኙ ሁሉም መዘጋጃ ቤቶች ከሚገኙ ኦፊሴላዊ ስታቲስቲክስ እና ከቁልፍ መረጃ ሰጪዎች ተገኝቷል፡፡ ተፈጥሯዊ ያልሆኑ ማዳበሪዎችን ለማስተዋወቅና ለመሸጥ የግብርና ባለሙያዎች ማበረታቻዎችን ያበረክታሉ ፡፡ እንዲሁም የምግብ ዕርዳታንና ከባለስልጣናት የሚያገኙዋቸውን ጥቅሞች የገበያ ማሻሻጫ ያረጉት ነበር፡፡ ለምሳሌ ማዳበርያ ካልገዛ የምግብ እርዳታ እንደማየሰጠው ይነገረዋል፡፡ በ 2016 ማዳበሪያው ለገበሬዎች የተሸጠበት አማካይ ዋጋ በኩንታል 1407 ብር ነበር፣ እንደ ማዳበርያው አይነትና ከአዲስ አበባ ባለው ርቀት የተወሰነ የዋጋ ልቱነት በማሳየት፡፡ በጥቁሩ ገበያ ላይ የነበረው አማካይ ዋጋ በኩንታል 731 ብር ነበር፡፡ ነገር ግን በሦስቱ ራያ አካባቢ ያሉ ወረዳዎች ውስጥ አማካይ ዋጋው በኩንታል 463 ብር ነበር፡፡ በራያ አካባቢ በበጋ ጊዜ የመስኖ እርሻ ያላቸው ገበሬዎች ብቻ ናቸው ማዳበሪያውን የሚፈልጉት፣ ሌሎቹ ይሸጡታል፡፡ አርሶ አደሮቹ አካባቢያቸው በጣም ሞቃታማ በመሆኑ የጠል ችግር እንዳለበትና በተጨማሪም መሬታቸው ከላይ ታጥቦ በሚመጣ ደለል ለም ስለሆነ ማዳበርያው እነደማያስፈልጋቸው ይናገራሉ፡፡ ካስፈለጋቸውም ከገበያ በፍላጎታቸው መግዛት እንደሚችሉ ይናገራሉ፡፡ በጥቁር ገበያ ውስጥ በአብዛኛው የተፈጥሮ ያልሆነ ማዳበሪያ በአካባቢው ከሚገኙ ነጋዴዎች ወይም ቤተሰብ የሆኑ ደላሎች በኩል በውጪ ተጠቃሚዎች ይገዛ ነበር፡፡ ከመጠን በላይ ማዳበሪያ ለግብርና ኩባንያዎች እና ነጋዴዎች ለመሸጥ በመቀበል አነስተኛ አርሶ አደሮች ከከፍተኛ ኪሳራ ራሳቸውን ያድኑ ነበር፡፡ ማዳበሪያ በኢትዮጵያ ውስጥ የእርሻ ምርትን በከፍተኛ ደረጃ እንዲያድግ ካደረጉት ነገሮች ውስጥ አንዱ ነው፡፡ ነገር ግን የማዳበሪያ ፖሊሲ በጣም በተሻለ ሁኔታ ሊስተካከል የሚገባውና በተሸጠው የማዳበርያ መጠን ሳይሆን ስነ-ምህዳራዊና ስነ-ግብርና መረጃዎችን መሰረት አድርጎ መሆን አለበት፡፡ አርሶ አደሮችን ያለፍላጎታቸው ማዳበርያ እንዲገዙ ማድረግ ለግብርና ልማቱ አደገኛ ነው፡፡

ጽንቁቕ መጠቓለሊ፡ መሬት፣ ማይ፣ ህዝቢን ገጸ-ምድሪን ግራበናት (Grabens) ሰሜን ኢትዮጵያ

ቢያድግልኝ ደምሴ፣ ጃን ኒሰንን ተሰፋኣለም ገብረዮሃንስን

[1]ክፍሊ ት/ቲ መጽናዕቲ ጂኦግራፊን ከባቢን፣ ዩኒቨርሲቲ መቐለ፣ ኢትዮጵያ

[2]ክፍሊ ት/ቲ መጽናዕቲ ጂኦግራፊ፣ ዩኒቨርሲቲ ጌንት፣ ቤልጅየም

I. መእተዊ

ኣብ ዕስራን ሓደን ምዕራፋት እዙይ መጽሓፍ ናይ ፕሮጀክት ግራበን ቲም (Graben TEAM) ዝተረኸባ ውጽኢታት ምርምር ኣቕሚጥናለና፡፡ ግራበን (Graben) ማለት መሰረቱ ናይ ቋንቋ ጀርመን እንትኸውን ትርጉሙ ድማ ብዙርያኡ በጸዳፋትን በረኽትን ቦታታት ዝተኸበበን ኣብ ሞንጎ ስምጥ ሽለቆን በረኽቲ ቦታተት ኢትዮጵያን ዝረከብ ነዊሕ ሽንጥሮ ማለት እዩ፡፡ ኣብዚ ክፋል እዚ መጽሓፍ ብዛዕባ እቲ ፕሮጀክት ኣብ መዕራፍ 1፣ ቀፂሉ ድማ ኣብ ምዕራፍ 2 ብዛዕባ እተን ቦታታት መጽናዕቲ ሕጽር ዝበለ መግለፂ ተዋሂቡ ኣሎ፡፡ ኣብ ውሽጢ እዙይ መጽሓፍ ተጠቒሶም ዘለዉ ዓመታት ብናይ ግሪጎርያን ኣቆጻጽራ ዘመን እዩ፡፡

ምዕራፍ 1፡ ፕሮጀክት ግራበን ቲም (Graben TEAM)

ፕሮጀክት ግራበን ቲም (Graben" TEAM) (2013-2018) ኣብ ሞንጎ ናይ ሰሜናዊ ኢትዮጵያ በረኽቲ ቦታታትን "ስምጥ ሽለቆን" ዝርከብ መተሓላለፊ/መራኸቢ ዕብየት ኢትዮጵያ ዝኾነ ቦታ ትኹረት ገይሩ ዝተሰርሐ እዩ፡፡ እዚ ኸባቢ ብኸባቢኡ ብዝርከቡ በረኽቲ ቦታታት ብዘሎ/በዘጋጥም ለወጢ ከባቢን ኣየርን ምኽንያት ብቐሊሉ ተጋላጺ እዩ፡፡ እዙይ ገጸ-መሬት ካብ ምርባሕ ከፍቲ ጀሚሩ እኽሊ መሰረት ዝገበረ ስርዓት ምህርቲ እኽሊ ክሳብ ክፋል ሞስኖ ተኮር ሕርሻ ንቑልጡፍ ለውጢ ዝተጋለጸ እዩ፤ በዚ ከባቢ ኣብ ሞንጎ ብምርባሕ ከፍቲ ዝመሓደሩ ዓፋርን ሕርሻ ዝመሓደሩ ናይ ኣምሓራን ትግራይን ሓረስቶት ናይ ምትሕብባርን ናይ ምግርጫውን ኩነታት ይረኣዩ እዮም፡፡ ኣብ ትልሚን ምሕደራን መሬትን ማይን ንምሕጋዝ ኣብ መሬት አጠቓቕማ፣ ናይ ሰባት ኣሰፋፍራን ስርዓት ሕርሻን ትኹረት ዝገበረ ዝተቀናጀወ መጽናዕቲ ምድራዊ መልክዕ ተገይሩ ኣሎ፡፡ እቲ መጽናዕቲ መቐለ ዩኒቨርሲቲን ኣብ ቤልጅየም ዝርከቡ ጌንት ዩኒቨርሲቲን ሉቨን ካቶሊክ ዩኒቨርሲቲ ዘካተተ እዩ፡፡

ምዕራፍ 2: ኣብ ሞንጎ መይዳ ደጉዓ ዓዲ ኢትዮጵያን ስምጥ ሽለቆን ዝርከቡ ቦታታት

ብዛዕባ ግራበናት (Grabens) ዝሓሸ ግንዛበ ንምርካብ ናይ ኣብዓላ፣ ካላ፣ ራያን አሸንጌን ኸባቢታት ኣውዚ መጽናዕቲ ወከልቲ ቦታታት ኮይነን ተመሪጸን ኣለዋ፡፡ እዚኣን ቦታታት ብኽፋል ጸዳፋት ብዝኾኑ በረኽቲ ቦታታት ዝተኸበባ እየን፡፡ በዚ ምኽንያት ሓመደንን ማየንን ካብላዕሊ ብዝወርድ ውሒጅን ደለል እንደገና ይምላእ፡፡
ኣብ ምዕራፍ ክልተ ብዝርዝር ከምዝተቐመጠ ዋና ዋና መግለፂ እተን ቦታታት እዘን ዝስዕባ እየን፣

- **ስነ ምድራዊ ትሕዝቶ**፣ ግራበን (Graben) ማለት ከም ጋብላ ብማዕዶ ማዕረ ንማዕረ ብዝኸዳ ዝንፈት መስመራት ዝተኸበበን ንታሕቲ ዝወረደን ጥምረት መሬት እዩ፡፡ እዙይ ጥምረት መሬት ሽንጥሮ ብምፍጣር ብጠርዚ ጸዳፋት ዝኾኑ በረኽቲ ቦታታት ኢትዮጵያ ማዕዶ ንማዕዶ ይኸይድ፡፡ ብትግርኛ እዙይ ንታሕቲ ዝወረደ ጥምረት መሬት ጎልጎል/መይዳ ዱልና ክንጽውዖ ንኽእል ኢና፡፡ ብኣብዓላ ከባቢ ናይ ኣንታሎ እምኒ ኖራ፣ ብራያ ኸባቢ ድማ ጸሊም እምኒ ብበዝሒ ይርከቡ፡፡ እተን ጎልጎላት ካብ ላዕሊ ብዝወረደ ደለል ዝተሸፈና እየን፡፡
- ኣብ ወሰን ስምጥ ሽለቆ ዝርከባ ጎልጎላት ብዋናነት ክፋል በረኻ ዝኾነ ንብረት ኣየር ኣለወን፡፡ ኽረምቲ እቲ ዋና ናይ ዝናብ ወቕተን እንትኸውን ከባቢ ራያ ግን ኣብ በልጊውን ዝናብ ይረክብ እዩ፡፡
- እቶም ሩባታት ካብ ጸዳፋት ዝኾኑ በረኽቲ ቦታታት ተላዒሎም ናብ ጎልጎላት ብምፍሳስ ኣብ ማእኸል እተን ጎልጎላት ናይ ባዕሎም ዝኾኑ ክፋላት ይሰርሑ፡፡ መብዛሕቲኦም ሩባታት ኣብተን ጎልጎላት ይውድኡ፡፡ ካብ ጎልጎል መውጻኢ እቶም ሩባታት ድማ ብምግሕጓሑ ምኽንያት ብጣዕሚ ዝጎደጎደ እዩ፡፡
- **ሓመድ**፣ ብዋናነት ናይ ራያን ሓሸንገን ሓመድ ዋልካ (ጸሊም) ሓመድ እንትኸውን ናይ ኣበዓላን ካላን ጎልጎላት ዓነደለዋይ/ቡን ሓመድ (Cambisols) ዝበሃል እዩ፡፡ ብአጠቓላሊ ጸዳፋት ኣብዝኾኑ በረኽቲ ቦታታት ዘሎ ጥምረት ዓይነት ሓመድ እምኒ ዝበዝሖ/ጭነጫ ሓመድ (Leptosols) እቲ ዝበዝሐ እዩ፡፡

- **በዝሒ ህዝቢ**፣ ኣብቶም ቦታታት መጽናዒቲ ብግምት 650000 ሰባት ይነብሩ፡፡ ራያን ኣሸንጌን ፁዑቕ ኣሰፋፍራ ኣለዎም፡፡ ኣብዚኦም ከባቢታት ብዋናነት ኣምሓርኛን ትግርኛን ተዛረብቲ ብተወሳሒ ድማ ዝተሓወሱ ኦሮምኛን ዓፋርኛን ተዛረብቲ ይርከቡ፡፡ ናይ ኣምሓርኛ፣ ትግርኛን ኦሮምኛ ተዛረብቲ ሕርሻ ዝማሓደሩ እንትኾውን ናይ ዓፋርኛ ተዛረብቲ ብምርባሕ እንስሳ ይማሓደሩ፡፡
- **ሽፋን መሬት**፣ናይተን ጎልጎላት ምዕራባዊን ምብራቃዊን በረኸቲ ቦታታት ብሳዕሪን ቑጥቋጦን ዝተሸፈና እንትኾውን እተን ጎልጎላት ግን ብዋናነት ናይ ሕርሻ ቦታታት እየን፡፡ ብምዕራባዊ በረኸቲ ቦታታት ናይ መሬት ግረባን ምድሓንን ስራሕቲ ስለዝተሰረሐ ዝሓሸ ሽፋን ደኒ (ተኽሊ) ኣለዎም፡፡

II. ኣብ ጠርዚ እተን በረኸቲ ቦታታት ሰሜን ኢትዮጵያ (ውጽኢት መጽናዕቲታት)

እዙይ ክፋል እዙይ ኣበተን በረኸቲ መይዳ ደጉዓ ቦታታት ጠመተ ገይሮም ዝተሰርሑ መጽናዕቲታት ትኹረት ዝገበረ እዩ፡፡ እዘን ቦታታት ካብተን ዓበይቲ ዝባሃላ ጎቦታት ኢትዮጵያ ዝርከበለን ኮይነን ማይ ድማ ካብዚኣን በረኸቲ ቦታታት ተላዒሉ ናብ እተን ጎልጎላት ዝፈሰሰን እየን፡፡ ኩነታት ከባቢታት ደጉዓ ኣብ ጫፍ ጸዳፋትን በረኸትን ቦታታት ኣብ *ምዕራፍ 3 ተቐሚጡ ኣሎ፡፡*

ምዕራፍ 3፡ ኩነታት ከባቢታት ደጉዓ ኣብ ጫፍ ጸዳፋትን በረኸትን ቦታታት

በረኸቲ ቦታታት ኢትዮጵያ ካብ 2000 ሜትሮ ልዕሊ ጸፍሒ ባሕሪ ንላዕሊ ዘለዉ ናይ ምብራቕ ኣፍሪቓ ቦታታት 50 ብሚኢታዊ ዝኾውን ስፍሓት ይሕዝ እዩ፡፡ እዚኦም ቦታታት ኣብ ኩነታት ደጉዓ መጽናዕቲ ንምግባር ተመረጽቲ ቦታታት እዮም፡፡ በዚ ምኽንያት ኣብ ሰሜናዊ ክፋል እትዮጵያ ዝርከቡ ሰለስተ ሰንሰለት ጎቦታት መጽናዕቲ ተገይሩ፡፡ እዚኦምውን ጎቦታት ሰሜን (4550 ሜትሮ ልዕሊ ጸፍሒ ባሕሪ)፣ ጎቦታት ኣቡነ ዮሴፍ (4277 ሜትሮ)ን ጎቦታት ፈራሕ ኣምባ (3939 ሜትሮ) እዮም፡፡ እዚኦም ገቦታት ናይ ቐደም ዝነበረ በረድን ከይዲ በረድን መረዳእታ ዝሓዙ እዮም፡፡ ናብ ሰሜን ኣንፈት ዝርኢ ላዕለዋይ ክፋል ሰንሰለት ጎቦታት ኣቡነ ዮሴፍ ኣናእሽቲ ናይ መደራጋሕ በረድ ኣናመገቦም ዝነበሩ ኣኻውሕ በረድ ከምዝነበሩ እቲ መጽናዕቲ የርኢ፡፡ ከሳብ ኸዚ ኣብ ኢትዮጵያ ጎቦታት ብኣነእሽቲ ናይ መደራጋሕ በረድ ኣናመገቦም ናይ ፕሌስቶሴኔ (Pleistocene) ኣኻውሕ በረድ ከምዝነበሩ ዘረጋገጸ መጽናዕቲ ኣይነበረን፡፡ ኣፍቲ ቦታ መጽናዕቲ እቲ ናይ መወዳእታ/ናይ ቐረባ ግዘ ኣኻውሕ በረድ ካብ ዝተራኣየሉ ጀሚሩ ናይ 6 °C ዝኾውን ወሰኽ ሙቐት ተጸብዪቡ ኣሎ፡፡ በዚ መጽናዕቲ ናይ ኣስሓይታ ከይዲ ተግባር ብኣስሓይታ ንቓዕን ኣናእሽቲ ባይታታት ተወሲኑ ይርከብ፡፡ ደኒ ናይ ቦታታት ደጉዓን ኣስሓይታን ካብ 3200-3700 ሜትሮ ብራኽ ኣበዘለዎም ቦታታት ይርከብ፡፡ ዋላኳዕ መጠን ሙቐት እንተወሰኸ ናይ ሻንቶ ተኽሊ መብቖዒ መስመር ብራኽ ኣይወሰኸን፡፡ ብሕቑ ምድሪ ኸባቢ (Tropical) ዝርከቡ ጎቦታት ኢትዮጵያ ናይ ኦም መስመር መብቖዒ ብናይ ደቒ ሰብ ኢድ ኣታውነት (anthropo-zoogenic) ዝተመስረተ እዩ፡፡ ኾይኑ ግን ኣብዝተሓለዉ ኽዛዕቲታት መጠን ሙቐት እቲ ዋና ወሳኒ መስመር መብቖዒ ኦም እዩ፡፡ ስለዚ ናይ ደኒ ጎቦታት ጥቕማጥቕሚ ስርዓት መሕዳር ናብ ዝነበረሉ ኩነታት ንምምላስ ናይ መሬት ምሕደራ ጠቃሚ እዩ፡፡

ኣብተን በረኽ ቦታታትውን ኣናእሽቲ ግራበናት (Grabens) ይርከባ እየን፡፡ ንኣብነት ኮረም፣ ሓሸንገን ማይጨውን እተን ዝጥቀሳ እየን፡፡ ኣብ ምዕራፍ 4 ኣብዚኣን ከባቢታት ዘሎ ኩነታት ጉሕጓሐ ሓመድ ጥቕልል ዱሉ ተቐሚጡ ኣሎ፡፡

ምዕራፍ 4፡ ናይ ነዊሕ ግዘ ምቡሕጓግ ሓመድ ቃላይ ኣሸንጌ

ብድንገተኛ ውሕጅ ዝተጠራቐመ ደለል መጽናዕቲ ብምግባር ኣብ ተፋሰሳት ንነዊሕ ግዘ ዝነበረ ምጉሕጓሕ መሬት ክንፈልጥ ይገብር፡፡ እዙይ ብምርዳእ ወካሊ እዩ ዝበልናዮ ናብ ቃላይ ሓሸንገ ዝኣቱ ፍግረ መሬት ንዝተወሰነ ግዘ ዝነበረ ኩነታት ምቡሕጓግ ሓመድ ኽትትል ብምግባር መጽናዕቲ ኣካይድና ኣለና፡፡ ኣብቲ ፍግረ መሬት ናብ ኣንፈት እቲ ቃላይ ዝርከቡ ቅደም ሰዓብ ዘለዎም ደለላት ምርምር ገይርና ኣለና፡፡ ብተወሳኺ ኣብ ውሽጢ እቲ ቃላይ ኣብ ዘሎ ደለል ናይ ስርሒትን ዕድመን ትንታነ ገይርና ኣለና፡፡ በዙይ መሰረት ኣብቲ ቃላይ ልዕል ዝበለ ደለል ዝነበረሉ ግዘ ክንፈልጥ ክኢልና ኢና፡፡ እዙይ ድማ ኣብ ተፋሰስ ሓሸንገ እቲ ዝዓበየ ምጉሕጓሕ መሬት መኣዝ ከምዝነበረ ክንፈልጥ ገይሩና ኣሎ፡፡ ኣብ ዝሓለፈ ፍርቂ ክፋል ዘመን ከይዲ ዝግመተ ለውጢ እቲ ፍግረ መሬት እንደገና ክንሃንጽ ክኢልና ኣለና፡፡ ናይ ኣየር ፎቶን ቃለ መጠይቕን ተጠቒምናውን ኣረጋጊጽና ኣለና፡፡ ውጽኢት ትንታነ ከይዲ ምሙላእ እቲ ፍግረ መሬትን ኣብቲ ቃላይ ዝተገበረ ትንታነ ዕድመ ደለልን ይጣዓዐም እዩ፡፡ ካብ 1970ታት ጀሚሩ ናይ ምውሳኽ ኩነታት ደለል ይረኣይ ነይሩ እዩ፡፡ በዚ ግዘ ኣብቲ ቃላይ

እቲ ዝዓበየ ደለል ሓሸዋ ተጠራቒሙ ነይሩ፡፡ ኣብ ቀረባ ግዘ ግን ብምኽንያት ምውሳኽ ሽፋን ደኒ (ተኽሊ) ተፋሰሳት ኣበቲ ቃላይ ኣብ ላዕሊ ዝርከብ ደለል መብዛሕቲኡ ትሕዝቶኡ ሓመድ እዩ፡፡

ኣብ ምዕራፍ ሓሙሽተ ስርዓት እቶት ዝራእቲ ኣብ በረኽትን ጸዳፋትን ቦታታይ ራያ ብሓፂር ተቐሚጡ ኣሎ፡፡

ምዕራፍ 5፡ ስርዓት እቶት ዝራእቲ ኣብ በረኽትን ጸደፍትን ቦታታይ ራያ

ኣብ በረኽቲ ቦታታት ሰሜን ኢትዮጵያ 33% ዝኸውን መሬት ንዝራእቲ ሕርሻ ኮይኑ እናገልገለ ይርከብ፡፡ እዙይ መሬት ብዋናነት ናይ ስርዓት እቶት ዝራእቶም ናይ ሃገር ቦቀል ፍልጠት ተጠቂሞም ብዝሰርሑ ኣናእሽቲ ሓረስቶት ዝተድሓዘ እዩ፡፡ እቲ ዘሎ ስርዓት እቶት ዝራእቲ ብካርታ ንምቕማጥን ምስ ዓመታዊ መጠን ዝናብ ዘለዎ ርክብን ብምርዳእ ኣብ በረኽቲ ቦታታት ሰሜን ኢትዮጵያ ዘሎ ትግበራ ስርዓት እቶት ዝራእቲ ግንዛበ ምርካብ ንኽእል ኢና፡፡ እዙይ ንምርዳእ ናይባዕሎም ንውሒ ወቕቲ ምህርቲን ጥምረት ግብኣትን ዘለዎም ሓሙሽተ ዝራእቲ ፈሊና ኣለና፡፡ እዚኦምውን ሓፂር ዑደት ዝራእቲ (ኣርባዕተ ወረሒ)፣ መደበኛ ሓፂር ዑደት ዝራእቲ (ሓሙሽተ ወርሒ)፣ መደበኛ ነዊሕ ዑደት ዝራእቲ (ሽዱሽተ ወርሒ)፣ ነዊሕ ዑደት ዝራእቲ (ትሽዓንተ ወርሒ)ን፣ ነዊሕ ኽልተ ዑደት ዝራእቲ (ዓሰርተ ወርሒ) እዮም፡፡ መብዛሕቲኦም ናይሓፂር ዑደት ዝራእቲ ኣብ ሽንጥሮ ጸግዒ እንትርከቡ ነዊሕ ዑደት ዝራእቲ ድማ ኣብ ውሽጢ ሽንጥሮ (ጎልጎል) ይርከቡ፡፡ ናይ ንውሒ ወቕቲ ምህርቲ ድማ ካብ ሰሜናዊ ምዕራብ ናብ ደቡባዊ ምዕራብ እናወሰኸ ይኸይድ፡፡ ኣብ ሓደ ስርዓት ግብኣት ዝራእቲ ናይ ጥምረት ምህርቲ ብኣፈላላይ ብራኸ ይላዋወጥ፡፡ ብተወሳኺ ስርዓት ግብኣት ዝራእቲ ምስ ናይ ዓመታዊ ለውጢ መጠን ዝናብ ይላዋወጥ፡፡ እዙይ ብምኺኑ ምኽንያት ብደረጃ ተፋሰስን ክልልን/ከባቢን ስርዓት ግብኣት ዝራእቲ ለውጢ የርእይ እዩ፣ ልዑል መጠን ዝናብ እንተሃልዉ ነዊሕ ወቕቲ ምህርቲ ክህሉ ይገብር፡፡

ኣብተን በረኽቲ ቦታታት ደቂ ሰባት ንነዊሕ ግዘ ይቕመጡለን ነይሮም እዮም፡፡ ምስዙይ ተዳሒዙ ድማ ምዕራፍ 6 ብዛዕባ ኣብ ቃላይ ሓሸንገ ከባቢኡን ዝነበረ ትሕዝቶ መሬት ብሓፂር ኣቐሚጡ ኣሎ፡፡

ምዕራፍ 6፡ ማዕረ ካብ ዘይኾነ ትሕዝቶ መሬት ናብ ማዕርነት፣ ኣብ ከባቢ ሓሸንገ ኣብ ዕንወት መሬት ዘለዎ ጽዕንቶ

ኣብ ከባቢ ቃላይ ሓሸንገ ነዝሓለፉ 100 ዓመታት ሸንሸና መሬት ብፍላይ ስርጭት መሬት ኣብ ምጉሕጓሕ ሓመድ ዘለዎ ግደ ርኢና ኣለና፡፡ ናይ ኣየር ፎቶን ቃለ መጠይቕን ተጠቒምና ኣብ ከይዲ ግዘ ዝነበር ትሕዝቶ መሬት ኣቐሚጥና ኣለና፡፡ ኣብቶም ዝነበሩ ዘመናት ፊውዳል ብጣዕሚ ዘይተለመዱ ትሕዝቶታት መሬት ነይሮም፡፡ ንኣብነት ኣብ ቑሸት መንከረ ሓደ ደጃዝማች 14 ሄክታር ካልኣት ፊውዳላትውን ካብኡ ንላዕሊ ዓውዪ መሬት ነይሩዎም፡፡ ነገር ግን ካብ 50 ንላዕሊ ዝኾኑ ስድራታት ምንም መሬት ኣይነበሮምን፡፡ ደርጊ ስልጣን ምስሓዘ ንመጀመርያ ግዘ ናይ መሬት ሸንሸና ንምግባር ሞኪሩ ነይሩ፡፡ ኾይኑ ግና ግልፂ ዘይኾነን ማዕረ ኽፍፍል ዘይገበረ እዩ ነይሩ፡፡ ሓደ ሓረስታይ "እቲ ወሳናይ ነገር ብእግርኻ ዲኻ መፂእኻ ወይስ ብኢደኻ" እዩ ዪሉ ተዛሪቡ፡፡ በዚ ምኽንታት ድማ እቶም ናይ ቐደም ፊውዳላት ዓበይቲ ትሐዝቶታት መሬት ክሕዙ ክኢሎም ኣለዉ፡፡ ህወሓት ብ1990 ዓ/ም ከባቢ ካሊእ መማሓየሺ ትሕዝቶ መሬት ገይሩ፡፡ ዕላማኡ ሕድሕድ ሓረስታይ (*ፆታ ከየጸፈለየ*) ማዕረ ትሕዝቶ ክህልዎ ምግባር እዩ፡፡ ጸኒሑውን ሓደሓደ ናይ ትሕቶ መስተኻኸሊ ተገይሩ ነይሩ፡፡ ስሩዕ ዝኾነ ዕዳጋ መሬትውን ነይሩ፡፡ ሓረስቶት መሬቶም የካርዩ ነይሮም፡፡ ነገር ግን ኣይሸጡን ነይሮም፡፡ በዚ ኽዚ ሰዓት ኣብ ቑሸት መንከረ ዝነብሩ 90% ዝኾኑ ሓረስቶት ክልተ ሰለስት ሕርሻታት ይሓርሱ እዮም፡፡ ኣብ ኢትዮጵያ ኣብ ዝሓለፈ 20 ዓመት ውሽጢ ምህርቲ ሕርሻ ብዝላዓለ መጠን እናወሰኸ መፂኡ ኣሎ፡፡ ኣዙይውን ምስ ናይ መሬት ምሕደራ ምምሕያሽ፣ ምዕባይ ስምዒት ዋኒንነት መሬትን፣ ኣብ ሕርሻ ዝተገበሩ እንቨስትመንታትን ዝተደሓዘ እዩ፡፡ ብተወሳኺውን ናይ ምብትታን መሬት ንመብዛሕቲኦም ሓረስቶት ዝተጠናኸረን ዝተፈላለየን ምስ "ዝንፍ ዘይብል ሕርሻ" ዝማዓራረ ስርዓት ሕርሻ ንክኽተሉ ዕድሉ ሂቡዎም ኣሎ፡፡ ኣብ መንከረ ኣብ ሞንጎ ስነሂወት-ኣካላዊን ማሕበራዊ ስርዓታትን ውስብስብ ዝኾነ ርክብ ኣሎ፡፡ ማዕረ ትሕዝቶ መሬት ክህሉ ጻዕሪ ተጉይሩ ኣሎ፡፡ ትሕዝቶ መሬት ብጣዕሚ ንኡሽተን እዩ፡፡ እዚ ኩነታት ተኽሊታት ወሰን (matrix vegetation) ንከይህልዉ ይገብር፡፡ ብዙሓት ሓረስቶት ካብ ሕርሻ ወጻኢ (ናይ ክፉል ወይለ ሙሉእ ግዘ) የድልዮም እዩ፡፡ እቶት ሕርሻን ግረባ ሓመድን ኣዚዩ ወሲኹ ኣሎ፡፡

III. ምንጪ ማይን ደለልን ዝኾባ ጸዳፋትን በረኽቲን ቦታታት

እቶም ተመራመርቲ ኣብተን ጸዳፋትን በረኽቲን ቦታታት ላዕልን ታሕቲን ዪሎም እተን መጽናዕቲታት ኣካይዶም ኣለዉ፡፡ ናይ ደቂ ሰብ ኢድ ኣታውነት ኣብ እተን ቦታታት ከባቢያዊ ለውጢ ዓውዩ እጃም ኣለዎም፡፡ በዚ ምኽንያት ውን ናይ ለውጢ

ሸፋን ደኒ (ተኽልታት) ብግልፂ ይረኣይ ኣሎ፡፡ ምልውዋጥ ኩነታት ኣየር ከ ክንዲምንታይ ተጽዕኖ ኣለዎ? ኣብዚ ክፋል ዘለዋ ምዕራፋት ብቀጥታ ወይለ ብተዘዋዋሪነት ኣብ ሸፋን ደኒ (ተኽልታት) ዘሎ ለውጢ የቕምጣ፡፡ ምዕራፍ ሸውዓተ ብዛዕባ ለውጥታት ሸፋን ተኽልታት ዕነጨይቲ ሕጽር ዝበለ መረዳእታ ይህበና፡፡

ምዕራፍ 7፡ ኣብ በረኸቲ ቦታታት ራያ ለውጢ ሸፋን መሬትን ተኽልታት ዕንጨይቲን (ካብ 1972 ክሳብ 2014 ዓ/ም)

ኣብ ጸዳፋትን በረኽቲን ቦታታት ራያ ኣብ ውሽጢ 1972 ክሳብ 2014 ዓ/ም ጊዜ ዝነበረ ለውጢ ሸፋን መሬት መረዳእታ ካብ ባይታን ካብ ላንድሳት ሳተላይት ምስሊ ወሲድና ገምጊምና ኣለና፡፡ ኣብቲ ከባቢ ምልማዕ መሬትን ምልምላምን የድሊ ስለዝነበረ ንምልምላም ተኽልታት ዕንጨይቲ ትኹረት ተዋሂቡዎ ነይሩ፡፡ እቶም ዋና ዋና ዝራእቲ ተኽልታት ዕንጨይቲውን ኣብ ባይታ ብዝተገበረ መጽናዕቲ ተፈሊዮም ተፈሊጦም ኣለዉ፡፡ ካብ 1972 ክሳብ 2014 ዓ/ም ብዝተመዝገበ ለውጢ ሸፋን መሬት ናይ ሕርሻ መሬት እናቐነሰ እንትኸይድ (ካብ 60% ናብ 35%) ሸፋን ተኽልታት ዕንጨይቲ ወሰኽ (ከ 33% ናብ 53%) ኣሪኦም ኣለዉ፡፡ ናይ ዳግም ምልምላም ኹነታት ተትረኣየውን እቲ ከባቢ ኣብቲ ከባቢ ብበዝሒ ብዝፍለጡ ዝራእቲ ተኽልታት ዕንጨይቲን (*ንኣብነት ታሕሰስ፣ ዓጋምን ኩልዖን*) ኣመላኸትቲ ምርባሽ ተኽልታት ዝኾኑ ዝራእቲ (*ንኣብነት ሸለን፣ በለስን ዕረን*) ልዕልና ወሲዶም ይርከቡ፡፡ ኣብ በረኽቲ ቦታታት ልዕልና ወሲዶም ዝነበሩ ደንጉዮም ዝመፁ/ዝልምልሙ ዝራእቲ ተኽልታት ዕንጨይቲ ካብ ገላጽ ደንታት ሙሉእ ንሙሉእ ጠፊኦም ኣለዉ፡፡ ኣብ ደንታት ቤተ ክርስቲያናት ጥራሕ ተወሲንም ይርከቡ፡፡ ስለዚ ኣብ ጫካን ደኒን ሓለዋን ግረባን (ሓደሽቲ ኽዛዕቲታት ብምምጻእ) ብፍላይ ኣብ ራያ በረኽቲ ቦታታት ደቡባዊ ኽፋል (ካብ ኣላማጣ ካብ ምዕራብ ጀሚሩ ክሳብ ሮቢት) ትኹረት ምግባር የድሊ እዩ፡፡ ኣብቲ መወዳእታ ገፂ እዙይ መጽሓፍ ትርጓመ ተኽልታት ተዋሂቡ ኣሎ፡፡

ድሕሪ ኣብ ምዕራፍ ሸውዓተ ዝተቐመጠ ለውጢ ሸፋን ደኒ እቲ ለውጢ ሸፋን መሬት ምህላዉን ምንባሩን ዝገልጽ መረዳእታ ኣብ ምዕራፍ ሸምንተ ተገሊጹ ኣሎ፡፡.

ምዕራፍ 8፡ ዕዉታት ስራሕቲ ምሕዋይ ተሸርሽሮም ዝነበሩ ተፋሰሳት መዕራባዊ ጻድፍ ሰሜን ኢትዮጵያ

ኣብ ምዕራባዊ ኣጻድፍ ሰሜን ኢትዮጵያ ዝርከቡ ተፋሰሳት ክሳብ መፋርቕ 1980ታት ብምኽንያት ምብራስ ኣግራብ (ደኒ) ንዝኸፍአ ምሸርሻር ተቓሊዖም ስለዝነበሩ ብሰንኪ'ዚ ድማ ጻዕቒ ዘለዎም ክሳብ ኣዝውሕ ሰርሲሮም ዘወረዱ ዓሞቕቲ ጉሕምታት(scars) ተፈጢሮም ዝነበሩ ክኾኑ ክለዉ ሓያል ዝናብ ኣብዝዘንቡሎም እዋናት እቶም ተፋሰሳት በዞም ጉሕምታት እዚኦም ኣቢሎም ሓንደበታዊን አዕነውትን ወሓይዝ ናብቶም ኣብ ሜዳ ራያ ዝርከቡ ዓድታትን ከተማታትን ብፍላይ ድማ ከተማ ኣላማጣ ይወርዱ ነይሮም፡፡ ብሰንኪ'ዚ ብዙሓት ትሕተ ቅርስታትን ናይ ሕርሻ ቦታትን ይዓንዉ ነይሮም፡፡ ከምኡ ድማ ሕይወት ወዲሰብን እንስሳታትን ይጠፍእ ነይሩ፡፡ ነዚ ጸገም'ዚ ንምፍታሕ ካብ መፋርቕ 1980ታት ዝተፈላለዩ ናይ ተፈጥሮ ምሕዋይ ስራሕቲ ተኣታትዮም ክስርሑ ጸኒሖም፡፡ ብፍላይ ድማ እቶም ኣዝዮም ዝተሸርሸሩ ተፋሰሳት ተሓዚኦም ጸኒሖምን አለዉን፡፡ ከምውጽኢት ናይ'ዞም ጻዕርታት ድማ መጠን ኣግራብ (እጽዋት) ናይቶም ተፋሰሳት ክውስኽ ክኢሉ እዩ፡፡ እዚ መ፟ናእቲ'ዚ ግደ ናይቶም ኣብዞም ተፋሰሳት ዝተ¥የዱ ዝተፈላለዩ ናይ ተፈጥሮ ምሕዋይ ስራሕቲ ኣብ ምንካይ ምሸርሻር ተፈጥራዊ ሃፍትታት ንምጽናእ ዝተኻየደ ክከውን ከሎ ነዚ ንምክያድ ድማ 20 ዝተፈላለየ መጠን ስፍሓትን ትሕዝቶ ኣግራብን (እጽዋት) ዘለዎም ተፋስሳት ተመሪëሀ አብ ሕድሕድ ተፋሰስ ዘለዉ ክሳብ ኣ¥ውሕ ሰርሲሮም ዘወረዱ ዓሞቕቲ ጉሕምታት(scars) ምስ አብ ነፍስወከፍ ተፋሰስ ዘሎ መጠን ቆ̂ለዋይነት አግራብ (Normalized Difference Vegetation Index) ብምውድዳርን አብ ሕድሕድ ተፋሰስ ናይ ዘለዉ ሩባታት ኣብ ስፍሓት ዕምቆትን ቅር̂ን ዝተርኣዩ ለውጥታትን መጠን ዐበይቲ ደናጉላታትን በምዕዛብን ዘተኻየደ መጽናዕቲ እዩ፡፡ ውጽኢት እቲ መ̂ናዕቲ ከምዘርእዮ ድማ እቶም አብዘን ተፋሰሳት እዚኤን ዝተ¥የዱ ስራሕቲ ምሕዋይ ተፈጥሮ ምስቶም ኣብዚ ከባቢ ዝተ¥የዱ ካልኦት ተመሳሰልቲ ሥራሕቲ ክወዳደሩ ከለዉ ኣብ ኣዝዩ ሓጺር ክበሃል ዝ¦እል ጊዜ (30 ዓመታት) መስተንክራዊ ዝኾነ ምሕዋይ ተፈጥሮ ከምዘም̂ኡን ከም ው̂ኢቱ ድማ ብፍላይ ድማ ምስ ምምሕያi መጠን ኣግራብ (ደኒ)እቶም ክሳብ መፋርቕ 1980ታት ብሰፊሑ ዝረኣዩ ዝነበሩ ዓሞቕቲ ጉሕምታት(scars) ብዘይካ ኣብተን ኣዝየን ì ዳፍ ዝ§ና ተፋሰሳት (with slope gradient >60%) ኣዝዮም ቀኒሶምን ሓውዮምን እዮም፡፡ ብተወሳኺ ድማ ወሰ¦ ናይ ኣግራብ (ደኒ) ካብቶም ተፋሰሳት ዝውሕዙ ንዝነበሩ ውሕጃትን ዓበይቲ ደናጉላን ክቕንሱ ስለዝገበረ እቶም ሩባታት ìቢቦምን ዓሚቖምን ከምኡ ድማ እቶም አቐድም አቢሎም ናብ ክልተን ልዕሊኡን ተመቓቒሎም ዝነበሩ ሩባታት ናበ ሓደ ተመሊሶም፡፡ በዚ መሰረት እቲ ናይ ተፈጥሮ

ምሕዋይ ስራሕቲ ብፍላይ ድማ ኣብቶም ክሳብ ሕጂ ዘይሓወዩ ተፋሰሳት ተጠናኺሩ ንክቕጽልን እቲ ኣብቶም ሓውዮም ዘለዉ ተፋሰሳት ዝግበሩ ዘለዎ ሓለዋታት ድማ ንክቕጽሉን ንላቦ፡፡

ድሕሪ እቲ ለውጢ ሽፋን መሬት (ምምሕያሽ ሽፋን ደኒ) ምቕናስ ውሕጅ ከመዘሎ ምዕራፍ 9 ኣቕሚጡልና ኣሎ፡፡

ምዕራፍ 9፡ ምጉዳል ሓንደበታውትን አዕንውትን ውሕጃት ኣብ ምዕራባዊ ኣጻድፍ ሰሜን ኢትዮጵያ

እዚ መጽናዕቲ'ዚ ነቶም ኣብ ምዕራባዊ ሰሜን ኢትዮጵያ ዝርከቡ ተፋሰሳት ንምሕዋይ ኣብ ካልኣይ መፋርቕ 1980ታት ዝተ¥የዱ ዝተፈላለዩ ናይ ተፈጥሮ ሃፍቲ ምሕዋይ ስራሕቲ ስዒቡ ዝመጸ ምምሕያሽ መጠን ኣግራብን (ደኒ)ኣብ መጠን እቶም ካብዞም ተፋሰሳት እዚኦም ናብ ጎላጉል ራያ ዝውሕዙ ዝነበሩ ሓንደበታዊ ውሕጃትዝመጸ ለውጢ ንምጽናዕ ዝተ¥የደ ምርምር እዩ፡፡ ነዚ ዕላማዚ ዲማ ኣብ 11 ተፋሰሳት 332 ናይ ውሕጅ ክስተታት ኣብ ሰለስተ ተኸታተልቲ ዓመታት (2012–2014) ዝዓቀንና ክንከውን ከለና ኣፈላላይ መጠን ዉሕጃት ኣብ መንጎ እቶም ነዚ መጽናዕቲ ዝተመረጹ ተፋሰሳት ድማ ብመጠን ኣግራብ፣ መጠን ዝናብን ዝተፈላለዩ ቶፖግራፊያዊ ባህርያት አተን ተፋሰሳት ብምውድዳር ተንቲንናዮ፡፡ ውፅኢት ናይዚ መፃናዕቲ እዚ ከምዘርእዮ ድማ እቶም ኣብዘን 11 ተፋሰሳት ዝተ¥የዱ ስራሕቲ ምሕዋይ ተፈጥሮ ነቲ መጠን ኣግራብ (ደኒ) ናይተን ተፋሰሳት ኣዝዩ ከምዘመሓየሾን፤ ምስ ምምሕያሽ ናይቲ መጠን ኣግራብ (ደኒ) ድማ እቶም ኣብ መጀመርያ መፋርቕ 1980ታት ካብቶም ተፋሰሳት ዝውሕዙ ዝነበሩ ሃንደበታውን ኣዕነውትን ውሕጃን እቲ ኣብ ጎላጉል ራያ ኣብ ሰብኣውን ንዋታውን ዘስእብዎ ስነበሩ ሐደጋታትን ኣዝዩ ከምዝቐነሰን የረጋግጽ፡፡ በዚ ምሰረት ድማ እቶም ክካየዱ ዝጸንሑ ናይ ተፈጥሮ ሃፍቲ ምሕዋይ ስራሕቲ ብፍላይ ድማ ምሕዛእ እቶም ክሳብ ሕጂ ኣጸቢቕም ዘይሓወዩ ተፋሰሳት ተጠናኺሮም ንክቕጽሉ ንላቦ፡፡

ኣብ ኣናእሽቲን ጸዳፋትን በረኸቲ ቦታታት እቲ ውሕጅ እቲ ዘሎ ሓመድ/ሓሸዋ ሓፂቡ ሒዙዎ ኣይከድን፡፡ ዝተወሰነ እምኒ ዝበዝሖ ደለል ኣብተን እግሪ ጎቦታት ገዲፉ ይኸይድ እዩ፡፡ ብዛዕባ እዙይ ድማ ኣብ ምዕራፍ 10 ተቐሚጡ ኣሎ፡፡.

ምዕራፍ 10፡ ደለል ኣእማን ኣብ እግሪ ጸዳፋትን በሪኽትን ጎቦታት

በዝሒ ዘለዎም ከዉሃዊ ደለላት ኣብ ደረቅ ምድራዊ ቀርሲ መሬት ይርከቡ እዮም፡፡ ዕላማ እዚ መጽናዕ ግራበን ዝተሸፈኑ ቦታታት ዘሎ ኣእማን/ኩረት ዝበዝሖ ቁላል ደለል ዝርግሐኡን ኣብ ናብራ ዘሕድሮ ጽዕንቶን ንምርማር ፡፡ ዝርገሐ ግራበን ኣብ ዝተሸፈኑ ቦታታት ዝርከብ ኩረት ዝበዝሖ ቁላል ደለልን እዚ ኣብ ናብራ ዘስዕቦ ሳዕቤንን ንምርኣይ ጎጉል አርዝ፣ ምስልታት ሳትላይትን ጽሑፋዊ መጠይቅን ኣብ ጥቅሚ ውዒሉ እዩ። እዚ መጽናዕቲ ከምዝሕብሮ ኩረት ዝበዝሖ ቁላል ደለል ኣብ መገጣጠሚ ኣጻድፋትን ጸፊሕ ታሕተዋይ ክፋል ግራበን ሓጓፍ ሸንጥሮን ከምዝፍጠር የመልክት። ከምኡ እውን ፣ መጠን ስፍሓት ኩረት ዝበዝሖ ቁላል ደለል ምስ ፍልፍል ማይ ወሓዚ ሩባ ቀጥታዊ ዝኾነ ዝምድና ከም ዘለዎ እውን እቲ ጽንኣት የርኢ። ብተወሳኺ፣ማእኸላይ መጠን ትሕዝቶ ኩረት ዝበዝሖ ቁላል ደለል ካብ ግራበን እምኒ ኖራ (0.08 ሚልየን ሜ^3) ኣብ ግራበን ጸሊም እምኒ (0.75 ሚልየን ሜ^3) ከምዝዓቢ የረድእ። ብተመሳሳሊ፣ ምስፍሕፋሕ ኩረት ዝበዝሖ ቁላል ደለል ኣብ ታሕተዋይ ክፋል ግራበን ዝርከብ ናይ ሕርሻ ቦታ ብውሕጅ ክዕልቅለቅ ከምዝገብር የገንዝብ። ብተነጻጻሪ ኩረት ዝበዝሖ ቁላል ደለል ወሓዚ ማይ ይመጥጥ፣ ልሙዕ ሓመድ ይፈጥሩን በዝሕን ዕምቆትን ዘለዎ ማይ ከርሰ ምድሪ ክዕቖር ይገብሩ። እዚ ብምኳኑ፣ ኣብ ሓጓፍ ሸንጥሮ ካብ ዝርከቡ ግራበናት ኣተኣማማኒ ዝኾነ ዕብየት ሕርሻዊ ምህርቲ ንምፍራይ ጥሙር ምሕደራ መሬትን ማይን ኣዝዩ ኣገዳሲ እዩ።

እቶም ዓበይቲ ሩባታት ካብተን በረኸቲ ቦታታት ዓዉዒ ደለል ናበተን ጎልጎላት ሒዞም ይወርዱ እዮም፡፡ ምዕራፍ ዓሰርተ ሓደ ድማ ምምላእ ደለል ድልድላት ሩባታት ራያ ዝተገበረ መጽናዕቲ ሒዙ ኣሎ፡፡

ምዕራፍ 11፡ ምምላእ ደለል ድልድላት ሩባታት ራያ

ጎልጎል ራያ ኣብ ወሳናወሰን ሓጓፍ ሸንጥሮ ስሜን ኢትዮጵያ ውሽጢ ዝርከብ ኮይኑ ብተፈጥሮ ዝተዓደለ ትኹረት ዝስሕቡ ዓበይቲ ሩባታት ዝሓዘ እዩ። እዞም ሩባታት ብኣንፈት ምዕራብ ጎልጎል ራያ ካብ ኣዝዮም በረኽቲ ቦታታት ተላዒሎም ዝፈሱ እንትኾኑ ዝናብ ኣብ ዝበዘሐሉ ወቅቲ ኣዝዩ ብዙሕ ደለል ሒዞም ይወርዱ። ኣብዚ እዋን እዚ ኣብቲ ናይቶም ሩባታታት መእተዊ ዝርከቡ ድልድላት ደለሎም ገዲፎም ይሓልፉ። ብዚ ምክንያት እዞም ድልድላት ንክይዕጸዉ እዞም ዝናብ ዝበዘሐም ውቕቲታት ምስ ሓለፉ ነዞም ዝናብ ዝበዘሐም ወቅቲታት ሓዊሱ እንተነኣሰ ብዓመት ክልተ ግዜ ወይ ካብኡ ብላዕሊ ደለል ናይ ምልዓል ስራሕ ይስራሕ። ነገር ግን ኣብ እግሪ እዞም ድልድላት ዝዕቆብ መጠን ደለል ብምብዝሑ ምኽንያት እንታይ ምዃኑ እኹል መጽናዕቲ ስለዘየለ ነዚ ንምፍላጥ ድማ ኣብዚ መጽናዕቲ ንምርኣይ ተፈቲኑ ኣሎ። እዚ መጽናዕቲ ከምዘመላኽቶ

ብዋናነት ኣብ ዙርያ እቶም ድልድላት ዘሎ ከይዲ ድፍኢት ማይ (hydraulic process) ምኽንያት እዚ ደለል ከምዝእከብ የርኢ። ከምኡ እውን ናይቶም ድልድላት ምጽባብ ከም ዓብዪ ምክንያት ኮይኑ ተረኺቡ። ናይቶም ድልድላት ስፍሓት ካብቶም ናይሩባታት ስፍሓት ብኽልተ ኢድ ዝነኣሰ ብምኳኑ ምክንያት ናብቶም ድልድላት ዝፈስስ ማይ ይጨናነቕ እሞ ሒዝዎ ዝመፆ ደለል ኣብ እግሪ እቶም ድልድላት ንክተርፍ ይግደድ። ጥንክር ብዝበለ ውጽኢት ቀመር ዋላ እንተተዘይተሓዝ ናይ ደኒ ሽፋን እውን ናይ ባዕሉ ዝኾነ ግደ ኣለዎ። ስለዚ እዚ መጽናዕቲ ከምዘርእዮ (1) ናይቶም ድልድላት ስፍሓት ብዝተኸኣለ መጠን (ወጻኢ ብዝቐጠበ መልክዑ) እንተነኣሰ ምስቲ ናይቶም ሩባታት ስፍሓት ማዕረ ኮይኖም እንተዝህነው፤ (2) ኣብቶም ተፋሰሳት ዘሎ ሽፋን ደኒ እውን ከውስኽ ብምግባር ካብ ላዕሊ ተሓፂቡ ዝመጽእ ደለል ምቕናስ ይከኣል፤ (3) እዞም ሩባታት ተፈጥሮኣዊ ከይድታቶም ተኸቲሎም ንከይኸዱ ዝገብሩ ስራሕቲ ምክልኻል ውሕጅ ስለዘለዉን ዝገደዱ መዕነውቲ ንክኾኑ ስለዝግብር ዘሎ ተፈጥሮኣዊ ከይዲታቶም ተኸቲሎም ክፈሱ እንተዝግበርን ኣብ ላዕለዋይ ክፋል እዞም ሩባታት ዳግመ ግረባ ሓመድን ማይን ብስፍሓት እንተዝስራሕ ዝሓሸ ውጽኢት ክርከብ ይክኣል እዩ።

IV. መይዳ ግራበናት (Grabens) ኣብዓላ፣ ካላን ራያን

ዝቕጽላ ሸውዓተ ምዕራፋት ኣብ ሃፍቲ ማይን መሬትን ጎልጎላት እተን ግራበናት (the Grabens) መሰረት ገይረን ዝተሰርሓ ውጽኢት መጽናዕቲታት ኣቕሚጠን ኣለዋ፡፡ ምዕራፍ ዓሰርተ ክልተ ብዛዕባ ምስ ግዘ ዝለዋወጡ ጠመዝማዛት ሩባታት ራያ የርእይ ኣሎ፡፡

ምዕራፍ 12፡ ምስ ግዘ ዝለዋወጡ ጠመዝማዛት ሩባታት ራያ

ሩባታታት ራያ ካብ ብምዕራብ ኣንፈት ጎልጎል ራያ ብዘሎ ኣዝዩ ጸዳፍን በሪኽን ቦታ ተላዒሎም ብቑልጡፍ ናብቲ ዓሚቕ ዝኾነ ጎልጎል ራያ ይኣቱው። ብዚ ምክንያት እዞም ሩባታታት ራያ ኣብ ጎልጎል ራያ ሰፊሕ ሽፋን ቦታ ኣለዎም። ምስዚ ተዳሓሒዙ እዞም ሩባታታት ዝህልዎም ባህሪ ውሕዘት በቢግዚኡ ናይ ስፍሓት፣ ንውሓትን ኣንፈትን ለውጢ የርእዩ። ንዝህልዎም ምክንያት ለውጢ ንውሓትን ስፍሓትን ድማ ብግልፂ ስለዘይፍለጥ ነዚ ዛዕባ ትኹረት ብምግባር ተጸኒዑ። ውጽኢት እዚ መጽናዕቲ ከምዘመላኽቶ ብዋናነት ናይ ላዕለዎት ተፋሰሳት ስፍሓት ወሳኒ ምኽንያት ምኳኑ ክፍለጥ ተኻኢሉ ኣሎ። ንኣብነት፦ ክሳብ 57% ዝኸውን ንውሓትን 66% ዝኸውን ኣብ ዝሸፍንዎ ስፍሓት መሬትን ዝረአ ለውጢ ብናይቶም ተፋሰሳት ስፍሓት ዝውሰን እዩ። ብተወሳኺ ብዝተገበረ መጽናዕቲ ካብ 1978 ዓ.ም ጀሚሩ ሽፋን ደኒ (ተኽሊ) እናወሰኸ ምኳኑ የመላኽት፤ ኣብ ማእኸል እውን ናይ ምውሳኽን ምቅናስን ኩነታት የርኢ። ስለዚ ሽፋን ደኒ ኣብ ንውሓትን ስፍሓትን ዘይናዓቅ ጽዕንቶ ከምዘለዎም ንምርዳእ ክኢልና። እዚ ብምኳኑ ዝኾኑ ኣግራባት ኣብ ስራሕቲ ሕርሻ ዘለዎም ጽዕንቶ ንምእላብን ብዉ ገይርካውን ናይቲ ሕበረተሰብ መነባብሮ ንምምሕያሽ ኣብ ዝግበር ስራሕ ምድሓን (ዳግመ ግረባ) መሬት ኣብ ዝስረሓሉ እዋን ኣብቶም ተፋሰሳት ሩባታታት ትኹረት ዝገበረ እንተኾይኑ ትሕዝቶ እዞም ሩባታታትን ናይ ምዕናው ኩነታት ምቅናስ ከምዝከኣል እዚ መጽናዕቲ የመላኽት።

ምእራፍ ዓሰርተ ሰለስተ ብዛዕባ ሃፍቲ ማይ ኣብዓላ ዘቕምጥ ኮይኑ ዝተኻኣለ ኩሉ መረዳእታ ንምርካብ ንዝተገበረ ጻዕሪ ከየመስገንና ኣይንሓልፍን፡፡

ምዕራፍ 13፡ ሃፍቲ ማይ ግራበን (Graben) ኣብዓላ

ንምፍራይ ተወሳኺ ምህርቲ ምግቢ፣ ኣብ መንጎ ክልተ ነቃዕ ዝሃመመ መሬት (ግራበን) ናይ ልምዓት ኮሪደራት እዮም፡፡ ይኹን ድኣምበር፣ ኣተኣማማይነት ሃፍቲታት ማይ ኣብ ግራበን ዝርከቡ ሓጓፍ ሽንጥሮታት ሰሜን ኢትዮጵያ ኣብ ትልምን ምሕደራን እዞም ሃፍቲታት ዘሎ ግንዛበ ክንዲ ዝድለ ኣይኮነን፡፡ ዕላማ እዚ መጽናዕቲ ጸገም መረዳእታ ኣብ ዘለዎ ኩነት እውን እንተኾነ፣ ኣብ ግራበን እምኒ ኖራ ኣብዓላ ዘሎ መጠን ማይ ንምፍታሽ ነይሩ፡፡ መጠን ዝናብ ዝገልጽ መረዳእታ ንምእካብ ንሰለስተ ዓመታት (2015-2017) መሳርሕታት መለክዒ መጠን ዝናብ (ሬንጌጅ) እውን ተኺልና ኢና። መጠን ዝናብ ተቀያያሪ ባህርያት ኣለውዎ። እዚ ድማ ቅልጡፍ ዋሕዚ ወይ ምዕልቅላቅ ማይ ብቐንዲ ወሓዚ ካብቲ ኣጻድፍ ናብ ታሕተዋይ ክፋል ግራበን ኣብዓላ ይምርሕ። እዚ ወሓዚ ማይ ብመተሓላለፊ ኣቢሉ ናብ ንቁልቁል ፈሲሱ ይተርፍ። ብተወሳኺ፣ ብዙሕ ማይ ብህፈተ-ላህላህታ ናብ ከባቢ ኣየር ይምለስ፡፡ ብሓፈሻ እቲ ጽሑፍ ኣብዚ ግራበን እምኒ ኖራ 36% ዋሕዚ ማይ ኣብ ታሕተዋይ ክፋል እቲ ግራበን ሰሪጉ ይኣቱ። ስለዚ ዝተዋደደ ምሕደራ ማይን ሓመድን ኣብ ግራበን ኣብዓላ ማይ ንክህሉ ይሕግዝ፧፡

ኣብ ኣብዓላ ዘሎ ለውጢ ገጸ-ምድሪ ኣብ ምዕራፍ 14 ተቐሚጡ ኣሎ፡፡

ምዕራፍ 14፡ ምልውዋጥ ገጸ መሬት ኣብ ጎልጎል ኣብዓላ

እዚ መጽናዕቲ ኣብ ገጸ መሬት ጎልጎል ኣብዓላ ንልዕሊ ሰለስተ ዓሰርተ ዓመታት ንዝነበረ ምልውዋጥ ኣጠቃቅማን ሽፋንን መሬት ኣብ መዋቅር ኣቀማምጣ መሬት ዝነበሮ ጽዕንቶ ትኹረት ገይሩ ዝተኻየደ እዩ፡፡ ብመሰረት እቲ መጽናዕቲ ታሓራሳይ መሬትን ናይ መንበሪ መሬትን ብመጠን ወሲኮም፡፡ ብተጻራሪ ከዓ መሬት ቑጥቋጦን ባዶ መሬትን ናይ ምኽናስ መጠን ከም ዘርኣዩ እቲ መጽናዕቲ የርኢ፡፡ ከም ሳዕቤኑ ከዓ መሬት ቑጥቋጦ ኣብ 1984 ዓ.ም ዝነበሮ 51% ሽፋን ኣብ 2018 ዓ.ም ናብ 38.9% ወሪዱ፡፡ ብተመሳሳሊ መንገዲ ባዶ መሬት ኣብ 1984 ዓ.ም ዝነበሮ 27% ሽፋን መሬት ኣብ 2018 ዓ.ም ናብ 22.3% ቀኒሱ፡፡ ናይዚኦም ጠንቂ ምኽንያታት ከዓ ቅልጡፍ ወሰክ በዝሒ ህዝቢን ከይዲ ኣብ ሓደ ከባቢ ተኣኪብካ ምንባርን ከም ዝኾኑ እቲ መጽናዕቲ ኣመላኪቱ፡፡ ወሰክ ታሓራሳይ መሬትን ናይ መንበሪ መሬትን ኣብ ገጸ መሬት ጎልጎል ኣብዓላ ልዑል ምብትታን ወሰኽ ኣኪቲሉ፡፡ ነዚ ተኪቲሉ እዚ መጽናዕቲ መንግስቲ ክልላዊን ከባቢያዊን ኣብ ታሓራሳይ መሬትን ናይ መንበሪ መሬትን ዝርአ ዘሎ ምስፍሕፋሕ ዓብዪ ትኹረት ክህብሉ ከም ዝግባእ የመላኽት፡፡ ካብዚ ብተወሳኪ ከይዲ ምትእኽካብ መንደራት ብዝተወደበ መልክዕን ብጥንቃቀን ክትግበር ከም ዘለዎ እዚ መጽናዕቲ የተሓሳስብ፡፡

ምዕራፍ ዓሰርተ ሓሙሽተ ኣብ ካላ ዘሎ ኣብ ማይን መውዐሊ ከፍቲን ዝግበር ንሕንሕ የሪኣና ኣሎ፡፡

ምዕራፍ 15፡ ንማይን መግሃጺ መሬትን ዝግበር ጎንጺ ኣብ ጎልጎል ኻላ

እዚ መጽናዕቲ ኣብ ሰሜን ኢትዮጵያ ዝርከብ ጎልጎል ኻላን ከባቢኡን ዘሎ ከይዲ ወቅታዊ ምንቅስቃስ ሰባትን እንስሳታት (Transhumance) ኣብ ማህበራዊን ስነ ኣከባቢያዊነን ዘለዎ ጽዕንቶ ንምጽናዕ ዝተገበረ መጽናዕቲ እዩ፡፡ ናይቲ መጽናዕቲ ውጽኢት ከም ዘመላክቶ ኣብ ጎልጎል ኻላን ከባቢኡን ዘሎ ወቅታዊ ምንቅስቃስ ሰባትን እንስሳታት (Transhumance) ኣብ መንጎ ነበርቲ ደጉዓን ቆላን ናይ ጥቅሚ ጎንፂ ኣኸቲሉ እዩ፡፡ እቲ ጥቅሚ ጎንፂ ብወገኑ ከዓ ምፍንቃል ሕብረተሰብን ምውዳም ሰፈር ደቂ ሰባትን ኣቲኹሉ፡፡ ኣብ ዝወደመ ሰፈር ደቂ ሰባትን ኣብ ኣጻድፍ ዋጅራትን ዝተገበረ ዳህሰሳ ሽፋን እጽዋት ከም ዝሕብሮ ኣብቲ ዝወደመ ሰፈር ደቂ ሰባትን ኣብ ኣጻድፍ ዋጅራትን ዘሎ ሽፋን እጽዋት ወሲኩ እዩ፡፡ ቀንዲ ምክንያት ወሰክ ዘሎ ሽፋን እጽዋት ከዓ ኣብቲ ዝወደመ መንደር ዝነበረ ናይ ሰብን እንስሳን ጸቕጢ ስለ ዝቀነሰን ኣብ ኣጻድፍ ዋጅራት ዝተከለለ ናይ ሕዛእቲ ቦታን ከምኡ እዉን ስራሕቲ ዕቀባ ሓመድን ማይን እዮም፡፡ እዚ መሰረት ብምግባር ኣውጻእቲ ፖሊሲን መንግስቲ ክልልን ምስ ወቅታዊ ምንቅስቃስ ሰባትን እንስሳታት (Transhumance) ተታሓሒዞም ዝመፁ ችግራት ትኩረት ክህብሉ ከም ዘለዎም እዚ መጽናዕቲ የተሓሳስብ፡፡ ካብዚ ብተወሳኪ ከዓ ዘላቅነት ዘለዎ ምሕደራ ገጸ መሬት ምርግጋጽን ጠንካራ ትካላት ሓለዋ ከባቢ ብምምስራትን ኣገዳሲ ከም ዝኾነ እዚ መጽናዕቲ ይሕብር፡፡ ኣብ መወዳእታ እቶም ዘጋጥሙ ጎንጽታት ምእላይ ምስ ዓበይቲ ዓድን መራሕቲ ሃይማኖታትን ብምዝታይ ሕጊ ኣተኣላልያ ጎንጽታት ምውጻእ ከም ዘድሊ እዚ መጽናዕቲ የመላኽት፡፡

ብተመሳሳሊ መልክዑ ሃፍቲ ማይ ጎልጎል ራያውን ኣብ ምዕራፍ ዓሰርተ ሹዱሽተ ተቐሚጡ ኣሎ፡፡

ምዕራፍ 16፡ ሃፍቲ ማይ ግራበን (Graben) ራያ

ምምጥጣን ድሌትን ኣቕችቦት ሕርሻ ማይ እናበርትዐ ዝከይድ ዘሎ እዩ፡፡ ዕላማ እዚ መጽናዕቲ ኣብ ግራበን ጸሊም እምኒ ራያን ሓሸንገን ዝርከቡ መጠን ማይ ብቁጽሪ ንምቅማጥ እዩ፡፡ መጠን ዝናብ ዝገልጽ መረዳእታ ንምእካብ ንሰለስተ ዓመታት (2015-2017) መሳርሕታት መለከዒ መጠን ዝናብ (ሬንጌጅ) እውን ተኺልና ኢና። ብተወሳኺ፣ ካብ ውሕጅ ዝፈስስ ብኣሃዝ ንምልካዕ ጌጃት ዓበይቲ ወሓዝቲ ሩባታት ተ]ኒåም እዮም። ብተመሳሳሊ፣ መጠን ማይ እቶም ቦታታት ንምስላሕ ወይ ንምግባጥ፣ ፍሰት ወይ ዋሕዚ ማይ፣ ጸባያት ሓመድ፣ መለከዒ ባህርያት ኩነታት ኣየርን ንኣጠቃቅማ መሬት ዝገልፁ መረዳእታታትን ከም መጠናኸርቲ ኮይኖም ኣገልጊሎም። እቲ መጽናዕቲ ከም ዝሕብሮ መጠን ዝናብ ተቀያያሪ ባህርያት ኣለውዎ። እዚ ድማ ቅልጡፍ ዋሕዚ ወይ ምዕልቅላቅ ማይ ብቐንዲ ወሓዚ ኣቢሉ ናብ ታሕተዋይ ክፋል ግራበን የምርሕ። ብተወሳኺ፣ ብመንጽር ዓመታዊ ማእኸላይ መጠን ዋሕዚ እንትረአ ብምኽንያት ካብ ስፍሓት ምሓዝ ማይ ዝህሉ ኣበርክቶን ብራኽ ፍልፍልማይ ዝበዝሐ ዋሕዚ ኣለዎ። ናብ ታሕተዋይ ክፋል ራያ ግራበን ካብ ዝውሕዝ ከባቢ 40% ወሓዚ ማይ ብመተሓላለፊ ኣቢሉ ፈሲሱ ይተርፍ። ኣብ ግራበን ጸሊም እምኒ ብዝናብ ካብ ዝእከብ ዓመታዊ መጠን ማይ ከባቢ 77% ዝኸውን ብትነት ይሃፍፍ። በዚ ምኽንያት ማእኸላይ ዓመታዊ ዋሕዚ ወይ ፍሰት ማይ ግራበን ራያን ግራበን ሓሸንገን ብቀደም ሰዓብ 16%ን 33%ን እዩ። ስለዝኾነ ሃፍቲታት መሬት ግራበናት ዝርከብ ማይ ገጸ መሬትን ከርሰ መሬትን ብግቡእ ተጠቂምካ ዝሓሸ ቁጠባዊ ዕብየት ንምምጻእ ግቡእ ምልዕዓል ክግበር ይግባእ። ውጽኢት እዚ መጽናዕቲ ኣብ ኣጠቃቅማ ሃፍቲታት ተፈጥሮ ግቡእ ዝኾነ ትልምን ምሕደራን ኣገዳሲ ከምዝኾነ የገንዝብ።

ምዕራፍ ዓሰርተ ሸውዓተ እተን ሩባታት ኣብ ለውጢ ገጽ-ምድሪ ጎልጎላት ዘለወን አጃም የርኢ፡፡

ምዕራፍ 17፡ ምልውዋጥ ስነ-ቕርፂ ሩባታት ራያን ለውጢ ሽፋን መሬትን

መጽናዕቲ ኣጠቓቕማ/ሽፋን መሬት ኣብዚ ሕዚ እዋን ተደላዪ ናይ መጽናዕቲ ባይታ እዩ። ኩነታት ኣጠቓቕማ/ሽፋን መሬት ሩባታት ትኹረት ዝደልዩ ኣካላት እዮም። እዚ መጽናዕቲ ሩባታት ራያ ካብቲ ኣንፈት ምዕራብ ዘሎ በሪኽ ቦታ ናብቲ ጎልጎል ኣብ ዝበጽሑሉ እዋን ኣብ ኣጠቓቕማ/ሽፋን መሬት ዘለዎም ጽዕንቶ ትኹረት ብምግባር ዝተጸነዐ እዩ። ኣብዚ መጽነዕቲ ኣብ መይዳ ቆቦ ዝርከብ ንሩባታት ራያ ይውክል ተባሂሉ ዝተኣመነሉ ሩባ ዋርሱ ትኹረት ገይሩ ተሰሪሑ ኣሎ። እዚ መጽናዕቲ ከምዘመላኽቶ ሩባታት ኣብ ዝተስፋፍሕሉ ቦታ ለውጢ ኣጠቓቕማ/ሽፋን መሬት ዑደት ከም ዘለዎ የርኢ። ካብ ሕርሻ ናብ ሩባ/ውሕጅ መውረዲ/ደለል፣ ካብ ሩባ/ውሕጅ መዎረዲ/ደለል ናብ ሳዕሪ/ቆጥቋጥ/ጫካ፣ ካብ ሳዕሪ/ቆጥቋጥ/ጫካ እንደገና ናብ ሕርሻ ናይ ምቅያር ኩነታት ይርአ። ከምዚ ዝኾነሉ ምኽንያት እዞም ሩባታት ናይቲ ሕርሻ ሓመድ ናብ ውሑጅ/ደለል ይቕይሩዎሞ ድሕሪ ዝተወሰነ ግዘ እቲ ሓመድ ኣብቲ ሩባ ይተርዝ፤ እንደገና ተመሊሱ ናብ ሳዕሪ/ቆጥቋጥ/ጫካ ይቕየር። ዝተወሰነ ግዘ ጸኒሑ እቲ ሓመድ ምስ ለምዐ በቲ ገባር ምሕራስ ይጅመር። ብሓፈሻ እቶም ሩባታትን ብኣጠቓቕማ/ሽፋን መሬትን ዝመጽእ ለውጢ ኣብ ልዕሊ ኩነታት ኣነባብራ ሓረስቶትን ምሕደራ መሬትን ዝለዓለ ትርጉም ኣለዎ። ለውጢ ሽፋን መሬት ካብ ለውጢ ስነ ቕርፂ ኣግራባት ጥራሕ ከይኮነስ ካብ ኢድ ኣታውነት ደቂ ሰባትን ዳግም ምውላድ/ምዕባይ ተኽለታትንውን ዝመጸ እዩ፡፡ ስለዚ ኣብ ስራሕቲ ኣተሓሕዛ መሬት ባህሪ ሩባታት ምግንዛብ ጽቡቅ ከምዝኾነ የመላኽት። ብተወሳኺ እቶም ሩባታታት ንምቁጽጻር ኣብ እንሰርሖም ስራሕቲ ናይቶም ሩባታታት ተፈጥሮኣዊ ባህርን ነጻነትን ምሕላው ዝሓሸ መማረፂ እዩ።

ምእራፍ 18 ብዛዕባ ጨውነት ማይ ኣብ ከባቢ ራያ ኣቕሚጡ ኣሎ፡፡

ምዕራፍ 18፡ ጨውነት ማይ ግራበን (Graben) ራያ

መጠን ወሰኽ ጨውነት ማይ ኣብ ደረቅ ከባቢ ኣስጋኢን ማሕለኻ ዕቤት ሕርሻ መሬት እዩ፡፡ ስለዝኾነ፣ ዕላማ እዚ መጽናዕቲ ብሓገዝ ኤለትሪካዊ ኮንዳክቲቪቲ ስርዓታት ጨውነት ማይ ብመንጽር ቦታን ግዜን ምንጻርን እዮም። ቀስ ብቀስ ንስርዓታት ጨውነት ማይ እቶም ቦታታት ብመንጽር ጊዜን ቦታን ንምርኣይ ብመሳርሒ ኤልትሪካዊ ኮንዳክቲቪቲ ከም ወሓዝቲ፣ ሩባታት፣ፍልፍላት፣ዒላታትን ቃላያትን ንዝበሉ ማያዊ ኣካላት ለኪዕናዮም ኢና። እዚ መጽናዕቲ ኣብ ግራበናት ዘሀልዉ ትሕዝቶታት ኤልክትሪካዊ ኮንዳክትቪቲ ኣብ መንን ክረምትን ሓጋይን ርኡይ ኣፋላላያት ከምዘሎ ይሕብር። ብተወሳኺ፣ መጠን ዓመታዊ ማእኸላይ ኤልክትሪካዊ ኮንዳክትቪቲ ማይ ካብ ኣÉድፍ ኣብ መፍስስ መኹባዕቲ መሬት ግራበናት ከምዝውስኽ የረድእ። ብዘገረም መልክዑ፣ ጨውነት ማይ ሞኽባዕቲ መሬት ግራበን ኣብ ዘተሓሳስብ ኩነት ይርከብ። ከም ጽውኢት ናይዚ ድማ እናለዓለ ዝመጽእ ዘሎ ጨውነት ማይ እቲ ከባቢ ብፍላይ ኣብ ገጸ መሬት ግራበናት ከይዲ ሕርሻ ብምሉእነት እንትስፍሕፉሕ ንፍርያት ሕርሻ ኣብ ሓደጋ ዘውድቕ እዩ። ስለዚ፣ ብግቡእ ዝተዋደደ ምሕደራ መፋስስ ኣብ ሓጓፍ ሽንጥሮታት ሰሜን ኢትዮጵያ ጽሬትን መጠን ዉሕስነት ይሕልው፡፡

V. ምሕደራ መሬት ኣብ ጎልጎል ራያ

ንዝሓለፉ በዙሓት ዓመታት ኣብ ጎልጎል ራያ ምስ ማይ፣ መሬትን፣ ህዝቢን ዝተራኸቡ ዝተፈላለዩ ዓይነታት ለውጢ ተራኢዩ ኣሎ፡፡ ምዕራፍ ዓሰርተ ትሽዓንተ ኣብ ራያ ዘለዋ ናይ ሕርሻ ኢንቨስትመንት (ሕርሻ ንግዲ) ኣብ ልዕሊ ለውጢ መሬት ዘለዎ አጃም ኣቕሚጡ ኣሎ፡፡

ምዕራፍ 19፡ ንማይን መግሃጺ መሬትን ዝግበር ጎንጺ ኣብ ጎልጎል ኻላ

እዚ መጽናዕቲ ኣብ ጎልጎል ራያ ዘሎ ምስፍሕፋሕ ኢንቨስትመንት ሕርሻ ኣብ ምልውዋጥ አጠቃቀማ መሬትን ሽፋን መሬትን ዘለዎ ጽዕንቶ ንምድህሳስ ዝተገበረ ምርምር እዩ፡፡ ብመሰረት ውጽኢት እቲ መጽናዕቲ ኣብ ጎልጎል ራያ ዘሎ ምስፍሕፋሕ ኢንቨስትመንት ሕርሻ ልዑል ምልውዋጥ አጠቃቀማ መሬትን ሽፋን መሬትን አኸቲሉ፡፡ ብሳዕቤኑ ኣብ ንኡስ ተፋሰስ ቆቦ ዝነበረ ሽፋን ደኒ ቀኒሱ፡፡ በዚ መሰረት ከዓ ካብ 2007-2014 ዓ.ም ኣብ ዘሎ ግዜ ኣብ ንኡስ ተፋሰስ ቆቦ ዝነበረ መጠን ሽፋን ደኒ ብ62% ቀኒሱ፡፡ ብተመሳሳሊ መንገዲ ኣብ ንኡስ ተፋሰስ መኮኒ ዘለዉ ኢንቨስተመንተ ሕርሻታት ዝነበረ መጠን ሽፋን ቆጥቋጥ ብ60% ቀኒሱ፡፡ ካብዚ ብተወሳኪ ኣብ ንኡስ ተፋሰስ መኮኒ ዝነበሩ ናይ መንበሪ መንደራት ተቀይሮም እዮም፡፡

ብተጻራሪ ኣብ ንኡስ ተፋሰስ ቆቦን መኮኒን ንሕርሻ መስኖ ዝውዕሉ ቦታታት ብቕደም ሰዓብ ብ 74% ን 73% ወሲኾም፡፡ ብሓፈሻ ኽርአ ከሎ ኣብ ጎልጎል ራያ ተጠናኪሮም ዝቅጽሉ ዘለዉ ኢንቨስትመንት ሕርሻታት ምልውዋጥ ኣጠቃቀማ መሬትን ሽፋን መሬትን ከምኡ እዉን ምልውዋጥ ኣገልግሎት ገጸ መሬትን ኣስዒቦም ኣለዉ፡፡ ስለዚ መንግስቲ ኢንቨስትመንት ሕርሻ ኽስፋሕፍሕ ኣብ ዝሕሰቡ ቦታታት ኣብ ገጸ መሬት ዘለዎም ጽዕንቶ ንምድህሳስ ገጸ መሬት መሰረት ዝገበረ መጽናዕቲ ከም ዘድሊ እዚ መጽናዕቲ የመላኽት፡፡

ለውጢ ከባቢን ለውጥታት ኣጠቃቅማ መሬትን በሓባር ለውጢ ገጸ-ምድሪ የምጽኣ፡፡ ምስ እዙይ ተዳሒዙ ለውጢ ገጸ-ምድሪ ጎልጎል ራያ ኣብ ምዕራፍ ዒስራተቐሚጡ ኣሎ፡፡.

ምዕራፍ 20፡ ምልውዋጥ ገጸ-ምድሪ ጎልጎል ራያን ዋና ምኽንያታቱን

እዙይ መጽናዕቲ ኣብ ጎልጎል ራያ ንሰለስተ ዓሰርተ ዓመታት ንዝነበረ ቅንብርን ወቅረትን ገጸ-ምድሪ ትኹረት ገይሩ ዝተኻየደ እንትኸውን ብመሰረት እቲ መጽናዕቲ ሕርሻ እቲ ዋና ኣካል ገጸ-ምድሪ እዩ፡፡ ንዝሓለፉ ሰለስተ ዓሰርተ ዓመታት ትርጉም ዘለዎ ወሰኽ ለውጢ መጠንን ምብትታንን ኣሪኡ ኣሎ፡፡ መሬት ቑጥቋጦ ናይ ምቕናስ መጠን ዘርኣየ እንትኸውን ልዑል ናይ ምብትታን ወሰኽ ኣሪኡ ኣሎ፡፡ ብተመሳሳሊ መልክዑ ናይ ደኒ ሽፋን ብተኽታታሉ እናቐነሰ ዝመጸ እንትኸውን ትርጉም ዘለዎ ናይ ምብትታን ወሰኽ ግን ኣያርኣየን፡፡ ናይ መንበሪ መንደራት ብመጠን እናወሰኻ ከምዝመጻ እቲ መጽናዕቲ የርኢ ኣሎ፡፡ ንደቂ ሰብ መንበሪ ዝኾና ኣናእሽተ ቦታታት ኣብ ጸግዒ ሕርሻ፣ መሬት ቑጥቋጦን፣ ደኒን ተዓጻቒን ይርከባ፡፡ እዚ መጽናዕቲ ዘልዐለን ለውጢታት ብዋናነት ምስ ምውሳኽ ድልየት ምግቢን መንበሪን ወዲ ሰብ ዝተራኽባ እየን፡፡ ብተወሳሒ ናይ ገጸር መንደራት ናብ ሓደ ከባቢ ናይምእካብ ከይዲውን ሓደ ምኽንያት ኾይኑ ተረኺቡ ኣሎ፡፡ ብተወሳሒ ናይ ንግዲ ሕርሻ ስራሕቲ ምስፍሕፋሕ ንለውጢ ገጸ-ምድሪ ጥንኩር ምኽንያት እዩ፡፡ ብአጠቓላሊ ኣብ ጎልጎል ራያ ዘሎ ኩነታት ኣሰፋፍራ ደቂሰባት ዓውዪ ትኹረትን ትልሚን ዝደሊ ጉዳይ እዩ፡፡ ምኽንያቱ ናይ መንበሪ መነደራት ኣብ ልዕሊ ሕራሻ፣ ዝለምዐ መሬት ቑጥቋጦን፣ ደኒን ኢዮም እናተስፋሕፍሑ ዝርከቡ፡፡

ኣብ መወዳእታ ምዕራፍ ዒስራን ሓደን ናይ ቀረባ ግዝ ኩነታት ማዳበርያ ኣብ ራያ ከባቢ ማእኸል ገይሩ ውጽኢት መጽናዕቲ ኣቐሚጡ ኣሎ፡፡.

ምዕራፍ 21፡ ኣብራያን ከባቢኡን ኪሳራ መጠን ማዳበርያ (. 2012-2016)

ብመንግስቲ ኣብ ዝቐርብን ኣብ ጸሊም ዕዳጋን ኣብ ዘሎ ዋጋ ማዳበርያ መጽናዕቲ ገይርና ኣለና፡፡ ኣብ ኢትዮጵያ ምሻጥ ማዳበርያ ብበዝሒ ከምዝወሰኽን ኣብ ሰሜናዊ ክፋል እታ ዓዲ ድማ እቲ ዘሎ ኣቕርቦት ካብ ድልየት ንላዕሊ ምዃኑ መረዳእታ የርኢ፡፡ እቲ መጽናዕቲ ብ2016 ኣብ ከባቢ ራያ ዝተገበረ እንትኸውን ካብተን ካልኦት ከባቢታት ይቃረን እዩ፡፡ ኣቕርቦት ማዳበርያ፣ ኣብ 2016 ዓ.ም መንግስት ዝሸጠሉን ኣብ ጸሊም ዕዳጋ ዝነበረ ዋጋ ማዳበርያ አሃዛዊ መረዳእታ ካብ 35 ወረዳታትን ኣብ ከባቢ ራያን ካብ ዝርከቡ ኹሎም ቤት መዘጋኛ ኦፊሴላዊ ሰታቲሰቲክስን ካብ ቑልፊ መረዳእታ አቕረብቲን ተረኺቡ ኣሎ፡፡ ተፈጥሯዊ ዘይኮኑ ማዳበርያታት ንምፍላጥን ንምሻጥን ባዓል ሞያታት ግብርና መበረታትዒ ከምዘበርኽቱ እቲ ዝተረኽበ መረዳእታ የረጋግጽ፡፡ ብተወሳኺ ናይ ሓገዝ ምግብን ምስ ባዓል ስልጣናት ዝርከብ ጥቕምን ከም መሻየጢ ዕዳጋ ይጥቀሙሉ ነይሮም፡፡ ንኣብነት ማዳበርያ ተዘይ ገዚኡ ሓገዝ ምግቢ ከምዘይግበረሉ ይንገሮ፡፡ ብ 2016 ንሓረስቶት ዝተሸጠሉ ማእኸላይ ዋጋ ማዳበርያ በኩንታል 1407 ብር ነይሩ፡፡ ከም ዓይነት እቲ ማዳበርያን ካብ ኣዲስ ኣበባ ዘለዎ ርሕቐትን መሰረት ገይሩ ናይ ዋጋ አፈላላይ ነይሩዎ፡፡ ኣብ ጸሊም ዕዳጋ ዝነበረ ማእኸላይ ዋጋ በኩንታል 731 ብር ነይሩ፡፡ ነገር ግን ኣብ ሰለስቲኣን ወረዳታት ራያ ማእኸላይ ዋጋ 463 ብር እዩ ነይሩ፡፡ ኣብ ከባቢታት ራያ ኣብ ሓጋይ ሞስኖ ዘለዎም ሓረስቶት ጥራሕ እዮም እቲ ማዳበርያ ዝደልዩዎ፡፡ እቶም ኻለኦት ይሸጡዎ፡፡ እቶም ሓረስቶት እቲ ከባቢ ብጣዕሚ ሙቐት ስለዝኾነ መሬቶም ናይ ጠሊ ጸገም ከምዘለዎን ብተወሳኺ ድማ ካብ ላዕሊ ብዝመጽእ ደለል ሉሙዕ ስለዝኾነ እቲ ማዳበርያ ከምዘየድልዮም ይዛረቡ፡፡ ተድልዮምውን ካብ ዕዳጋ ከገዝኡ ከምዝኽእሉ ይናገሩ፡፡ ብጸሊም ዕዳጋ መብዛሕቲኡ እቲ ናይ ተፈጥሮ ዘይኾነ ማዳበርያ ብነጋዶን ቤተሰብ ብዝኾኑ ደለልትን ገይሩ ብደገ ተጠቀምቲ ይግዛእ ነይሩ፡፡ እቶም ሓረስቶት ማዳበርያ ካብ መንግስቲ ብምውሳድ ንማዳበርያ ኩባንያታትን ነጋዶን ብምሻጥ ዓርሶም ክበጽሓም ካብ ዝነበረ ዓውዪ ኪሳራ የድሕኑ ነይሮም፡፡ ማዳበርያ ኣብ ምህርቲ ሕርሻ ኢትዮጵያ ኣዚዩ ክዓብይ ካብ ዝገብሩ ነገራት ሓደ እዩ፡፡ ኾይኑ ግን ፖሊሲ እቲ ናይ ማዳበርያ ኣዚዩ ብዝሓሸ ኩነታት ክማሓየሽ ዝግበአ ኾይኑ ብዝተሸጠ መጠን ማዳበርያ ከይኾነስ ብስነ-ምህዳራዊን ስነ-ሕርሻን መረዳኢታታት መሰረት ገይሩ ክኸውን ኣለዎ፡፡ ሓረስቶት ብዘይ ድልየቶም ማዳበርያ ከገዝኡ ምግባር ነቲ ልምዓት ሕርሻ ሓደገኛ እዩ፡፡

Kiilbati Ethiopiah Garben (Graben) baaxoo lee ummata kee baaxoo Gon

Biyaxgilign Demisee, Gan Nisen kee Tesfaalem Gebreyohans

1. *Baaxoo-Kusaaq (Geography) Department፣ Mekele Jaamiqat፣ Ethiopia*
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I. Culma

Ta kiitab labataana kee inki fotiima luk Garben butta (Graben TEAM) Proojektil gytimteh taan kusaaqite ele tunkutubeh tan . Garbe jarmanak getimtee qaangara kinuk qaalelii maaroh edeyaan fidiin booxaa eyanaam kinii. Kitaabak ta exaal uxux …. Inikhayto fotiimal taan namahytoo footiima kusaq elle yeke baxooh caalad yabta

Makra 1: Garben (Graben TEAM) proojekt

Garben butta Awroobah L.L 2013-2018 kilbaati Ethiopiak fayaa le taan baxoo kee fidiin baxooh fanal gytimtam kinuk Ethiopialh dadala kaxxam ede antifiquk sugtee.le Taa baxool baxabaxsa yan giino milaagi elesuge kinuk Dacaayro ,buqreq kee garaab daayroo dinaa ele taan. Taa baxool taan ummatah fanad biceeway saqii qayso kee kallah taan taaqabiteh taagah sugeem tammixigee.Mekele Jaamiqaat beljemil gytimtah taan katolik jaamiqaatk GENT kee LUVAN diqsitaa taan jaamiqatite luk tama baxol kuasaqa abte.

Makra 2: Ethipiak qallela kee booxa fanad geytimtah taan baaxoo

Garben kusaaqah Abqalla, yakalla ,Raya kee Casheng doornee. Qallela kee daqorti tasgaleemih taagah weeqii mango.
Balaaqe ele askatuk gytima.
Baaxoo: Garben eyanam gubaal afah gexxah tan xaayit kee kaxxa qallelak tunkulukee baxoo eyanaam kinii. Cellaloh, Abqaala intaaloo Xaa ,Rayak kootebe daata xaa tonaah booxa ballaqek kibimteeh tan baxoo kinni.
Refty valy: edexayeh tan baxoo mangih sacra kinuk roob saanat inki wak raada, Raya wagitenee kaa tekek sanatad nama wak raada.Faya lee baxool radah yan roobih weqaayti kaxaa daqoorwa
Yaklukee.
Ballaqe: Raya kee cassengel data ballaqe, abqaalla kee kaalal burahin ballaqe geytimtaa.
<u>**Ummataa qadad:**</u> Taa kusaq elee yeke baxool 650000 takeh tan ummata ele taan ,Raya kee

Cashengel amara kee Tigray ummata getimta kadu Orroomo kee Qafar yas galee mari ele gytima. Tiray kee oroomo darqii kee garab darqiih xiinii kaadu Qafar dacayro xiinah taan.

Baxoo: Ayroo culmaa kee Ayroo mawqad tan baxoo qaysoo le, Ayroo culmaak fayale baaxoo kadu mango coox ele tabuke.

II. Kilbati Ethiopiak qallelaa kee faya le baaxool geytimeh yan kusaaq

Taa footmal qallela kee fayale baxool yekeh yan kussaqa wagita.Taa baxoo ethiopiak kaxaa qalleli elle geytima baaxoo kinuk qallelak obay yan weqii raamma lee baxooh lee raeena yake.

Makra 3: Qallela kee faya le baaxoh silayti caalat

Ethiopiak faya le baaxoo Afrikah gaysal 2000m badak fayaluk getimta baaxok 50% taabixee. Tohuh taagah kiilbatii Ethiopia 3 qallelal kusaq yeke. To qallelah tu gacte katekek, Kiilbati qallela 4550 m, Abne Yosu qalle 4277 m kee Ferac Imbah qalle 3939 m. Tama qallelal duma xex wakti kaxaa BARAAD elle sugemim baxa baxsa lee Maasaya getimte. Tahak duma ta baaxoo BARAAD lem yascase kusaq makina. Taway yekeh yaan kusaqal BARAAD elle sugee caadok (daamacaa) 6°C laaqna osism yascasee.

Faya le baaxol qonxaa GARBEN geytimte. Cellaloh KOREM, MACHEW kee CASHENGE.

Makra 4: Cashengeh badiih xeex widiir sugeteh tan ballaqe gexoo (weqii beya ballaqe)

Weqii beyeh yaan ballaqe xeex waktih baxool sugeh qaabar yascasee. Tahak ugut abak cashengel sugteh taan ballaqe ballaqe weqii sabatah abak teen gexoo wagitak kussaq abne.Kad tama badak adal mango waktii sugeh yan ballaqe kooboxul kusaq abne. Tuhuk ugu abak ballaqe gexxa malqoo elle tekem naxagoo dunde. 1970 qimbisahanam ballaqe koobox osisak yemetem tambulwe.

Makra 5: Raayyal fayya le baaxooxa daro xalootih gexsit

Kilbatti etiyobiyal fayya le baaxooxal 33% takkeh tan baaxoo buqre daroh anfiquk geytima.

Ta baaxo baxsa luk daro xalootih gexsit ikraaro baaxo dadoosih iddigat antafaquk taamittah tan qunda buqraabeyniitit tibixsimem kinni. Tanih tan daro dalootih gexsit kartal daffeesoonuh sanat roobih ixma lih leh yanih yan angaarawat radak kilbatti itiobiyak fayya le baaxooxal daro dalootih gexsit mannal aboonuh linoh nan mabla fayya haynam duudnah. Tahamat radoonuh sinni murti wakti yaydeeroonu kee xaloo nammadirrib leh tan koona daroora neyyeeqe. Oson ux daroh wakti (affara alsitte), madab ux daroh wakti (koona alsitte), madab der daroh wakti (laca alsa), der daroh wakti (sagla alsa) kee der namma daro wakti (taban kee namma alsa) kinni. Mangom ux wakti leh tan daroora golo rigidit geytimtawak der wakti leh tan daroora golo booxah addal geytiman. Murti wakti deddar kilbatti ayroh Culmaak gabbi ayroh culmal osak gexa. Inki daro xalootih gexsitih addal murti nammadiribih kadda baxsal milalaagima. Ossotinah daro dalootih gexsit sanat roobih ixmah baxsaluk milalaagima. Tah kinniimih sabbitih leelwah cayxiixa kee rakaakay caddol daro dalootih gexsit milaagu yayballe. Fayya le sanat roobih caddo tanih tan wak murti wakti akah yaddeerennah aba. Begirabenochu amol sinam der sanootaak qimbisak elle waaran.

Taalih abxisuk leceyhayto footima lih ashange badat sinam guubuh elle gaciyyaa kee baaxoo mabuurih caagiida daffeysa.

Makra 6: Qasri inki qick akke baaxo baar, inkigide Abiyya, ashenge badal baaha

tukkal-warraye 100 sanath baaxo kurim kee antifiqiyyi, ballaq(kalla) quurol baaheun nubleh. Satilete fotat kee asserabak eddurul yanih yani baaxoh antifaaqe kartah bicisak missosneh. Taturte waktiz sugte naquswainki darifal 14 kektar take baaxo isinih alluk, raqtem qersi abba qubaytitluk ten. Dergidoolat reedek lakal baaxo qaqizaak leemarah kureh uxih baadu inkigideh makurinna. Kinnimih uxih naquswa gabat kibi baaxo raqte. TPLF 1990 xabba haanam baaxo kurriya qaqsika labhaytu kee saynumuh inkigide akah guftanna iyyananlak ten. Tahih taagah baaxo aylame wanamah-mardoh yaceenim kee mango baqure yabqurelim xiqimteh. Awayih uddurul 90% takke buqare –aba sidicuk muxxi takke baqure –qidan. Tah uqut abak itiyobbiyal baqure xali usak geytima, tah akah takku xiqtem, axali akah qeytimu xiqem yiysisen baaxoh xinisso kee invetiment baarisiyya kinnini.ussotinah tayse baqure abah sirrat kee xinissory, hisodo qablisiyi faxximamih taaqah-kaxxa hangisso kee cubbi faxxima

III. Lee Kee ball.

Lee Kee ballaqey/qind raceenahtan bola kee fayyale arooca-faxxima uyta geyonuh zutaxago-mango kusaq-qalela, bolal lee baxol mango macal abak geytiman. Inkih akah naxigennah sehaayti a botoota garbo baxacal kaxxa tukkal kataasa .kaadu hawal baaha milaaqi maca ceelah? Ta esserorah gacsah fyta qasri baxxaqsele.

Makra 7. Lyto Qasri, Rayyah darifak, baaxo kee, rayyah dariifal baaxo kee coox baxcahih milaaqu (All 1972-2014 E1)fan.

LL 1972-2014 E1, fan yanih yan wakti addat, rayyah dariifal suge coox baxac, satelitik geyni uytal agaradneeh. Kusaq elle abne rayyah dariifa baaxo qaqitak akah yaysnabo ken gurrah, anxaxaxos kee cood dabisiyya bxsa lee hangi necceh sugne. A dariifal bocoh yakke caxah samad xefleh knsaaqisak baxseenih.LL 1972-2014 fan yan wakfih addat yumbuliyye caxah baarih milaqi baqure baaxo kaxxa ramma aybbulluk (60%-35%) rammoyte. Boocoh yakke coox tonnah (33%-53%) fan useeh. Kaadu baaxoh anxaxas yambulluyay . immay xaflih baaxo sugte caxah samad celalloh (ketketay, agame kee xaxaho)kee cooxbaxce abbixuk boxce kala cooxih samad (shelen, ashwa kee balas)cooxi kaxxa baaxo abbixuk baxxa dariifa yabbixen. Qaleeli baxoxal kaxxa manga ruk sugte cooxuy, isih yabuke (saraw kee wagar) coox amok amoh bayeh, dagoo samad keenik kanisah-dagiirih addat geytima. Tohih taagah garbo kee coox dacayroh, anxaxxosuh baxsale darrifa bicisak axcih rayyak ayro culmah darifal (allamatak ayrocumaay – ila roobit –fanah)baxsake hangi yaceenim faxximta.

Makra 8: Hatto exxa Kilbatti qaxih ityopiyal geytimah yan qaleela kee ullullu leh tan dariifal gexsaanah yanin gino gaddih taama

Kilbatti qaxih itiyopiyal geytimtahtan gino gaddittek coox kee dorritiiy 1970 fanahaay gibdih tan gino qawalayla tet toofeh sugteh tanimiiy tamixxige. Tahak ugutakaay tama taqabittek gexxamah kaadukuuy tamahak fanak radah yan ruub kataasah yan weeqiiy rayya kee dariifalaay sahadaytu kee uwwaytil inkkih kaxxa taqabi kataasak sugemiiy aydaadi yascasse. Tama taqabi yafdigoonuh faranggi liggidih loowok 1975 baxaabaxsa leh tan gino gadda dacrisaanamih taama baxsale gurral akah tekkeh tanim kee baxsaluk kaadukuuy qabaarat biyyakitteh tan dariifa anxxax cooxuh sarsaanamih taama elle faxxintannal tekkeh tanimiiy tamixxige. Tama tawayi kusaaq kaadukuuy too saaku tekkeh tan gino gaddih dacayrih taamak ugutak yekkeh yan kusaaq kinnih tanimiiy warsan. Tama kusaaq baxsa le gurral kaadukuuy 20 takkeh tan baxaabaxsale coox kee weeqi dira leh tan dariifa meexak yekkeh yan kusaq kinnih tanimiiy tamixxige. Tah dubuk hinnay kaadukuy tama kusaaqay coox inxixi kee (normalized difference ation index) qalalisanam kee coox miduuy wakti elle kortaamal taqabik ken catam xiqah yan caagd cubit haak yekke kusaaq kinnih tanimiiy tamixxige. Tama kusaaqih xali elle yascasseh yan innalaay gersi dariifal yekkeh yan kusaaqaluk nableh nan wakaay gersi kusaaqittek muxxiiy (30) sanat tuttaqbi sinnim coox anxaxinuk akah sugtah tan innah absiisam xiqah yan kusaaq kinnih tanimiiy tamixxige. Tahat ossotinah kaadukuuy 1975 boodeh sugeh yan qabaar (scars)

60% akah yankusennah absiisam xiqah yan kusaaq kinnih tanimiiy timixxige. Tah dubuk hinnay kaadukuuy gino taqabik qabaar kataaseh sugeh yan taqabittek gexxamahaay bayteh sugteh coox kaadukuuy akah taabukenna kee mariiy amok obak sugteh tan weeqaytitte kaadukuuy inkikke fanah adarukuuy ummattah ayfaafay akah taceh tan innah faxximtah tan taama tekkeh tanimiiy tamixxige

Weqaytitte uxi kinnihiiy kaxxa cayla leh tanim takkay ikkaha tama caagidik addaffakoot 9 hatto mafdagal daffeytehiiy geytimtah

Makra 9: Kiblatti ethiopial geytimtah tan fayya fayya lee baxooxal caxittah tan dorrit yaynukusenimi

Aa kiblatti ethiopiahl geytimtah tan fayya le dorrit 1975 ligiddaah Eouropah lowok xabba haaanam akkuk sugteh tn gino gaddih tamoomi dooritil gino gaddih aw baaxo qnxixxoh daggosul axci , axcih kaaduk garbo saalyu yaynabbonuh axcih kaaduk woo dorritil obak sugeh yan wqih daggosul Abeenih yani gicloy tekkeh tanim geysisonuh yekkeh yan kusaqa. Tonna kinnuk a kusaqah doreenih yanin 11 dorrit(weqidira) sidica sanat titta lakleh(2012_2014) fanat weqay obah yanih aqikinuk gexsiten kusaq kinni. Kulli dorrakyiqi kkinwn weqih kimatih baxsay roouk edde raddeh gideey:garbo kiimatay, kulli garbok baaxo dafdafit caalat fat kasal haak baxabaxsa luk daffesen. Kusaq mihrat edde yaybulleh yaninnalwo doorritil tekkeh tan gaddih aydakakan tamoomi aa dorrit aw aa garbo aydakakanak taturrateh, a dorritik caxitak suge weeqi meqennah akah daggowanna kee ,adorrit Rayyal geytimta madarrite kee katamoomil katasak sugeh yan ayyuntiny, Qidaddoy adm baxat bahak sugeh yanim daggowtem yaybulle.

Toh kinnimih sabbitih aa dorritilgexsitak sugtegino gaddih loysis taamomi daggowak gexxama axcuk tarusna fayu.

Makra 10: Ullulu leh tan qaleelak gubaldaffeyeh yan xetti qadad.

Mangoh tan arroqi kafin baaxol geytimta, akusaqak hadaf adda adda le baaxoxa, qidde leh mango qiddele baaxoxa kee manol katasah yanim yamirmirenih , abaarid katasah yan taqabi yablonuh Arzi, satellite fotota kee kutbrh essertimta. Akusaq arruqa mangoh tan boloola elle tangaleh tan ikkel girabenool gulbak gubi dafdef tantifiqe.

Makra 11: Exxa rayya weeqaytih holholwa qendek yangeenimi

Rayya dariifay kiblati Ethiopiak addah raqtah tanih tan baaxok baaxok teyna kinnih tanim kee tama dariifal kaaduk kaxxa kaxxa weeqaytittee kee sahdayti baxak hangi beytah tan gino gadda leh tan dariifa kinnih tanim tamixxige tama weeqaytitti kaadukuuy rayyak ayro mawqa dariifak qaleela leh tan dariifak oobak booxal caxittah tan weeqaytitti kinnim tamixxige tahaak ugutak weeqi akak oobah yan dariifal weeqi daritte bicsaanamih taama kulli sanatal namma adda akkuk geytimtam tamixxige takkay immay becsaanah yanin holholwak guba haanah yanin aalat yamaggemik sabab takkem qemmo faxxima kusaq akah gexsewaanamih sabbataay kinnim tama caagidal gexseenih yanin kusaq elle yascassenal qemmohuuy holholwa bisan widdir lee mangak kusaq gexsewaanam kee (haydrolic process) kattaate waanamih taqabi kinnih tanim timixxige baxsaluk holholwa ceenosaanam taaqabi yanim timixxige holhol becsan widdir kaaduy fiddinoose waanamk gexxaamah holholul adda gexxa lee cenootak holhol yaggileenim tamaate tahaak ugutak kusaq elle yascassennal (1) holholwa fiddinaani elle xiqqahaanamal baar bahsisaanam kee lee akak tabtam xeqe wayta gurral kaa bicsaanama, (2) weeqayti elle caxitah yan dariifa kaaduy gino gaddak garbo elle taabukeh taninna absiisanama, (3) weeqayti ginoh gexso elle katam xeqe waah yan inna absiisah amok rada weeqih qawwalayla elle kalalaanam xiqaanah yanin taama abaanama

IV.Abqaalak, Kaalal, Rayya booxal

Makra 12: Wakti caalaatallih milallaagimta rayyak makkoki le daqorti

Raya daqorti k rayya booxak ayro culmak katu raqta kaxxa fayyo le qaleek qimmisak cayyla luk caxitak gesi katul ramma le booxal cula. Tohuh taagah raya booxak mango booxa yabiixe. Tahalluk leh yan cayxi caaltih cayxil, xexxax kee mafkanal, baxsa yayballaye. Leh yan xexxax ke arac abbixiyi taqabi akah yaniimik sabab amixxigewaamih taagah a kusaq acaagid hangit haak bicicciime. Kasaq elle yayyabuluyenal taga raaqa baarre cayxih taqabi kinnimnasmitu dudne. Ceelalloh 57% take daqor xexxex 65% take baarle baaxo tabbixe daqaorti taagi kinni taybulle sabab akak. Qagitaak yekke kusaaqal 1978 I.L garbo baar osak yemetem taybulluye, fanal osak aynukusuk yememtem kaadu yaybulluye. Tohuh taagah tohuh taagah garbo baar taqoorit baar kee xexxaxal waaso or gexejalit akukuk geytimta. Tohuh taagah faxe daqoorit bure taamal le yan taqabi yayanukusoonuh, kaaduk ummatta manol yaysiisoonuh abaanah yanin baaxo dayla cayxi kayu kee daqoorit mafkanal yaceenih yanin hangi haytam takkeemil daqar maado ke kay baysiyyi cayla daggosaanam xiiqimtam kusaq yayballaye do ke kay baysiyyi cayla daggosaanam xiiqimtam kusaq yayballaye

Makra 13: Abqaala goloh leegadda

Rammata baaxol ethiopiah gooloolah addal geytimta lee kee gersi ginoggadat aaman le manfaqah tan taddera hangissokaxxam dago. Takkay ikkah kusaq hadaf oyti taqabi yannim takkay immay, abqaalal geytima limestone xaa goloolal tan le highlightih nablu. Robti manga wagitta oytitte yaskatoonuh sidiica sanatak(2015-2017) xabba hak robti manga kusaaqissa aloota (rainguage) mudneh aw soolisneh. Qaagitak daqaarak caxittah tan lee manga yasfuroonuh robt tasfure allota manfaqal asseh. Robti mang baxaabaxsa caalota le. Ta caalotah baxsi leeh cayxi tambaggem kee baaxo darraoosak abqaalak gubi goolo fan gexa. Qaagitak baaxok qaran fan gexxa le mangoh. Sittat limeston golo k caxittah tan leek 36% gubi kolo fan gexxa. Tahih taagah bure muri geynuh elle faxximtannal koboxxeh tan lee kee baaxoh masmaaqa kee gersi caagiida akah bicisak faxximta afkan akal abaanam faxximta. Xayi udduuruk aqadal abqaala booxal baaaxo bagih milaagi yanbulle. Ah wagsiisak aben kusaq xaalot makrak 14 il daffeyteh tan.

Makra 14: Abqaalak rammale baaxoh milallaagu

A kusaq abqaalak rammal e baaxo bagul baaaxo manfaq kee baaxo baar milaagu ke baaxo elle tan maqnal baahen baaxo milaaguk ten. Kasaaqak ugutak abqaalal sanat 1984-2018 yan qaktil rammat baxooxax kaqshbuurat atnbukunem kee foyyah elle takkem faxxiimak tenekkel buxaaxa kee yabquren baxooxxah qadad ambagguk geytimam tutbulluye. Taahak ugtteemih kaqashbuurat tunbukune baaxo kee sinam elle ane sinni arooca sugteemik 58% kee 27% sanat 2008 elaa 38.9 kee 22.3% sitallakleh yunkuse. Tahak sadhu guubitte 1984 elle tenikkek 3.3% sanat 2018 elaa 12.4% fayya iyye. Baxsaluk ummata qadad doolatal, baaxol, sittat baxsaluk qagitaak abqaalal gexsitak geytimta xooquh xiina ganda gaaboyso waane taagah dadal fayya iyye dabqi gandah baaxoh abquriyyi osak amakkaquk baaxo finqisiyyah bathe. Takkay ikkah a kusaq agat kee dariifa dooltih buqre kee sigma guubih baaritiyyah ahngi yaccenim faxximtam yayballaye qagitaak kusaq sinam ganda gaaboyso waanel maqar leh ikraaro le gital abbinoosanam faximtam yayballaye. Kaala dariifal lee kee baxoh le tan qalayli awgittaml makrak 15 siinih naybulluye

Makra 15: Kaalal rammata baaxo kee baaxoh gitosh yakke yan boodu

A kusaq kilbatti etiyopiyal geytimta kaalah raamle arooca kee dariifal sinam kee saqi angagoyyih gexso kee ayyunyti dariifah le yan angaaraw wagittaamal tekkemi. Kusaq kaalak ramma ta baaxol saqa kee sinaamak wagti angagoyyi lqain baaxo kee xacmin baaxoh suguntit fanal manfaqat bood yani yaybulluye. Yekkeh yan bood kaaduk baaxoh cabti kee guub baysiyya kataase. Coox baarihaqakkaaneh kusaq elle yaybulluyennal bayeh yan guub kee baytemil coox osim yunbulluye. Cooxisimk sabak kaaduk kaalak ramma le baaxo sugte saqa kee sinam kuamolayyo daggoosaanam keebayteemil tekke daarat, lee kee ballaaqe dawro taamoomi kinni. Takkay immal poliisi tayyeqit kee agat doolta sina ke saqak wakti angagoyyallih yamaateh yan calwayitte akkalat haanam kee hangi kah yaceenim faxximtam yuybuluyye. Ta waarle baaxobbagih dafeynah xiinisso yasmiteebim, cayla le dariifa dacayrih makaado xisaanama, bood elle yafdigen caalotah madqa bicsaanam kee cawalay mafdagah gexsot diini abobti kee baaxoh idoola edde yasgallenim faxximta Rayyak lee gadda wagittaamal makrak 16 dfeeyimteh tan

Makra 16: Rayyak raamta baaxok leeggada

Ramma itta baaxo tibbixe etiyopiyah goloolal geytimta leeggdi amaana lennal yantifqeenimih ikraaro kee mabbux le yan hanigisso dogom kinni. Takkay ikkah kusaq hadaf raya kee hasingel tata xeeti goolol geytimta lee mangah dagar loowol daffesaanama.

Gittakkiino baxxaqissa oytitte yaskattoonuh sidiica sanatah [2015-2018] robti qadad tasfure[lowta] owwayti kadeedineh sugne.kaadu daqaarak caxittah tan lee qadad loowol daffeesa uwwayti[gejoch] nintifiqe.ceelaak woo rakaakayal tan leeh qadad naaxaguh leeh cayxiiy,bullaaqeh caalataay,silayti afkanitteh asfuriyyaa kee baxooh intifaaq diggosnuh neh tanfiqe.woo kusaq elle yescessennal wokkel yan robti caalat waktittel baxsa le.tama caalat baxsi sissik lee manguk ilaa adda le daqar fanah caxitta.kaadu sanatal fanti leeh cayxi wagna waqdi rayyak fayya le arooca ramma le aroocak[p<0.001] muxxi caxitta .rayyak addah raqta aroocak caxitta leek 40% tabsiyyi aracak caxitteh raqta.data xeetih addal raqta leek 77% factah[buubtah].tohih taagah rayya kee cashange leeh caxtiyyih gaba 16% kee 33% take.amogacaak ta leeh manfaqat qidaddoo dariifah yaalluh kaad muxxi taaminnam faxximta.leet faxximtannal yantifiqeenim kee baaxo meqennal yabbixeenim qiddadoh meqe.a arooca lee xayyoosaanamaksah booxaaxah meqe doori digirta. Ciggiila taban kee malcintah makra rayyak doqooritil kee blooxal baaha korsa yaybulle.

Makra 17: Rayyak doqoorit kee booxax baar korankorsa

Baaxo manfaqat kee baar kusaq awaktil mihimmi yan.baaxo caagidil doqoorit kaxxa dawro faxa.takusaq rayyak ayroccu;ma katuk tan qaleelak obta lee booxal leh tan baaxo manfaqat kee baaral aben kusaaqa.tohuh kobo booxal yan rayya daqaarak awlisah iyyeeneh elle yaaminen warsi daqaara cubbi aba.kusaq elle yabluusennal doqoorit elle mango aroocal baaxoh baar milaagu lem yabluuse. tah kah takkem buqre baaxo weeqat doqoorit fan kortawak waktiik lakal qaysoh kortsa.waktiik lakal baaxo ballaaqe bicca intawak buqre abeenit buqre qimmissa.amogacaak weeqayti anfiqiyyaa kee baaxo baar korsi buqre abeenit maqaashal kaxxah yan doori le.baaxok baar korsi dibuukdoqoorit milaagu hinnay sihdayti gabat agel edde anuk coox kee aysukbiyyat yan. Tohih taagah baaxo meqennal yabbixeenim faxximtam yaybulle.kaadu doqoorit lowsiish taamoom abna ginoh caalat teetik abbixuk abnam tayse.

Makra 18:   Rayyak galal leeh qasboh caalata

Kafin aroocal qasbo kaxxa taqabi akkuk temeete. Electric conductivitit catiimak leeh qasbo aalliyyi arac kee wakti caalat cubit haak qaddoysa mara.callaatih woo aracal geytima qasboh caalat kee wakti katuk abluk electric conductivity iyyan doqoorit uwwaytiiy, raceenaay,boodad lee kee kalu ceela leeh arac gexaanam abne.a kusaq addah iyya electric conductivity aalliyyi karma kee cagay uddur baxsa lem yaybulle

Tahat osak, sanatal fanti leeh electric conductivity qaleelal le qadadak golaalal geytimta addah edde ossam kassiisa. Qajab celtaamah golaal geytimta ramma ta baaxol geytimta leeh qasbo aalliyyi umannal geytimta. Ahak xali elle yabluuse innal kaadu ossa baaxoh ramma le leeh qasboo,baxsa le gaabin maaxoh caalih angoyyi inkih yan baadal abeenik buqrel taqab katassa. Kaadu, itiyobbiyah golal addal geytimta leeh gaddi meqe qidaddo bahsiisa.

V. Booxal baaxoh miraaciini caagid

Tatre sanootat rayyah dariifal leey, baaxoo, kee ummattallih agle le mango milaagi yumbulliye. Tahat axawah anuk

Makra 19: Hayto makra meeri kee investment baaxol le milaahu yabluuse

Ta kusaq makra meeri kee investimenti baxxoxal bahah yan taqbitte naxxiguh aban kussaq.ta kussaqak ukummo rayya baxxol makra meeri kee investimenti yasmaqeenim kaxxxam baxxoh kaxxa barssa taysubulle. Ossotinna kussaq ale yascasssenah makra meeri kee investimenti barsa luk dadal yasbulle. Tonah coor sittat2007_2014 ligidah 62% unkusse.kallah tonah makooni investiment arcittel argiqiyyi sittatal 60% unkusse.ossotinnah makooni investiment arrocalbuxaxi keenik finqitte.kalah kaxxu kobo kee mokooni arrocal yan weqaytti buqreh arrocak 74% kee 73% ossotinna usbuule.sittatluk rayya baxxol buqre yasmaagennim kaxxam baxxol buqre barssa luk getimtta. Tonah rayya baxxol taqbi yakumem yakem bicttah.

Labaatanni haytih amonttal ta caagid wagsiisak kusaq dafesneh nan.

Makra 20: Labaatanni haytoh makra: rayya booxah milalaagu kee fula le sababiteeta

Ta kusaaq rayya buuxal sidiica uduurah yekkeh yan baaxo bagih kuraakursal kusaq abe. Kussaqaak ugutaak buqre baaxo ifu luk tanballeyeh tan baaxo baguk tiyakb teena.taturteh tan soddom sanatitteh maqna lehtan baar kee baxaabaxsimiyyi milaagi yunbulliyeh suge, cotaanah yanin ardit baar dagoowiyyi yuybuliyeh sugem takkay immay maqna leh tan baxaabxsimiyyi milaagi manbalayinna. Tonnah garbo ittallaklel ankusuk temeetem takkay immay maqna leh yan baxaabaxsimiyyi usositina maybalayinna. Buxaaxiqarwa osotina taybulliyem a kusaaq qadoosa. Buxaaxi elle gactuh xisintte arooca buqrebaaxoo kee baxaabaxsale garboobat buulimeh geytima. Ta kusaaqal tunbuliyeh tan milaagitee baxsaluk sahdayti kalleb kee buxaaxih fayxih osotinalluk temeetem kinni. Barritte buxaaxi titta fan baahaanam sababittek tiyakteenah geytima. Tonnah buqretaamoomi telemmoh yantifiqeenim baaxo bagih milaaguk sababittek tiyak teenah geytima. Ittal gacissa haynaddur rayya buuxa tan umatta baxsale cubbi faxxa. Kah kinnim buxaaxi qarwa yubquren baaxooxay kee garboobah aroocal caylaluk baarimak geytiman. Elecaboh labaatanni haytih amonttal xayiuduurut amotabi kusaq dafeesele.

Makra 21: Labaatann kee inikhayti makra: rayaa kee rayya baaxooxal maxaaberya

kisaara loowo (fereng loowoh 2012-2016) madaaberyah qaadih tan gabaaya kee tata gabaayah telemmoh kusaq abneh. Maxaaberya telemmo Etopiyah addal kaxxam osimtem kee tonnah kilbatti katul yanih yan gabaayah xayoosiyyi fayxik fula luk yanim kusaq qadoosa.ta kusaq yekkem Etopiyah loowok 2016 rayya baaxooxal kinni waqdi maxaaberya telemmo gersi waradoodik baxsale. Maxaaberyah xayoosiyyi Ethiopiah loowok 2016 madqagabaaya kee tatagabaayak telemo oyti 35 waradoodiiy , rayya baxooxay geytimta mazajaga beet geytimta madqak tan gabaayah istatistics raceena geyne. Ginino akke wayta madaaberyaayi aysixigiyaa kee kaliyyal buqre tu taaxagoh acwa yacen. Tonnah irdatah deyan maqooqaa kee miraaceenitik geyaanah yanin nafqatiteeta telemmoh haysitak sugen. Ceelalloh , maxaaberya xaame week irdaata kaah cee weelem kaah warsa. Afrengi loowoh 2016 madaaberya buqre abeenitih edde kalen limo kuntaala 1407 birrik ten, Maxaberya maabryak leh tan milaagul kee addis abeba leh tan xexaarak ugutaak dagoo limo baxsa toybuliyeemih taagah. Madqak iroh tan telemmoh gabaayal kuntaalal 731 birrik sugte. Takkay immay siddiica rayya dariifatal tan waradoodih addal kuntaalal 463 birrk ten. Reyya dariifatal cagay waktitte dara buqre lem buqraabeenit dubuh kinni maxaaberya faxxam, kalah yan mari kalah. Buqreh xiina baaxa keenik kaxxam laqanowtaamih taagah gibta taqabi leemih taagah tonnah madaaberya faxaanam warisan. Faxaanah yanin waqdi gabaayak xaamitaanam xaqe waanam warsan. Madqaak iroh tan telemaamil ginoh maxaaberyitte akke wayta maxaaberitte baaxooxal geytimta telemmo abak kee buxammarah yanih yan dalaalak kaamak sugen. Kaxxam fula leh tan maxaaberya buqraaba kubaaniyya kee telemo abah kalaay keenik beetak dagooh tan buqraaba mangoh tanih tan kisaarak catiimak sugen. Maxaaberya Ethiopiyah addal buqre baaxo caylaluk akah dadal tannah abtaamak tiyak teena kinni. Takkay immay maxaaberya gexsit (madqa) kaxxam bicam faxiima caagid kee tomcowimeh tan maxaabery hinnay buqre oyti elle yaninnal takem faximta. Buqreh xiina isinni fayxiik iroh maxaaberya akah xaaman innah buqreh biiroh kaxxa taqabile.

Chapter 1: The "Graben" TEAM project

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1. Project summary

The "Graben" TEAM project (2013-2018) focused on a major development corridor of Ethiopia, the closed basins at the interface between the Highlands and the Rift Valley. Such basins (grabens) currently undergo rapid land use changes and are also sensitive to environmental changes on the surrounding escarpments as well as to climate variability. The landscapes are subjected to rapid changes, from (agro-)pastoralism through cereal-based cropping systems to semi-intensive irrigated agriculture. Cooperation and conflicts exist between pastoralist Afar lowlanders and Tigray and Amhara subsistence crop farmers. We conducted an integrated geographical study of land use, settlement and agricultural systems, in order to contribute to planning and management of land and water in these grabens. The project involved the Department of Geography and Environmental Studies (DGeES) of Mekelle University and the Universities of Gent, and K.U. Leuven in Belgium.

2. Partners and funding

Mekelle University (MU) is a fully-fledged university located in Northern Ethiopia. It was established in 2001 as a merger of two pre-existing University Colleges (Dryland Agriculture and Natural Resources; Business and Economics). Based on its research experience, MU has been at the forefront in influencing policy issues in Ethiopia. It is one of the few higher education institutions in Ethiopia with national and international reputation in research. In particular, MU's Dept. of Geography and Environmental Sciences runs undergraduate and graduate study programmes and is actively involved in research and consultancy works at local, regional and national scale.

Ghent University (Dept. of Geography; Profs Nyssen and Van Eetvelde) was the lead partner from the side of the Flemish Universities, Belgium and hosted the PhD students recruited from MU. Jan Nyssen has been working in several VLIR-UOS projects in Mekelle University (Ethiopia) and has built up a strong expertise regarding the physical geography of that country. The TEAM project, while involving a new partner department, has built upon 20 years positive experience of cooperation between VLIR-UOS and Mekelle University. Furthermore, as a large part of the project dealt with human-environment interactions, landscape geographer Prof. Van Eetvelde has led the related research topics.

The Department of Earth and Environmental Sciences (KU Leuven) availed senior expertise of Profs. Poesen (land degradation, runoff and sediment transport, soil and water conservation) and Deckers (soil geography, land evaluation and management) who both have been actively involved in various research projects in Ethiopia as well as elsewhere in Africa, South America and Asia.

Core funding for this "Graben TEAM" university cooperation project was provided by VLIR-UOS, the development cooperation organisation of universities in the Flemish region, Belgium.

Matching funds were provided by UGent (through the BOF scholarship scheme, as well as staff and MSc student time), Mekelle University (approx. 10 years of staff time) and KU Leuven (staff and MSc student time).

3. Analysis of the main problems the sector is confronted with (developmental problem)

The study area covers a 15 to 30 km wide and 300 km long string of grabens[1] at the foot of the rift escarpment, forming a clearly delimited transition zone between the highlands and the lowland deserts in north Ethiopia. It stretches from (14°N, 39.85°E) to (11.25°N, 39.65°E) and is a development corridor in Ethiopia (several new roads and a railway line are planned and partially under construction), which is however particularly sensitive to environmental changes (land use and climate). This is the western margin of the northern part of the Ethiopian Rift Valley (Fig. 1). Its elevation ranges between 1000 and 4000 m a.s.l. Yearly rainfall varies between 600 and 1000 mm, and it is bimodal, with the small *belg* rainy season (mid-March to Mid-May) allowing for a second harvest in some parts of the study area.

Fig. 1. The graben study area within Ethiopia. The Afar region is located in the Rift Valley at elevations reaching -140 m a.s.l.; Tigray and Amhara regions are in the highlands with typical elevations between 2000 and 4000 m a.s.l. The study area, the escarpment between these two physiographic units, is also a contact zone between different populations and agricultural systems: pastoralist Afar in the lowlands, permanent agriculture by Tigray and Amhara in the highlands. (For sake of scale: Ethiopia is roughly 1250 km x 1250 km).

Fig. 2. The closed basins (labelled A to L) of the Rift Valley grabens that were the focus for this study. The Ethiopian highlands are to the West, the Rift Valley to the East. Elevations range between 500 (yellow) and 4200 m a.s.l. (dark. brown), contour intervals every 500 m. Individual basin areas range between 75 and 2727 km² with a total area of 9595 km².

[1] A **graben** is a tectonically induced elongated depression. As it is bound by two faults, its morphology presents a flat bottom surrounded by steep escarpments.

The valley bottoms are bound at the east by a series of horsts[2], which makes these grabens to act as (semi-) closed systems that receive runoff from the escarpment (Fig. 2). The graben bottoms have recently undergone strong agricultural intensification recently (partially at the expense of pastoral land). On the escarpment, food production is based on rain-fed permanent farming with ox-drawn ploughing for cereal cultivation, combined with livestock keeping. A similar farming system is expanding towards the graben lowlands, where irrigation agriculture is also largely implemented. Until now, part of the graben bottoms are used by Afar pastoralists – hence leading to a potential conflict situation, which was studied by this project. Traditionally, settlements consist of small permanent nuclei of thatched stone houses in the agricultural areas and temporal dwellings made of woods and mats in the pastoral areas. Over the last decade, there has been a strong development of iron roof housing, particularly concentrating along roads. The escarpment consists of (a) highland smallholder agriculture in the upper part but also along the escarpment, (b) strongly degraded grazing areas, (c) remnant forests and (d) recent vegetation recovery through exclosures and reforestation, among others with the aim of protecting lowland areas from seasonal flooding.
In order to assess effects of climate change, a preliminary simulation with the EdGCM model (Chandler et al., 2005) was used to show changing precipitation under a CO_2 trend of A1FI IPCC scenario of a future world with emphasis on fossil-fuel intensive sources. For the period 2041-2050, the IPCC A1FI scenario predicts an increase of annual precipitation by approx. 120 mm yr^{-1}, as compared to 1972-1984 (Lanckriet et al., 2012). This is in accordance with most climate models, predicting a wetter Northeast-African climate under conditions of global warming. However, a warm pool over the Indian Ocean, and the associated movement of heated air by Walker north-eastern trade winds towards eastern Africa, would suppress short spring (*belg*) rains. Given the expected increase in annual precipitation, one may reasonably expect strongly increased rainfall intensities (Lanckriet et al., 2012) and changes in runoff response.

4. Problem statement

These graben systems, consisting of almost closed basins, are very important for agricultural production, resulting in an intensification of land use (and hence an improvement of the livelihood of the communities). However, this livelihood may be threatened by (1) changes in input of runoff and sediment from the highlands (any land use or climate change in the highlands will affect runoff, soil erosion rates, sediment delivery, and water supply to the graben), (2) rapid migration of populations from the highlands towards the graben areas, that used to be a no-man's land between different population groups (Tigray, Amhara, Afar), leading to potential conflicts between agriculturalists and pastoralists, (3) occupation of the land resulting in new settlements and a combination of traditional and new agricultural systems that have to accommodate early and recent smallholder settlers, as well as private investors, and (4) long-term evolution of such graben basins may lead to rapid drainage (through river captures) and subsequent desertification of these basins. This project aimed to address all these problems and to formulate recommendations for the sustainable management of these graben systems. We studied in detail the threats (1)-(4) in three basins, representative for the grabens, did

[2] A **horst** is a raised block of the Earth's crust that has been lifted up, or has remained stationary, while the land on either side has subsided.

relevant sampling in the other basins and developed conceptual, quantitative and spatially-distributed models that can be applied to all basins.

Hence, the project comprised a wide array of interrelated researchable issues, the outcome of which will be important for the management of the grabens by the local communities and policy makers as well as for the scientific community.

5. The objectives of the 'Graben' TEAM project

Overall Academic Objective: Improvement of staff capacity of MU's Department of Geography and Environmental Studies and partner organisations through research and long-term training

Overall Developmental Objective: Contribution to sustainable management of land and water on the escarpment and in the closed basins of the grabens of Ethiopia's Rift Valley

Specific Academic Objective: Increased capacity of MU's Department of Geography and Environmental Studies and partner organizations (PhD and MSc training) and integration among stakeholders in the closed basin areas

Specific Developmental Objective: Integrated geographical study on land use, settlement and agricultural systems, in order to develop tools and strategies that contribute to proper planning and management of land and water on the escarpment and in the closed basins of the grabens of Ethiopia's Rift Valley

6. MSc and PhD studies that contributed to the 'Graben' project

Alemework Amsalu, 2018. Landscape dynamics and major drivers in the Raya graben. M.Sc. thesis study, Department of Geography and Environmental Studies, Mekelle University.

Anthony Denaeyer, 2016. Impact of land distribution and tenure on environmental degradation in the North Ethiopian Highlands. M.Sc. thesis study, Faculty of Bioscience Engineering, Ghent University.

Belete Fentaye, 2017. Characteristics of debris cones and their controlling factors at the edge of marginal grabens of North Ethiopia. M.Sc. thesis study, Department of Geography and Environmental Studies, Mekelle University.

Biadgilgn Demissie Mullaw, 2016. Ephemeral stream dynamics, land cover changes and climate variability in the marginal grabens of the northern Ethiopian Rift Valley. PhD thesis, Department of Geography, Ghent University.

Birhanu Biruk, 2017. Landscape services dynamics in relation to investments in the marginal Graben of Northern Ethiopia. M.Sc. thesis study, Department of Geography and Environmental Studies, Mekelle University.

Etefa Guyassa, 2017. Hydrological response to land cover and management (1935-2014) in a semi-arid mountainous catchment of northern Ethiopia. PhD thesis, Department of Geography, Ghent University.

Hailemariam Meaza, 2015. Integrated study of natural resources in the closed basins of rift valley marginal grabens in northern Ethiopia. Pre-doctoral thesis, Department of Geography, Ghent University.

Hailemariam Meaza, 2018. Sustainability of land and water resources in the marginal grabens of northern Ethiopia's Rift Valley. PhD thesis, Department of Geography, Ghent University.

Laurens Hermans, 2017. Spatial and temporal patterns of water salinity in the marginal graben basins of North Ethiopia. M.Sc. thesis study, Department of Earth & Environmental Sciences, KU Leuven.

Miro Jacob, 2015. Treeline dynamics and forest cover change in afro-alpine Ethiopia, as affected by climate change and anthropo-zoogenic impacts. PhD thesis, Department of Geography, Ghent University.

Sil Lanckriet, 2016. Exploring causality in interactions between climate shifts, land degradation and humans: evidence from the Horn of Africa. PhD thesis, Department of Geography, Ghent University.

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Tesfaalem Ghebreyohannes, 2015. Mountain Stream Dynamics as Impacted by Rainfall Variability and Land Cover Change in the western Rift Valley Escarpment of Northern Ethiopia. PhD thesis, Department of Geography, Ghent University.

Zbelo Tesfamariam, 2015. Landscape change trajectories and agricultural systems in the closed basins along Ethiopia's Rift Valley. Pre-doctoral thesis, Department of Geography, Ghent University.

Zbelo Tesfamariam, 2019. Landscape dynamics and agricultural systems in the marginal grabens of Northern Ethiopia. PhD thesis, Department of Geography, Ghent University.

7. Acknowledgements

Besides all contributors, i.e. the MSc and PhD students working in this project, we wish to extend our acknowledgements to the 'Graben' projects' staff: secretary Selamawit Girmay, driver Kassu Kiros, and research assistant Birhanu Haftu. At Mekelle University, the project was well embedded in the Department of Geography and Environmental Studies; we got support from and efficient Steering Committee (Dr. Gebrehiwot Tadesse, Dr. Amanuel Zenebe (local project leader), Dr. Alemtsehay Tsegay, Dr. Zenawi Zerihun, Dr. Berhanu Getahun, Dr. Tesfaalem Ghebreyohannes (local deputy project leader)) and backstopping from former president Prof. Dr. Mitiku Haile. We thank all inhabitants of the studied grabens for accepting us to conduct research in their landscape. Though some suspected that our dataloggers were there to change the weather to less rain so that the Chinese company could build a railway (what led to destruction of some installations), overall there was a positive mood, and much more work than expected could be carried. Thanks for guiding, interviews, sharing your wealth of knowledge and numerous coffees, ሰው, ጠላ, faarso and sahi! Authorities and government officials in the Aba'ala, Hintalo-Wajirat, Raya-Azebo, Ofla, Raya-Alamata and Raya-Kobo districts greatly facilitated our research. Administrative and technical staff at UGent's Geography Department supported this project in various ways. Many more people deserve to be acknowledged, for which we refer to the acknowledgements sections of the PhD and MSc theses mentioned above.

Chapter 2: At the edge between Ethiopian plateau and Rift Valley

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1. Location

Northern Ethiopia is characterized by a wide variety of landscapes that are dissected by the Rift Valley. At the northern side of the Rift Valley, the Danakil basin covers an area of 52,740 km² in Ethiopia with many closed and semi-closed grabens (Fig. 1).

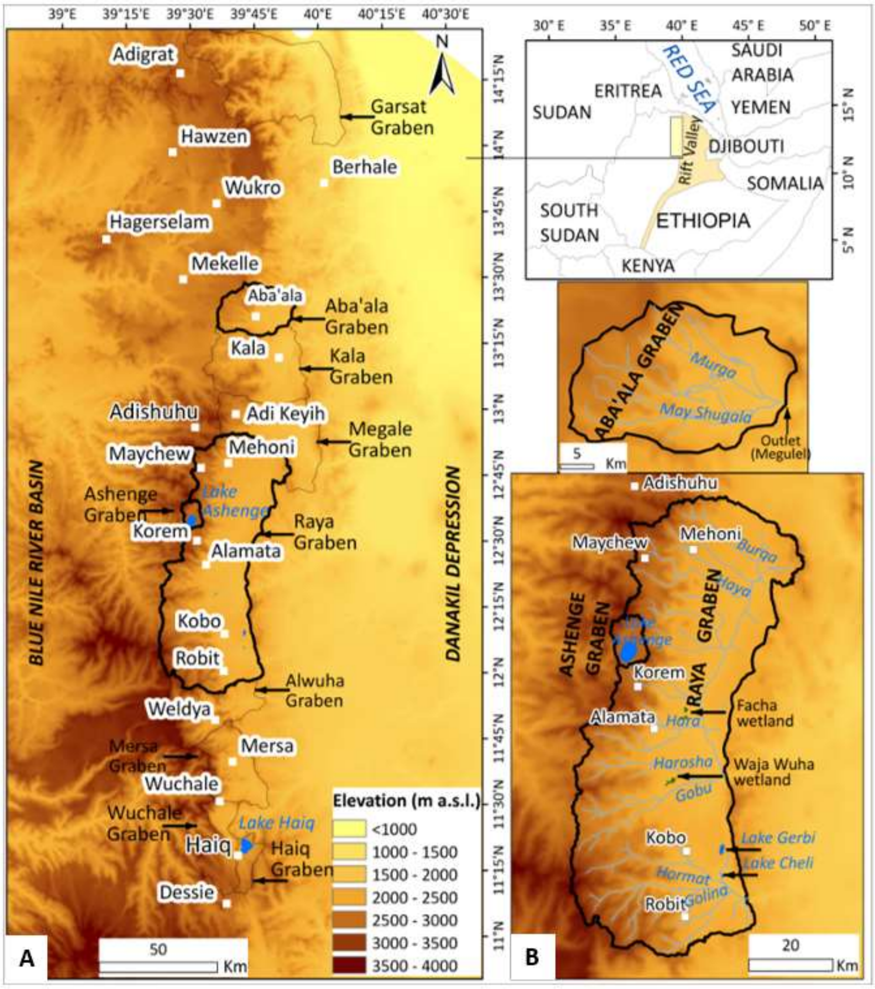

Fig. 1. Marginal grabens of the western fringe of the northern Ethiopia's Rift Valley (A) and the representative studied grabens with their catchments (B): Aba'ala, Raya and Ashenge grabens.

To acquire a better understanding of marginal grabens, we selected a representative research area located between 14° N, 39.85° E and 11.25° N, 39.65° E on the western shoulder of the Ethiopian Rift Valley. All the grabens in Fig. 1(A) cover 9600 km² with a continuous chain of grabens and their corresponding escarpments (15-30 km wide and 300 km long). The representative studied grabens include the Aba'ala, Kalla, Raya and Ashenge grabens.

All the marginal grabens are semi-surrounded by escarpments. As a result, their soil and water resources are always replenished by the floods and sediments that flow from the escarpments. However, the landscapes of the marginal grabens are differently affected by the economic activities of the communities who reside within and around the marginal grabens. Besides, their attractiveness to investments is different. Most marginal grabens have similarities in terms of economic activities of the communities in the grabens. However, Raya graben, which is the largest graben, has wider fertile land that has been attracting agricultural investments. As a result, Raya graben is identified as a development corridor by the government of Ethiopia in general and by the regional government of Tigray in particular, which increased land use intensification and extensification in the graben. Also, the majority of the communities in the Aba'ala and Kalla grabens are dominantly pastoralists and transhumants, partly on the way to sedentarisation.

2. Geology

A graben is a block of land bounded by parallel faults in which the block has been downthrown, producing a narrow valley that, in this case, runs parallel to the margin of the Ethiopian plateau. Such marginal grabens can be full or half grabens depending on the fault system (Fig. 2), and they are related in this case to the formation of the Ethiopian Rift Valley, cutting across various lithologies.

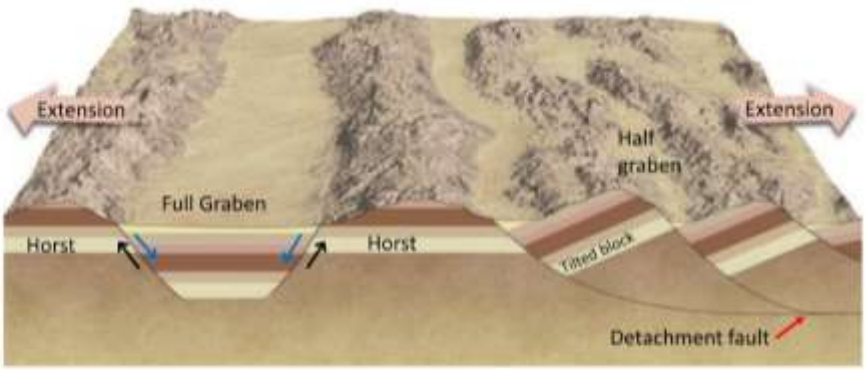

Fig. 2. Landforms associated with tensional stresses and normal faulting. Full grabens are bound by faults on both sides, while tilted blocks have been faulted just along one side, forming half grabens. Horsts are blocks that have known no (or less) subsidence. Modified after McKnight et al. (2014)

Major lithologies in the studied grabens are Antalo Limestone that dominates the Aba'ala graben, and basalts and other volcanic rocks along the Raya graben (Fig. 3). The western escarpment supplies materials for alluvial deposits to all the graben bottoms. These sediments have a high infiltration capacity.

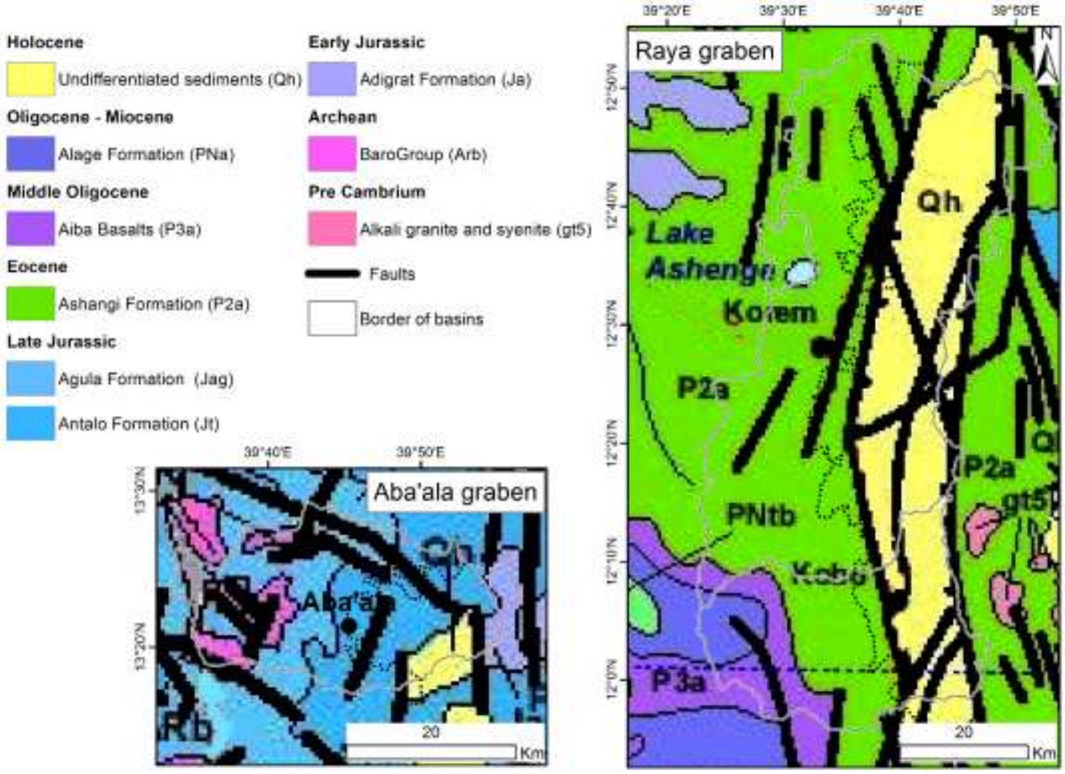

Fig. 3. Geology of the study area reproduced from the geological map of Ethiopia

3. Climate

The marginal grabens have generally an arid and semi-arid climate. More precisely, the graben escarpment experiences a cool and humid climate, whereas the graben bottom is characterised by arid and semi-arid conditions (Fig. 4).

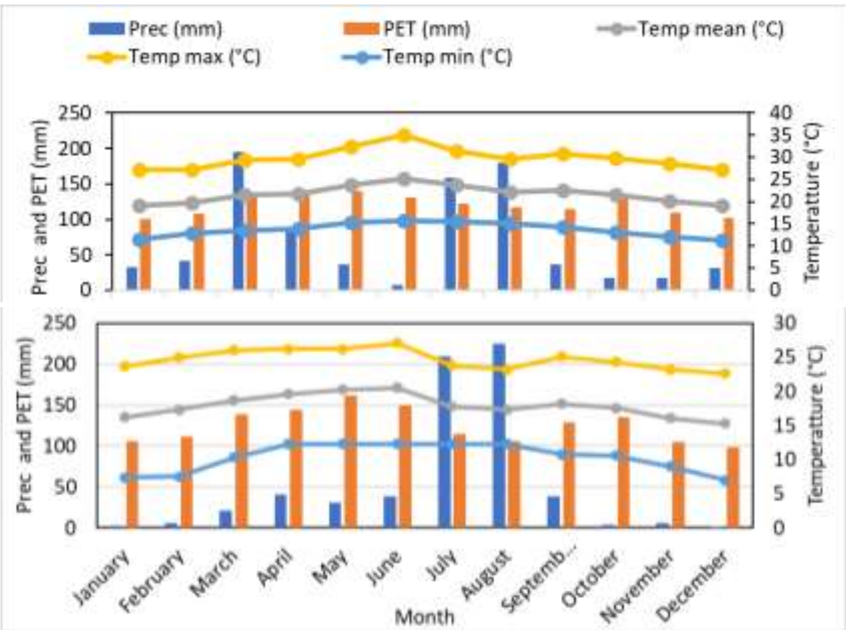

Fig. 4. The long-term average value of weather parameters, (top) in the Raya graben (12.41°, 39.55°) and (bottom) in the Aba'ala graben (13.35°, 39.75°) (NewLocClim1.10.).

There is a bimodal rainfall pattern consisting of *kremet*, the primary wet season (July to September), *belg*, a short and wet period (March to May), and a dry season with little rainfall, which occurs due to the dry air from Arabian Desert. The *belg* rains are clearly present in the Raya graben, allowing for a second crop in the uplands, whereas they are absent in Aba'ala (Fig. 4).

4. Hydrography

The elevation of the study area ranges from 1300 to 4000 metres above sea level. As a result, the drainage system varies following the geomorphology of the study area (Fig. 1). The Aba'ala western escarpment is drained by May Shugala, May Aba'ala, Murga and Liena streams. In the rainy season, these rivers meet in the graben bottom and leave the graben through Megulel outlet that cuts across the eastern horst.

In the Raya graben, 26 rivers drain the western escarpment to the graben bottom. Because of physiographic asymmetry, the rivers flow from the foot of the escarpment to the centre of the basin, mostly forming terminal distributary systems. The majority of the floods of these rivers sink before reaching the outlets. The only river with a well-defined channel across the graben bottom is Golina. The northern part of Raya graben is drained out through the Selekberi outlet and the southern part through the Melkehora outlet. Both outlets are deeply incised gorges across the eastern Zobel horst, towards the main Rift Valley. High up, and parallel to the Raya graben, the Ashenge graben is an endorheic basin without any river outlet.

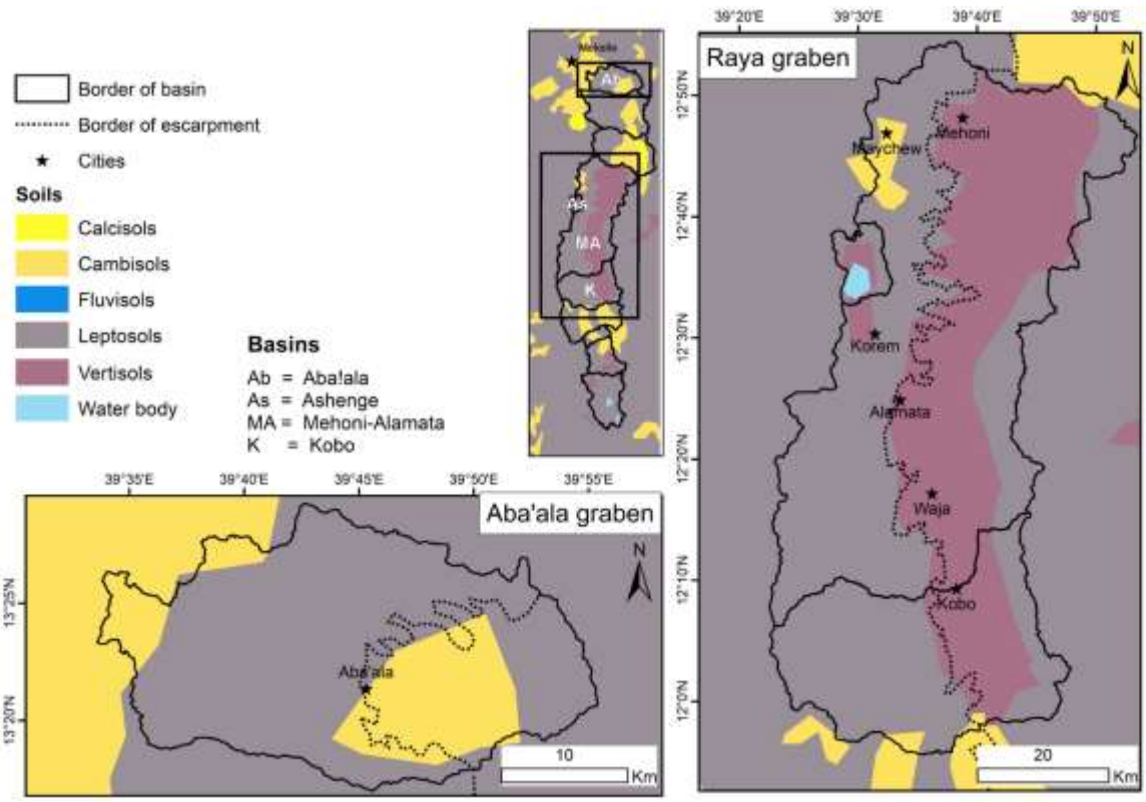

Fig. 5. Generalised soil map of the study area, based on the Soil Atlas of Africa with the borders of the graben basins indicated

5. Soils

A very generalised soil map shows the main occurrences of soil types in the grabens (Fig. 5). The Raya and Ashenge graben bottoms are dominated by Vertisols, and the Aba'ala and Kalla graben bottoms by Cambisols. Overall, on the escarpment, soil associations are dominated by Leptosols, though locally Phaeozems may occur (in remnant forests), as well as Regosols and Cambisols (in areas under cropland). Except Leptosols, the other soils are deep and mostly have a good soil structure, workability and infiltration. The soils of the graben bottoms are generally fertile and suitable for agriculture.

6. Population and socio-economic organisation

An approximate 650,000 people live in the studied grabens. Most densely populated are the Raya and Ashenge graben bottoms. The population comprises several ethnic groups: (1) Amhara, generally living south of the Gobu River, (2) Tigraians, occupying the major part of the study area, particularly the western uplands as well as the escarpment and also the central and northern part of the Raya graben bottom; many Tigraians have also migrated to the Aba'ala graben over the decades, (3) Oromo form an ancient population group in the Raya graben that has been partly assimilated to the surrounding Tigraians and Amhara – in most places the Oromifa language is not anymore used on a daily basis; they live in dispersed villages across the wider area between Alamata, Mohoni and Chercher, as well as east of Kobo and on the Zobel horst, (4) Afar are dominant in the Aba'ala and Kalla grabens, and also share settlements in the Raya graben's eastern horsts. In major towns such as Alamata, Korem or Maychew, Amharic may be used as trade language.

The Amhara, Tigraians and assimilated Oromos on the escarpments and in the Raya graben are mainly engaged in smallholder agriculture, often using spate irrigation with floods from the escarpment. In recent years they have started dry season irrigation agriculture, stimulated by government-established groundwater pumps and by mimicking commercial farms that have been attracted. Settlements are mainly along roads and iron roofed. Amhara and Tigraians are dominantly Orthodox Christians, though some villages follow Islam, such as Hugumburda in the Ashenge graben and other villages in the Raya graben bottom.

The Afar pastoralists in the Aba'ala and Kalla grabens practice transhumance, during drought periods, to remote areas, especially to the escarpment and highlands of Tigray. Movements to Tigray uplands allow the Afar pastoralists to herd their livestock on denser vegetation as well as on standing stubble of croplands. Currently, the Afar pastoralists in the Aba'ala graben become mixed farmers, as they have also established permanent croplands. Communities have clan-based organisations. Most settlements in Aba'ala graben are composed of a mixture of clans although each locality is identified with a major clan, which allows them to organize social, economic and political support in times of crisis. The majority of the Aba'ala graben communities are Afar and Muslim. However, Hidmo's population are all Christian Tigraians who came from the highlands in the mid-20th Century. Unlike most of the houses of the Afar, houses of this Tigraian village are built by stones and mud, the traditional building style of the nearby Inderta district in Tigray.

7. Land use and land cover

The landscapes of the marginal grabens have diversified land use and land covers (Fig. 6). Grassland and shrubs are the dominant land cover in the western escarpments and eastern horsts, whereas cropland is the dominant land cover in the graben bottoms. The western escarpment has better tree cover than the graben bottom (Fig. 6).

Land cover on the escarpments of the Raya graben is dynamic due to human interventions and rainfall variability. In the Raya graben bottom, teff, maize and sorghum are the dominant rainfed crops produced. The availability of groundwater in Raya graben has encouraged agricultural investors and local farmers to intensify their agriculture.

Settlements of the graben bottom are traditionally located on rock outcrops and alluvial fans or debris cones. The town of Alamata is a striking example, but all along the margins of the grabens small settlements are located in such positions. Unlike the Aba'ala graben, some settlements in the Raya graben are located in the plain where agriculture is dominantly practised. The more ancient settlements in the highlands and on the escarpment, jointly with total dependence on natural resources of the basins, have resulted in the severe degradation of these highland areas, that has been curbed in many places due to reforestation activities that can be clearly recognised on the land use map (northern part of the western escarpment, Fig. 6).

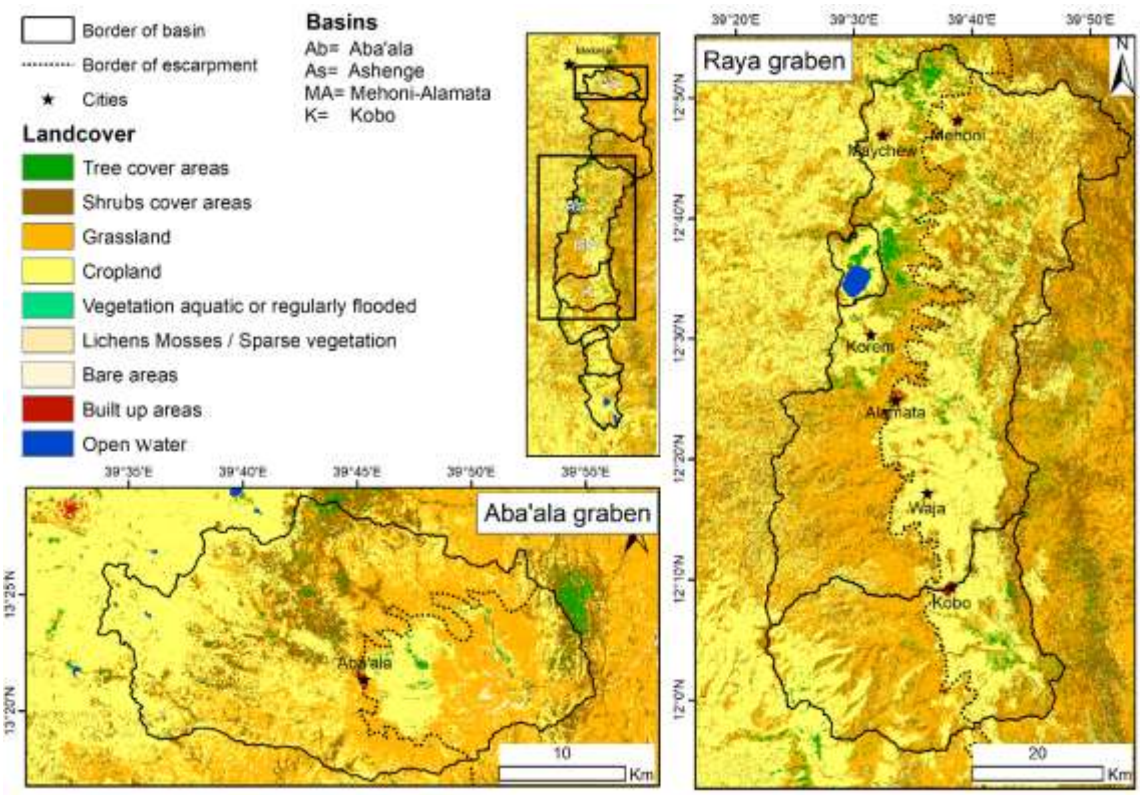

Fig. 6. Land cover of the study area based on the land cover map at 20 m of Africa 2016 (http://2016africalandcover20m.esrin.esa.int/).

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Chapter 3: On top of the escarpment: the afro-alpine environment

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Introduction

The Ethiopian highlands comprise about 50 percent of the mountains of Africa above 2000 m which provided Ethiopia with the nickname "Roof of Africa". For instance, when passing through the Raya graben, a dark skyline of high mountains, reaching 4000 metre height, form the horizon. There is Lib Amba Mt. (12°04'N, 39°22'E, 3993 m above sea level) of the Abune Yosef Mts.; and Ferrah Amba Mt. (12°52'N, 39°30'E, 3939 m a.s.l.) the highest peak of Tigray. Farther away, we have the Simen Mts. (13°16'N, 38°24'E, 4540 m a.s.l.) home to the highest peak of Ethiopia (Ras Dejen Mt.) (Fig. 1).

These highlands, many of which are source of the rivers that flow to the grabens, form a good context to study the afro-alpine environment, including glacial and periglacial geomorphology and mountainous forests and treeline dynamics.

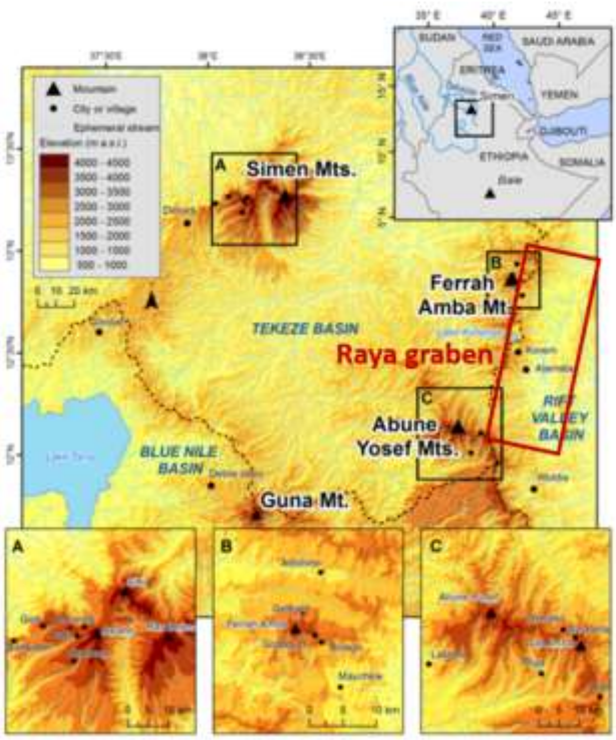

Fig. 1. Location of the three main study areas: Simen Mts. (A), Ferrah Amba Mt. (B) and Abuna Yosef Mts. (C).

Glacial and periglacial geomorphology

Current glaciations in the tropics are limited to small, mostly vanishing glaciers on high peaks. However, landforms of past glaciations are more prominent and have been described at the Drakenberg of South Africa, the Atlas Mountains in Morocco, the high volcanic plateaus and the equatorial high mountains of East Africa. In the Ethiopian Highlands, at least three mountain regions bear evidence of past glaciations (Fig. 2). Below historical glaciers, presumably dating from the Late Glacial Maximum (LGM, some 20,000 years ago), evidence of intense periglacial activity has been observed. The mapping of these landforms is important to reconstruct the paleoclimate in the area. This study serves as a case study for the middle range mountains (3500–4000 metres high) in the North Ethiopian highlands, where glacial and periglacial research is limited.

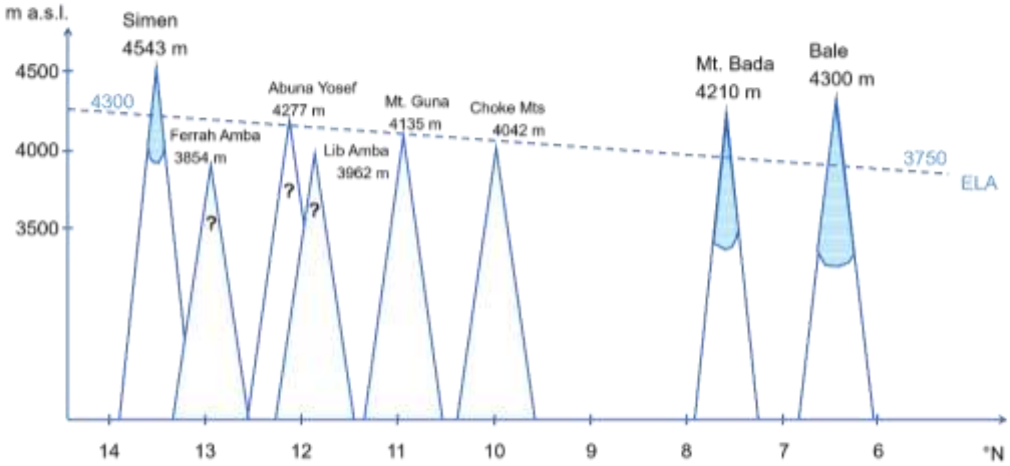

Fig. 2. Conceptual visualization of the occurrence of past glaciations in Ethiopia, found in the Simen, Mt Bada and Bale Mts. The equilibrium-line altitude (ELA) on glaciers is the average elevation of the zone where ice accumulation equals ablation over a 1-year period. Mountain regions below this historical ELA are less likely to have contained glaciations during the Last Glacial Maximum.

In all three study areas, inactive gelifluction lobes (Fig. 3A) were found. In the highest study area of Abuna Yosef, three sites were discovered bearing morainic material from small late Pleistocene glaciers (Fig. 3B). These marginal glaciers occurred below the modeled snowline and existed because of local topo-climatic conditions. Evidence of such Pleistocene avalanche-fed glaciers in Ethiopia (and Africa) has not been produced earlier. Current frost action is limited to frost cracks and small-scale patterned ground phenomena (Fig. 3C-E).

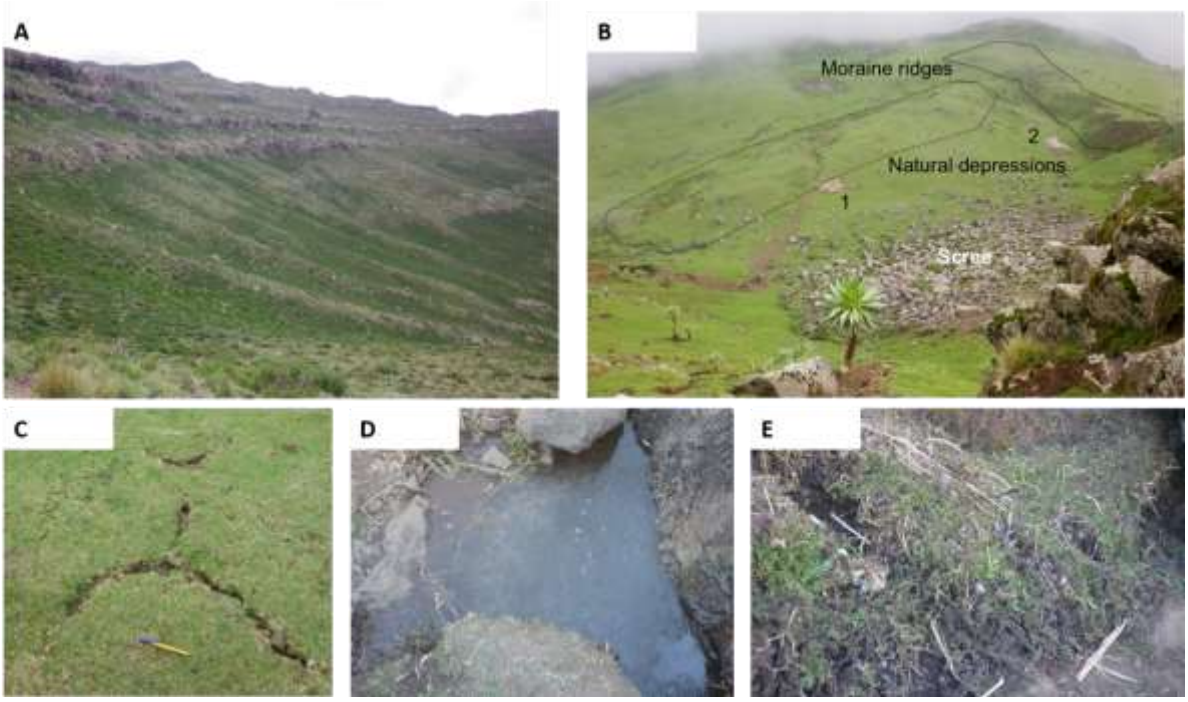

Fig. 3. Glacial and periglacial landforms found in the study area. Past landforms include gelifluction lobes (A) and morainic ridges (B). Current periglacial processes are linked to frost and thaw cycles, including frost cracks and small-scale patterned ground (C), evidence of frost (D) and needle ice (E).

The lowering of the altitudinal belts of periglacial and glacial processes during the last cold period was assessed through periglacial and glacial landform mapping and comparisons with data from other mountain areas taking latitude into account. A lowering of approximately 600 metres implies a temperature drop around 6 °C in the last cold period (Fig. 4B). This cooling is in line with temperature drops elsewhere in East Africa during the LGM (Fig. 4A).

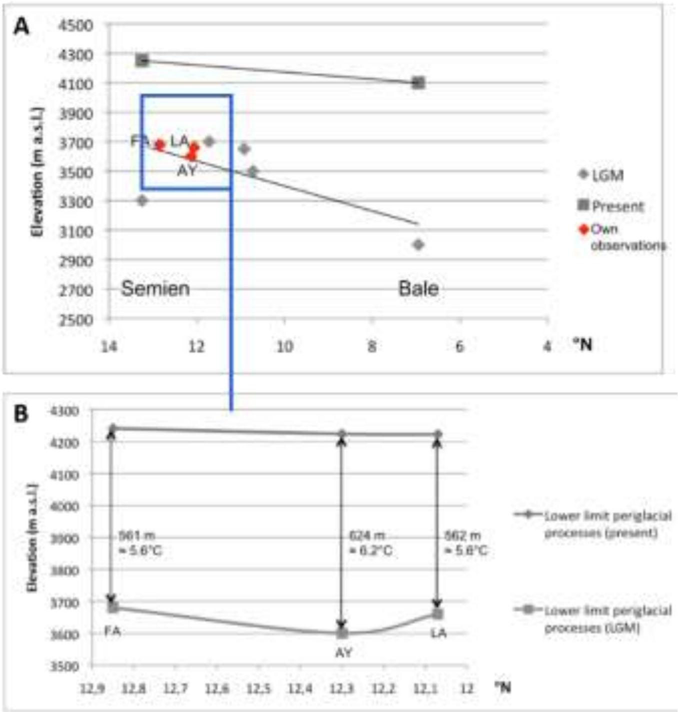

Fig. 4. A) The lower limit of the periglacial geomorphic processes during the LGM and at present in Ethiopia, by latitude, based on earlier research and our own observations. B) Altitudinal depression of periglacial processes in the study area. FA = Ferrah Amba, AY = Abune Yosef, LA = Lib Amba

Mountain forests and treeline dynamics

Vulnerable tropical mountain forests provide important ecosystem services for surrounding communities and for biodiversity. At present, this fragile environment is subjected to biophysical and socio-economic drivers of change. Human induced land use and land cover changes have had an undeniable impact on natural vegetation. Consequently, the ecosystem services of the mountain forests (capturing and storing rainfall, regulating flows, reducing soil erosion and protecting against floods, landslides and rock fall). Moreover, treelines are temperature sensitive and thus potentially responsive to climate change.

The studied mountains mountains are peaking above the present ericaceous belt (3200-3700 m a.s.l.), thus containing the treeline (Fig. 5). Despite recent temperature increase, treelines have not risen to higher altitudes in the tropical African highlands. Instead, high human pressure has caused stabilization and even recession of the treelines below their natural climatic limit, particularly through livestock herding. Additionally, long-term drought periods can be a trigger for fire-induced deforestation of the treeline vegetation. Overall, the main drivers of treeline change in the African tropical highlands are anthropogenic pressure and fire. Treeline dynamics can thus not simply be used as a proxy of climate change for the African tropical highlands. This also indicates that there is a great need for improved forest protection in order to allow a natural recovery of the forest.

Fig. 5. Erica arborea L. forest at the northern slope of Lib Amba Mountain (3993 m a.s.l.) part of the Abune Yosef Mountain range, with in the background the treeline (white arrow) at approx. 3700 m a.s.l. These are the headwaters of the Hormat River that flows down to Kobo. Photo Miró Jacob (3 November 2014).

In Lib Amba Mt., the history of forest cover change is opposite between the afromontane forest belt (between 2000-3200 m a.s.l., dominated by *Juniperus*) and the afro-alpine forest belt (above 3200 m a.s.l., dominated by *Erica arborea*). The afro-alpine forest declined between 1964 and 1982 and extended between 1982 and 2015, whereas, the afromontane forest was stable between 1964 and 1982 and strongly declined between 1982 and 2015 (Fig. 6).

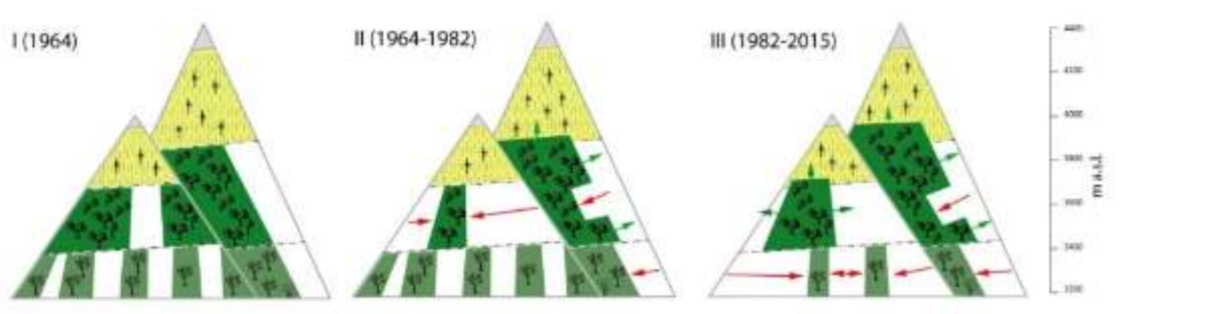

Fig. 6. Conceptual model of mountain vegetation dynamics in the North Ethiopian highlands between 1964 and 2015. Successive vegetation belts: afro-alpine grasslands (yellow), afro-alpine Erica arborea forests (dark green), and afromontane forests (light green). Forest dynamics are visualized with arrows; forest contraction (red arrows) and forest expansion (green arrows).

Landscape changes on the slope of Aboy Gerey Mt., a peak that stands high above the Raya graben, were studied using repeat photographs (1917-2013). Although we have only one historical terrestrial photograph for the study area, this photograph has proven important since it allows a unique comparison of the land cover over a period of almost 100 year (Fig. 7). The repeat photograph of 2013 shows that there has been an important land occupation of the mountain slope since 1917, which is accompanied by an agricultural expansion upwards the mountain. Indicators of these changes are new settlements on the previously inhabited mountain slopes and cultivation terraces that reshaped the mountain flanks. The human occupation of the mountain slope has clearly affected the forest. At some places the forest is replaced by cropland and overall there has been a severe decrease of the density of the remaining forest. Measurement of the canopy cover, with a GRS densitometer, indicated that the canopy cover has reduced to only 15% cover in 2013.

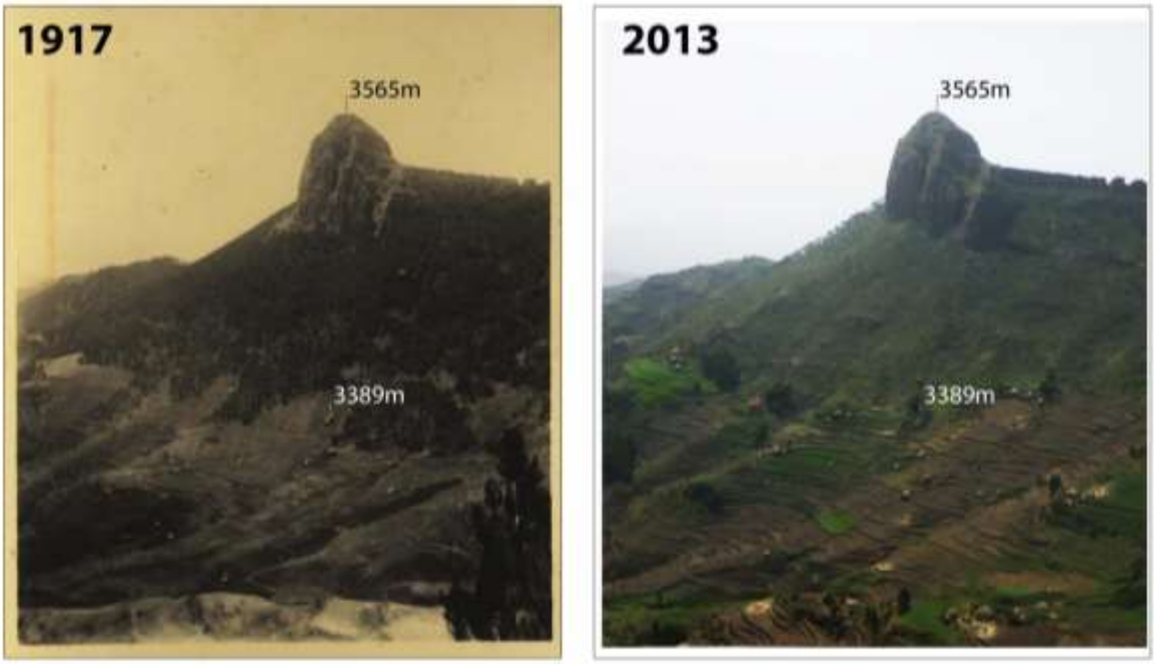

Fig. 7. Repeat photograph of Aboy Gerey Mountain (3565 m a.s.l.) in the headwaters of Hormat R.; (left) historical terrestrial photograph by Conte Filippo M. Visconti while he was travelling by mule from Leggu (Woldia) to Tembien © Italian Military Geographical Institute, Firenze; (right) repetition in 2013.

Conclusions

— The North Ethiopian highlands bare evidence of past glaciations and periglacial processes. Current periglacial processes are limited to small scale frost cracks, polygon patterns and needle ice.
— Although the study area lies underneath the glacier equilibrium line altitude, small avalanche-fed glaciers most probably existed in the upper north-facing slopes of the Abuna Yosef range.
— With these observations, a temperature drop of around 6 °C was calculated for the Last Glacial Maximum in the study area.
— The treeline position in the tropical afro-alpine mountains of North Ethiopia is primarily anthropo-zoogenic driven.

— Under protected conditions air temperature is the dominant driver of the treeline limit in the North Ethiopian highlands.
— Management interventions are vital to restore the important ecosystem services of mountain forests.

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Chapter 4: Soil erosion around Lake Ashenge in historical times

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Introduction

Sediment transport can be used as a valuable research tool for the assessment of environmental degradation in regions with a strongly contrasted climate (alternating wet and dry seasons). For instance, sediment yield can be used as an effective desertification risk indicator. In particular, it is recognized that sediment deposited in alluvial fans located downstream of gullies can hold valuable information concerning environmental change and environmental degradation. Alluvial debris fans indeed have a 'preservational role' as storage zones that contain information on (past) environmental change. Consequently, alluvial fan sediments can be useful as research 'proxies' for land degradation assessment.

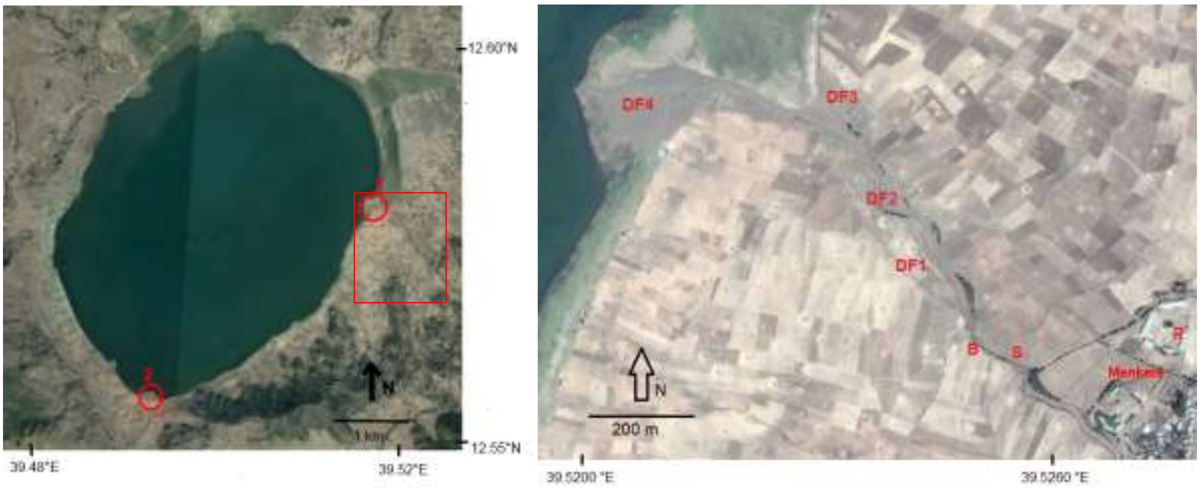

Figure 1. Location of the study site (1 indicates the Menkere gully) (upper photo); and location of the debris fans (DF4, DF3, DF2, DF1) (lower image), where sediment deposition rates were monitored, as well as the location of a bed load trap (B), a staff gage and suspended sediment sampling (S) and a rain gage (R). Background is given by CNES-Astrium images (18/01/2014) and the village of Menkere is indicated.

Methodology

Our studied 'Menkere gully' lies adjacent to the village of Menkere, to the East of lake Ashenge (Figure 1). Upstream, the gully incises rather shallow colluvium on steep slopes. Downstream, the gully incises a flat but thick alluvial-colluvial mantle. The gully catchment is mainly composed of croplands, with some areas of woody vegetation on the steeper slopes. In the gully, a sequence of three debris fans is evident (coded DF1 to DF3) and one additional fan extends into the lake (DF4, at the closest position by the lake) (Figure 1). Just Northeast of DF4, a conical spot of grazing lands most probably also corresponds to an inactive debris fan (Figure 1), although this could not be clearly substantiated on the field. Cross-sections of the debris fans show that they are built-up by stony debris. The gully catchment has an area of 221 ha.

An in-depth assessment of contemporary hydro sedimentary processes now in operation is a prerequisite for understanding past sedimentary behavior. Therefore, we measured (i) rainfall, (ii) peak discharge, (iii) bed load transport, (iv) suspended sediment load and (v) spatially distributed sediment deposition rates along the Menkere gully. We also conducted interviews with nearby farmers and investigated (historical) aerial photographs.

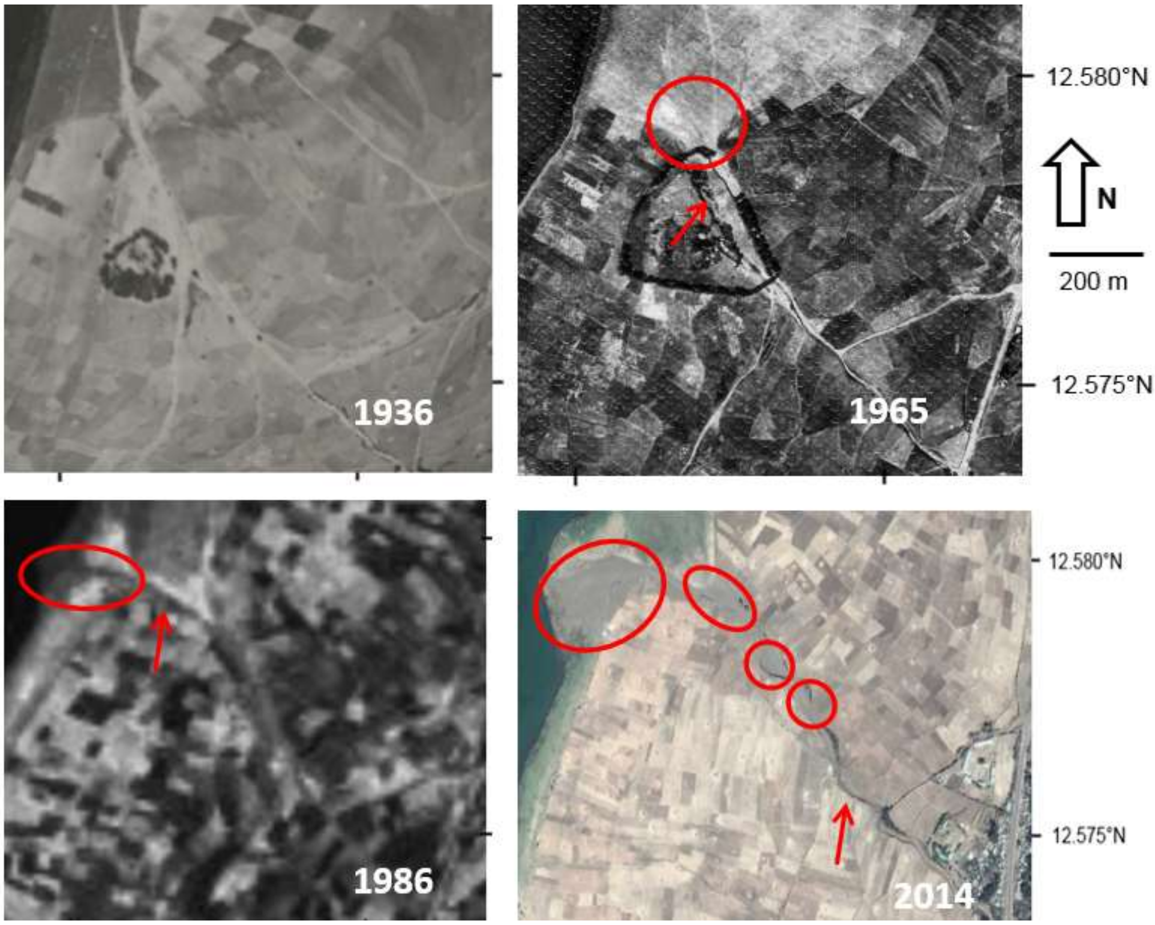

Figure 2. The Menkere gully as visible on the aerial photographs since 1936. Minor flat zones (sediment accumulations) are indicated with red circles; active incisions with red arrows.

What alluvial debris fans can tell us about past environmental change

Linking the interviews, the sequence of aerial photographs, and the discharge/sediment measurements, allowed us to reconstruct the sedimentary evolution of the gully since the 1930s (Figure 2). Conceptually, we identify five different sedimentary "periods"; in doing so, we show that flashflood sediments can be useful proxies for land degradation.

Sedimentary Phase I (1930s – 1950s): low peak discharges

As there are no debris fans visible on the early aerial photograph, the first half of the 20th century was a period with relatively low peak discharges. Upslope gullies around Ashenge were stabilized during this period.

Sedimentary Phase II (1960s – 1970s): increasing discharges and sediment supply

The aerial photograph shows sediment accumulation along the gully at the current location of DF3 (Figure 2), although there is no sign of debris fans at the lake shore. This must have been a period with predominantly higher discharges and sediment supply from the catchment.

Sedimentary Phase III (1970s – 1990s): high discharges

The interview records on this period are in line with the appearance of DF4 on the aerial photograph of 1986, while the former sediment accumulation (DF3) gets incised. This indicates a period with predominantly high discharges and high amounts of sediment towards DF4 and the lake.

Sedimentary Phase IV (2000s): upslope migrating debris cones

Following the interviews and the appearance of DF1 and DF2, the debris fans are developing as an "upslope migrating" sequence. DF4 continues to grow and DF3 reappears, pointing to a period with decreasing discharges.

Sedimentary Phase V (2010's): observations of a 'clear water effect'

We observed recent gully incision activity, indicative of even lower amounts of sediment supply towards the gully segment. In particular, DF1 and DF2 are incised by a channel, according to all farmers no older than 3 years. About 100 m upstream of DF1, this young channel incises the former gully bottom. Decreased amounts of upstream sediment supply are indicative of a 'clear water effect', meaning that the floods come with less sediment and have power to incise the gully bed.

Conclusions

In this integrated study of hydro-sedimentary changes around Lake Ashenge, we identified distinct sedimentary periods over the past decades:

(i) a period of sedimentary stability in the early 20th century;

(ii) a period of sedimentary destabilization in the 1960s – 1970s;

(iii) a phase of sedimentary instability in the 1970s – 1980s;

(iv) a phase of upslope migrating debris cones in the 1990s – 2000s;

(v) a period with more clear water effects (2010s).

During phases of retreating gully heads, progressive downstream sedimentation occurs in the alluvial debris fans, while 'clearer water' results in increased deposition of finer sediment particles in the lake. The periods of active gully sedimentation correlate well with periods of intensive gully erosion and clearly co-evolve with periods of decreased vegetation cover under insecure land tenure, drought and lower base levels. These findings illustrate the usefulness of sediments in alluvial and lacustrine debris fans as adequate proxies for past land degradation analyses.

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Chapter 5: Cropping systems in the Raya uplands

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Introduction

About 33% of the Northern Ethiopian Highlands is used as cropland. Nearly all this land is cultivated by smallholders who each have about a hectare. Through centuries of practice and experience, communities have developed their farming systems to optimize production (Fig. 1). The resultant indigenous knowledge on farming practices has been transferred from generation to generation. Such indigenous knowledge is generally perceived as being very valuable, as it has allowed communities to farm in a relatively sustainable way over many centuries. The aim of this study was to investigate the relationships between spatio-temporal variability in cropping systems and rainfall in Northern Ethiopia.

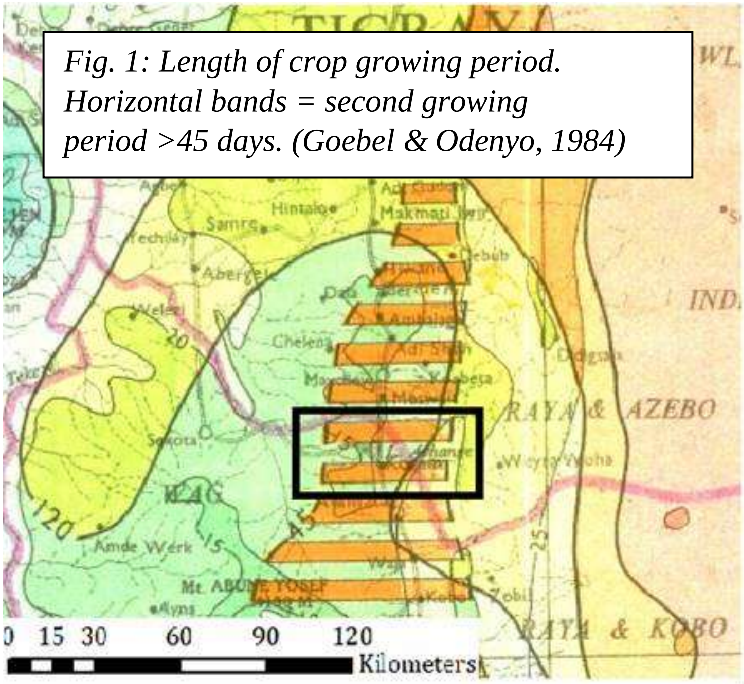

Fig. 1: Length of crop growing period. Horizontal bands = second growing period >45 days. (Goebel & Odenyo, 1984)

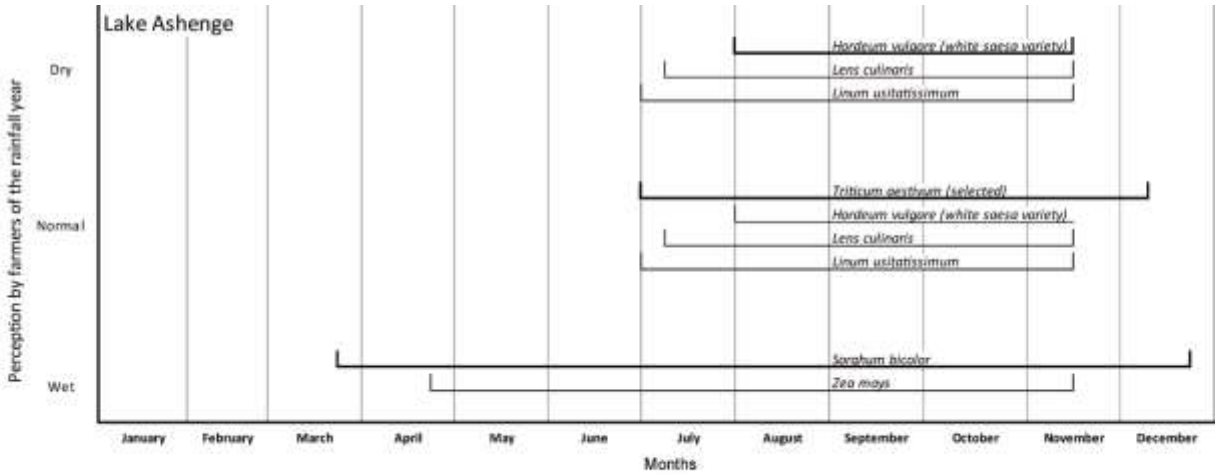

Fig 2. Cropping calendars in the valley bottoms around Lake Ashenge for years perceived by farmers as dry, normal and wet. Major crops are indicated with a thicker line.

Methodology: Defining the cropping calendars

Cropping calendars were created based on the period between the first day of sowing and the last day of harvesting. Cropping calendars were produced for years perceived as dry, normal and wet by farmers (Fig. 2). Therefore, farmers were asked to list dry, normal and wet years, and to define the cropping system they applied. Annual precipitation maps were used to define dry, normal and wet years in terms of the annual rainfall. Farmers' perceptions of the rainy season are, however, not only based on the total yearly precipitation but also on the distribution of rainfall throughout the cropping season. Case studies were done in ten catchments between Senkata and Korem. Here we illustrate it with the case of Menkere near Lake Ashenge.

Variability in cropping systems as related to rainfall

An analysis of spatial variability in cropping systems indicated that three gradients occurred in the distribution of cropping systems.

- **Catchment gradient**: a result of topography, soils and hydrology with longer crop cycles in the valley bottoms than on the valleysides and flats.
- **Latitudinal gradient**: shorter to longer cropping systems from north to south. This corresponds to the north to south increase in precipitation.
- **Altitudinal gradient**: caused changes in temperature with altitude. This is important for plant associations within cropping systems. For example, fenugreek as a leguminous crop will not be included in crop rotations at high elevation but instead horse bean will be cultivated. Similarly, among the barley cultivars, *burguda* will not be part of the LNC at high elevations but instead *shewa* will be cultivated.

Table 1 Properties of the cropping systems in Northern Ethiopian Highlands.

Cropping system	Duration of the cropping system (months)	Sowing month	Major crops
Short crop cycle	4	July/August	Barley (*Hordeum vulgare*, "*white saesa*" variety) and lentil (*Lens culinaris)*
Short normal crop cycle	5	June/July	Wheat *(Triticum aestivum "selected"* variety*)* with barley (*"white saesa"* variety*)* or lentil
Long normal crop cycle	6	May/June	Barley *("burguda"* variety*)*, wheat *("black" and "local"* variety*)* and/or tef (*Eragrostis tef "red"* variety*)*
Long crop cycle	9	March/April	Sorghum (*Sorghum bicolor),* Maize *(Zea mays)*
Long two crop cycle	10	January/February and July/August	Two crops in one year: barley (*Hordeum vulgare*)/ wheat (*Triticum aestivum*) and horse bean (*Vicia faba*)/ field pea (*Pisum sativum*)

As a result, shifts between dry and wet years will cause catchment-scale and north-south shifts in the cropping systems. Five cropping systems were identified with typical cropping season lengths: short crop cycle (four months), short normal crop cycle (five months), long normal crop cycle (six months), long crop cycle (nine months) and long two crop cycle (ten months) (Table 1).

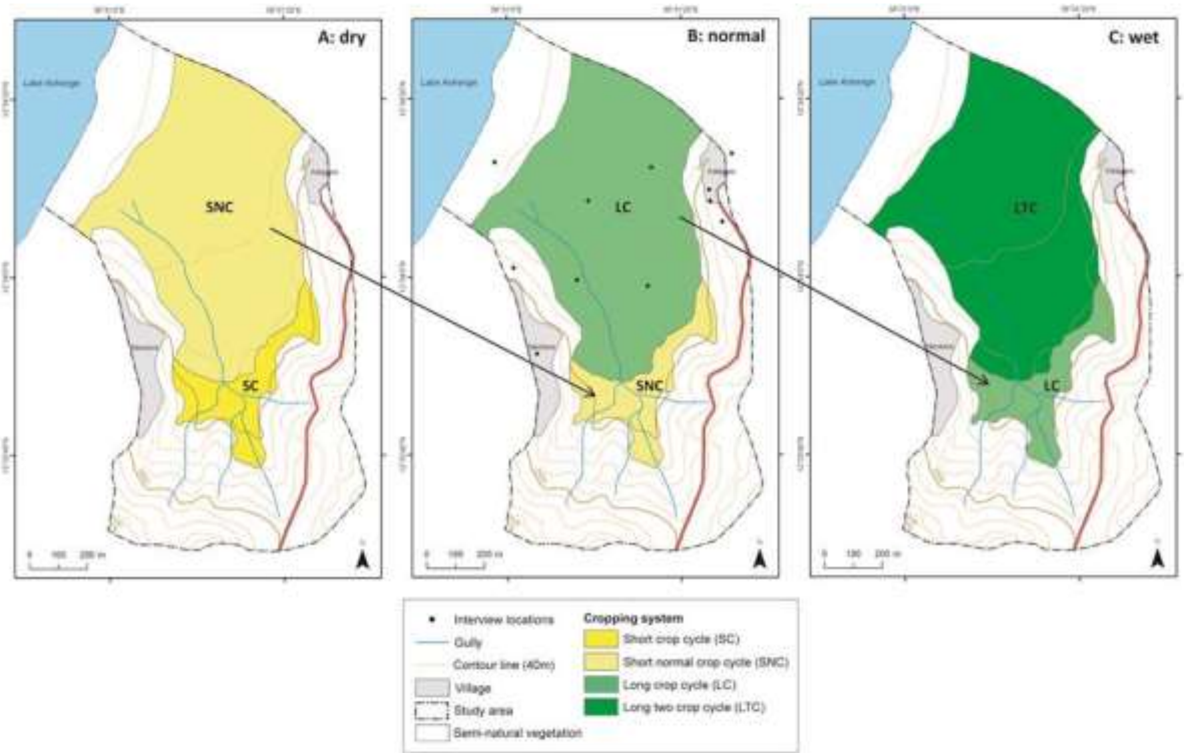

Fig 3. Cropping systems maps for the Lake Ashenge study area for years perceived as dry, normal and wet by farmers. A: dry year (e.g. 2004), B: normal year (e.g. 2009) and C: wet year (e.g. 2006).

Conclusion

Farmers in the Northern Ethiopian Highlands have adopted flexible farming systems that consider local environmental conditions as well as inter-annual variations in rainfall. Each of these systems has a typical crop association. At the catchment scale, cropping systems on valleysides are of shorter duration than cropping systems in valley bottoms, which reflects contrasting soil and hydrological conditions. At a regional scale, a north to south change in cropping systems occurs, with crop calendar length increasing towards the south.

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Chapter 6: Unequal land access or equity: impacts on land degradation around Lake Ashenge

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Introduction

Land degradation is Ethiopia's biggest environmental problem, as it has an adverse impact on soil productivity, and therefore it threatens food security and livelihoods. In parallel, land reforms and redistributions took place, particularly between the late 1970s and early 1990s. We investigated the land tenure policies in the uplands along the grabens over more than 100 years, and particularly how land distribution impacted land degradation.

We considered the context of socioeconomic, cultural and political factors in order to understand the characteristics of change in farmers' decisions regarding sustainable land management, and towards sustainable soil conservation investment in order to reduce land degradation.

1868 © K.O.R. Museum, Lancaster (U.K.)

1937 © AOI Archives, Firenze (I.)

1961 © A.T. (Dick) Grove

1975 © R. Neil Munro

2007 © Jan Nyssen

Fig. 1 Five photos (through time) of the landscape around Menkere. Note that the first one is taken from the northern side.

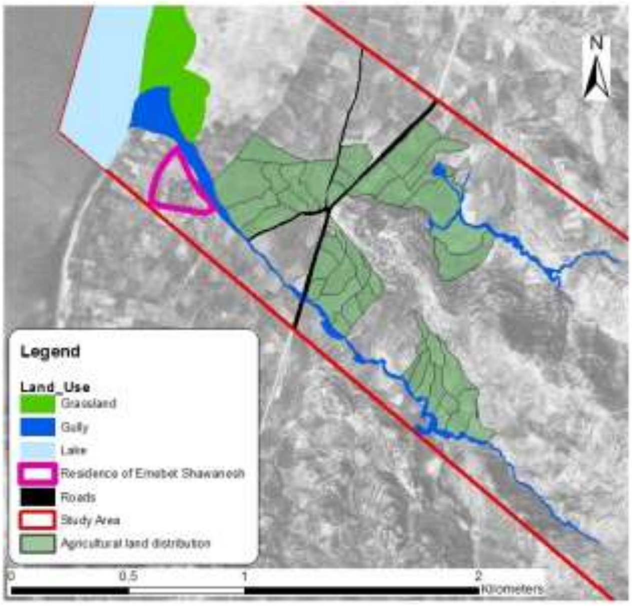
Fig. 2. Aerial photograph of the Menkere area in March 1936 (Source: AOI, 1939). The village of Menkere is on the hill in the centre of the photo. The small forest indicates the compound of Dejazmach Hailu Kebede (one of his three residences). Nowadays the trees have been cut, but they are visible on the 1937-1961-1975 photos (Figure 1).

Methodology

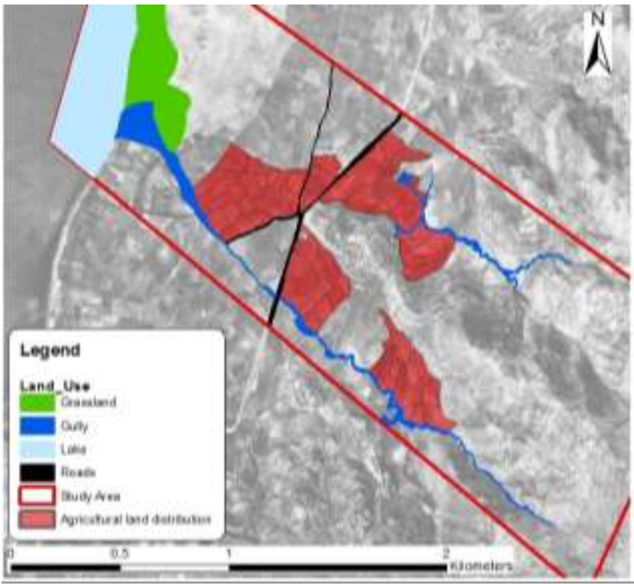
The study was carried out in Menkere, a village in the catchment of Lake Ashenge (Fig. 1). It is based on the interpretation of aerial photographs since the 1930s (Fig. 2), before land reform, and a detailed field survey among 104 farmers and on 113 plots located on different catenary positions. In addition, 25 topsoil samples were collected for soil fertility analysis and 11 profile pits were made in order to map soil variability.

Land tenure through the 20th Century

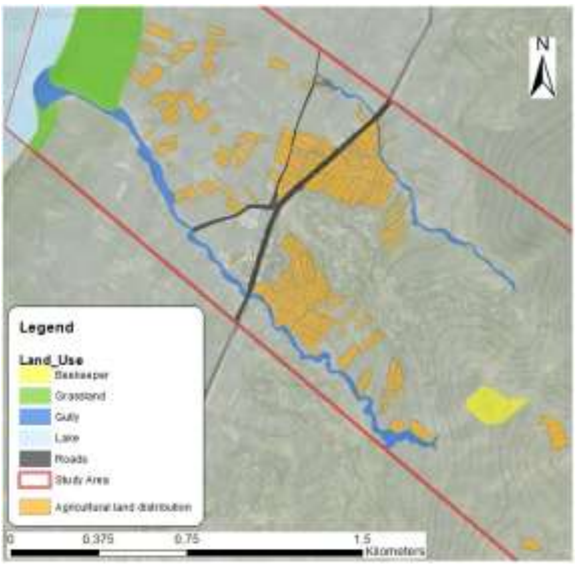
Up to 1975, there was feudality and usufruct tenure with large landholders and many tenant slaves. The village of Menkere was controlled by Dejazmach Hailu Kebede, who was killed by the Italian army in 1937, after organising strong resistance. In the feudal regime, the richer farmers typically had large lands on the footslopes, whereas the wetter and colder areas near the lake and also the mountain area were cultivated by the poorest farmers. The interviewed farmers typically remembered that Emebet Shawanesh, widow of Dejazmatch Hailu, owned large lands, though the lower ranked feudals managed to get hold of some of her lands. We could map these lands in the field using focus group discussion methods, for the situation of 1964, 1977 and nowadays (Fig. 3).



1964.
Land near the lake (at left of the photo) and in the mountains (right) were left fallow or ploughed by the poor.



Derg period.



2014.
Some areas in the mountains have been closed and reforested. Note the presence of a beekeeper.

Fig. 3. Maps of land holdings in Menkere. Areas not mapped represent disagreements and uncertainties during group discussion.

Table 1. Land holdings in Menkere during feudal and Derg times

Rank in feudal period	Number	Feudal times average (hectare)	Derg period average (hectare)
Dejazmatch	1	14	3.3
Grazmatch	4	9	1.9
Kegnazmatch	5	8	1.6
Balambaras	6	5	1.6
Balabat	1	6	0.8
Chikashum	1	4	0.7
Farmers	21	4	0.9
Tenant farmers	More than 50	0	no information

At the feudal times, there were very unequal areas of land holding (Table 1). When the Derg government came to power, they did a first land reform. All interviewees stated that this land distribution was hastily and not equally done. One farmer said that "it depended whether you came by foot or by hand". Table 1 (last column) shows that, indeed, the previous feudals managed to larger land holdings.

The TPLF fighters organised another land reform around 1990, that is still prevalent. Locally some corrections have been done, but the aim is to have the same land area to every farmer (men and women). Some land readjustments have been done so that youngsters could get land, through lottery system. Land certification has been done afterwards, and no further sharing is allowed. However, informally there is a land market; people are renting, but not selling land. All in all, nowadays, most farmers cultivate two or three plots (Fig. 4).

In Ethiopia, over the last 20 years, cereal production (par area of land, and per capita) has strongly increased (Fig. 6). This is related to the efforts for land management, the feeling of ownership of the land, and investments done in agriculture. The land fragmentation, to a large extent, allows also the farmers to apply very intensified and diversified agriculture, that comes close to "precision agriculture".

Conclusions

- In Menkere, there is a complex interaction between biophysical and social system
- Equal land sharing is attempted
- Land holdings are small
    - This leads to removal of the matrix vegetation
    - Many farmers need off-farm income (part- or full-time)
- Crop production and soil conservation have strongly increased

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Chapter 7: Land cover and woody vegetation cover changes along the Raya escarpment

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Introduction

During the 20th century, the Ethiopian highlands have faced serious environmental degradation due to high human population and livestock densities. Recent observations, however, suggest a reversal towards a greener, more rehabilitated environment due to the establishment of soil and water conservation activities since the mid-1980s.

In this study, we analysed the land cover changes along the Raya escarpment using ground reference data (ground control points and semi-structured interviews) and multi-temporal Landsat satellite images for the period 1972 to 2014. As a re-greening of the study area was expected, special attention was given to the distribution of woody vegetation species in the area.

Methodology

An extensive field campaign was conducted in the summer of 2014. 500 ground control points were collected for the supervised classification of atmospherically and topographically corrected Landsat images of 1972, 1986, 2000, 2005, 2010 and 2014. Based on map differencing, the evolution of the different land cover classes over time was studied, with a special focus on the woody vegetation classes (bushland and forest). In the field, the main woody vegetation species were identified, and their spatial distribution was studied. The land cover changes were then linked to (i) regional environmental policies and (ii) rainfall variability, using locally corrected satellite-derived rainfall estimates.

Land cover changes (1972 – 2014), environmental policies and rainfall variability

All land cover maps (Fig. 1) were produced with reasonably high accuracies (Kappa coefficients greater than 0.82), which allowed us to study the land cover changes over time. The main observed results (Fig. 2) were a strong decline in farmland (from 60% to 35%) and an important increase in woody vegetation (from 33% to 53%) between 1972 and 2014.

In 1972, the study area was degraded as a result of social and land inequities during the feudal era (before 1974). Due to the civil war, a severe drought (1979 - 1984) and the inherited environmental situation, the physical landscape continued to degrade until 1991 in most places of northern Ethiopia. However, new land reforms (nationalisation of farms and land redistribution to all households) were implemented between 1974 - 1991 and soil and water conservation efforts were undertaken starting from the late 1970s. Most of the re-greening of the Raya escarpment already occurred between 1972 and 1986, resulting in a nearly constant proportion of woody vegetation (53%) until 2014. Most probably, this 'early rehabilitation' can be attributed to the marginal location of the area, adjacent to the fertile Raya Graben, as protection started later in the open fields of the Ethiopian Plateau. From the 1991 onwards, a new land reform was organized (all farmers received a similar share of land) and soil and water conservation measures were implemented at large scale to restore degraded soils and vegetation.

While most land cover changes may be attributed to environmental policies, rainfall variability proved to have its share as well. According to statistical analysis, the land cover changes in the study area have to some extent been impacted by rainfall variability between 2000 and 2014. Indeed, a very strong correlation between forest shrinkage and decreases in 5-year average annual rainfall was observed. As these results only explain a small proportion of the observed land cover changes, it can be concluded that human impact is the main driver of these changes.

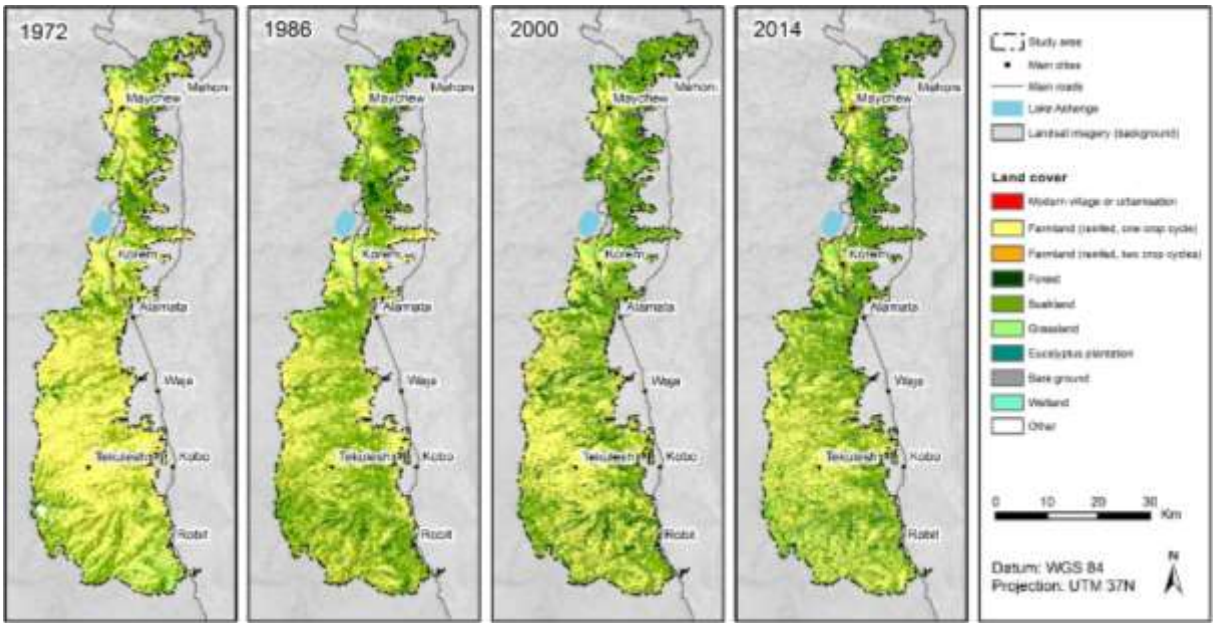

Fig. 1 Land cover maps of the Raya escarpments for the period 1972 to 2014

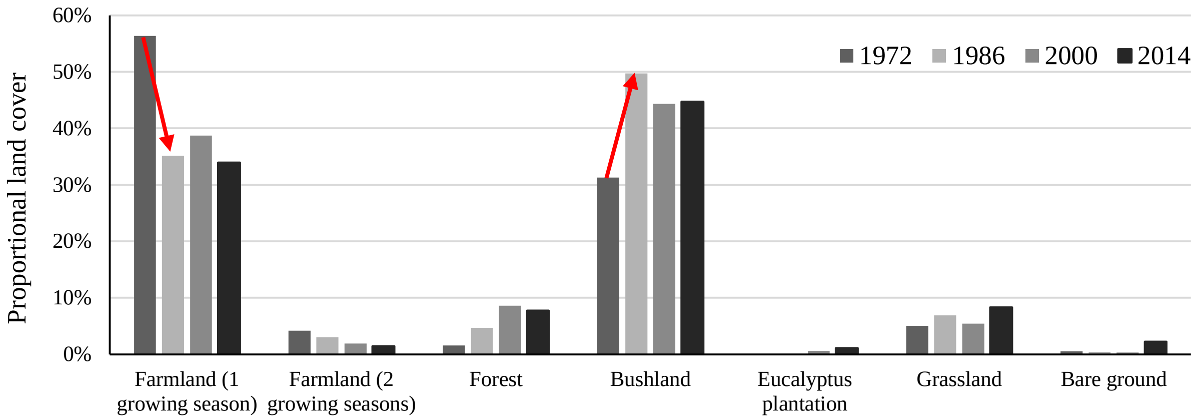

Fig. 2 Observed land cover proportions for the period 1972 to 2014

As historical terrestrial photographs were available for the Gira-Kahsu catchment, an additional verification of the results was done by comparing these photographs with the mapped land cover changes (Fig. 3). Here, based on both sources, we observed the evolution of a degraded catchment (1972) towards an almost fully protected forest (2014).

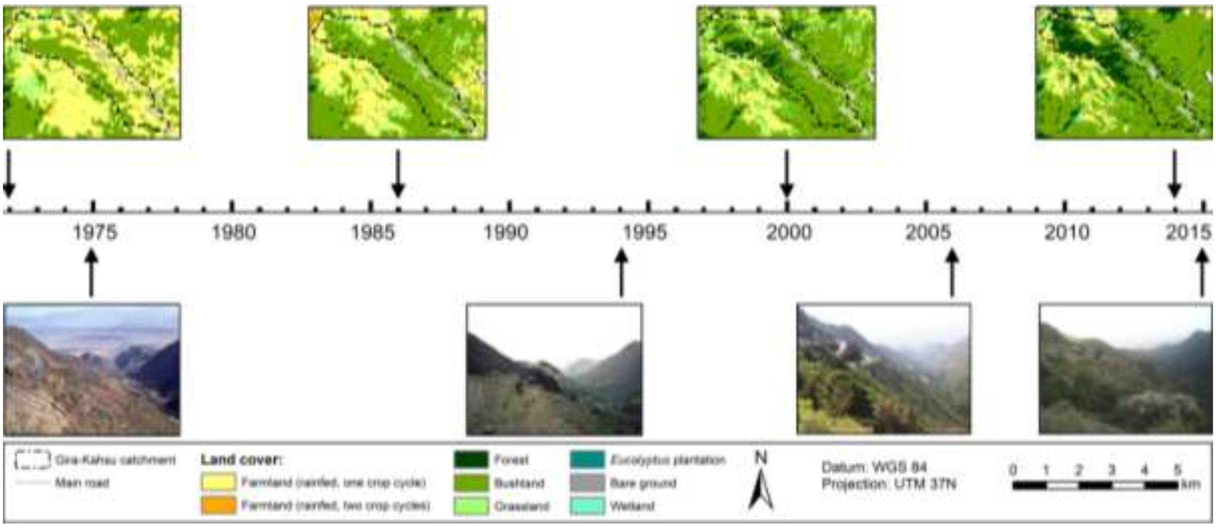

Fig. 3 Time lapse of the land cover changes in the Gira-Kahsu catchment (1972 – 2014) (Sources repeat photographs: R.N Munro (1975), A. Crismer (1994) and J. Nyssen (2006, 2015))

Woody vegetation cover (2014)

During the field campaign, a total of 243 woody vegetation assemblages were observed along the escarpment, stretching over an elevation gradient of about 2200 m (1455 to 3660 m a.s.l.). Fig. 4 gives an overview of the altitudinal distribution of the dominant woody vegetation species that were observed at least 20 times. Observations of the afro-alpine zone (e.g. bushes of *Erica arborea*, *Helichrysum* sp. and *Lobelia rhynchopetalum*) are not included. Overall, the woody vegetation cover in the area is dominated by pioneer species (e.g. *Dodonea angustifolia*, *Carissa edulis* and *Euclea racemosa*) and indicator species for disturbance (e.g. *Cadia purpurea*, *Opuntia ficus-indica* and *Aloe* sp.). Late-successional species that once dominated the escarpment (e.g. *Juniperus procera* and *Olea europaea*), almost completely disappeared from the open-access forests, and only can be found in protected (church) forests.

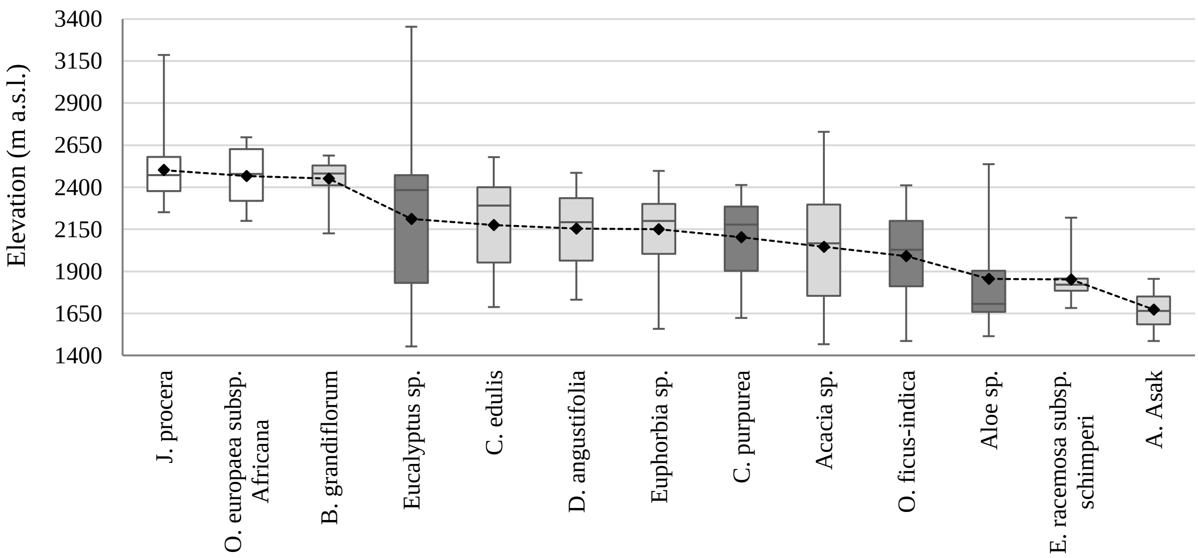

Fig. 4 Main woody vegetation distribution along the Raya escarpment (exotic species in dark grey, pioneer species and indicator species for disturbance in light grey)

Conclusions

- Re-greening of the Raya escarpment between 1972 and 2014, with a nearly constant proportion of woody vegetation cover (53%) since 1986
- The re-greening most probably is the result of effective environmental policies, but can also partly be attributed to rainfall variability
- Despite the re-greening of the area, only 8% of the Raya escarpment is covered by dense forest in 2014
- The omnipresence of pioneer species and indicator species for disturbance, highlights that a lot of effort still must be done to further rehabilitate the area

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Chapter 8: Successful land rehabilitation on the escarpment

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Introduction

Owing to high rate of deforestation, the catchments in the western rift valley escarpment of Ethiopia were severely degraded by the first half of the 1980s.The severity of the land degradation was mostly evidenced by various hydro-geomorphologic features including development of dense gullies and scar networks (Fig.1) in the steep slopes transporting huge amount of floods and sediment composed of very big boulders down to the Raya graben. To reverse land degradation in general and protect Alamata town from the devastative floods in particular, reforestation interventions that included establishment of exclosures were initiated in the mid-1980s.

Fig.1: Scars incised to the bed rock on steep slope mountains with less vegetation cover

The objective of this study was to (1) examine the role of the rehabilitation intervention on reduction of land degradation as represented by scar networks; and (2) identify the major stream channel adjustments occurred in response to vegetation cover changes.

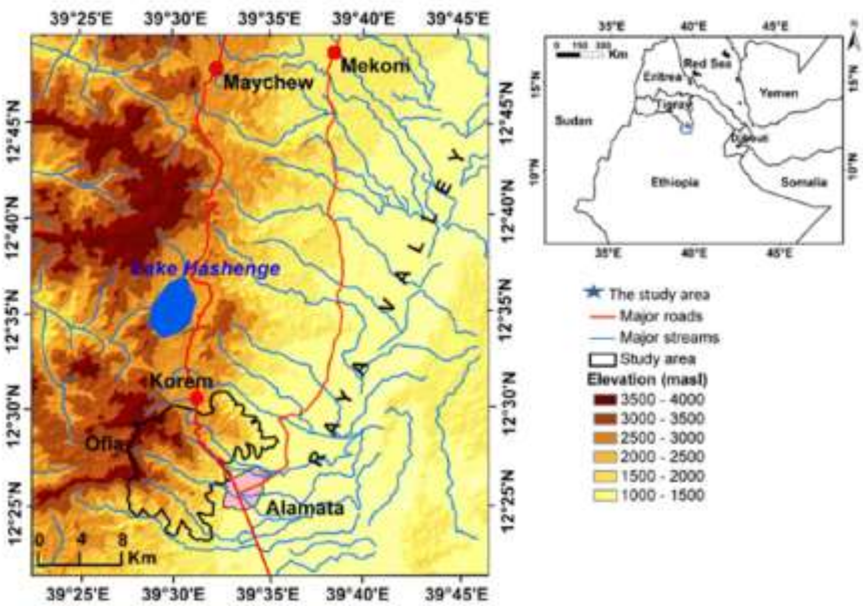

Fig.2: Location of the study area.

Methodology

Twenty adjacent catchments (12º22'-12º30'N; 39º27'-39º35'E) (Fig.2) which were severely degraded up to the mid-1980s and were later reforested to various degrees were selected (Fig.3). Mean Normalized Difference Vegetation Index (NDVI) values of each catchment were computed from Landsat satellite image (Thematic Mapper) of 25 December 2010. NDVI is a measure of greenness of an area, it represents vegetation cover. To examine the impact of the reforestation intervention on minimizing land degradation as represented by density of scar networks, all scar network on the steep slopes of the 20 catchments were mapped on Google Earth imagery (acquired in October 2005) and were verified in the field. Then the average scar density of each catchment was explained in terms of average NDVI and topographic characteristics of the catchments. Detail field surveys and interviews with elderly local farmers were carried out to identify the major stream hydro-geomorphologic adjustments occurred in response to reforestation interventions.

Fig.3: The incidental series of repeated photographs of the Gira Kahsu catchment shows good vegetation cover in 1939, expansion of agricultural land in 1970s and a marked reforestation thereafter. Photo credits: 1939 IAO, 1970 Larry Workman, 2006 Jan Nyssen, 2015 Tesfaalem G.

Improvement in vegetation cover and reduction in land degradation

The results indicate that the vegetation cover of many catchments in the study area has improved due to the rehabilitation interventions that have been carried out starting from the mid-1980s. Consequently, land degradation as represented by scar density has decreased with increasing NDVI (Fig. 4A) except for the sloping catchments with very steep slope gradient (>60%) where scar density increased with increasing slope gradient (Fig.4B). Particularly, in the Gira Kahsu catchment (Fig. 3), where the most intensive rehabilitation activities were carried out and where the larger part of the catchment is exclosed, the improvement in vegetation cover was remarkable. Hence, the lowest scar density was observed.

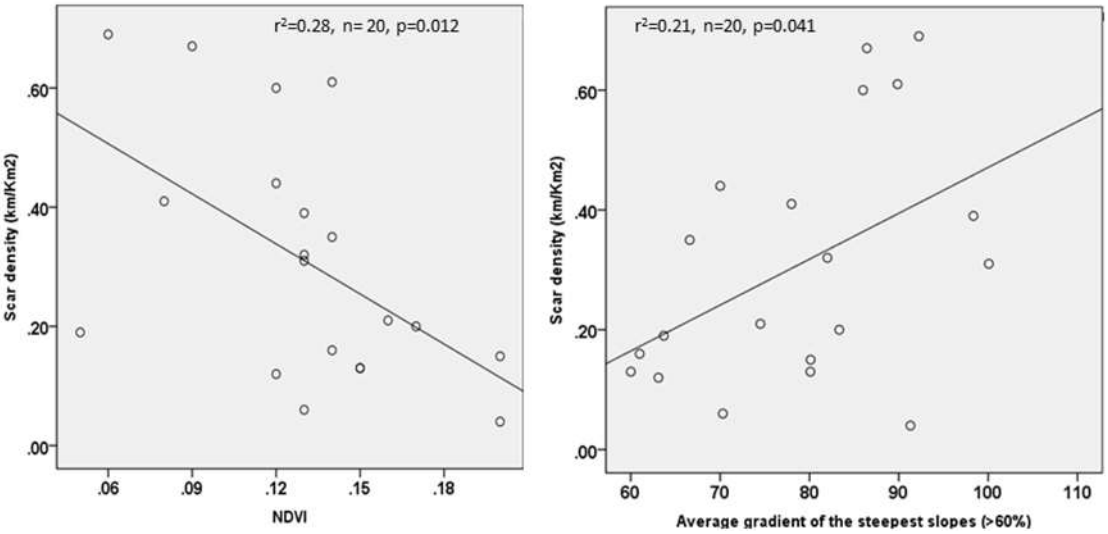

Fig. 4: Relationship between NDVI and scar density (left) and between average gradient of the steepest slopes (>60%) and scar density (right).

Adjustments of stream channels in response to vegetation cover improvement

The improvement in vegetation cover was also associated with reduction in peak discharge and size and volume of bedload sediment flux. Subsequently, various stream channel adjustments occurred. Notably, abandonment of many of the previously braided stream channels in favor of single thread streams, stabilization and colonization of lateral bars by vegetation and incision of lower stream channels were observed in the field.

Fig.5: Large boulders recently deposited in the active channel of the less forested catchment (A) and the gravelly active channel of the reforested Gira Kahsu catchment, finding its way between older boulder deposits (B).

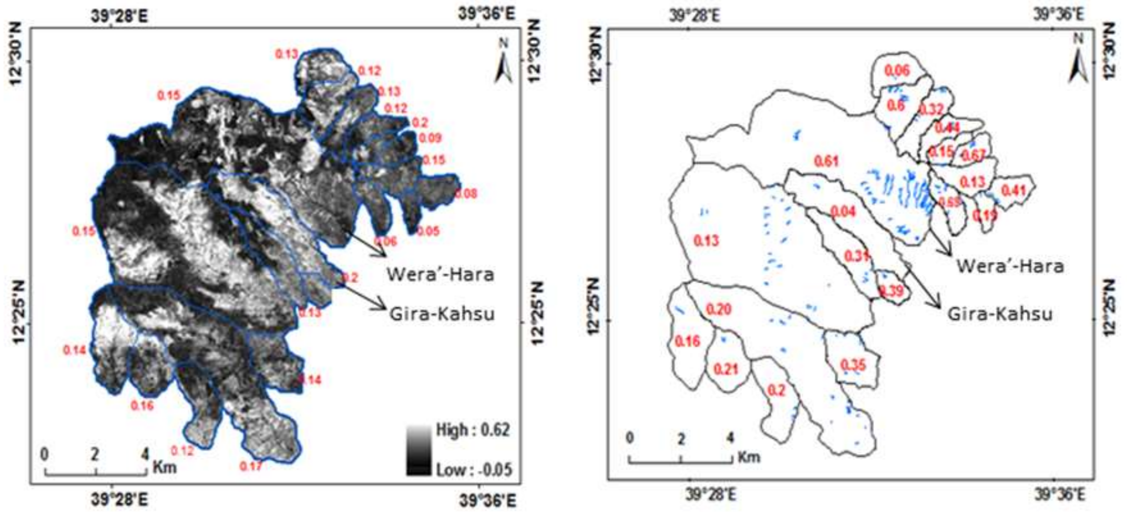

***Fig**.6: Average NDVI values (left) and scar density (km/km²) of the 20 catchments (right)*

Conclusion

Unlike earlier catchment studies in nearby areas where catchments were insufficiently differentiated to demonstrate effects of variable land use, this study has shown that catchment reforestation in northern Ethiopia has led to a remarkable stabilisation of the slopes in less than 30 years as well as to narrowing and incising rivers that should be interpreted as signs of a resilient catchment.

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Chapter 9: The floods from the escarpment

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Introduction

The hydrological behaviour of mountain streams is controlled mainly by interrelations of precipitation variability, vegetation cover change, and local topographic factors. Particularly, a change in vegetation cover effectively regulates flood generation from mountainous catchments in a relatively short period of time. With deforestation, due to their steep stream gradient profiles, the high intensity of precipitation in such catchments leads to high flow velocities and extreme peak discharges; usually associated with destructive torrents and floods that usually produce environmental, economic and human losses.

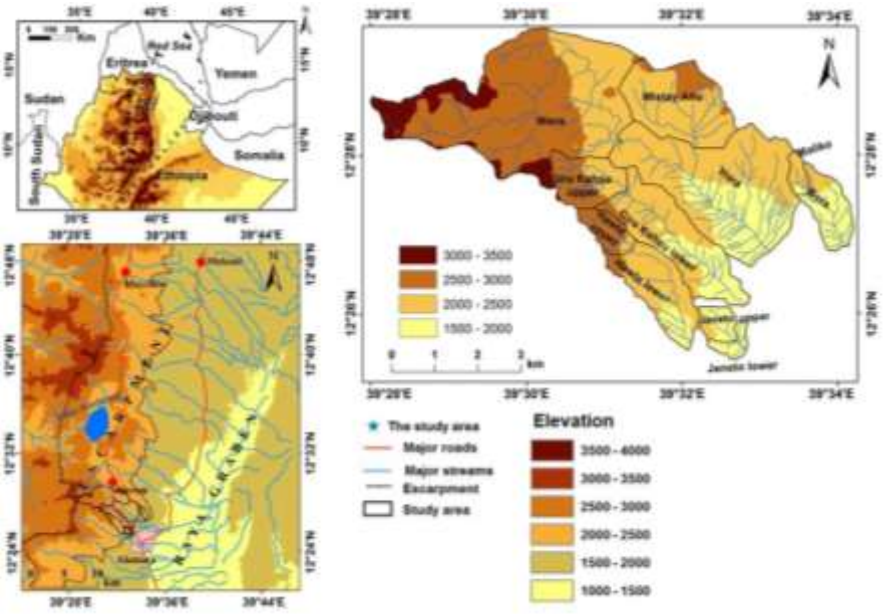

Fig.1: Location and altitude map of the study area

By taking five steep mountain catchments in the western Rift valley escarpment of Ethiopia (Fig.1) which were deforested by the mid-1980s and reforested later, this research aimed at: (1) analyzing the runoff response of steep mountain catchments which are under way of forest restoration; (2) examining the relationship between estimated peak discharge event, vegetation cover and geomorphologic factors; and (3) testing the usefulness of simple daily measurements of precipitation and estimated peak discharge to analyze the hydrological behavior of mountain catchments.

Methodology

Monitoring precipitation distribution

Seven rain gauges were installed to collect daily rainfall events between 2012 and 2014 (Fig. 2). The locations of the rain gauges were selected based on geographic spreading, topography, altitude and accessibility, giving a density of one rain gauge per 5.2 km^2. This allows for accurate representations of spatio-temporal rainfall variability. The station precipitation data were converted in to a daily precipitation map using the Thiessen Polygon method and finally, area-weighted average daily precipitations over the catchments (P_d) were calculated.

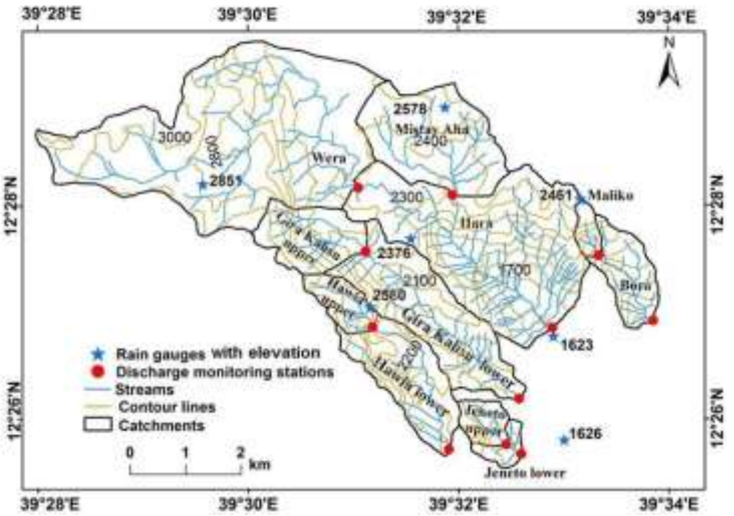

Figure 2: Location of precipitation and discharge monitoring stations.

Land cover mapping

Land cover mapping was carried out based on very high-resolution Google Earth imagery (GeoEye image with 0.6 m resolution of February 1, 2014) using on-screen digitization process. Having prepared the land cover map, detailed field verifications were carried out. Finally, the percentage of each land cover class was computed per catchment.

Geomorphometric analysis

The morphometric characteristics of catchments and their streams are important factors affecting various aspects of runoff. These factors influence mainly the concentration or time distribution of runoff from catchments and stream channels. Hence, for every catchment, 12 geo-morphometric factors which mainly affect runoff were calculated based on ASTER-DEM with 30 m spatial resolution and topographic maps with a scale of 1:50,000.

Calculation of peak discharge

The amount of discharge from catchments can be directly measured in different ways. In mountainous streams, however, direct measurement during the floods presents many challenges mainly due to the flashness of the flow and its destructive character. Most stream flow data in such occasions are collected indirectly using crest stage gauges which are able to measure the flood stages of the highest stream flow events. Hence, in the current study, 332 flood stage events were measured in the rainy seasons of (2012 to 2014) using 11 crest stage gauges (Fig. 3) which were installed in the outlets of the catchments (Fig.4). Flood peak stages were converted to peak discharge (Q_p) values using the Manning's equation. To neutralize the effect of rainfall and size of catchments on runoff, the Q_p values were converted to Catchment Specific Peak Discharge Coefficient (C_p).

Fig. 3: Crest stage gauge (A), sawdust being placed in the bowl of the lower cap before and after measuring peak stage (B), remnants of sawdust on wood staff indicating the highest peak stage of the flood (C), and wood staff being cleaned for the next flood (D).

Fig.4. Daily rainfall of 21.1 mm in Wera catchment (23/8/2013) resulted in a flash flood peak of 128 m^3 per second. Crest stage gauge appears in the middle of the opposite bank.

Variability in flooding (peak discharge)

Great differences were observed in peak discharge (Q_p) ranging from 5.24 to 77.74 m^3 per second and in catchment-specific peak discharge coefficient (C_p) among the 11 catchments. Maliko, Bora and Hawla upper stations showed highest C_p. Conversely, Gira Kahsu lower and Gira Kahsu upper catchments showed the lowest C_p (Table 1).

Table 1: Major results, related to the peak floods observed in the catchments

Catchment	Catchment Area (km^2)	Mean Q_p (m^3 per second)	C_p	Time of concentration (min)[1]	Vegetation cover (%)	Area weighted Event rainfall (mm)
Wera	12.52	63	0.29	61	28.4	19.0
Mistay Aha	3.79	16	0.26	23	29.6	16.9
Hara	24.47	78	0.20	71	25.4	15.3
G. Kahsu upper	1.87	5	0.16	14	51.0	16.9
G.Kahsu lower	5.89	11	0.11	31	57.5	15.5
Hawla upper	0.83	13	0.74	8	3.9	20.8
Hawla lower	3.38	28	0.44	25	15.5	18.8
Jeneto upper	0.60	9	0.72	8	8.9	19.8
Jeneto lower	1.00	16	0.72	10	8.4	19.5
Maliko	0.36	5.63	0.87	4.19	16.0	19.5
Bora	1.76	25.48	0.79	12.88	12.7	19.5

[1]Time of concentration (T_c) is used as a proxy of the time for runoff to flow from the catchment divide to the outlet.

Major determinant factors of peak discharge

As presented in table 1, the catchments vary in size and this is expected to influence the amount of rainfall they received. Hence, the catchment-specific peak discharge coefficient (C_p) neutralizes the effect of these variables and thus, appropriately compares catchments in terms of their runoff responses. Therefore, in this study, focus is given to catchment-specific peak discharge coefficient (C_p) than to peak discharge (Q_p).
A statistical analysis showed that vegetation cover is one of the most important variables that strongly influences runoff response of the catchments (Fig.5).

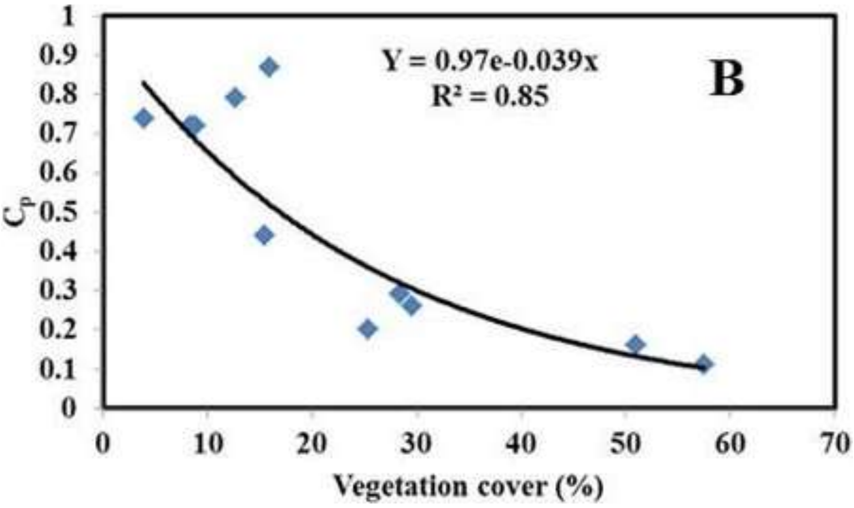

Fig.5: Relationship between percentages of vegetation cover and catchment-specific discharge coefficient (C_p)

Moreover, out of the 12 morphometric variables calculated, only three variables; average catchment slope gradient (R^2 = 0.37, P<0.05), catchment length (R^2 = 0.37, P<0.05) and calculated time of concentration (R^2 = 0.43, P<0.05) were positively related to C_p.

Conclusions

1. The hydrologic behavior of reforesting steep mountain catchments is strongly determined by percentage of vegetation cover.
2. In steep mountainous catchments where it is difficult to directly measure discharges using the conventional techniques, the hydrological behavior of such mountains could be successfully understood using simple measurements of daily rainfall and peak discharges

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Chapter 10: Rocky deposits on the foot of the escarpment

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Introduction

Hydrogeomorphic processes associated with gravity and running water are frequent events in mountainous streams. As a sediment storage type, rocky deposits/debris cones are widespread terrestrial landforms along the Rift Valley. Despite their geographical expansion, the characteristics of the debris cones with their headwater are unknown to policymakers. Hence, we examined the distribution and their livelihood effects of debris cones on the foot of the escarpment.

Methods and materials

The study area is located in the western margin of the Rift Valley (Figure 1). Google Earth Pro, Landsat images and questionnaires were used to address the objectives. Inferential statistics and coupled criteria analysis were applied to define the thresholds of the parameters of debris cones.

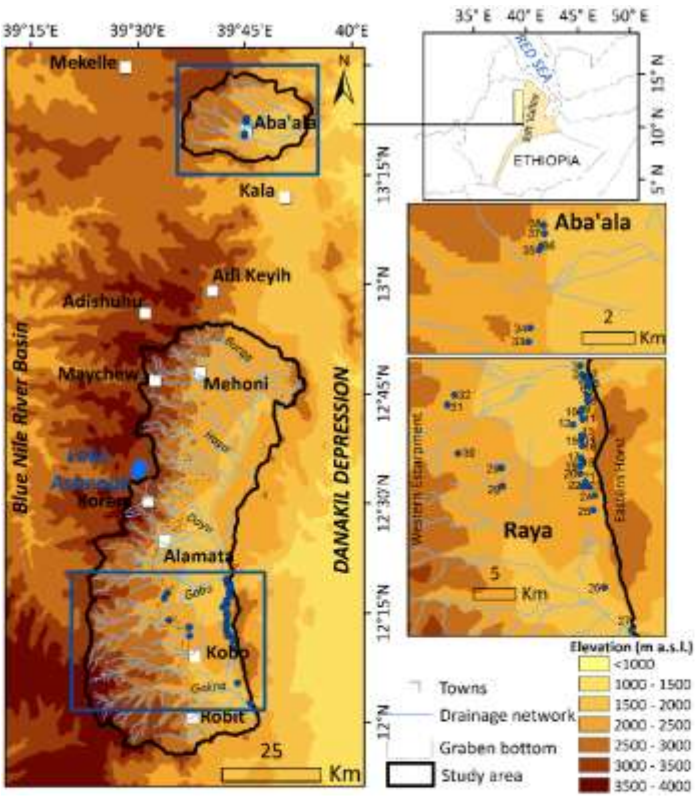

Figure 1: Location of the study area.

Characteristics of debris cones and their formation

The majority of the debris cones in Raya graben are located at the eastern horst (98%) whereas limited debris cones were found at the western mountain (2%). In Aba'ala graben, however, all debris cones were found at the western escarpment. Also, the characteristics of debris cones varied between Aba'ala and Raya grabens (Table 2). The Raya graben had a larger average area of sediment cones (411 ha) than the Aba'ala (15 ha).

Table 2: Physical characteristics of debris cones (mean) in the Aba'ala and Raya grabens.

Morphometric parameter	Raya graben debris cones (n=32)			Aba'ala graben debris cones (n=6)		
	M±SD	Min	Max	M±SD	Min	Max
Slope (%)	13.1±5.3	5.0	26.0	14.8±6.7	8.0	26.0
Depth (m)	3.8±2.12	0.2	8.0	2.8±1.2	2.8	6.0
Area (ha)	12.8±2.5	0.2	92.9	2.49±1.8	0.8	5.6
Volume (million m^3)	0.75 ±0.15	0.003	7.43	0.08±0.04	0.05	0.16
Elevation (m a.s.l)	1462±59	1352	1602	1490±18	1465	1535

The characteristics of the upper catchment control the development of debris cones. The flow length of the headwaters was the major predictor to the debris cone formation. The slope gradient of the upper catchments is also a boundary condition for the response of debris cones (Figure 2).

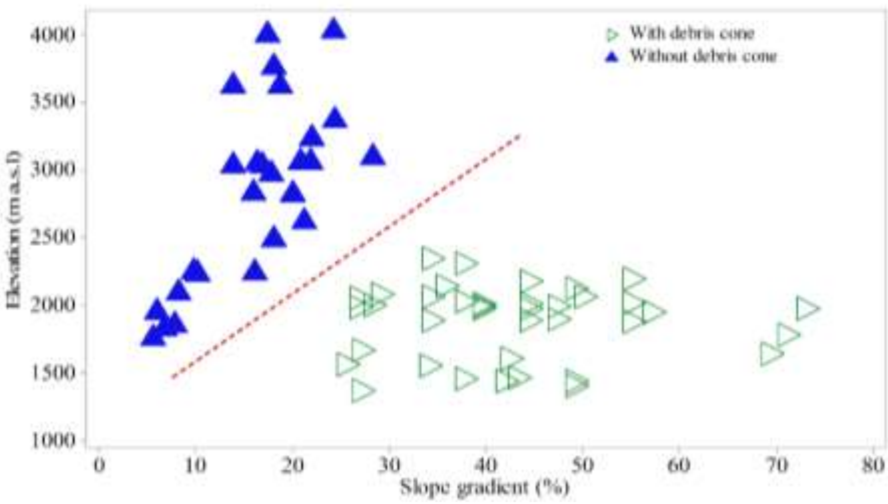

Figure 2: The elevation and average slope of the upper catchment with and without debris cones.

Expansion of debris cones affected the livelihoods of farmers

Excessive destruction of natural assets related to debris cones has a negative implication on the lives of the farmers. In particular, the expansion of debris cones devastated 112 ha of farmland (Figure 3). Also, the unexpected flash floods displaced 35 smallholders. Thus, an excess sediment export from the headwaters could risk the sustainable agriculture in the downstream (Figure 4).

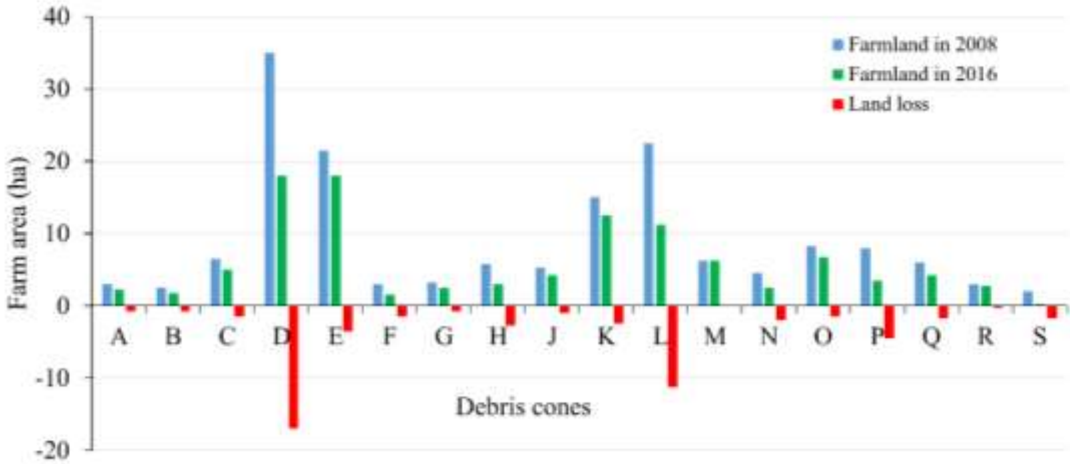

Figure 3: Farmland size between 2008 and 2016 on the foot of the debris cones in the grabens.

Figure 4: Illustration of the debris cone and their implications at the graben bottoms: A) Enquyber debris cone that expands to crop fields, B) sediment deposition affecting new houses in Aba'ala graben and C) flash floods deposited large debris volumes in Raya eastern horst.

Managed debris cones render the societal and environmental benefits to the farmers. In the rainy season, rocky deposits retained floodwater from the headwaters. The alluvial sediments at the loops of the debris cones are also fertile soils that could allow crop cultivation. Furthermore, the debris cones are essential landscapes for spate irrigation. As a result, the gentle gradients of the debris cones are desirable sites for the residential area.

Conclusion

Rocky deposits were formed at the juncture of steep hillslopes and the flatter graben bottoms, agriculturally productive areas. As an indicator for soil erosion at the upper catchment, we found large debris cones on the slopes. The expansion of debris cones affected the livelihoods of the graben farmers. To conclude, debris cones have spatial heterogeneities with increasing geohazards to the lives of the graben farmers. We suggest integrated headwater rehabilitation could reduce the expansion of debris cones to the agricultural productive areas.

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Chapter 11: River sedimentation at bridges in the Raya graben

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Introduction

The Raya graben is a semi-closed marginal graben of the Ethiopian Rift Valley (with a total area of 3,750 km^2 located between 12°–13°N and 39.5°–39.8°E) and a typical semi-arid depositional area onto which several ephemeral rivers draining the graben shoulders transfer large quantities of sediment through the main river stems and wide distributary systems. There is a big concern of thick bridge sedimentation and consequently frequent excavation of sediments under the bridges in Raya graben (Fig. 1). This study investigates the temporal variability and effects of bio-climatic factors and bridges on local hydro-geomorphic conditions that cause excess sedimentation and flood hazard in rivers of the Raya graben. Vegetation cover, rainfall (Fig. 2), river channel geomorphology, and hydraulic conditions were taken into account to understand the thick sediment deposition under the bridges.

Figure 1. Thick sediment deposition in Gobu River at the small town of Waja.

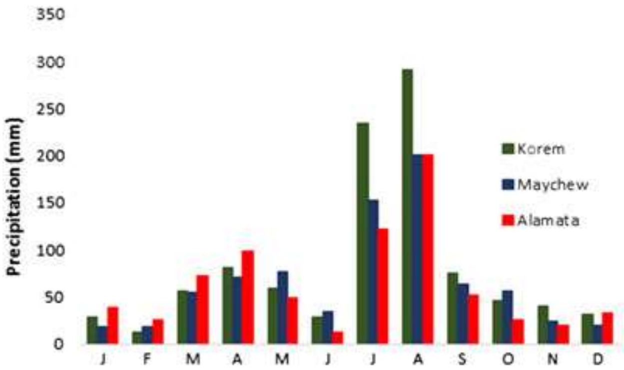

Figure 2. Average monthly rainfall distribution in the study area.

Methodology

This study was conducted based on bio-physical and hydro-geomophologic analysis in the Raya graben 16 rivers that extend from the southern to the northern part of the graben. In order to understand the reason for a thick sediment deposition under the bridges in the rivers, vegetation cover was analysed using NDVI, rainfall probability was analysed using the meteorological data of Alamata, Korem and Maychew. Moreover, grain size data was collected from the river beds from the bridges up to100 m upstream of the bridges. The stream-bed gradient was measured with a Leica Disto D8 distance meter. The local hydraulic process around the bridge ridges were analysed.

Channel/Bank erosion and deposition

Channel and bank erosion are frequent phenomena in the rivers in Raya graben (Fig. 3). Sediment thickness was measured in 16 bridges that were built in 2002. In some bridges, the sediment thickness reaches up to 1·6 m. From field observation and local people key informants, we also learned that in the last 15 years, the bridges experience thick sedimentation and clogging accompanied by excavations to protect the nearby settlements and cropland from flooding. Previous studies on the Raya graben ephemeral streams and unsystematic observations of specifically dug pits and pits excavated for sand harvesting by local people at bridges (Fig. 4) indicate that the thickness of an individual flood layer deposit ranges from 0·3 to 1·0 m (Figure 4). Two or three consecutive intermediate to high floods are therefore capable to lay down a thick deposit and almost to close the span of a bridge like that depicted in Figure 1. These bridge sediments are yearly excavated before and at the middle of the rainy season.

Figure 3. Bank erosion in upstream reach of Oda River. The flow direction is to the right of the photo.

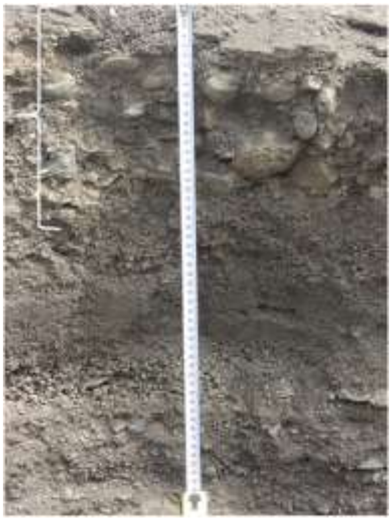

Figure 4. Deposition by an individual flash flood, an example from Hara River.

Channel geomorphology

The main geomorphic characteristics and the median grain size of the reaches upstream of the study bridges were measured in the field, and the main data are reported in Table 1. The mean width of the channel upstream of the bridge is almost double the average bridge span. For all the bridges, the average W_b/W_c ratio is 0·53. That is, the upstream channel has its width almost halved as it approaches the bridge.

The stream-bed gradient at the bridges (mean values 1.65%) is commonly steeper than in the upstream channel (mean value 1.24%) (Table 1).

Bed material is mainly sand and, subordinately, gravelly sand. The coarsest sediment is found in the Etu River where the upstream channel median grain size (D_{50c}) is 4·31 mm, whereas at the bridge (D_{50b}), it is 5·38 mm. The finer river reach is Gobu north with 0·34 and 0·37mm, upstream and at the bridge, respectively. Similarly to stream-bed gradient, average D_{50} at bridges is by 20% larger than in the upstream channel, and in only four rivers, D_{50c} is coarser than D_{50b}, namely Boyru, Agagatulo, Burqa, and Lalatera; it is worth noticing that three of these rivers (Boyru, Burqa, and Lalatera) have bridge spans larger than the upstream channel width.

Table 1. Main characteristics of the reaches upstream of the study river bridges

B_n	River (bridges)	A (km^2)	W_c (m)	W_b (m)	S_c (%)	S_b (%)	D_{50c} (mm)	D_{50b} (mm)
1	Gobu north	274	22.4	4.03	0.25	0.46	0.34	0.37
2	Gobu N of Waja	274	183.5	82.48	0.46	1.05	0.31	0.88
3	Gobu at Waja	274	72.8	58.57	0.78	0.8	0.46	0.48
4	Gobu south	274	54.0	27.28	0.18	0.69	0.55	0.55
5	Harosha north	138	72.5	35.29	1.07	0.78	0.57	0.99
6	Harosha south	138	142.6	29.84	0.26	1.23	0.65	0.74
7	Haya	82	42.6	28.98	0.48	0.74	0.85	2.30
8	Diqala	72	60.7	23.38	1.24	1.56	0.71	-
9	Boyru	69	10.6	17.70	0.82	0.72	2.18	0.76
10	Agagatulo	69	4.3	2.25	3.31	4.91	3.10	2.65
11	Beri Teklay	69	3.5	2.53	3.53	5	2.62	2.60
12	Dwealga	58	37.1	16.50	1.02	0.45	1.68	3.19
13	Burqa	53	14.8	19.40	0.70	1.18	2.46	1.28
14	Tirqe	41	11.6	11.83	1.30	0.37	1.49	1.43
15	Hara	39	96.0	80.00	1.24	1.84	1.74	2.79
16	Etu	34	20.0	19.00	1.36	2.85	4.61	5.38
17	Oda	68	83.2	23.11	1.17	0.53	0.51	0.54
18	Lalatera	20	3.9	6.96	0.96	1.3	1.99	0.97
19	Warsu	12	29.5	23.31	1.58	2.56	1.84	3.60
20	Hada Ayferah	4	5.7	2.50	3.03	4.01	1.33	3.45
	mean	**103**	***48.6***	***25.75***	1.24	1.65	***1.50***	***1.84***

B_n, bridge number; A, catchment area (km^2);W_c, upstream channel width (m); W_b, bridge span (m); S_c, stream-bed gradient of the upstream channel; S_b, stream-bed gradient at the bridge; D_{50c}, bed material median grain size of the upstream channel stream bed (mm); D_{50b}, median grain size of bed material at the bridge (mm).

Hydrogeomorphologic processes and sediment deposition

Figures 5 and 6 show that the original stream-bed gradient and bed material grain size change as the rivers approach the bridge, and the bridge narrowing has some effect on them. Hence, as few researches suggest, it is important to analyze the local hydro-geomorphic processes and their potential impact on river sedimentation.

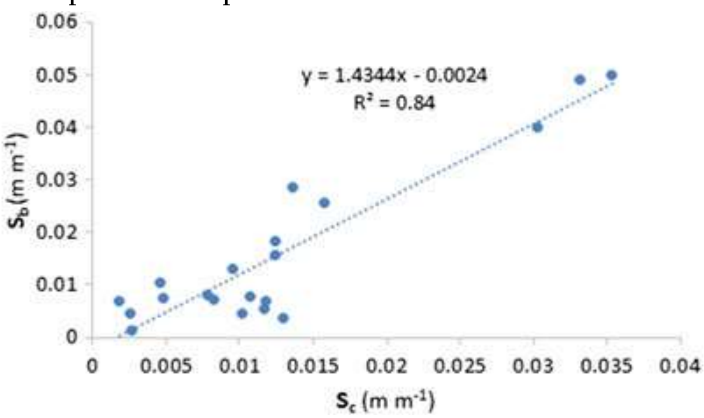

Figure 5. Correlation between the stream-bed gradient in the bridge reaches (S_b) versus that of the upstream channel (S_c)

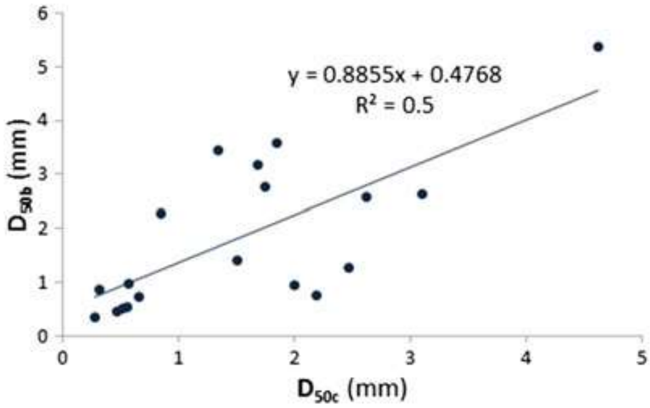

Figure 6. Plot diagram of bed material median grain size in the bridge reaches (D_{50b}) and in the upstream channel (D_{50c}).

Conclusions

- During the last two decades, many of the river bridges of the Raya graben experienced high rates of sedimentation to such an extent that the bridge span was totally obstructed
- The Raya graben ephemeral streams are very wide, in a few cases as much as 300 m, upstream of the road bridges that, by contrast, are very narrow, typically 50% narrower than the upstream channel.
- A simple hydraulic analysis demonstrates that the abrupt change in channel width as the river approaches the bridge is the main cause of the thick deposition.
- Hence, it is recommended that the width of the bridges should be at least as wide as the upstream channel reaches.
- For example, in the case of the town of Waja, instead of moving the town, making wider bridges at a lower financial and social cost is recommended.

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Chapter 12: Temporal meandering rivers in the Raya graben bottom

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Introduction

Rivers draining arid and semi-arid floodplains have extremely variable flows in timing, duration and extent. Their morphology is very sensitive to land use and land cover changes and changes in flood discharges and sediment fluxes, and rapid morphologic changes may occur over a few years. Common morphologic changes are stream narrowing or widening due to alternations in discharge and sediment load. River pattern changes are also common. The Raya Graben is a marginal graben of the Ethiopian Rift Valley located in North Ethiopia (12°–13°N and 39·5°–39·8°E). The purpose of this study was to investigate the impacts of biophysical factors in the headwater catchments on the morphology of rivers in the graben bottom (Fig. 1) over the period between 1986 and 2010.

Figure 1. Flat-bedded river channel. Upslope view of Hara river towards the escarpments (upper catchment).

Methodology

In this study, 20 representative catchments on the escarpment were selected to analyse the relationship between the morphology (length and area) of the ephemeral rivers in the graben bottom and the biophysical controls in upper catchments (vegetation cover, extremely degraded land, catchment area, compactness, and slope gradient in both the steep upper catchments and the gentle graben bottom). Landsat imageries (captured in 1986, 2000, 2005, 2010) were used to calculate the normalized difference vegetation index (NDVI), and to map vegetation cover and the total length of the rivers (Fig., 2). Spot imagery available from Google Earth was used to quantify the total area of the rivers in 2005. In total, 664 (out of which 342 for first-order, 277 for second-order and 45 for third-order reach) sample width measurements were taken in 20 rivers.

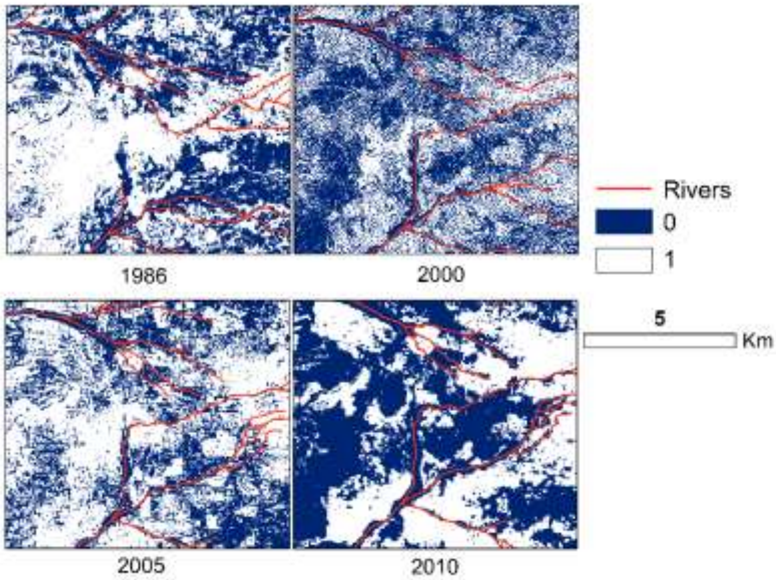

Figure 2. Classification of NDVI values from 1986 to 2010 (shown for part of the study area as example) based on the average NDVI. Pixels with an NDVI below the year's average NDVI are classified as 0, and pixels above the average NDVI are classified as 1

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Length of rivers in graben bottom and biophysical controls

In order to examine the relationship between length of rivers in graben bottom and biophysical factors, multiple regression analysis was performed with six variables (area, compactness, gradient, vegetation cover and extremely degraded land of upper catchments, and gradient of graben bottom). In the multiple regression model, only the area of the upper catchments was significantly correlated to length of rivers in the graben bottom. The positive regression weight indicates that larger catchments have longer river lengths in the graben bottom (Fig. 3 and 4).

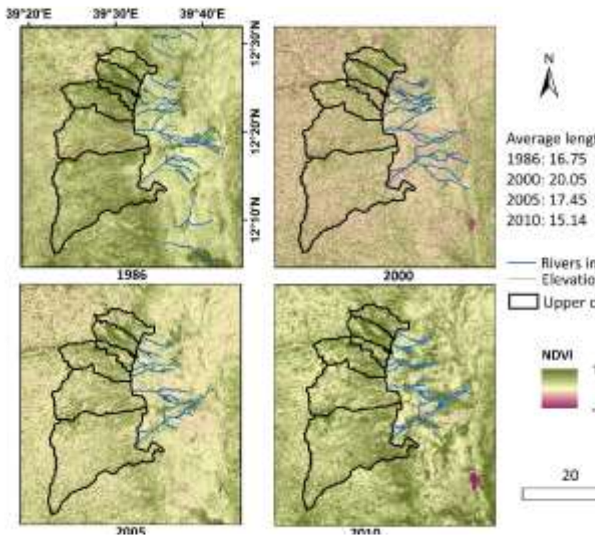

Figure 3. Map of the length of the rivers in the graben bottom for a few catchments in the Raya Graben.

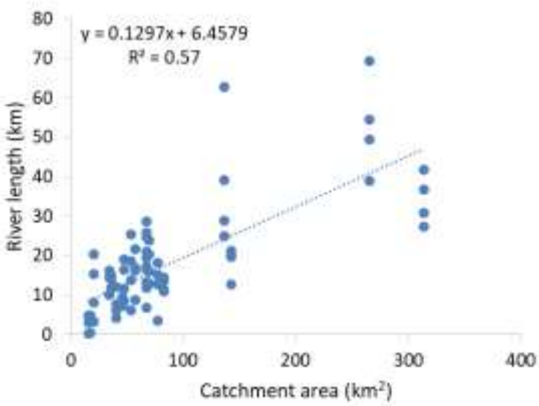

Figure 4. Correlation between upper catchment area and river length in the graben bottom

Area occupied by rivers and biophysical factors

The relationship between area occupied by the rivers in the graben bottom (Fig. 5) on the one hand and various predictor variables (average NDVI, area, compactness, gradient and extremely degraded land of upper catchments, and gradient of graben bottom) was analysed using multiple regression. In the regression analysis, area of upper catchments was significantly correlated; larger catchments have larger area occupied by the rivers in the graben bottom (Fig. 6).

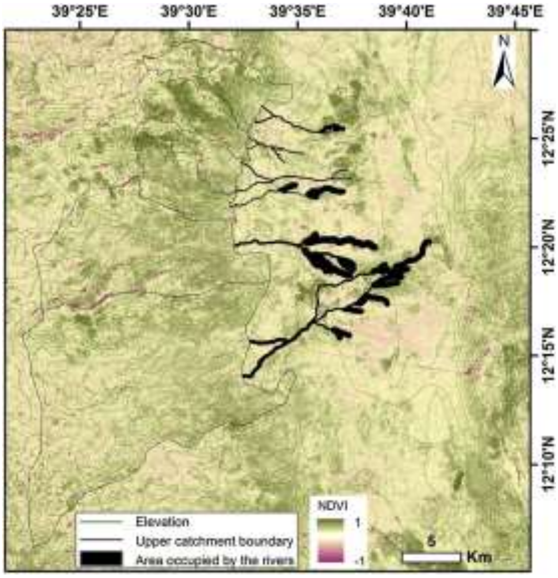

Figure 5. Map of the area occupied by the ephemeral rivers in the graben bottom for a few catchments in the Raya graben,

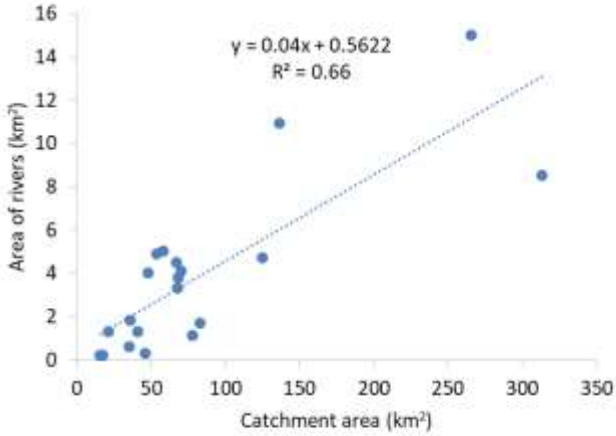

Figure 6. Correlation between upper catchment area and area occupied by the rivers in the graben bottom.

Vegetation cover change

Vegetation cover in the whole upper catchments of the study area was analysed using NDVI for the period between 1972 and 2010. The changes show that there is large increase of vegetation cover from 2000 to 2005, also witnessed by the uniform recently regenerated tree stands (Fig. 7A). For the rest of the years, the rate of increases is very low. The decreases in vegetation cover are large for the periods from 1986 to 2000 and 2005 to 2010, which may be related to Eucalyptus tree cutting (Fig. 7B). Overall, vegetation cover has shown an increasing trend from1986 to 2010 (Fig. 7).

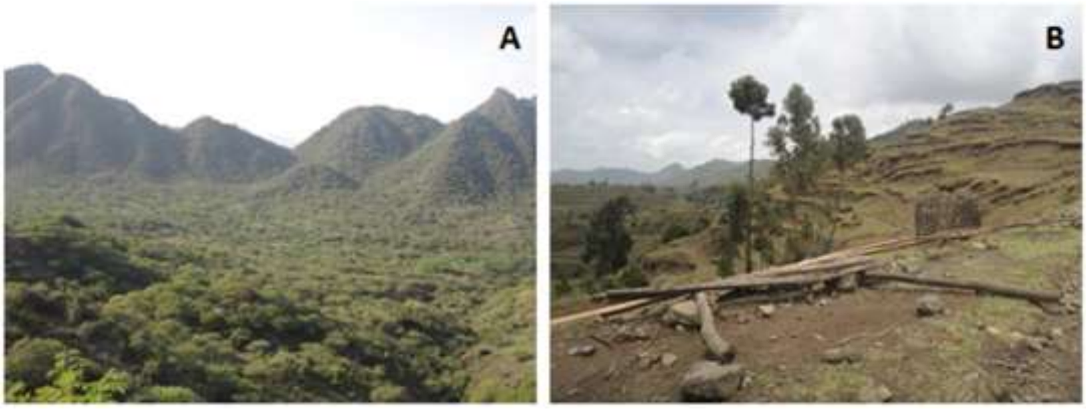

Figure 7. Vegetation cover changes in the upper catchments. (A) Regeneration of woody vegetation cover as indicated by the uniform stands and (B) cutting of eucalyptus trees.

Relation between vegetation cover and length of rivers

The average NDVI in the upper catchment indicates an increasing trend. A reverse trend is also shown in the length of rivers in the graben bottom (Fig. 8). Even though there is no significant relationship between NDVI and length of rivers, in recent years, the proportion of farmland in the escarpment showed a trend (41% in 2000 and 34% in 2005) parallel to the length of the rivers in which higher proportion of farmland in the escarpment tend to cause longer rivers in the graben bottom. The increase in the length of rivers with increase in vegetation cover in the period 1986 – 2000 and the reversal in river length after 2000 seems to be also related to lag time.

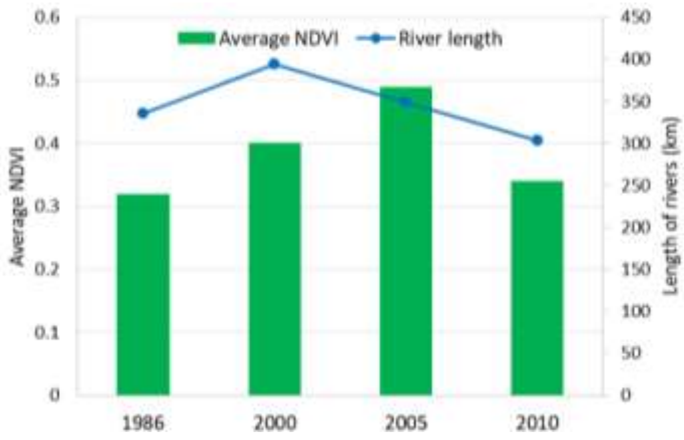

Figure 8. Evolution of the average length of rivers per catchment in the graben bottom and average NDVI of upper catchments.

Conclusions

- Catchment area determines 57% of the variance of the length of rivers and about 66% of the variance of the areas occupied by the rivers in the Raya graben bottom.
- Vegetation cover in upper catchments is also an important controlling factor
- Measures geared towards reducing the impacts of river dynamics on agricultural activities and thereby the livelihood of the society in dryland areas with ephemeral rivers needs to focus on rehabilitation activities (soil and water conservation) in both the river reaches and upper catchments.

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Chapter 13: The water of the Aba'ala graben

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Introduction

Balancing water for humans and nature remains a critical challenge of our time. The imbalance of water availability and agricultural requirement poses a serious threat to the grabens that are targeted for agricultural development. The hydrological processes of the grabens need to be understood to improve agricultural development. With this knowledge gap in mind, we investigated the water balance of the Aba'ala graben under the challenge of data scarcity.

Method and materials

The study area (553 km²; Figure 1) is part of the escarpment between the Danakil depression of the Rift Valley and the Ethiopian plateau. The escarpment is the main water recharge zone whereas the graben bottom is a flat area that receives sediments and water (Figure 2).

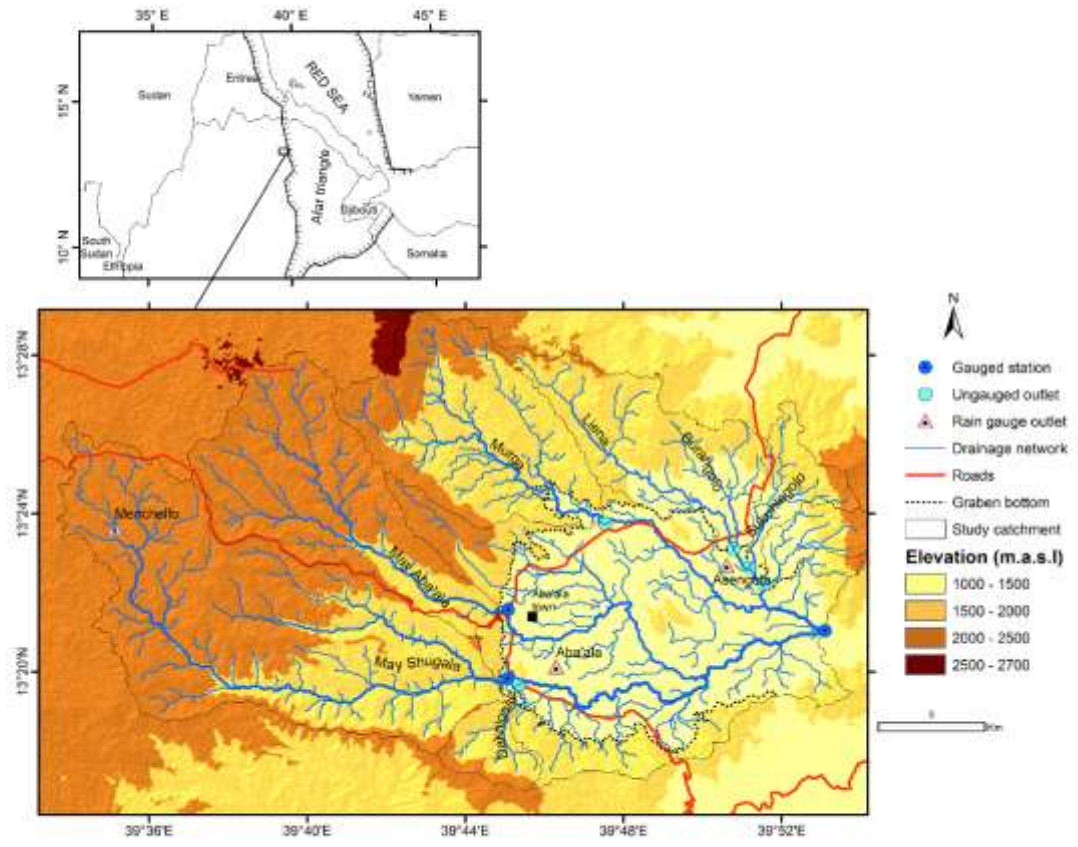

Figure 1: Location of Aba'ala graben and its catchment in northern Ethiopia.

We established rain gauges, pressure transducers, and staff gauges to analyze the runoff components of the Aba'ala graben (2015-2016). Moreover, weather data were obtained from the National Meteorological Service Agency. A conceptual block diagram of the graben assisted in analyzing the water balance components in the graben (Figure 2).

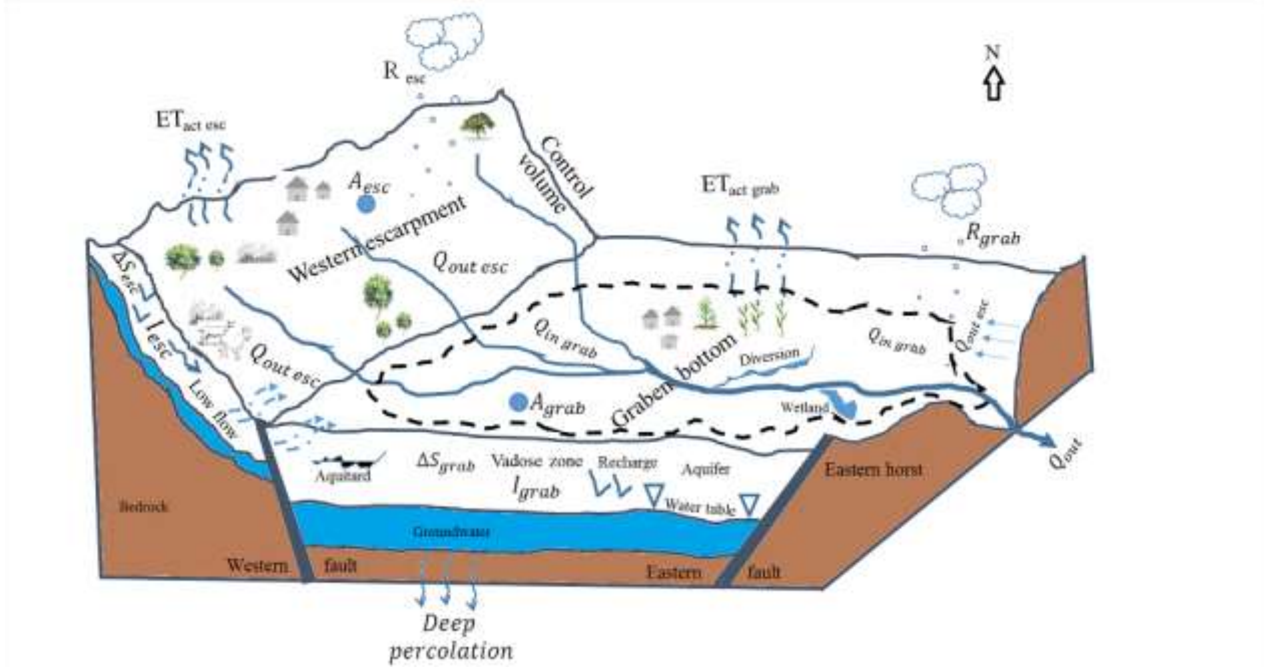

Figure 2: Block diagram of Aba'ala graben and its water balance components.

Water balance components

Daily rainfall depths and rain events showed a marked variation between the escarpment and the plain (Figure 3), where better rainfall depth was found on the escarpment.

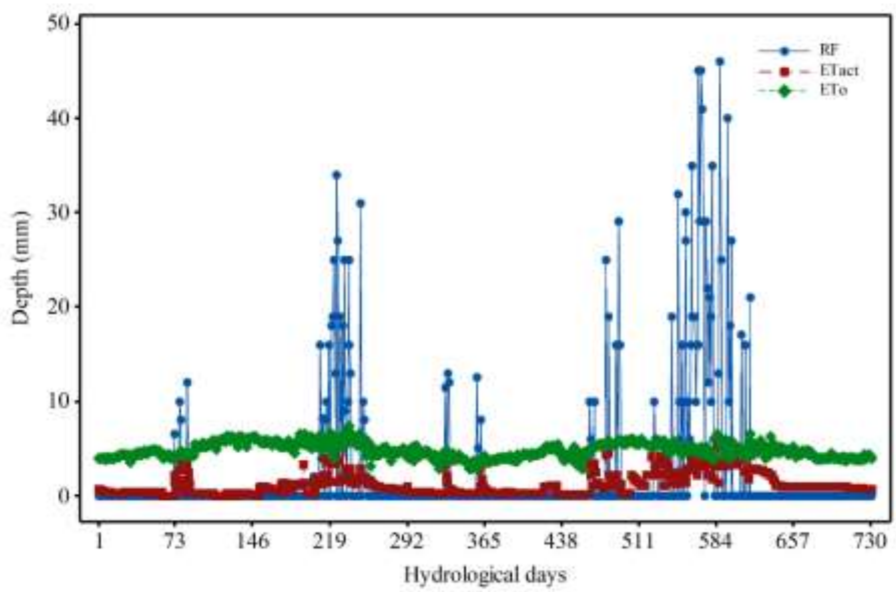

Figure 3: Daily distribution of average RF (rainfall), ETact (actual evapotranspiration) and ET_o (reference evapotranspiration) 2015-2016 in Aba'ala graben.

We explicitly reported that rainfall depths in 2016 were nearly three times the received amount in 2015 owing to La Niña/El Niño. Moreover, the rainfall volume in the Aba'ala graben has an erratic behavior, and led to a rapid flood runoff (up to 666 m^3 per second) of the major river into the graben bottom (Table 1). Similar to the magnitude of rainfall, the flood discharges of the storms in 2016 were 4.4 times larger than those in 2015. Furthermore, a much larger percentage of the inflow left the Aba'ala graben. For example, large discharge volumes (25.2 million m^3) left the graben bottom via Megulel outlet during the rainy season (Figure 4).

Table 1: Compilation of maximum and minimum event discharges in Aba'ala graben

Discharge	**May Shugala**		**May Aba'ala**		**Megulel**	
(Q, m^3 per sec)	**2015**	**2016**	**2015**	**2016**	**2015**	**2016**
Low Q	0.16	1.24	2.5	1.96	0.9	4.62
Peak Q	98.05	178.5	103	282.2	149.25	666
RD (mm)	0.52±0.1	2.72±0.86	0.84±0.4	1.91±0.4	0.571±0.05	1.41±.01
RC (%)	8.73	6.90	8.74	6.30	6.32	4.86

RD = daily runoff depth; RC = annual runoff coefficients

The actual evapotranspiration (312.6 million m^3) as vertical water balance component affected water availability in the graben system (Figure 2). In most of the year, the amount of available green water in the soil was much lower than the rainfall due to water losses. Thus, the vertical and horizontal water balance components exhibit a large spatio-temporal variability in the graben.

Understanding water storage

The average annual water gains and losses varied in Aba'ala graben (Figure 4). For the first time, the study indicates that about 15% (in 2015) and 36% (in 2016) of the inputs of the water balance was either stored as groundwater or deeply percolated to the lower plain areas. We assume that the graben faults influence the green and blue water storages in the subsurface. In particular, the eastward dipping transversal faults could have facilitated the downward water movement. As the graben is characterized by fractures faults and karstic conduits in the limestone fault, the presence of thick sedimentary rocks could lead to fast water flow into very deep the graben bottom towards the base level in the center of the Danakil depression. In this context, the water table in the graben bottom is deeper than basalt grabens. Hence, the irregularities of rainfall and runoff components affected the water balance in the graben system.

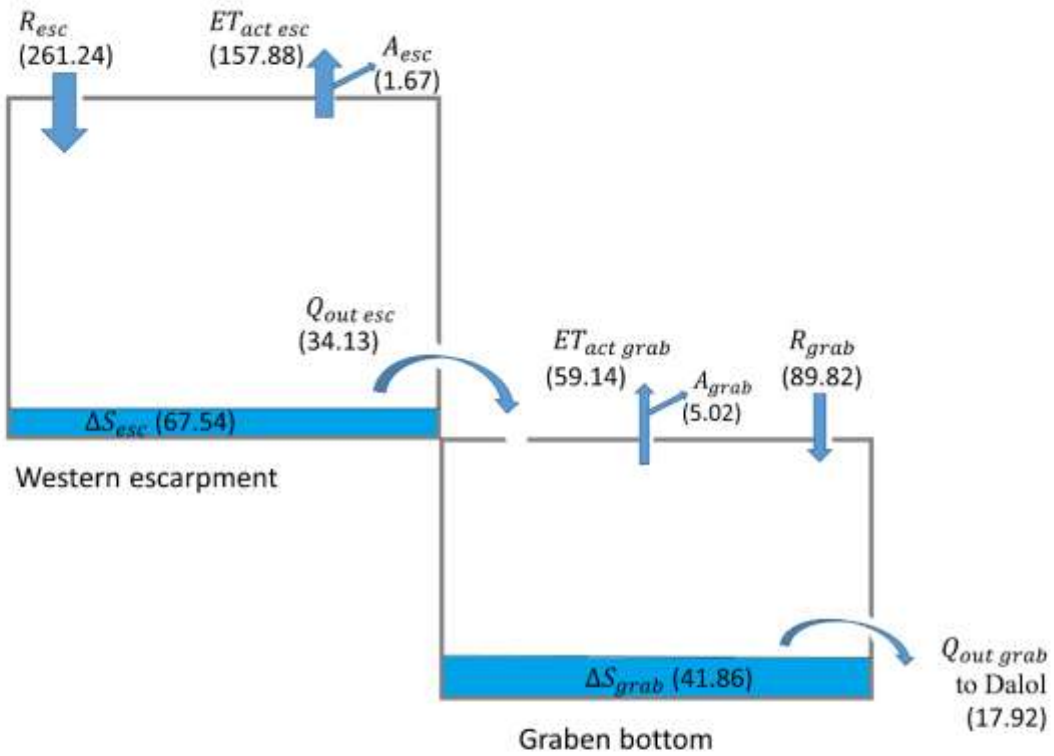

Figure 4: The average annual water balance (volumes in million m^3) of Aba'ala graben in the hydrological years 2015-2016. The thickness of the arrows is proportional to volumes.

Conclusion

The study shows that water inputs and outputs exhibit considerable spatio-temporal variability in the graben. From hydrologic perspective, large quantities of flash floods have been left unutilized while there is 10,052 ha of land suitable for agriculture development. The fast water flows in the limestone fault lines and thick sediment deposits led to deeper groundwater level. With the increasing water security risks, future work should focus on the construction of dams in the gorges to trap water in the Aba'ala graben.

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Chapter 14: Changing landscapes in the Aba'ala graben bottom

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Introduction

Human activities have also been playing a pivotal role in changing the earth surface in general, the natural resources in particular through several land cover, and land use changes. As a result, LULC dynamics have become common indicators of the impact of human activities on the earth surface. Besides, land use and land cover changes, which are caused by several factors have been considered as the indicators of global environmental dynamics. The dynamics of land use and land cover also affects landscape pattern of a given area. We analysed the nature and frequency of LULC changes in the Aba'ala graben bottom between 1984 and 2018 and the impact of LULC changes on landscape structure of Aba'ala graben.

Methodology

We employed Landsat Thematic Mapper (TM) of the years 1984, Enhanced Thematic Mapper Plus (ETM+) of 2001 and the Landsat Operational Land Imager of 2018 to analyze land use and land cover dynamics of the Aba'ala graben bottom. Landscape metrics at class and landscape level were used to examine the impact of land use and land cover changes on landscape structures in the Aba'ala graben. In doing so, we analyzed the persistence (unchanged or stable areas) of the LULC types.

Land use and land cover of Aba'ala graben bottom from 1984 to 2018

In 1984, shrubland covered the largest area (51%) of the total study area (Table 1). Bare land accounted for 27% as the second of the total area of the graben. Farmland accounted for 18% whereas settlement has the lowest areal fraction (3%) in 1984. Similar to 1984, shrubland was the dominant (54%) land cover in 2001 in the Aba'ala graben. In 2001, the coverage of farmland, settlement and bare land was 22%, 5% and 19%, respectively. This indicates that about 76% of the total area of the graben was covered by shrubland and farmland. The remaining 24% of the area of the graben was covered by bare land and settlement.

Land use and land cover change from 1984 to 2001

The findings of the change detection of 1984 and 2001 show that farmland increased by 6.7 km^2 due to high conversion of bare land to this class, which resulted in the decrease of bare land. Shrubland also increased due to the conversion of bare land and farmland to this class. From the total area of bare land in 2001, 18 km^2 was persistent. All the other areas changed into farmland (17.6 km^2), settlement (2.8 km^2) and shrubland (10.9 km^2). The total amount of persistence area of farmland in 2001 was 10.9 km^2. However, settlement showed an increment by 3 km^2 from 1984 to 2001.

Land use and land cover change between 2001 and 2018

The total amount of persistence of bare land 2001 to 2018 was 19 km^2. However, 11 km^2 of bare land was converted into farmland, 3.5 km^2 into settlement and 2 km^2 into shrubland. Similarly, while 17 km^2 of farmland was counted as persistence, the other areas were changed into bare land (13 km^2), settlement (5 km^2) and shrubland (4 km^2). Generally, from 2001 to 2018, shrubland showed a strong decrease (27 km^2).

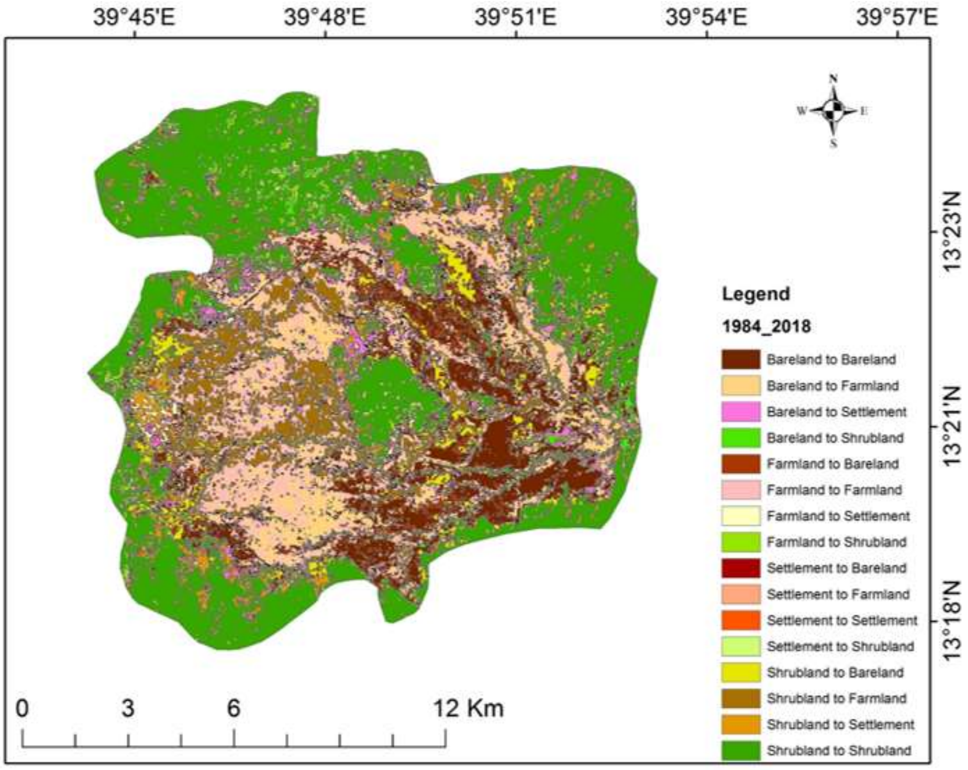

Figure 1. LULC change map from 1984 to 2018

Mid-term land use and land cover change (from 1984 to 2018)

In 2018, 20 km^2 of the total area of bare land remained unchanged. But, the other areas are changed to farmland (20 km^2), settlement (5 km^2) and shrubland (3 km^2). From the total of area of farmland in 2018, 14 km^2 was stable, while 19 km^2 was converted to bare land (9 km^2), settlement (5 km^2) and shrubland (6 km^2). Talking on the same year, 1.3 km^2 of settlement remained unchanged while the remaining areas were changed into bare land (1.6 km^2), farmland (1.2 km^2) and shrubland (1.8 km^2). From the total area of shrubland in 2018, 60 km^2 remained unchanged while 10 km^2, 12.5 km^2 and 11 km^2 of land were changed to bare land, farmland and settlement, respectively. Generally, shrubland has decreased by 22 km^2 between 1984 and 2018. Similarly, bare land has decreased by 9 km^2 between 1984 and 2018. Conversely, farmland has increased between 1984 and 2018 due to the conversion of lare areas of shrubland and bare land (Figure 1, Figure 2).

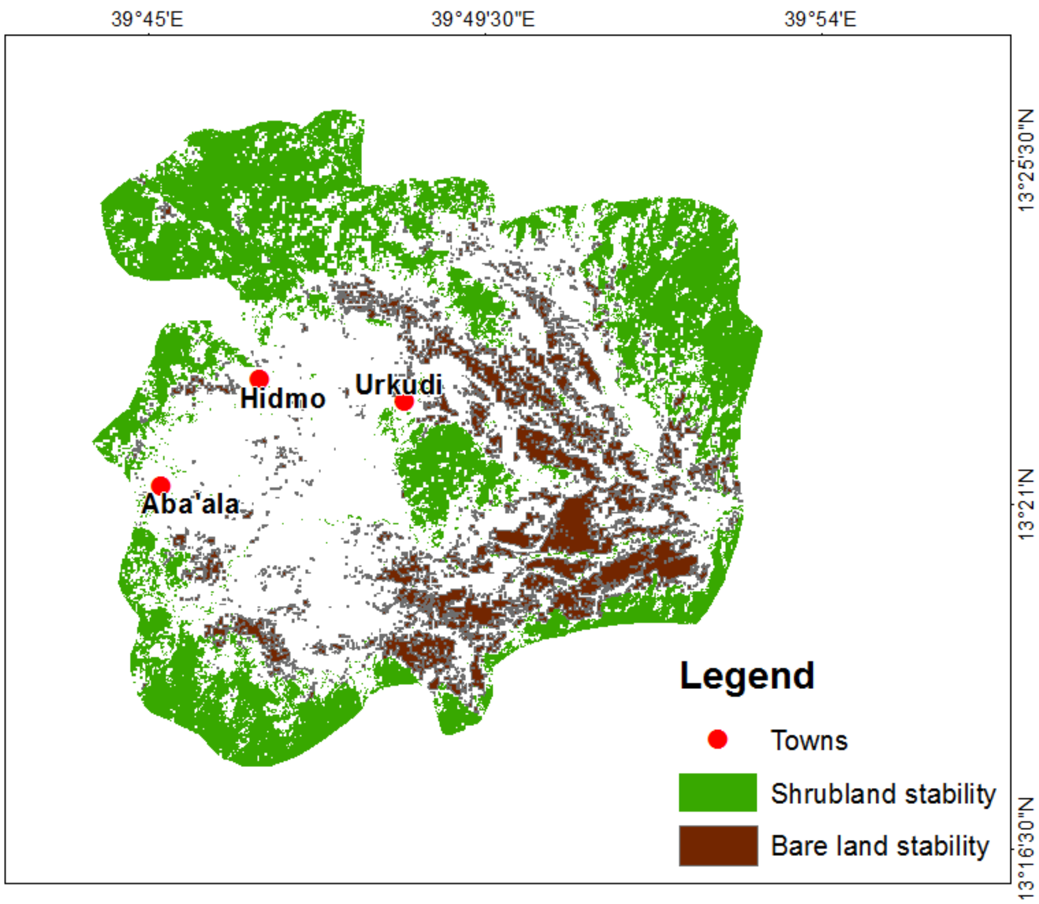

Figure 2. The trend of shrubland and bare land

Land use and land cover change and landscape structure dynamics

At class level

The analysis of the landscape structure dynamics shows that the Number of patches (NP) of shrubland, settlement and farmland increased continuously from the year 1984 to 2018, which indicates the increase of fragmentation of the landscape in Aba'ala graben. Similarly, the Interspersion and Juxtaposition index (IJI) of shrubland, settlement and farmland has been continuously decreased throughout the study period (1984-2018). Less or decreasing trend of IJI of LULC types implies that the patch distribution of settlement, shrubland and farmland is uneven.

Table 1. Results of class metrics at class level within the graben landscape

Year	Calculated metrics		
	LULC type	**NP (numbers)**	**IJI (%)**
1984	Bare land	459	71.3
	Farmland	1622	82.7
	Settlement	957	93.5
	Shrubland	340	86.4
2001	Bare land	2344	61
	Farmland	2187	73
	Settlement	2314	74.4
	Shrubland	794	76.1
2018	Bare land	1640	75.8
	Farmland	1089	67.6
	Settlement	3262	76.4
	Shrubland	1108	67.4

NP = Number of patches; IJI= interspersion and juxtaposition index

At landscape level

The total area of landscape of the study area is accounted for 181 km². In this landscape, the number of patch (NP) increased from 3378 in 1984 to 7653 in 2001; and decreased from 7653 in 2001 to 7113 in 2018. This shows that the landscape was highly fragmented from 1984 to 2001. However, the fragmentation slightly showed a decrement from 2001 to 2018. Similarly, patch density (PD) also increased from 18.7 in 1984 to 42 in 2001; and decreased from 42 in 2001 to 39 in 2018. These results indicate that there is high fragmentation of landscape within the study area. Overall, landscape fragmentation was greater in 2001 and lower in 2018 (Table 1). Moreover, the increase of the number of patches and patch density between 1984 and 2018 in the Aba'ala graben is an indicator of the decrease of landscape homogeneity.

Conclusions

The results of the study also depict that the area coverage of shrubland and bare land in Aba'ala graben has decreased from 51% and 27% in 1984 to 39% and 22% in 2018. Conversely, the study also found that the area coverage of settlement dramatically increased from 3.3% in 1984 to 12% in 2018. The study also found that farmland was the most dynamic land use and land cover type, which experienced high exchange of coverage areas. This study documented a dramatic land use and land cover change trajectories between 1984 and 2018, which are associated with the rapidly growing population and transformation of the communities in the Aba'ala graben.

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Chapter 15: Conflicts for water and grazing land in the Kalla graben

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Introduction

Transhumance, defined as the seasonal movement of livestock between two places in the search for water and forage, has been a common farming system in several parts of the world. Transhumance between the Afar lowlands and Tigray escarpments has also been a common practice in northern Ethiopia. Transhumance is a livelihood strategy for many pastoralists and agro-pastoralists in several parts of the world. However, transhumance is associated with several problems, such as conflicts, which ultimately exert pressure on the landscape. We examined the process of transhumance and the linkages between the social and biophysical aspects of the landscapes in the grabens of northern Ethiopia.

Methodology

The study was carried out in the Kalla graben and its environs. Google Earth (2010-2016) and Landsat Imageries (1995-2015) were used to analyse the spatio-temporal landscape changes. Normalized Difference Vegetation Index (NDVI) was applied to measure the change in vegetation cover. Interview and Focus Group Discussions were used to collect the perception of communities on landscape change.

Transhumance in the study areas

Transhumance has been practiced between Kalla graben and the escarpments of Wejerat due to three reasons: a problem with access to water, pasture, and mental land claim. The Afar pastoralists in the Kalla graben practice transhumance during the dry season both to the Kalla graben rangelands and to the Tigray escarpments to access pasture, which belongs to the Gonka and Seneale villages (Figure 1). The Afar pastoralists go to the Tigray highlands during the dry season because of the erratic rainfall in the graben.

Transhumance, conflict and displacements

Despite its advantage as a livelihood strategy, transhumance has been associated with an occurrence of conflicts between communities. The conflicts are associated with mental territorial claims of both communities. The absence of clearly demarcated boundaries within the country in general and in the study area, in particular, has paved the way for various territorial claiming disputes. The key informants underlined that the boundary confusion has been compelling them to look for grazing land aggressively. "*The area that is being used for grazing instead of agriculture belongs to us*" (quote of an elder in Seneale, Wejerat, Tigray). The conflict between the two groups has resulted in loss of human lives and livestock. In addition to the loss of human lives and livestock, the conflict has resulted in the displacement of communities from their hamlet. For instance, the Afar pastoralists (who used to live in Giraed) have been displaced due to the conflict. They currently reside in a small village called Haygolo, located at the foot of an escarpment.

Figure 1. Goats eating and walking to the escarpment for grazing (A), cattle of the highlanders accessing water in the lowland (B), partial views of Kalla graben, transhumance area (C) and Gonka village (D). The photos were taken in 2015.

Transhumance induced displacement and landscape change

The visual time series analysis of the Google Earth Imageries of the study areas revealed that there has been a temporal change in the vegetation cover and settlements due to overgrazing and displacement of communities. This is the case in Giraed. In the period of 2010, the individual homesteads are clearly visible on the aerial image. A low vegetation cover and a low tree density also characterise the area. In 2016, the settlement has been abandoned and the individual homesteads could hardly be identified. In addition, the vegetation cover has increased resulting in a denser pattern of scattered trees and shrubs. The reverse situation is seen in Haygolo (Figure 2).

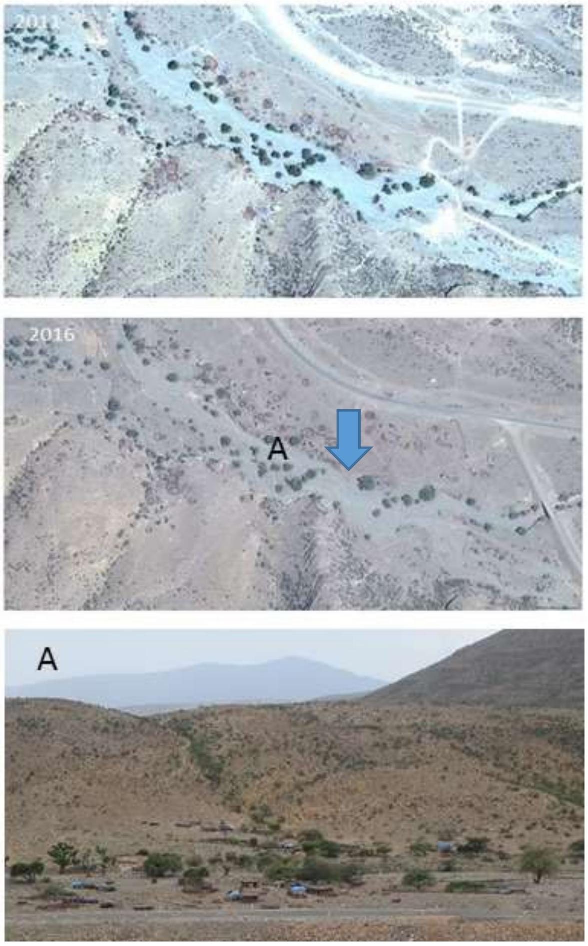

Figure 2. Temporal changes of the settlements and vegetation cover in Haygolo, Kalla Graben, as an example of a resettlement. The number of homesteads increased between 2011 and 2016 and the vegetation cover became less dense. (Source: Google Earth). The photo at the bottom (A) shows development of settlements in Haygolo in 2016.

Conclusion

The study has demonstrated that transhumance has resulted in conflicts between the pastoralists and agro-pastoralists, which in turn has brought about the displacement of communities. The study has also shown that the transhumance induced-displacements of communities have caused an increase in the vegetation cover of the abandoned village. However, the vegetation cover of the resettled village has mainly decreased by the cutting of trees for house construction and overgrazing for the newly displaced communities.

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Chapter 16: The waters of the Raya graben

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Introduction

Marginal grabens are productive agricultural areas. However, matching agricultural water demand and supply in these grabens is a critical policy challenge. Graben farming systems hasve suffered from meteorological and hydrological droughts. As a result, agricultural production is low during these drought years. Hence, we investigated the water balance (Figure 1) in the Raya (3507 km^2) and the Ashenge (81 km^2) basalt grabens to achieve reliable agricultural development (Figure 2).

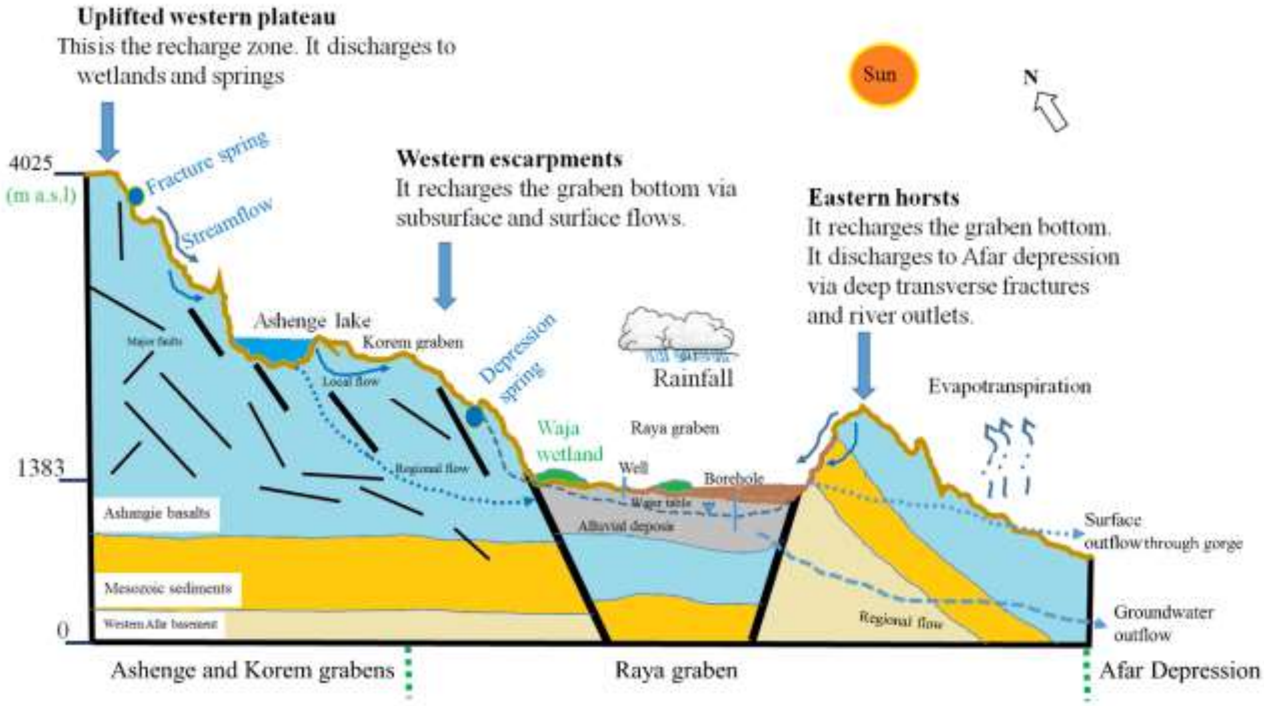

Figure 1: Conceptual topographic model depicting the water fluxes in the grabens.

Methods and materials

The study area (Figure 2) is located at the western escarpment of northern Ethiopia. Topographic, land cover, rainfall, river flow, water withdrawal, and evapotranspiration parameters were collected (2015-2017) to address the study objective. We developed a conceptual topographic model to understand the water fluxes in the marginal grabens (Figure 1).

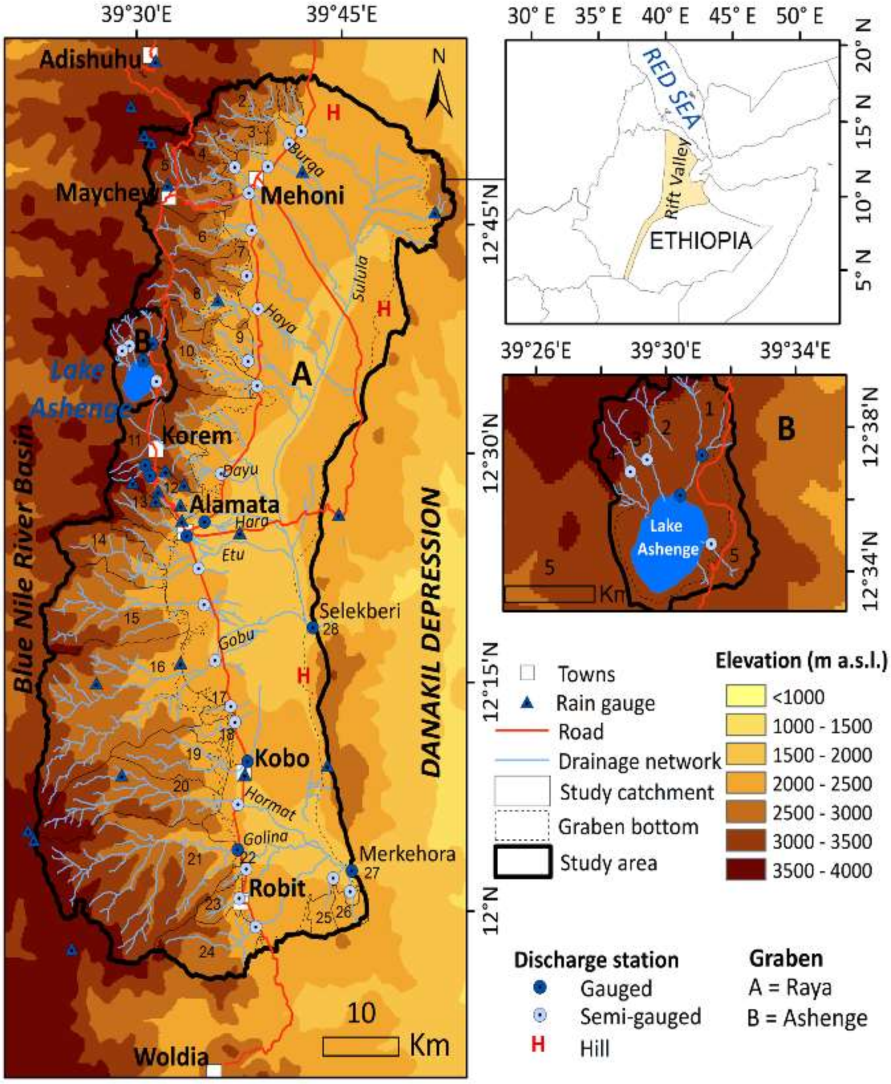

Figure 2: Study area locations: A) Raya graben and B) Ashenge graben.

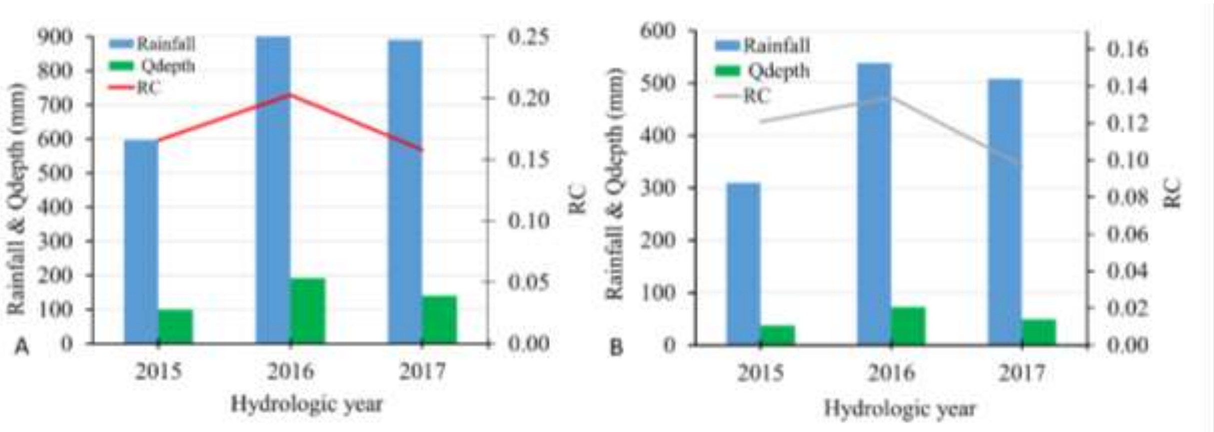

Figure 3: Comparison of the rainfall, runoff depth and (runoff) coefficient (RC) between the graben escarpment (A) and the bottom (B).

Water budget components

Rainfall depths showed temporal variations in the grabens (Figure 3). The rainfall depth of 2016 (746 mm) was higher than what was received in 2015 (454 mm). The study also showed that the annual rainfall depths of the western escarpment (806 mm) was higher than the graben bottom (508 mm). In addition, the rainfall quantities were higher towards the southern direction. Rainstorms at the western escarpments produce floods up to 732 m³ per second (Figure 4). Also, 24% of the water entering the graben bottoms comes from the runoff from the adjacent slopes. Up to 40% of these runoff discharges reaching the Raya graben bottom flushed out at its outlets. Approximately 80% of the annual rainfall of the graben bottom returned to the atmosphere via actual evapotranspiration. Generally, the studied graben bottoms experienced a period with inadequate surface water resources.

Figure 4: Illustration of some flash flood events: A) Golina River (13/8/2017), B) Merkehora outlet (14/8/2017) and C) Ashenge inlet (20/8/2017).

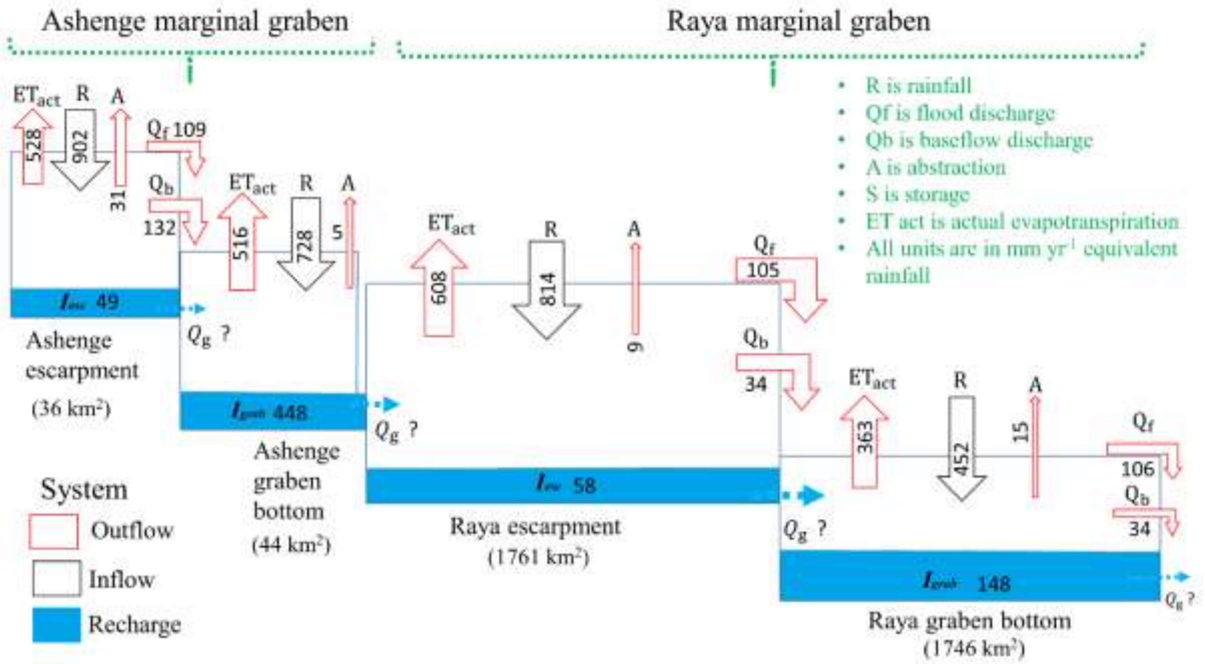

Figure 5: Water balance components in the basalt grabens.

Annual groundwater recharges

Figure 5 portrays the water balance components in the basalt grabens. In the Raya graben, the mean annual recharge of the graben escarpment and bottom amounted to 7% and 25% of their annual inflows, respectively. Besides, the average annual water recharge of Raya graben bottom was 258 million m^3 per year. As a response to the aquifer properties, the groundwater is shallower than Aba'ala limestone graben. It is reported that the groundwater potential of Raya graben bottom is about 9791 million m^3. With this terrestrial water storage, graben bottom is overlooked for irrigation development. Therefore, basalt aquifers the capacity to store large volumes of water that could be sustainably used to improve the food security of the graben farmers.

Conclusions

The rainfall depth variations in the grabens governed the spatiotemporal magnitude of flash floods, baseflows and actual evapotranspiration. The study highlights that the annual groundwater recharge of the graben bottoms larger than the escarpments. The groundwater stored is largely underutilized in the graben bottom. As food insecurity is related to water shortage, increasing water availability to the graben farmers is indispensable in eradicating food insecurity from the grabens.

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Chapter 17: Land cover in relation to stream dynamics in the Raya graben

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Introduction

Land cover change remains a priority research need as it translates various aspects of human activities and earth surface processes, for example, reflecting increasing or decreasing cropland size. Rivers are important elements of a landscape and they modify land at various scales. The purpose of this study was to investigate the link between stream distributary systems and land cover changes in a graben bottom of a dryland area for the last five decades. The study focuses on the changes that happen in land use/cover in the graben bottom due to the dynamics in the distributary system of a river and the implication to land management and livelihood (Fig. 1).

Figure 1. Land cover changes along a river distributary system: at left, farmlands taken by the river and turned into alluvial deposits (the farmer ploughs and struggles to recover it); at right, vegetation regeneration on ancient alluvial deposits.

Methodology

The study site, Warsu catchment (12°11′–12°13′N and 39°33′–39°38′E) is found in the Kobo basin, in the Raya graben along the Ethiopian Rift Valley margin. Aerial photographs of 1965 and 1986 with an approximate scale of 1:50,000 were collected from the Ethiopian Mapping Authority. SPOT satellite images of 2007 and 2014 with spatial resolution of 2.5 m were consulted on Google Earth. Moreover, two 1:50,000 topographical maps of the study area (Alamata and Kobo) were used. To extract features, subsequent screen digitizing of user-defined land units was performed on the aerial photographs and the satellite images in ArcGIS. To analyze land cover changes over time, post-classification comparison change detection technique was used.

Land unit distribution

The distribution of land-unit types over the last five decades (Fig. 2) shows that within the given influence areas of the distributary system of the Warsu River, farmland had the highest proportion for all study periods (84% in 1965, 78% in 1986, 76% in 2007, and 81% in 2014).

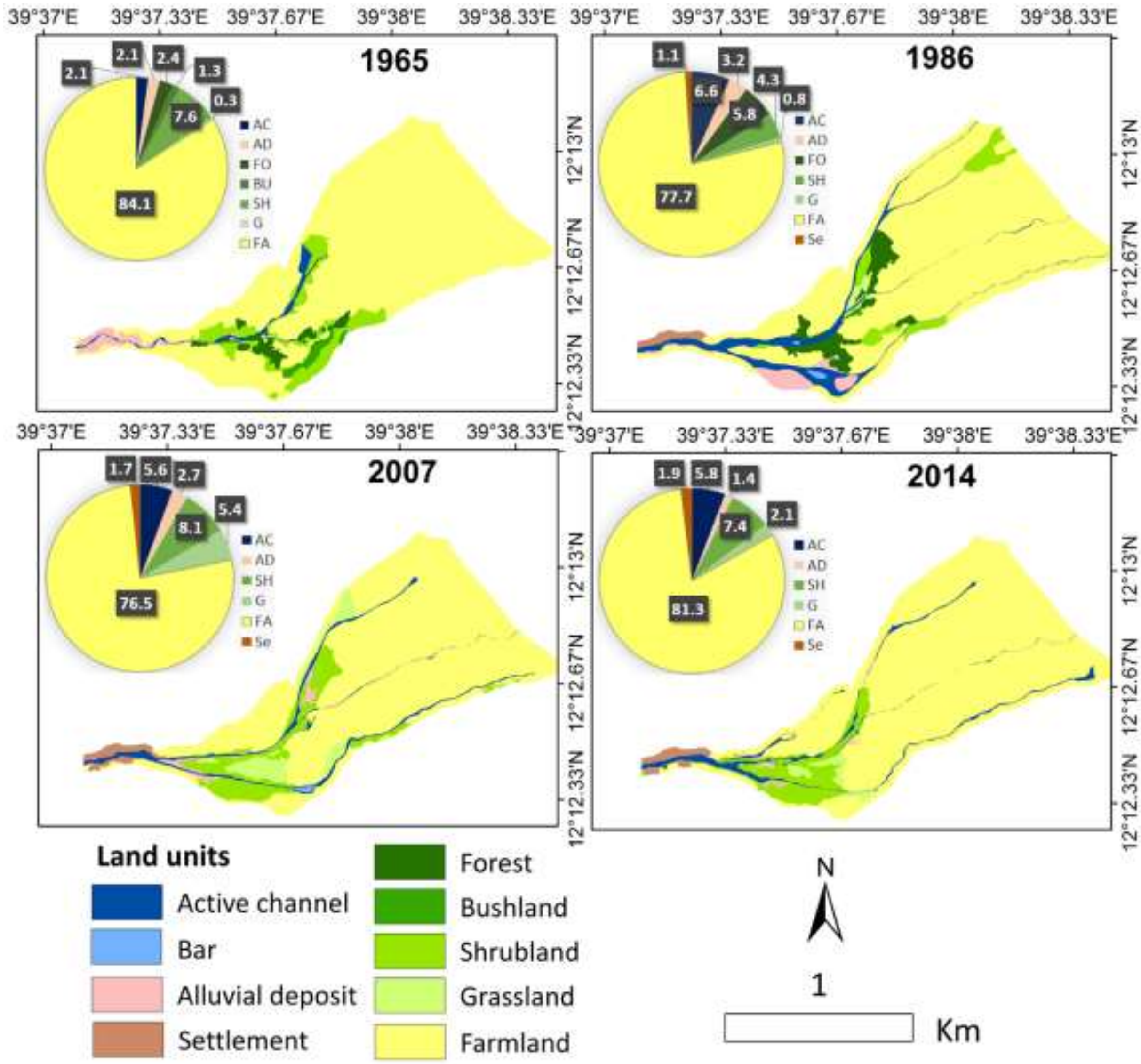

Figure 2. Landscape map of the Warsu River in 1965, 1986, 2007, and 2014. Active channel (AC), Farmland (FA). Alluvial deposit (AD), Shrubland (SH), Settlement (Se), Grassland (G), Forest (FO), Bushland (BU).

Land unit transitions

Over the last five decades (1965–2014) (Fig. 3), both shrubland and farmland have experienced losses of 6.6 and 9.9%, and gains of 7.2 and 8.7% of the entire landscape, respectively. Remarkably, shrublands in 1965 were systematically replaced by farmlands by 2014, following transitions from alluvial deposits to settlement and active channel.

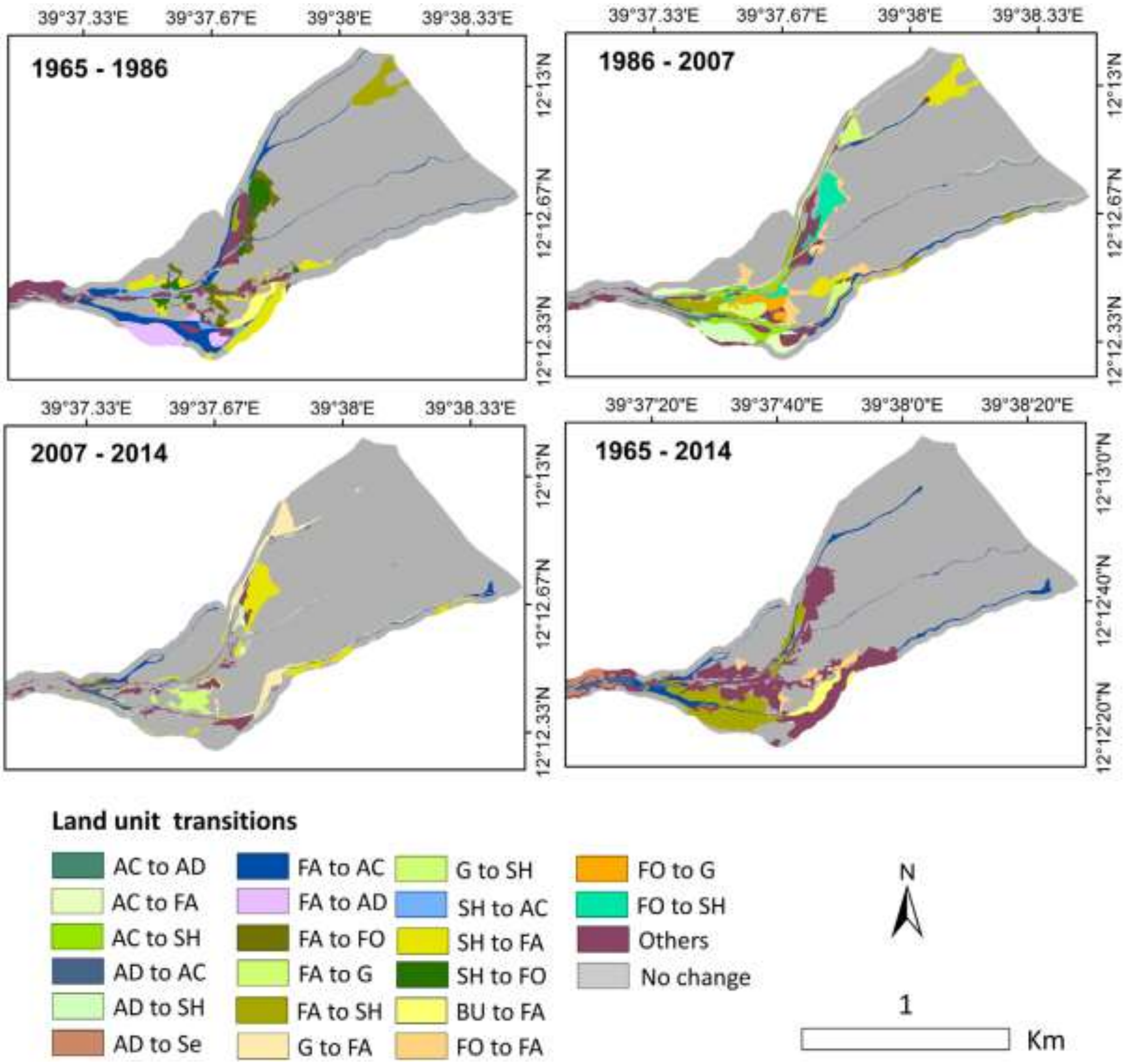

Figure 3. A trajectory of the major land-unit changes in three successive transformation periods. Acronyms in in Fig. 2

Cyclic transition

This study confirms that farmlands inundated by the river in earlier periods (1965–2007) and converted to shrubland and grassland were later transformed to farmland in the period between 2007 and 2014. These transitions have a cyclic pattern; i.e. after time, the land reverts to the original land use (Fig. 4). While the period between 1965 and 1986 was a period of river distributary system expansion, the period between 1986 and 2007 was a period of natural vegetation succession. The period between 2007 and 2014 was a period of reclamation when farmers claimed back farmlands that had been taken and later abandoned by the river distributary system.

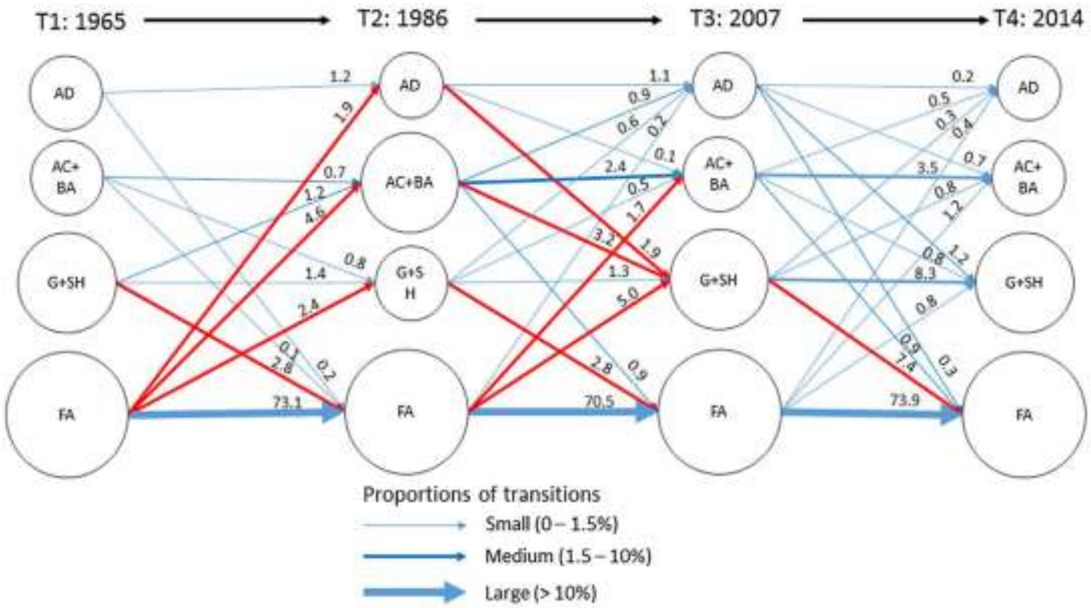

Figure 4. Cyclic major land cover changes (indicated by red arrows) over the last five decades in the Raya graben bottom. Circles are proportional to the size of the land units in the landscape (averaged), whereas thickness of the arrows indicates the magnitude of transition/persistence among land units from one time step to the next. Acronyms as in Fig. 2.

Implication to livelihood and land management

Overall, it is conceptualized that the expansion of rivers, particularly toward farmlands, adversely affects the livelihood of the farmer households by reducing the size of cultivable plots and destroying crops, and settlements (Figure 5). Hence, an increase in management interventions that keep the natural processes of the river distributary systems and improving river water use in the graben bottom could ensure a better livelihood in the study area.

Figure 5. Land management practices in the graben bottom related to rivers: (A) traditional land management practices; (B) gabion structures for protection from flooding; (C) gabion dykes to protect Waja town; and (D) the Gubena village, covered with metres-thick sediment of Gobu River. Note the roof of a house emerging above the sediment; the people moved to the new house behind it.

Conclusions

- A cyclic land transition pattern is clearly observed in the graben bottom due to mainly dynamics of river distributary system.
- Land cover changes are not only related to a distributary river system but also that human intervention and natural vegetation regeneration are important.
- Land management interventions should consider the behaviour and impact of river systems.
- Allowing rivers to follow their natural bed can make rivers easily manageable

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Chapter 18: Salinity conditions in the Raya graben

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Introduction

Rising salinity is a severe problem of land degradation that affected agricultural production. With an increasing irrigation momentum in productive grabens, understanding salinization helps to seek sustainable options. Hence, the objective of this study is to understand the spatiotemporal patterns of water salinity in marginal grabens and their implication for downstream water availability.

Methods and materials

The study area (Figure 1) consists of four representative graben basins along the Ethiopian Rift Valley. We measured the electrical conductivity (EC) of flash floods, baseflows, springs, wells, and lakes. A total of 1168 samples was collected from 177 water points (2016 - 2017) for this study. Electrical conductivity is expressed in micro-siemens per cm (µS cm^{-1}) and is strongly correlated to water salinity.

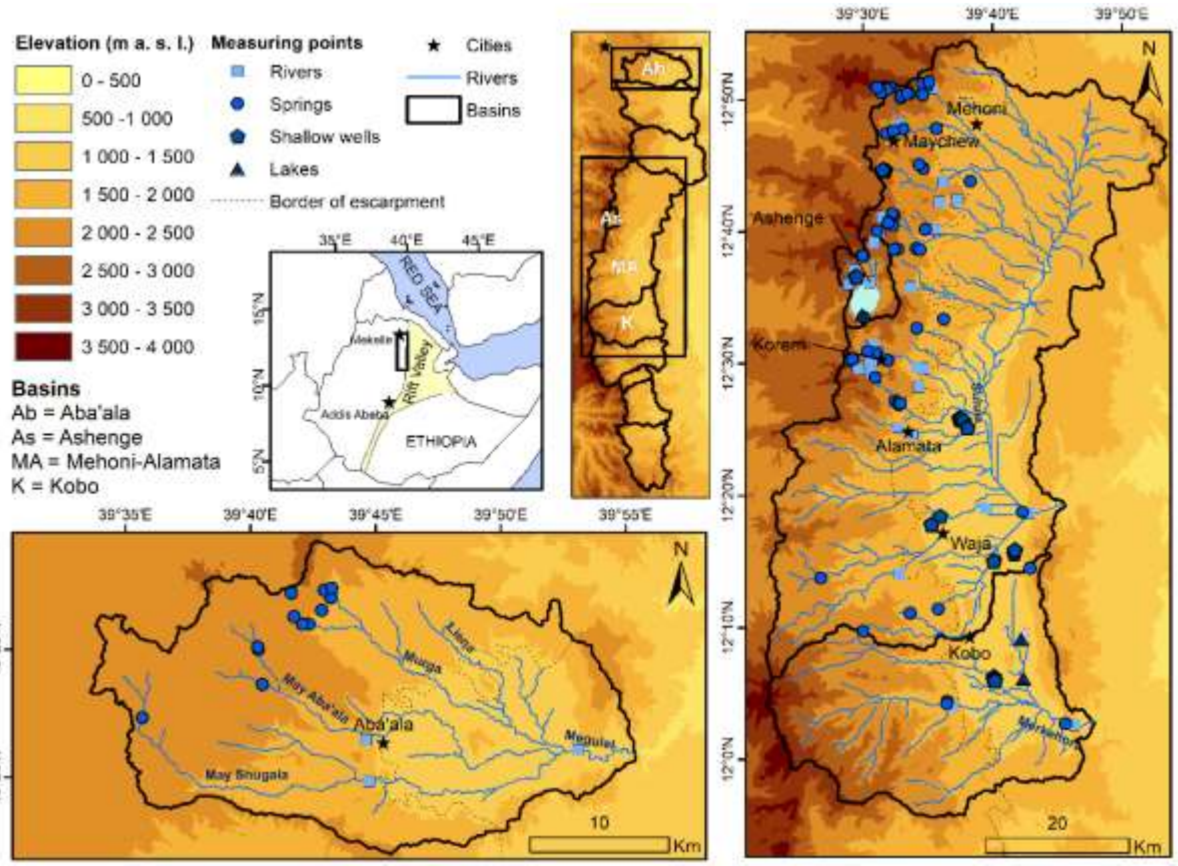

Figure 1: Location of the four graben basins: Aba'ala, Mehoni-Alamata, Kobo and Ashenge.

The water salinity distribution

The water EC values of the graben basins varied between 2016 and 2017. There was a significant difference in the water EC values of the river baseflow between rainy (1403±425 µS cm^{-1}) and dry seasons (2261±258 µS cm^{-1}). The EC values decreased when the river discharges increased in the rainy seasons. In contrast, the EC values of river discharges grew in the dry seasons due to <u>less</u> water residuals. Water EC of the river discharges during the rainy season doubled as compared to the dry season due to the rainwater.

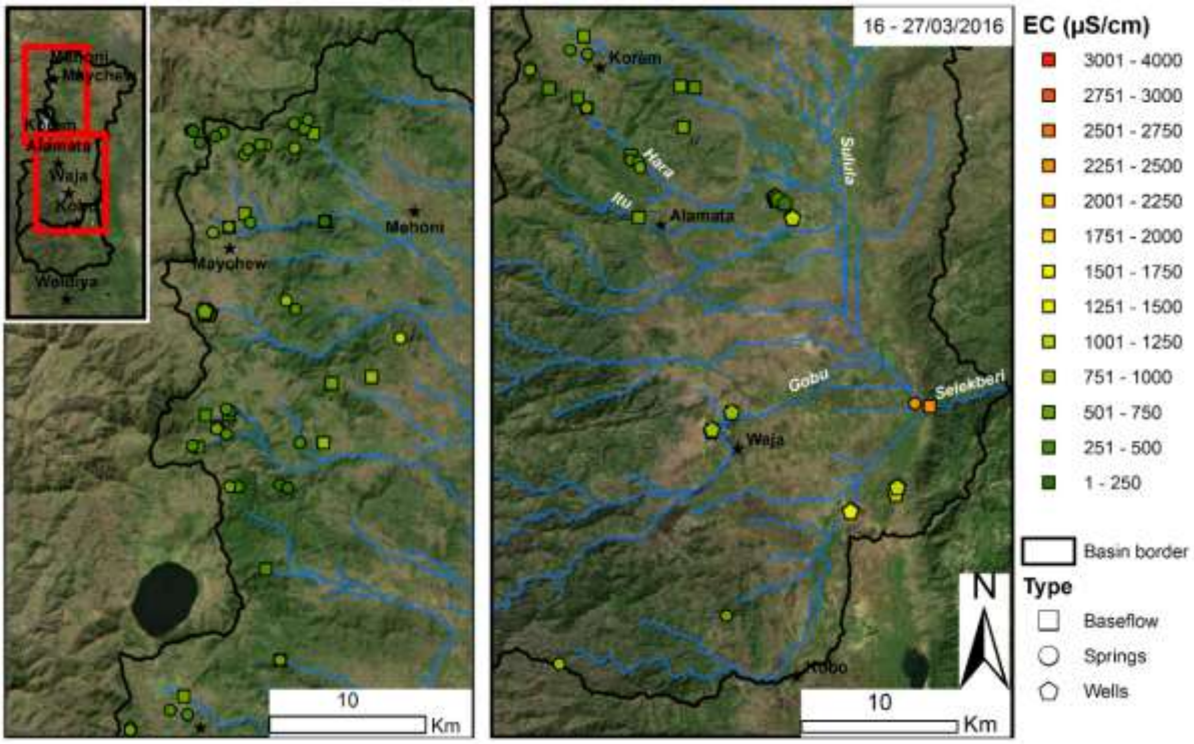

Figure 2: The spatial distribution of the EC values in the Mohoni-Alamata basin (2016).

Based on the origins of solutes, the water EC values of the studied water points varied in space (Figure 2 & 3). The water EC values increased from the western escarpment (≤750 µS cm^{-1}) towards the basin outlets (3278 µS cm^{-1}) in Raya graben. At the Afrera Lake, the EC of springs was 50-100 times larger than the studied graben basin due to the restricted water flushing (Figure 4). The EC values of water resources increased downstream due to the evapotranspiration while water was traveling to the outlets (Figure 3). Also, the average value of the water EC was higher in Aba'ala limestone area than in Raya basalt grabens (Figure 1). In the tectonic depressions, the excess salinity can decrease available plant water and cause plant stress.

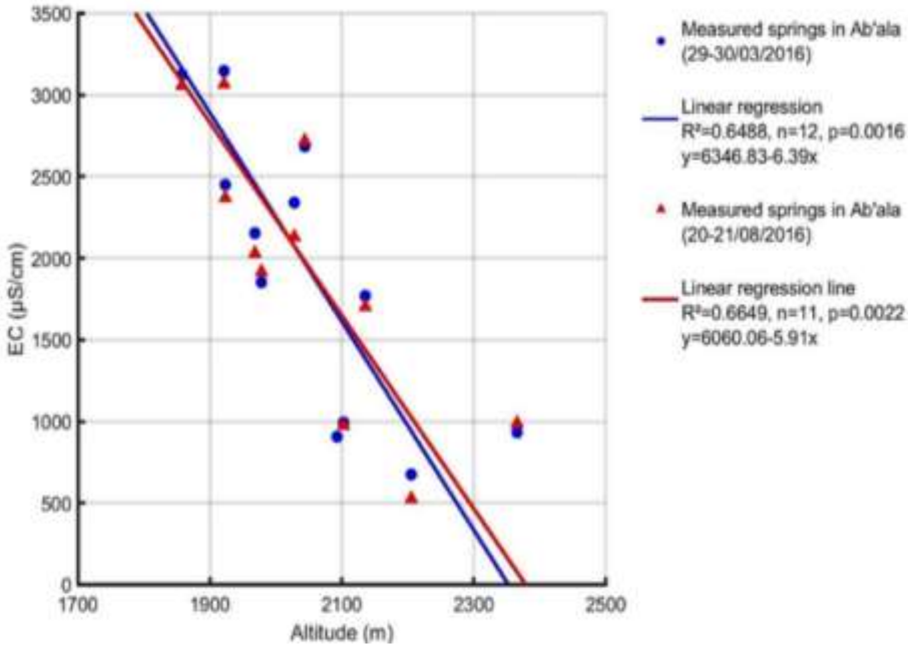

Figure 3: Relation between the altitude and EC value of springs in the Aba'ala graben basin.

Status of the graben basins' closure

Water salinization is linked to the process of river basin closure. During the last few decades, low-lying areas had a water shortage due to the rising water demand and rainfall variabilities.

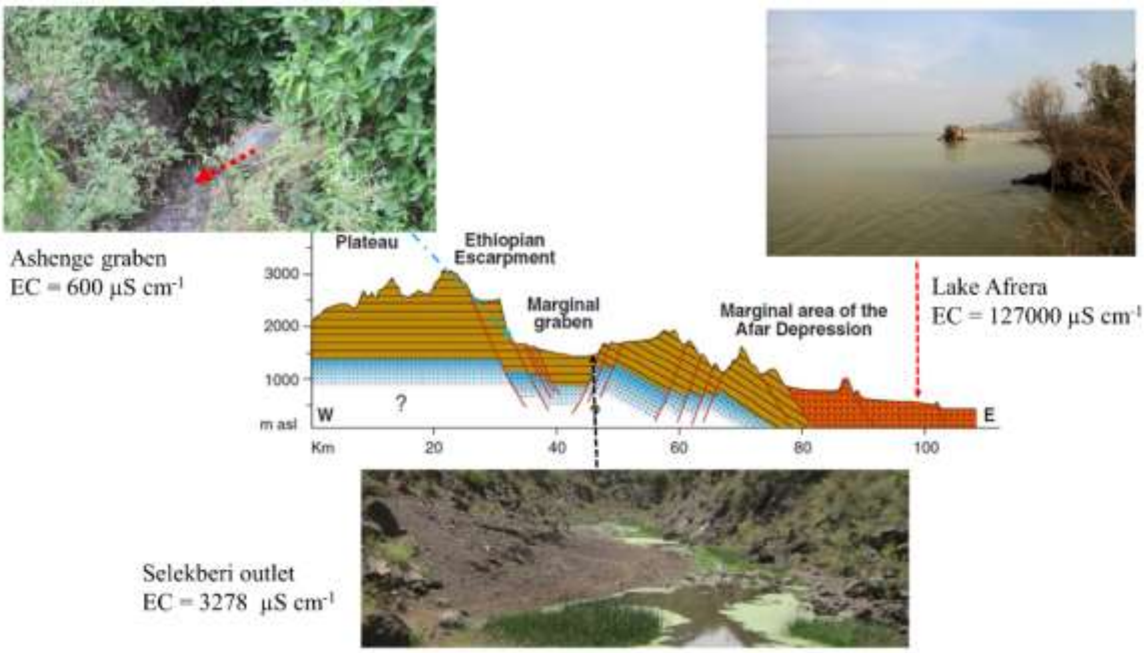

Figure 4: A topographic cross-section of NW Ethiopia from the west to the east (Billi, 2015) with a representative observation in the dry season (2016) on similar locations along the study area.

Aba'ala and Mehoni-Alamata sub-grabens were closing (Table 1). However, downstream grabens such as Afrera basins were closed, and these grabens lack water to meet the local demands and downstream environmental requirements. In contrast, the Kobo and Ashenge basins were classified as open as there exited available water that supports the graben farmers and ecosystem functions.

Table 1: Closure status of the graben river basins based on the river discharge and maximum EC measured at the basin outlets.

Study site	River discharge	Max EC (µS per cm)	Basin closure status
Aba'ala basin	Flow for 2-3 months	2,500	Closing
Mehoni-Alamata basin	No flow for two weeks	2,500	Closing
Kobo basin	Flow >0.02 m^3 per sec.	1,270	Open
Ashenge basin	Flow >0.02 m^3 per sec.	2,000	Open
Afrera basin	No flow	127,000	Closed

Water scarcity hotspots travel downstream due to the human interventions to fulfill the water demands. The overexploitation of waters during the dry season exacerbated the degree of the river basin closure and salinization. Overall, most of the graben basins are at the state of closing and closed basins. In the wider study area, the river basin closures are prevalent in the graben basins.

Conclusions

The runoff regulated the water salinity in grabens. The results show that the average water EC value of the dry seasons was double what was recorded in the rainy seasons. Moreover, water salinity hotspots increased downstream areas due to rapid abstractions. With growing irrigation, water degradation could further threaten the agricultural sustainability in the agricultural grabens.

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Chapter 19: Agricultural investments and land use change in the Raya graben

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Introduction

Ethiopian government has recently given much emphasis to agricultural mechanization to meet the growing demand of the society for landscape services. Consequently, agricultural investments have been highly increasing in the country in general and in the marginal grabnes of north Ethiopia in particular. Nevertheless, agricultural investments, which highly focus on intensification and extensifications, lead to landscape changes. Expansion and growth of agricultural investments are associated with land use and land cover changes, considered as indicators of landscape changes. We investigated the rate of land use and land cover change in relation to agricultural investment in the Raya graben.

Methodology

The study was conducted in the Raya graben, north Ethiopia. Google Earth Images of 2005, 2007, 2009, 2014, 2016 and 2017 were used to detect the changes in the land use and land cover due to the expansion of agricultural investments. Household survey, interviews, and focus group discussions were used to collect data about the pulling factors for investment, impact of agricultural investments on land use and land cover change.

Land use and land cover change and agricultural investment

Land use and land cover changes due to the agricultural investment activities have been found in the graben through transferring land to private investors and expropriation of communal landholding rights. Land use and land cover changes occur due to the reason that investors start their business first by clearing the existing natural resources (e.g., forests, shrubs and bushes) and change to irrigated land.

Land use and cover before and after agricultural investment in the investment areas of the Kobo basin

The expansion of agricultural investment has brought about land use and land cover changes in Kobo sub-basin between 2014 and 2017. Accordingly, from the total area 796.4 ha of the investment sites studied in this study, the coverage of forest decreased from 77.6% between 2007 and 2014 to 15.2% between 2016 and 2017, which indicates that forest cover area has decreased by 62.4% after investment (between 2016 and 2017). There were no irrigable lands between 2007 and 2014, but recently 582.5 ha of land is irrigable due to the introduction of agricultural investment between 2016 and 2017 (Table 1). Besides, the expansion of agricultural investment has led to the expansion of irrigation in the Kobo sub-basin. Consequently, several land use and land cover classes were converted to irrigable land.

For example, 241.9 ha of land, which was covered by forest in 2007 has been converted to irrigable land in 2017. Besides, 70.4 ha of farmland is converted to irrigable land. Similarly, 184 ha of forest area has been converted to irrigable land between 2007 and 2016. Out of the 116.1 ha of forest in 2014, only 62 ha was persistent while the remaining 54.1 ha was converted into irrigable land. Generally, irrigable land in the studied investment sites of Kobo sub-basin gained 582.6 ha between 2016 and 2017. Conversely, forest lost 496.6 ha (Table 1).

Table 1. Land use and cover before and after agricultural investment in Kobo sub-basin

LULC	***Before Investment (2007-2014)***		***After investment (2016-2017)***		***change (ha)***	***Change (%)***
	Area (ha)	***%***	***Area (ha)***	***%***		
Bushland	87.4	11.0	87.8	11.0		
Grassland	6.4	0.8	3.3	0.4	-3.1	-0.4
Forest	617.7	77.6	120.7	15.2	-497	-62.4
Farmland	70.4	8.8	0	0.0	-70.4	-8.8
Irrigable land	0	0	582.5	73.1	582.5	73.1
Bare land	14.5	1.8	0	0.0	-14.5	-1.8
Nursery site	0	0	1	0.1	1	0.1
Water reservoir	0	0	1.1	0.1	1.1	0.1
Total	796.4	100.0	796.4	100.0		

Land use and cover before agricultural investment and after it, in the investment areas of the Mehoni sub-basin

Agricultural investment activities in Mehoni sub-basin affected the situation of several land and land cover classes. Consequently, shrubland cover in Mehoni decreased from 85.9% in 2014 to 26.4% in 2017. Similarly, bare land and settlement have been abandoned in 2017. Conversely, the irrigable land increased from 0% in 2014 and 73.6%, suggesting that irrigable land has become the dominant LULC type in the selected sites of Mehoni sub-basin. Besides, the LULC change analysis of Mehoni between 2014 and 2017 reveals that 705 ha of shrubland was changed into (lost) irrigable land while 308.8 ha of shrubland was persistent. Similarly, 140.8 ha of farm and has been changed into irrigable land. Besides, 17.8 ha of bare land and 3.9 ha of settlement were changed into irrigable land in 2017. The total loss of bare land between 2014 and 2017 accounted for 17.8 ha. Conversely, the total gain of irrigable land between 2014 and 2017 accounted for 867.5 ha. This is due to the conversion of large areas of shrubland, farmland and bare land to this class, irrigable land (Table 2).

Table 2. Land use and cover before and after agricultural investment in Mehoni sub-basin

LULC	Before Investment (2014)		After investment (2017)		change (ha)	Change (%)
	Area (ha)	%	Area (ha)	%		
Shrubland	1013.8	85.9	311.8	26.4	-702	-59.5
Bare land	18.5	1.6	0	0.0	-18.5	-1.6
Settlement	5.5	0.5	0	0.0	-5.5	-0.5
Farmland	142.1	12.0	0	0.0	-142.1	-12.0
Irrigable land	0	0.0	867.5	73.6	867.5	73.6
Total	**1179.9**	**100.0**	**1179.3**	**100.0**		

Land use and cover before agricultural investment and after it, in the investment areas of the Alamata sub-basin

Like Kobo and Mehoni, Alamata basin is also one of the development corridors identified for agricultural investments in Ethiopia. As a result, irrigation activities have been expanded after the start of investment activities in the area, but to a lesser extent than in the other districts. In the 45.3 ha of selected agricultural investment sites, after 2005, 13.6 ha has been irrigated and 31.7 ha remained rainfed cropland.

Conclusion

The study found that the expansion of agricultural investment has resulted in land use and land cover changes in Raya graben. Forest coverage in the investment areas of Kobo sub-basin decreased by 62.4%. In Mehoni sub-basin, shrubland in the selected investment areas decreased by 59.5%. Besides, settlements in the investment sites of Mehoni have been demolished. Conversely, the findings also indicate that irrigable land in Kobo sub-basin has increased by 73.6% and it also increased by 73.1% in Mehoni sub-basin. The study also found that the agricultural induced land use and land cover changes in Raya graben have affected the landscape services of the graben. Particularly, the allocation of more than 6 km² of remnant forests to commercial agriculture is striking.

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Chapter 20: Landscape dynamics and major drivers in the Raya graben bottom

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Introduction

The aim of this study was to investigate landscape dynamics along the Raya graben bottom. This study area is a semi-closed marginal graben found along the Ethiopian Rift Valley system. It is located between 12°–13°N and 39.5°–39.8°E, the graben bottom. The elevation of the study area is between 1300 m above sea level at the foot of the eastern horsts and 1600 m at the foot of the western escarpment. The graben bottom is invaded by ephemeral rivers that deposit large sediment volumes washed out from the escarpment. The area has a diversified land use and land cover. Agricultural land and shrubland are the most dominant ones.

Methodology

This study examined landscape composition and configuration in the 2379 km^2 wide Raya graben bottom over a period of three decades. Landsat satellite images captured in 1986, 2000, 2010 and 2017 were used to analyze land cover and changes in landscape in the study area. The FRAGSTAT programme was used to analyze fragmentation and composition of the landscape. Field measurements, in-depth interview, and focus group discussion were carried out. The field visits were conducted to observe real landscape features and to collect ground control points along transects from the foot of the western escarpment to the foot of the eastern horsts in the study area. During classification, the maximum likelihood classifier (MLC) was applied. In order to understand the disintegration of a class of land, the number of patches (discrete areas of relatively homogeneous environmental conditions) was analysed. Similarly, quantifying spatial diversity was essential to clarify spatial patterns of patches in the landscape. Hence, the Shannon Diversity Index (SHDI) was used to quantify the distribution (regular or irregular) of patches in the study area.

Dynamics of landscape metrics at class level

Farmland is the predominant landscape element in the study area. It has shown increase in size in the last three decades (Fig. 1). The number of farmland patches increased from 1584 in 1986 to 166,748 in 2017. This indicates that there is a very important fragmentation within farmland. At shrubland class metrics, the number of patches has increased (2168 to 254,428), and the proportion of shrubland in the landscape has decreased. This indicates high fragmentation of shrubland. Shrubland in Mehoni is characterized by cactus (locally called *beles*). Forest cover decreased progressively throughout the study period. The number of forest patches did not increase significantly between 1986 and 2017. For villages both the mean patch size and number of patches have increased significantly, hence a progressive increase in villages over the three decades. Built-up patches are consolidated around the cultivated land, shrubland, and at the edge of forests. River bed patches are concentrated around the edge of the escarpment and expand into farmlands in a scattered way in the graben bottom around their distributary systems.

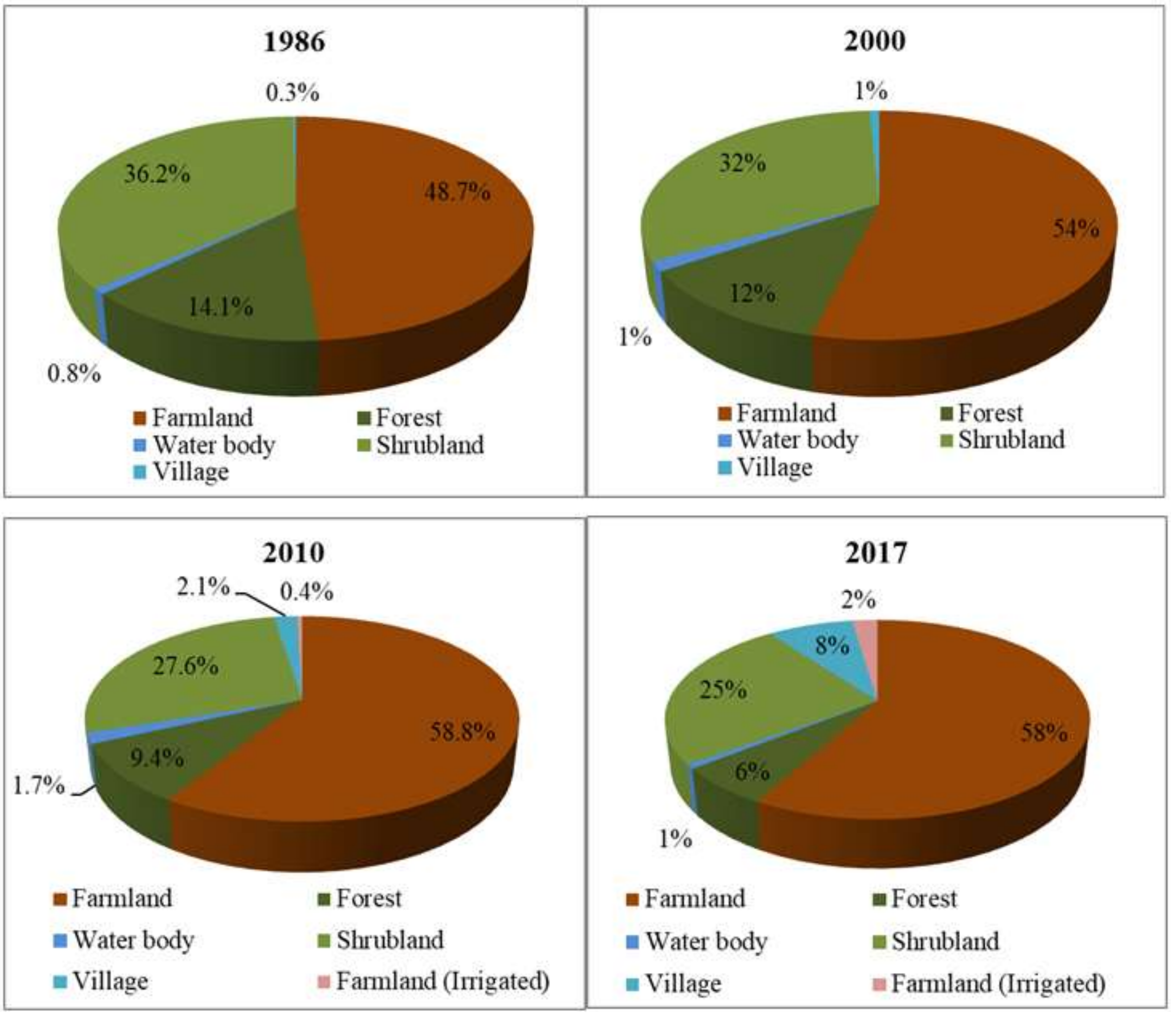

Figure 1. Land cover distribution in the Raya graben bottom from 1986 to 2017.

Dynamics of landscape metrics at landscape level

In the study area landscape, the number of patches (NP) has increased across the study period from 1986 to 2017 (Fig. 2). In 1986, the number of patches within the landscape was 8147 and in 2017 it increased to 886,893. This indicates that there is high fragmentation of landscape within the study area. The distribution of patches in the landscape of the study area was regular in 1986 and it became irregular towards 2017 (Fig. 3).

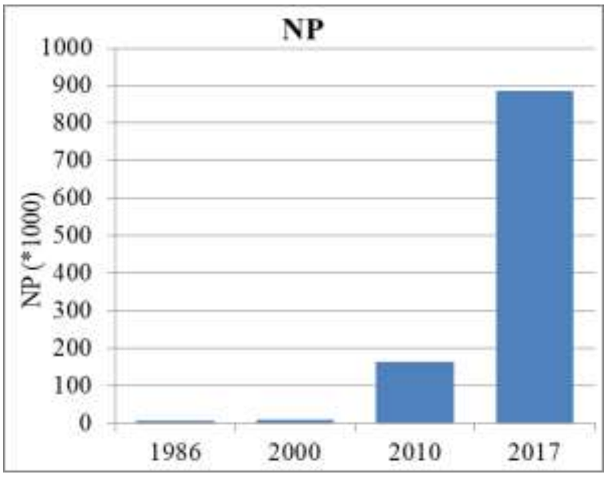

Figure 2. The distribution of number of patches (NP) over the years between 1986 and 2017.

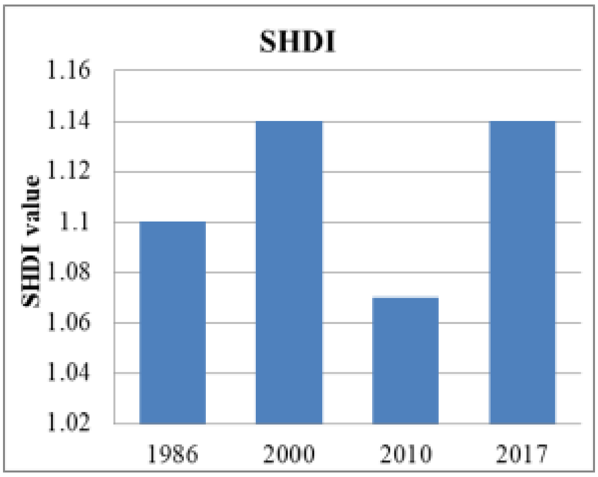

Figure 3. The distribution of Shannon Diversity Index over the years between 1986 and 2017.

Major causes of landscape change

In the study area, changes are commonly human driven due to an increasing demand for food and settlement, directly related to increase in population size. There was an increase in the size of farmland and villages (Fig. 3), and at the same time a decrease in shrubland and forest cover. For example, in Kobo basin (near to Golina river), shrubland in 1986 was changed to farmland in 2017. The unplanned development of villages and encroachment of farmlands towards shrubland and forests might have contributed to the strong increase in the number of patches in different landscape elements. In contrast, there was contraction of villages due to pooling up of scattered villages by the government to enhance access to facilities and infrastructures; whereas the people cut trees for constructing their houses. In addition to increase in population size and infrastructural development, larger scale agricultural investments are strong causes of landscape changes in the study area, particularly in the graben bottom (Fig. 4).

Figure 3. Expansion of villages in 2017 in Kobo, most villages are characterized by an iron roof. Photo by Alemewerk

Figure 4. Expansion of commercial agriculture in the study area. Photo by Alemewerk

Conclusion

- The study indicates that there is fragmentation of land units in to smaller sizes over the last three decades.
- Shrubland and forest have small number of patches and are gradually converted into farmland and villages.
- The number of patches of farmland and village increased through time.
- The diversity of land cover of the landscape of the study area increased over the last three decades.
- The main drivers of landscape change in this study area were agricultural intensification, development of commercial agriculture, rural settlement expansion, infrastructural expansion, rural and urban linkage and land distribution for youth people.

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Chapter 21: The fertiliser excess crisis in the Raya graben and beyond (2012-2016)

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Introduction

Low mineral fertiliser use received much attention in Africa over the last decades. As fertiliser sales have exponentially grown in Ethiopia, and evidence exists of a supply that was beyond the demand in the drier northern parts of the country, we investigated the inorganic fertiliser sales and its black-market resale prices in north Ethiopia.

Fertiliser black markets with prices below the official rate set by the government may have various causes such as smuggling of highly subsidised fertiliser from Nigeria to Niger, and massive reselling below officially imposed rate in Mexico in the framework of the "Green Revolution" programme of the 1950s-1960s. There, inorganic fertiliser was resold to the black market, immediately upon delivery at the cooperatives, which led to their indebtedness. The term "black market" usually refers to those transactions which take place illegally at prices higher than a legal maximum. Essentially the same phenomenon is observed when the illegal transactions take place at prices **below** a legal minimum. In the latter case, a black market will develop if the official price is above the hypothetical free market price, so that at the legal price less fertiliser is demanded than will be supplied. That is on the condition that some buyers and sellers can be found who are willing to buy and sell at prices lower than the official price despite possible penalties involved.

Fig. 1. *Study area in the Raya graben and its main physiographic units (in black).*

Methods

The research was conducted in 2016 in 34 districts located in Tigray, as well as in the adjacent Kobo district (part of Amhara region). The latter was included in order to conduct a detailed analysis in the three adjacent districts that form the Raya graben, where the environment is very contrasted along a topographical zonation that cuts across the three districts (Fig. 1). Quantitative data on fertiliser provision, official prices and black-market prices in 2016 were obtained from official statistics and from key informants in each of the 35 studied districts and in all municipalities of the Raya area.

To understand the importance of environmental conditions, the three districts of the Raya graben were surveyed in detail. For each of the municipalities in the Raya-Azebo, Alamata and Kobo districts, areas of rain-fed and irrigated cropland as well as quantities of DAP/NPS and urea formally sold were obtained from district authorities, whereas narrative interviews were carried out to obtain the monthly fertiliser price on the black market, which was the same for the two main fertilisers. Every municipality was also classified according to its location in physiographic units (1) the elongated marginal graben bottom with main road and towns, (2) the western escarpment that forms an extensive zone between the graben bottom and the edge of the Ethiopian plateau (including for instance Tekulesh), or (3) the eastern horst, a ridge between the graben bottom and the main Rift Valley, including places such as Chercher and Zobel (Fig. 1). Some municipalities extend over two different physiographic units; they were classified under the unit where most of its farmlands are located.

How was fertiliser distributed in 2016?

To promote inorganic fertiliser, agricultural experts used incentives, and also bartered the purchase of fertiliser by a farmer against food aid or other advantages from the authorities. The high application rate that was aimed at (2 Qt per hectare) contrasts with the dominance of less-responsive soils in large parts of the study area, for which inorganic fertiliser application does not result in higher crop yields, or even leads to root burn. The quantitative analysis shows that 40,700 tonnes of fertiliser were officially sold in the study area in 2016 at high price, which corresponds to 0.5 Qt per hectare. This is notably different from the application rate, as reselling widely occurred, at 50% of the official price for diammonium phosphate (DAP) and 54% for urea, mostly to users outside the community. In 2016, the average official price at which the fertiliser was sold to the farmers was 1407 Birr per Qt, with variations for type of fertiliser and distance to Addis Ababa. The average price on the black market in the whole study area was 731 Birr per Qt, but only 463 Birr per Qt in the three graben woredas.

Why did the farmers resell fertiliser?

The first reason given by farmers who resold their fertiliser was that they did not need it. They particularly feared that, in case of a dry spell in the onset of the rainy season, the plant root system will be insufficiently developed to transfer soil moisture to the lush vegetative growth that is induced by inorganic fertiliser. Farmers frequently reported that excessive application of inorganic fertiliser on rain-fed crops results in decreased yields: in addition to the problems induced by drought, in case of good rains after excessive fertiliser application, "the crop doesn't give good yields but only vegetative growth which will be useful as straw only". In the Raya graben, only farmers with dry season irrigation state that they need fertiliser, others will sell it off. Here, most of the irrigation farming is done by large and middle level investors rather than small farmers, who preferred to sell their fertiliser to such customers. On irrigated land, fertiliser is only used for vegetables and not for tef, sorghum or maize (which are the main crops in the area). The farmers claimed that first of all the graben is a very hot area with moisture deficit (late start, early end, and erratic rainfall), and secondly the land is fertile, in relation to the yearly deposition of a thin layer of alluvium (containing organic matter and inorganic fertiliser) originating from the escarpment (Fig. 2). We anticipate that the large volumes of water involved in spate irrigation would also leach part of the applied fertiliser.

Fig. 2*. Spate irrigation in the Raya graben bottom (August 2016): at left a main intake canal where the flood is diverted towards croplands (Photo J. Poesen), and at right the ultimate distributary canals leading the sediment-laden floods into the cropland (Photo W. D'Hoore). The entire irrigation scheme is operated through a traditional management system that has its own byelaws. In both photographs, the flow direction is away from the reader.*

Who was buying fertiliser and what were the black-market rates?

Most of the inorganic fertiliser on the black market was purchased by external users, with the help of local merchants or relatives who act as brokers. A merchant who was rounding villages in the Raya graben with a light Isuzu lorry in order to purchase inorganic fertiliser told that he intended to sell it to agricultural companies near regional towns and to smallholders in central Tigray. According to him, the business opportunity started in 2012. Reportedly, fertiliser was often transported by light lorries to the sesame producing areas in W Ethiopia and to central Ethiopia. The volume of inorganic fertiliser which was actually sold through the black market was difficult to measure, as it was often transferred from farm to farm or taken by small lorries that travelled in different directions. In the Kobo and Raya-Azebo graben bottom it was even claimed that almost all farmers without access to formal irrigation resold all fertiliser they bought, because they feared for drought in relation to high temperatures in the area. Hence, the price in the black market was cheapest in the three districts of the Raya graben.

The variable fertiliser black market in the Raya graben

When considering the 72 municipalities of the Raya graben, there were striking contrasts between the graben bottom and both escarpments, with regard to fertiliser purchase, black market rates, and price variation throughout 2016 (Table 1). Similar relatively low quantities of fertiliser were sold in municipalities of the escarpment and in the graben bottom (15 and 17 kg per hectare), against even less in the often remote and dry horst municipalities (6 kg per hectare). The black-market rate for inorganic fertiliser is relatively high in the western escarpment (52%) but less in the graben bottom and horst (33-38%). In the latter physiographic unit, not only little quantities were purchased formally, but even large parts of these little quantities were sold off, as indicated by the low black-market rate.

Table 1. *Number of tabias/kebeles in the Raya graben by main physiographic units and corresponding average fertiliser price and sale in 2016.*

	Number of kebeles or tabias	Average price of fertilisers in the black market (Birr per Qt)	Volume of fertiliser that was sold (kg per ha)
Graben bottom	33	483	15
Western escarpment	28	666	17
Eastern escarpment and horst	11	420	6

Note: six tabias or kebeles with insufficient data were not considered.

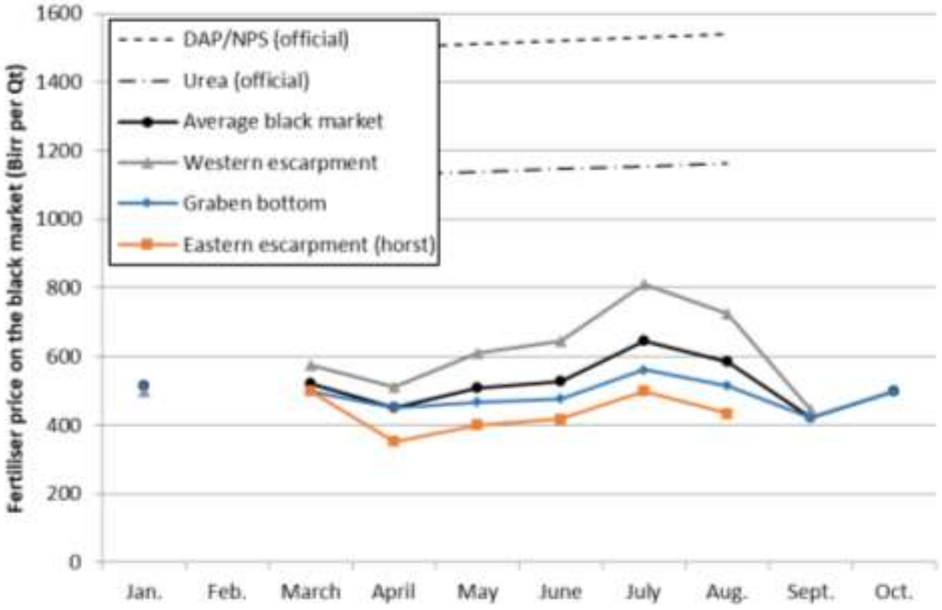

***Fig. 3**. Monthly fertiliser price on the black market in the Raya graben in 2016, as average of all municipalities per physiographic unit.*

Detailed recording of black-market fertiliser prices in all municipalities of the Raya graben showed contrasts between physiographic regions throughout the year 2016 (Fig. 3). Prices were higher in the main rainy season. Some marketing took also place in September-October and in January in relation to irrigation activities.

Discussion: excess fertiliser in all places with spate irrigation

In contrast, in the four districts with spate irrigation, black market prices for inorganic fertiliser are low (35% of the official rate) and small quantities are sold officially (32 kg per hectare). This corresponds to the farmers' saying that there "nobody needs inorganic fertiliser since the spate irrigation adds organic and inorganic nutrients yearly". Indeed, on the maps of the soil fertility atlas for Tigray, the soils of the graben bottoms in Raya-Azebo and Alamata districts show high organic matter content, and optimum total Nitrogen, Phosphorus and Potassium. Similarly, in Eritrea, the annual sediment deposition on farmlands with spate irrigation enabled the farmers to harvest crops without application of fertilisers since the last 100 years. More to the South, in 2012-2016, merchants travelled from Gojjam and Gondar to the grabens around Weldiya and Kombolcha in order to purchase fertiliser at a rate that was 30% below the official price, because also in those areas with spate irrigation there was selling of excess fertiliser.

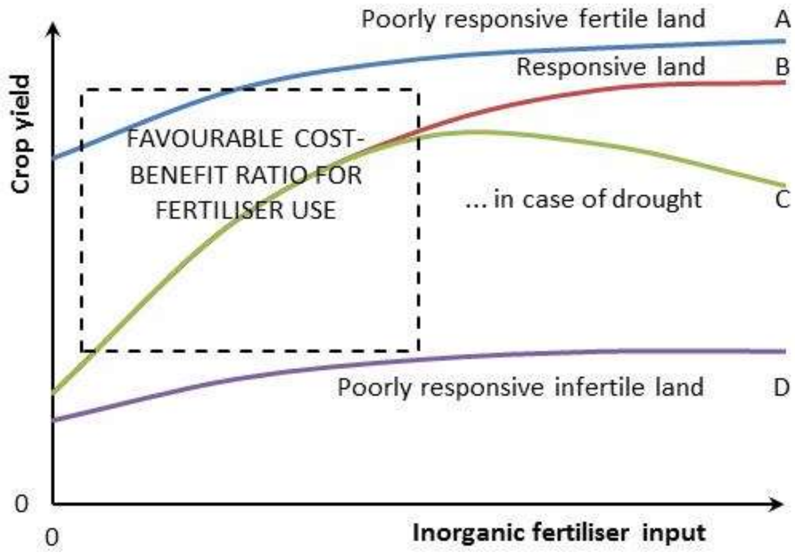

Fig. 4*. Conceptual model, according to Tittonell and Giller, representing the variability in crop response to inorganic fertiliser in North Ethiopia in relation to fertility status. (A) fertile land where inorganic fertiliser application will not lead to substantial crop yield increase (example: the graben bottoms); (B) responsive fields for fertiliser application; (C) responsive fields affected by dry spell leading, in case of fertiliser application, to premature growth and/or "root burn" or "fertiliser injury"; (D) less fertile land, due to excessive soil erosion, that first needs long-term additions of organic matter.*

Towards a voluntary fertiliser policy based on real needs

By accepting to sell excess fertiliser to agricultural companies and traders, smallholders saved themselves from greater losses. In the four districts with spate irrigation, black market prices for inorganic fertiliser were low (35% of the official rate) and small quantities were sold officially (32 kg per hectare). This corresponds to the farmers' saying that there "nobody needs inorganic fertiliser since the spate irrigation adds organic and inorganic nutrients yearly". We found similarities to what happened during the 'Green Revolution' in Mexico in the years 1970: the forced delivery of high-cost fertiliser, and the reselling at half price in the black market.

Inorganic fertilisers are one of the elements that have allowed to boost agricultural production in Ethiopia, but in our study area, the fertiliser policy needs to be much more fine-tuned so that it is led by agronomic needs, rather than by statistics of sold volumes of inorganic fertiliser. The availability of the soil nutrient atlas of Tigray as well as our conceptual model (Fig. 4) must allow correctly trained experts to recommend suitable application rates of the appropriate blend, taking into account that pressurising smallholder farmers to purchase fertiliser against their will is a bad service to agricultural development.

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Scientific and vernacular names of woody plant species

In this book, sometimes scientific names (in Latin language, italic letters) are used. We have chosen to keep the scientific names, and to translate them here.

Scientific name	English	አማርኛ	ትግርኛ
Acacia asak	Acacia	ሳላንሳ	ጓዳደ፣ ሓቕ፣ ሰለዋ
Acacia sp.	Acacia	ግራር	ጫዓ
Aloe sp.	Aloe	እሬት	ዕረ
Becium grandiflorum	Cat's whiskers	መንጠሴ	ጠበብ
Cadia purpurea	Cadia	ሽለን	ሽልኣን
Carissa edulis	Num-num	አጋም	ዓጋም
Dodonaea angustifolia	Sand olive	ክትክታ	ታሕሰስ
Erica arborea	Giant heath	አዳሌ, አስታ, ውጨና	ሻንቶ
Eucalyptus	Eucalyptus	ባሕር ዛፍ	ባሕር ዛፍ
Euclea racemosa	Guarrie	ደደሆ	ኩለዖ
Euphorbia	Euphorbia	ቁልቋል	ቆልቋል
Helichrysum	Everlasting flower		
Juniperus procera	Ethiopian cedar	ጥድ	ፅሕዲ
Lobelia rhynchopetalum	Giant lobelia	ጅባር	
Olea europaea	Olive tree	ወይራ	ኣውልዕ
Opuntia ficus-indica	Prickly pear	አሸዋ ቁልቋል	በለስ

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