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Creating Resilience against Climate Change and Population Growth through Agroecosystem Restoration: The Case of Abreha we Atsbeha, Northern Ethiopia

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Abstract

In Africa, where 65% of the continent's population use subsistence agriculture to create their livelihoods, projected changes to rainfall patterns, warmer average temperatures and rapid population growth will place increasing pressure on smallholder production systems. Landscape restoration is a strategy that aims to reverse land degradation and rebuild biodiversity in attempt to optimize the contribution that ecosystem services make to the resilience of the people. However, transformation of degraded landscapes into functional and mature agroecosystems is a slow and complex process, so there is a need to find ways to optimize the efficiency with which overall resilience is created. In order to address this objective, a qualitative study of a landscape undergoing restoration was conducted to form a holistic perspective of the relationships between processes of change and factors that influence resilience. The research, conducted in a semi-arid Ethiopian landscape that is vulnerable to climate change and population growth, used semi-structured interviews and observations of ten households on either side of the food-secure—food-insecure scale, to inform the discourse around pathways with the greatest potential for accelerating change. The study found that two main factors combine to influence resilience: (1) That a change to one part of the system that has a strengthening effect on household resilience, in the form of agricultural extension services that help farmers to increase yields by providing access to industrial inputs has an unanticipated limiting effect elsewhere in the system, in the form of ineffective dissemination of composting. (2) The effect that culture's norms and traditions have on resilience, specifically the habit of cooking *injera* using fire that is fueled with manure and crop residue. The results of this study help to illuminate the ways that landscape restoration can be optimized so that greater overall resilience is achieved. New and ongoing landscape restoration projects must strike a balance between interventions aimed at short-term improvement of livelihood outcomes, and long-term strategies that aim to build resilience in anticipation of predicted changes. This can be achieved by creating awareness among local communities about the long-term benefits of building soil structure, so that they are willing to participate in developing new pathways to biomass recycling that is feasible for their specific landscape.

Keywords: landscape restoration, transformation, livelihoods, nutrient cycling, resilience.

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Contents

1. Introduction

1.1 The African context: Climate change, landscape restoration and ecosystem services

The livelihoods of small-scale farming communities throughout the developing world are at risk of deteriorating as the human population expands and the climate changes. For Africa, climate change models predict drying associated with warmer average temperatures and shorter, less predictable rainfall seasons(IPCC, 2014) (IPCC, 2014). This, on a continent where agriculture is the primary livelihood strategy of two thirds of the population's poor (Pretty et al., 2011), and where 96% of farmers rely on rainfall to irrigate staple crops (IAASTD, 2009). Rapid population growth adds further pressure on African production systems (IAASTD, 2008, Giller et al., 2011), with aggregate studies showing a decline of per capita food production, despite a threefold increase of net crop production (Pretty et al., 2011). Landscapes degraded by unsustainable resource use and outdated farming techniques are characterised by low biodiversity and soil with inadequate fertility and limited water holding capacity (IAASTD, 2009). The farming communities living in these degraded landscapes have reduced ability to cope with and recover from climatic stressors such as floods and droughts (IPCC, 2014). Historically, rural African societies could migrate and cultivate other regions when the land became degraded, but high population density and competition for land from other human activities, restrict that. Therefore, the ecological restoration of degraded landscapes should be prioritized as an adaptation strategy to reduce the stress that an increased demand for food will place on a region's finite resources and to increase farming communities' resilience to cope with and mitigate climate change (Barral et al., 2015, Pretty et al., 2011). The goal of ecological landscape restoration is to recreate balanced agroecosystems where biodiversity is able to mature by itself, allowing for natural evolution to take place alongside climate changes (Clewell et al., 2000). The inhabitants of functional ecosystems benefit from increased biodiversity through gaining better access to more and improved ecosystem services, which they can combine to create a livelihood (Tscharntke et al., 2012, Barral et al., 2015). Ultimately, the desirable outcome is a mature agroecosystem that continues to thrive indefinitely, despite changes to future climatic, economic and socio-political externalities of the landscape (Barral et al., 2015). Thus, because the transformation of entire ecosystems is a complex and timely process (Clewell et al.,

2000), there is an urgent need to understand the practical pathways that lead to effective, extensive and permanent change.

1.2 Landscape restoration in Abreha we Atsbeha

The recent history of the village of Abreha we Atsbeha, northern Ethiopia is an example of how restoration on a landscape scale can improve livelihoods and increase food security (Araya and Edwards, 2006, Tafere et al., 2013, UNDP, 2013). By the early 1990's, the landscape had been degraded to the point where the Ethiopian government planned to relocate the villagers (Tafere et al., 2013, UNDP, 2013), but they decided to stay and by 2012, an estimated 85% of the community had become food secure (Lamond, 2012). The rehabilitation of the landscape was part of the Ethiopian government's development program for the region; The Sustainable Development and Ecological Land Management with Farming Communities Projects in Tigray, Ethiopia, or 'Tigray project' for short. The ongoing project aims to improve the livelihoods of smallholder farmers by using ecological principles and a community-based approach to rehabilitate the landscape and improve crop production (Araya and Edwards, 2006). Throughout Tigray, community members provided manual labor for the construction of infrastructure for water conservation (hillside terracing, gulley reinforcement, percolation trenches) and water resource development (wells, check dams, catchment ponds) (Edwards et al., 2012, UNDP, 2013). Efforts to rehabilitate the soil included training on composting, tree planting on degraded land, and local bylaws restricting free grazing of animals and the cutting of woody vegetation (Edwards et al., 2012, UNDP, 2013). The village of Abreha we Atsbeha soon stood out from others in Tigray, and eventually won international acclaim and attention for its landscape rehabilitation progress (UNDP, 2013). Thus, the village could be regarded as a natural experiment in systems transformation; one where the community changed their shared belief system to the effect that positive change manifested itself on the landscape scale. A defining characteristic that Abreha we Atsbeha possesses, is its influential local leadership. The chairman of the local parish, Abu Hawi ("father of fire") was the catalyst that motivated and mobilized the community members to take on investments and large-scale tasks that would only show returns in the distant future (Tafere et al., 2013). In addition, he continued to encourage the experimentation and adoption of bundled support packages offered by the state, which included agricultural inputs such as fertilizer, pesticide and improved seed varieties, access to water pumps and beehives, and the provision of

extension services and information regarding market drivers and best practices (Wolde-Georgis et al., 2010). The expansion of biodiversity and ecosystem services due to these interventions provides a contemporary example to other degraded landscapes in search of pathways towards resilience (UNDP, 2013). However, despite the positive progress of the last two decades, there are still households that are not food secure, and pressure on resources will continue to rise due to climate change and population growth. An understanding of the factors that limit the creation of a fully functional agro-ecosystem, and the opportunities that exist to overcome them, will benefit Abreha we Atsbeha (and other landscapes) as they continue to adapt to change.

1.3 Objectives and research questions

Knowledge is needed on the most effective pathways for making changes to the fundamental level of a system, that result in permanent transformation at the landscape scale. The need for such knowledge by landscapes that have not undergone any change is apparent, but for landscapes that have already made progress towards restoring the agro-ecosystem, a renewed strategy might be needed to accelerate maturation and avoid stagnation. The village was chosen for the study because it represents an example of a high-altitude, semi-arid, subsistence farming system in Africa undergoing transformation, with households that represent different points on the scale between food insecurity and food security. Instead of a progress report on the landscape rehabilitation efforts in Abreha we Atsbeha, a case study provides a subjective 'snapshot' of the landscape to explore the effect that landscape restoration is having on households' resilience. The following two questions guided the search for adjustment points in the agro-ecosystem with the most potential for strengthening resilience:

Question 1:

What are the similarities and contrasts between the livelihood strategies of the relatively rich (food secure) and the relatively poor (food insecure) in Abreha we Atsbeha, Ethiopia?

Question 2:

How can overall (rich and poor's) resilience in the landscape be strengthened sustainably?

Household and landscape data was collected by using semi-structured interviews and observations during ten weeks of immersed research in the village. A sustainable livelihood framework guided a qualitative comparison of the endowments and livelihood strategies that food insecure, and food secure households in the village had access to. The most prominent differences were then used as the starting point for answering Question 2. These endowment and livelihood factors that limited and contributed to resilience was regarded in terms of their relationship with the unique socio-economic, socio-political and cultural externalities of the landscape. The relationships, and their interactions with one another was scrutinized in the hope of identifying adjustment points in the system that had potential to cause further evolution to a mature and functional agro-ecosystem. Later, the results are discussed in light of a hypothetical transformation program for Abreha we Atsbeha, that aims to serve as a contribution to discourses on transformation, climate change adaptation and ecological landscape restoration.

2. Materials, methodology and methods

2.1 Study area

The research was conducted in Abreha we Atsbeha (13°50'51"N; 39°32'2"E, 1950-2100m above sea level), a village situated in the rugged and mountainous Tigray province of northern Ethiopia (img. 1). Overgrazing, fuel-wood harvesting and expansion of land for cultivation combined to erode the soil to the point where Tigray is considered to be the most degraded part of the country (Araya and Edwards, 2006). Rainfall is characterized by short and intense storms, and the village receives most of its annual average of 619mm from July to September, with small amounts of rain occasionally falling in February and March, but that are predicted to disappear entirely due to rising temperatures surface temperatures of the Indian Ocean (IPCC, 2014). The average annual temperature of 19,3°C classifies the biome as hot, semi-arid steppe. Soils are categorized as either cambisols, fluvisols or vertisols, and are low in total nitrogen and available phosphorous, but have moderately sufficient potassium (Beyene

et al., 2006). The farmers categorize the soil according to its fertility into thick (*reguid)*, medium (*ma'akhelay*) or thin (*rekik*) soil. Thin (or shallow) soil represents more than 50% of the land available for cultivation, and has naturally low organic content (Beyene et al., 2006). Household income is primarily generated by mixed crop–livestock subsistence farming that takes place, on average, on less than one hectare of land (Tafere et al., 2013, Araya and Edwards, 2006). Traditional cereal crops such as maize, sorghum, wheat, finger millet and *Eragrostis tef (E.tef)* are cultivated during the rainy season. During the dry season, increased access to irrigation enables some farmers to cultivate cash crops of vegetables and spices; such as potatoes, onions, tomatoes, chili and garlic (Wolde-Georgis et al., 2010). Irrigation ponds and wells near homesteads also allows for the proliferation of fruit trees; mainly guava, papaya and mango, but also to a lesser extent orange avocado and coffee, which diversifies the households' diets and income (Wolde-Georgis et al., 2010). Surplus crop production is sold at weekly markets in the village or the closest town, Wukro, but is mostly used to meet the households' personal nutritional demands. Animal husbandry consists of the maintenance of small herds of cattle, sheep, chickens and donkeys. Livestock serve multiple purposes on the farm; they provide nutrition to the household in the form of meat, milk and eggs, as a form of financial security when animals are sold during desperate times to generate income, as draft power and as a way to cycle nutrients on the farm (IAASTD, 2009, Baudron et al., 2015). The field work of the present investigation took place in the fall of 2016, 12 years after the "Tigray Project", a major landscape restoration program, started to rehabilitate the degraded landscape (UNDP, 2013).

Image 1: Satellite image showing the approximate location of the case farms (Maps, 2017)

2.2 Methodology

The endowments and livelihood strategies of ten households were studied that represented the dichotomy between food security and food insecurity within the landscape. A multiple case study was used wherein each household was considered as a unique case not representing anything other than itself, but rather as a separate entity that is formed by and contributes to the environment and the community that it is a part of. In addition to the ten households that were studied, the researcher witnessed daily life as a resident at the village chairman's household for the ten-week period of the fieldwork. The case study utilized the sustainable livelihoods framework (SLF) to guide the collection of qualitative data of each households' capacity for strengthening their resilience. The framework, as shown in fig. 1, is an adaptation of the model that Adato and Meinzen-Dick (2002) used for studying new agricultural technologies' efficacy at improving livelihoods of subsistence farmers. However, instead of studying one specific intervention or technology, this study regarded the transformation of the landscape in its entirety as the intervention under investigation. The primary level of enquiry was the household, and data collected on each household's unique endowments and livelihood strategies provided the perspective of the individuals who are striving to make a living, while simultaneously situating them in the greater context of the changing agroecosystem; as entities that are competing and cooperating for access to vital resources. The literal replication of findings between similar cases, and the theoretical replication between similar and contrasting cases provided compelling support for valid and reliable conclusions about factors that limit household resilience. By describing and analyzing such observed interrelationships and through analytical generalization to literature on the emerging themes, the study learned of the level of resilience, opportunities to decrease limiting factors and support contributing factors, and the implications of the newly gained insight beyond the case(s) (Yin, 2013). The prominent themes that emerged from the analysis above were viewed through the lenses of landscape restoration, government and institutional support, and culture. In this way, the SLF narrowed the focus to the contributions and shortcomings that changes beyond the villagers' control had on their resilience. Furthermore, the framework provided structure to the exploration of the ways that interconnected political, socio-economic, cultural and physical externalities influence households' livelihood strategies, which, when combined with individual actions, enabled a generalization of the landscape's overall level of resilience.

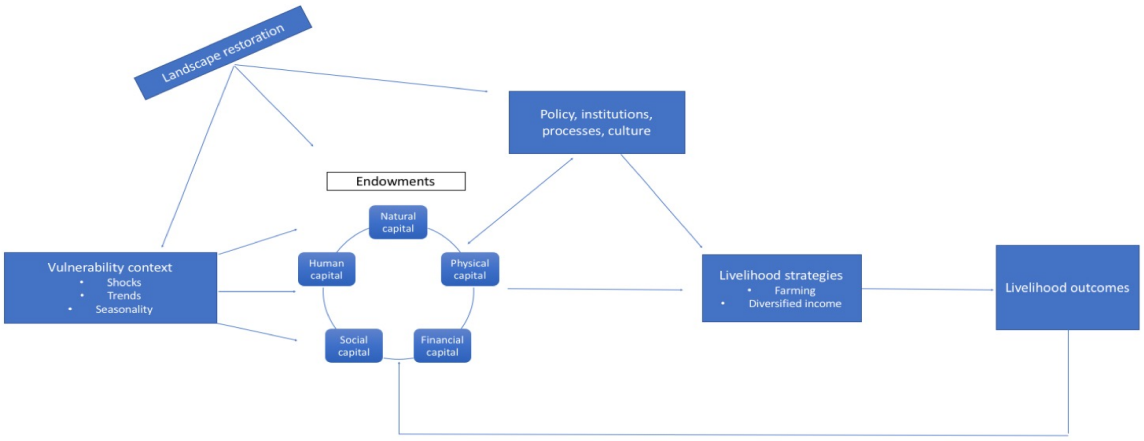

Figure 1: The Sustainable livelihood framework: Endowments; Human capital (labour, skills and experience), Natural capital (Land, water, ecosystem services), Physical capital (wells, water pumps, electricity), Social capital (communal labour, trust groups), Financial capital (livestock, savings, credit.

2.3 Methods

Multiple sources of evidence were used in the data collection process to enable converging lines of inquiry, thus increasing the accuracy and construct validity of the study. As the study was of a contemporary agroecosystem, emphasis was placed on collecting data that reflected the present-day situation, as opposed to archival records and historic documents. For the household level of enquiry, the researcher attempted to collect data that reflected the amount of access that each household had to its endowments, as well as the endowments' size and quality relative to one another. The different forms of capital used by the SLF structured the enquiry to ensure that data was collected on all the primary endowments that influence resilience (fig.1). As for data on livelihood strategies, the enquiry focused on the priorities of the households, their farming practices, and their sources of income. The primary methods used for collecting the household-data was semi-structured interviews and observation (participant and casual). Landscape, or contextual data on external influences collected by an open-minded and subjective integration in the community, and through key-informant interviews, informal conversations and casual observations of as much of the villagers' daily interactions as possible. The case study protocol[1] delimited the goals of data collection and

[1] Section 1 of appendix

defined the daily and weekly operational procedures, to serve as a blueprint of the study so that others could return to the landscape and conduct the methodology themselves, to test its reliability. The following methods were selected based on their potential efficacy of providing information that would answer the study's research questions.

2.3.1 Semi-structured interviews

Before each of three rounds of interviews with the ten households that constituted the case study, an interview guide was developed and then adapted for each individual household. This guide ensured that sufficient data was collected on identified themes, but also allowed flexibility for the interviewer to delve deeper into certain topics or explore emerging themes, based on the interviewees' answers. The translated answers were written down directly, and the researcher noted the non-verbal communication of the interviewee while they were answering questions in their language. The interviews were recorded and later played back to check for, and amend inconsistencies that occurred during the initial capturing. The first round focused on framing an objective view of the basic endowments that each household owned, or had access to. Questions were designed to collect data regarding household economy, enterprise diversity, farming practices, and farmers' outlook for the future. The 2nd round of interviews focused on clarifying inconsistencies of answers from the first round, and on further questioning regarding themes from the first round. The final round of questioning delved deeper into themes that was identified upon reflection of the data up to that point, and included topics such as labour, composting, apiculture, but also enquiries into personal opinions and struggles. The interviewer was mindful of opportunities to supplement the line of questioning with open-ended questions, and the tone of the interviews were always conversational. Finally, a round of open-ended interviews were conducted with key informants (agricultural researchers and specialists at the University of Mekelle) to triangulate and supplement the data collected in the field. The results of the interviews were analysed by applying the data to a conceptual logic model, in the form of the SLF in fig.1, that tracked the sequence of events that lead to the livelihood creation of each household. The models were then compared with one another using a "most similar" approach to identify only the significant differences among the similar, or comparable households, which was then used to explain the affect that external forces and the landscape restoration efforts had on households' endowments and livelihood strategies.

2.3.2 Participant observation

As a resident in the village, the researcher immersed himself in the daily livelihood creation of the villagers by working on farms, participating in village life, and by attending formal and casual social events. The researcher endeavoured to utilise all opportunities to observe phenomena relatable to the main themes of enquiry as outlined by the SLF and mentioned above, as well as themes that emerged upon reflection of collected data. In this way, the researcher directly observed the villagers livelihood strategies in action, information that would be otherwise inaccessible to direct quantitative investigation (Checkland, 1999, Yin, 2013). Although the village chairman's household was not treated as a case farm and interviews were not conducted, observation of the endowments and livelihood strategies of the richest farmer in the village was made possible, to create a yardstick to compare other households to. Each case study farm was visited at least once a week to participate in daily livelihood activities, and to make participant-observations. During these visits and whilst performing interviews, observations were made of the general state of the household's infrastructure, the extent of physical capital, the condition of livestock, the tools used for cooking and the ways that biomass was handled and stored. In addition, transect walks of the entire landscape was performed on a rotational basis, as well as walks to neighbouring villages to collect direct observational data regarding livelihood strategies/farming practices of the region in general. Furthermore, daily, informal interactions with the community members led to the establishment of relationships of trust that allowed for collection of anecdotes that might otherwise have been missed by structured questioning. Interactions with the local inhabitants were approached with an interested and open-minded demeanour, which in one example allowed for a friendly relationship to develop between the researcher and Daniel Berhe, the operational manager of the province's only abattoir. A visit to the abattoir and casual conversations with Daniel provided insight into the region's meat industry, that was not anticipated in the original planning of the fieldwork. The observational data was documented as a combination of field notes and photographs, which were organized under major themes, before data analysis started. Photography, and the search for pictures that illustrate the research findings, aided the investigation by forcing the researcher to apply observation to all scales, from the macro to the landscape scale. Photographs were used during the dissemination of data to refresh the researcher's memory of the place, but was also added to this document to connect the reader to that precise moment in time. The data

contained in field notes were analyzed in the logic models mentioned above, and mainly constituted the data on the vulnerability context and the externalities that influence livelihood creation in the landscape.

2.4 Conceptual framework

2.4.1 Resilience

The term resilience describes a system with the capacity to absorb and cope with major shocks while maintaining function, that includes the ability to adapt and re-organize in order to actively shape further change (Adger, 2006, Masten, 2007, Folke, 2006). The system in this case, can be either the household or the entire agro-ecosystem (Berkes, 2007). A resilient household is regarded as one that can maintain positive livelihood outcomes (food, income, health) despite sudden shocks to its political, physical, economic or cultural externalities. As such, a household's endowments are their resilience resources, and their livelihood strategies are how they use them to cope with, and adapt to the shocks (Yaro, 2004). Furthermore, resilience is also associated with the household's adaptive capacity in response to changes to the externalities that occur gradually over longer periods of time, like warming average temperatures, or rising population pressure. Overall resilience on the landscape scale, refers to the collective capacity of all households to deal with and recover from sudden shocks and gradual change, and includes the contribution to resilience made by the policies and institutions of the place.

Resilience research is closely associated with vulnerability research, with many elements of each being shared with one another. Vulnerability refers to the state of sensitivity to harm caused by changes to the physical and social externalities, due to the absence of the capacity to adapt. (Adger, 2006). As opposed to a resilient household, a vulnerable household is not able to absorb the stress brought about by the sudden change (drought, for example), through spreading it around the different endowments and therefore having some capacity intact to recover once the sudden change has passed. The primary focus of this study is to find ways to increase resilience, instead of describing the state of vulnerability. As such, there are occasions where factors that cause fluctuations in vulnerability are rather regarded and discussed in terms of factors that limit or contribute to resilience.

2.4.2 Transformation

Transformation is a fundamental change to the structure of a social system, or subsystem, and more specifically, the overall dismantling and redesign of the components of the system that lead to increased risk and vulnerability of the population (Wamsler and Brink, 2015). Lately, the term is widely used to describe efforts aimed at enabling people to cope with climate stressors, using rhetoric with terms such as ‘reduce vulnerability’ and ‘improve livelihoods’ (Orlove, 2009, Lemos et al., 2007, Agrawal, 2010). Transformation is distinctly different to the concept of adaptation, which is criticized for its tendency to fail to address the root causes of vulnerability, and thus reinforces the same risks (Wamsler and Brink, 2015). Instead of adapting to the current situation through some creative solution or technology, transformation aims for the redesign of whole parts of the system.

Transformation takes place within three spheres of influence; the practical, political, and personal spheres. Within the practical sphere, infrastructure and technologies are transformed (biogas, renewable electricity, the internet), while the political sphere is where changes are made to power structures that govern groups and individuals in society (Kebele chairman, extension agents, regional and state governance, geographical location). In the personal sphere, changes are made to the belief systems and cultural norms and traditions of people (ploughing, cooking on fire, not composting). For transformation to be optimally successful, change needs to manifest within the root systems of all these spheres. Adjustments to root causes in a system through bold transformation in the personal and practical spheres, can create enough momentum and influence so that positive change also manifests in the political sphere.

3. Results

3.1 Homogeneous characteristics of the cases

3.1.1 Livelihood strategies

Farmers in Abreha we Atsbeha practice integrated crop–livestock farming with staple grains and cattle as the main features of the system (field notes, 2016). A multi-cropping strategy is used to cultivate grains such as wheat, maize, finger millet, sorghum, and *Eragrostis teff (E. teff)*. Historically, land was left fallow to allow for natural rejuvenation, but this does not happen anymore, as "they cannot afford to plant nothing" (case interviews, 2016). Mineral fertilizer is the primary input of nutrients and is delivered to the village by the regional government's agricultural extension service, along with herbicides, pesticides, and improved seed varieties. All the households bought the hybrid wheat seeds every season, while seed saving and trading is common practice. Farmers favor the cultivation of crops such as *E. teff* for its high market value, or finger-millet for its high yield bulk, but lately also factor in the utility of a crop's residue as a fuel and fodder source (field notes, 2016). The farmers aim to maintain or grow their livestock herds, as the animals provide food, financial security, draft power, and manure for burning and, to some extent, soil amendment (field notes, 2016). Oxen provide draft power during ploughing and threshing processes and donkeys are used for transport. Out of the ten case farms, nine farmers stated that the ox was their most valuable animal, the exception being a female farmer who mentioned the cow because it provides milk (case interviews, 2016). In accordance with the community bylaw that prevents free grazing of livestock, animals are tethered near the homestead during all hours of the day, except when they are taken to get watered. Occasionally, the herds would feed opportunistically on crops and roadside vegetation as they are corralled through the landscape. At the homestead, they are fed grass, crop residue and the leftovers from the *sua* [2]making process, and during times of drought, cactus leaves are used to increase the bulk of the available feed (case interviews, 2016). During the rainfall season, households are allowed to graze their oxen on a communal area of grassland in the center of the landscape.

[2] Local alcoholic drink made from a mixture of grains, such as *E. teff* and sorghum, bread and crushed *Rhamnus prinoides* (Shiny-leafed Buckthorn) leaves.

Despite initiatives by the regional government to disseminate the making and using of compost, this nutrient cycling technique has not been adopted by farmers in Abreha we Atsbeha. Instead, the farmers prioritize the use of manure as fuel for cooking fires, and keep unmanaged heaps of organic material. The farmers of the studied households knew about compost to the extent that they referred to unturned and exposed manure heaps as compost. Household-1' male said that he had problems with termites on his crops when he used organic fertilizer, which is likely because the heap did not reach the peak temperature period, while all but one of the other case farmers stated that they never turned or watered their compost (case interviews, 2016; key-informant interviews). Some manure is dried and used as a fuel source and the remainder is kept on a heap near their homesteads that consisted of dried manure and small amounts of organic material such kitchen scraps, ash, and the leftover straw from the animals' housing (img.2). The heaps were unturned and exposed to sun and wind. Some of the case farmers seemed ashamed when asked about their composting practices, and were reluctant to show their heaps to the researcher (field notes, 2016). Despite most of the case farmers stating that their crops yielded more when they use organic fertilizer, especially during dry years, the main input of nutrients on all the case farms is through the application of mineral fertilizer.

Image 2: Examples of unmanaged heaps of biomass, or "compost"

3.1.2 Endowments

Access to most endowments in the landscape are homogeneous among all households. The physical endowments, like the roads, school, mill, and market are similar for all, while the natural endowments such as ecosystem services and the climate are also mostly the same across the landscape. There were no perceivable differences between social endowments such as family groups, neighborly help, or participation in landscape restoration efforts. For instance, it is the law that community members must give twenty days of their labor to the landscape restoration's building projects, and households throughout the landscape were observed to have supporting groups of family and neighbors that lived in their vicinity who helped one another with harvesting and threshing tasks. As for human endowments, these were similar in terms of the knowledge regarding farming practices that had been passed down the generations and had been performed according to traditions and customs engrained in the culture.

3.2 Heterogeneous characteristics of the cases

3.2.1 Livelihood strategies

Despite the partial restoration of the landscape's agroecosystem, there are still households who do not produce enough food to meet their family's annual nutritional demands. Food secure farmers stated that they produced enough grain crops during a year to sell a surplus in the market after feeding their families (case interviews, 2016). Households with high crop productivity further benefited from having more crop residue to feed to their livestock. Although all the studied households paid for extra fodder, the food insecure farmers with less livestock, bought more fodder than the food secure households. In addition, the food secure households had diversified their farming enterprises beyond the customary crops and livestock, and cultivated fruit orchards and/or practiced apiculture. The necessity for income to pay for household expenses[3] meant that food insecure households, or households with low on-farm productivity, sold a greater part of their crop production in the market, despite not having enough food to feed their family. The food insecure households resorted to different strategies to compensate for the lack of sufficient crop yield: food aid, the cultivation of home

[3] Clothes, soap, coffee, sugar, oil, medicine, transport, school fees, etc.

gardens of tomato, chili, grapes and pumpkin for household consumption, and off-farm labor such as masonry and agricultural work for income to buy food. Certain food secure households stood out for employing livelihood strategies that diversified their income streams: Households 4 and 6 cultivated fruit trees, household 10 invested in a water pump to enable the cultivation of cash crops in the dry season and household 5 kept modern bee hives to produce honey. With her 5 modern bee hives, the farmer generated approximately 10 000birr/year (US$370), which is more than the total annual expenses of food insecure-household 7. The initial investment for the hive and the colony is 4000-5000birr (~US$146-182), after which further inputs are low relative to other farming enterprises in the landscape. The only labor requirement is to monitor and clean the inside of the hives, additional input is limited to the occasional sugar syrup supplement when there is not enough natural pollinating flora. A strong demand for honey in urban Ethiopia, where city goers pay 350birr/kg (~US$13/kg) means that farmers can sell their honey at 250birr/kg (~US$9/kg). The other households of the study said that they did not keep bees because their homestead was not in a suitable location in terms of water, pollinating flora or predators (wasps, birds etc). Some farmers said that they kept bees before, but that the colony absconded after the first season. It seems that the most likely cause for colonies absconding is due to ineffective hive management (key-informant interviews, 2016). These brief and shallow distinctions between the two groups show the varying livelihood strategies that households on opposing sides of the food insecure–food secure scale utilize to create a livelihood out of the capital that they have access to.

Some households had biogas digesters, but many of the installations were in disuse (img.3). The case farmers' reasons given for not using the technology were that they did "not have enough material to put in", "a flood destroyed it" and "the flame is too weak to make *injera*" (field notes, 2016).

Image 3: Biogas installations in disuse. Note the photo on the right; manure is being dried on top of the digester.

3.2.2 Endowments

3.2.2.1 Access to labor

Both farming and household tasks in Abreha we Atsbeha are done manually and all family members participate to some degree. Household 7, in the food insecure group, had nine members of which two were adults and seven children, as opposed to household 3, in the food secure group, that had six members of which four adults and two children. Although the children on household-7 helped with household tasks such as cooking, cleaning and caring for their siblings, the mother had to take near continuous care of consecutive infants over the last ten years. In contrast, household-3 with their four adults, could afford to let their adult son take the sheep herd to an adjacent valley every day, where the zero-grazing rule did not apply. Thus, the number of able-bodied adults in the household gave household-3 access to fodder resources and nutrient input that household-7 did not have access to. The 83-year male head of household-4 said that farming tasks were becoming too demanding on him and his wife's bodies, and that they were now forced to rent day laborers at 100birr/day (US$4) to perform the tasks that they could do themselves only a few years ago. An elderly widow who was not part of the case study said that she could not perform farming tasks anymore, and had to rent out her field and receive 30% of the harvest (field notes, 2016). Household-1 and household-10's males are in their 40's and are occupied with farming tasks during most of the daylight hours; their mobility and workload stand in stark contrast to that of the elderly members of

household-4. Both men and women contribute to the household's labor, but some of the society's traditions and customs dictate the gender specialization of certain tasks. In addition to daily household tasks that only women perform, like cooking, cleaning, serving meals, performing coffee ceremonies, and caring for children, women also assist the men to raise animals, plough fields, plant, weed, harvest, store, thresh and sell crops at the market (img.4). Furthermore, the local custom decrees that only men may plough, so in cases where wives had been widowed, or had sick or absent husbands, the women must pay for a (male) day laborer to plough their fields.

Image 4: The entire household contributing their labor to the maize harvest

3.2.2.2 Access to land

Farmers with access to land cultivate crops that provide food for their families and livestock, while surplus crop production is sold in the local market for cash. Factors that influence the production potential of land are size, location, and the nature of ownership. Household-9, of the food insecure group, located on the Rocky Hill, was the only household in the case study that did not own land, so the farmer was forced to rent land to cultivate crops. The rate for renting land is half of the harvest. Similarly, household-4 owns more land than they are capable of cultivating, so they could rent out a field and passively receive 50% of another farmer's harvest. The male head of household-1, of the food secure group, took out a loan to buy land in the Church Valley, that was allocated to him by the local council in 2010, as he

had no parents to inherit from. Before that, his best livelihood option was to work as a day laborer, but since purchasing the land he can provide for his family without having to rely on food aid. Furthermore, land-owning farmers can cultivate cacti on field margins to harvest as supplement feed for their livestock during periods of drought, or when crop reduction had been low (field notes, 2016). Most households own at least some land, but the size of the fields varies from one household to the next. Bigger fields require more input, yet if the harvest is successful the household gain a greater volume of food, surplus grain to sell in the market and crop residue to use as fodder. The food insecure group had smaller fields and had owned their property for shorter times than the rich farms. All the households in the food secure group had been owned by the respective families since 1974, when the Coordinating Committee of the Armed Forces, Police and Territorial Army (DERG) overthrew the emperor Haile Selassie and redistributed land among the people (field notes, 2016). These original farms were characterized by having fields adjacent to the homestead, as opposed to households-8 and 9 on the Rocky Hill, who had to walk ~2,5km to their nearest field, or did not own any fields, respectively. Moreover, the location of the farm is directly linked to access to groundwater. A strong stream flows from a spring halfway up the hillside in the mountain valley; there the farms located closest to the source have access to a steady flow of water as late as February, 6 months after the last rains (personal communication, 2017). The spring's water is diverted to fields, orchards and concrete holding dams via a system of trenches dug into the earth that connects to a main concrete spillway from the source via rudimentary water gates, that was constructed as part of the landscape rehabilitation project (img.5). Households located near this stream have free access to a vital natural resource, an endowment that most other farmers do not have. Other households have access to wells or to fields next to the river, but most of the villagers must rely on the annual rains to irrigate their crops. A few individuals have land next to the Suluh river that forms the Western boundary of the landscape, which they either cultivate and irrigate themselves, or rent out to get 50% of a valuable dry season harvest (field notes, 2016*).* An example of the value of land next to the river is the case of household 10, who took the risk of borrowing money for a water pump so that they can rent a field next to the river and gain access to 50% of dry season harvest of chili and tomato (img.6).

Image 5: The spillway that leads water from a spring down to the households in the Mountain Valley. Note the rudimentary water gate of stones that divert water to the shallow trench to the right.

3.2.2.3 Access to water for dry season irrigation

The farmers of Abreha we Atsbeha rely primarily on a short summer rainfall season (*kremit,* in the local vernacular) from June to September for irrigation, unless they have access to groundwater for irrigation during the rest of the year. The groundwater in Abreha we Atsbeha has risen over the last decade because of the landscape restoration program; springs have started to flow again and villagers are able to dig wells by hand to access the shallow water table (case interviews, 2016). The inconsistent and sporadic nature of the rainfall in the high plateau topography cause spatial variation in the amount of rain that falls on different farms (field notes, 2016). This sporadic rainfall sometimes result in the failure of individual households' harvest, despite a generally good rainy season. Farmers who have access to groundwater for irrigation prevent crop failure due to lack of rain, and have the opportunity for a second harvest during the dry season. Those who did have regular access to groundwater irrigated cash crops like potato, tomato, chili and maize during the dry season and fruit orchards with high water requirements throughout the year. The infrastructure development that is a part of the landscape project is helping some farmers adapt, such as the spillway built

on the Eastern side[4] of the Suluh river (img.7). Farmers on land adjacent to the spillway can irrigate their lands without the use of a water pump, by controlling the flow of river-water onto their land by opening and closing a rudimentary water gate (field notes, 2016). As such, the value of these fields increased due to the labor of the community members, or in other words, the land-endowment's quality improved due its relationship with social capital. Farmers without access to river water, could still access the groundwater if they had a well or catchment dam close to their fields, as was the case with the four richest farms of the case study. Abu Hawi, the *kebele* chairman, and richest farmer in the community, has a well in the middle of his compound with which he irrigates his fruit trees every morning (field notes, 2016). Household-5, located near the bottom of the Mountain Valley, has a concrete dam that enables the farmer to plant guava, mango and banana trees. When frankly asked what she wanted for the future, she answered, "a bigger well", illustrating the value she places on having access to groundwater. Household-4, the 83-year elderly man and his family, generates additional income from a mature orchard of guava, mango and papaya that they irrigate with a water pump from a deep shaded well. This is not so labor demanding for them, as the water is pumped out with a diesel pump onto the orchard adjacent to the well. The family's granddaughter sells the produce for them in the local market. Household-1 (food secure), with access to a well on one of their fields, combined that physical endowment (the well) with a social endowment in the form of a neighbor with a water pump to cultivate cash crops in the dry season. Interestingly, this household's other characteristics are comparable to the food insecure farms (one of the newer farms, 4 children, no fruit trees or bees), yet he proudly stated that he never relies on food aid. The areas with most wells or collection ponds is also the area where most of the original farms are located; the Mountain and the Church valley, while newer farms on the Rocky Hill had no access to the groundwater (img.1).

[4] the land on the eastern side of the river forms part of Abreha we Atsbeha, and falls under Abu Hawi's control

Image 6: Household-10's rented field of chili under irrigation on the left. On the right the farmer is transporting his water-pump back to the homestead.

3.2.2.4 Access to effective guided knowledge

Information about agricultural practices and strategies reach Abreha we Atsbeha through local television and radio broadcasts, extension agents, and university projects, resulting in a community with varying degrees of access to knowledge. All households cannot participate in university or research projects, and not all farmers have televisions or radios. In addition, more complex factors further contribute to the efficacy with which specific information reach their intended targets. As such, the influence that effective knowledge transfer has on resilience is illuminated by the examples of cases where focused information did manifest itself appropriately. Household-5 generated approximately 10 000birr (~US$370) annually by selling honey, which was only possible because the colonies did not abscond as they effectively managed the five modern beehives over the last six years. Likewise, household-10 who rents land next to the river to diversify their income by cultivating cash crops in the dry season, based their decision to risk investing in a water pump on information about irrigation, credit loans and market trends that they got from extension agents and public broadcasting channels (case interviews, 2016).

3.3 Contextual data situating the households within the landscape

3.3.1 The influence of landscape restoration on long-term resilience

The overall resilience of the community strengthened during the last two decades as the physical and natural endowments of the landscape improved due to the ongoing landscape restoration efforts; the water table rose, and biomass and biodiversity increased. At the project's inception in the village, the leadership prioritized the restoration of the hydrological system, and efforts focused on the construction of water-conservation infrastructure and community bylaws were set in place to restrict the destruction of hill-side vegetation. These improvements made it possible for farmers to diversify their farming enterprises and add to their income sources. The raised water table, in conjunction with the construction of strategically located dams and spillways, provided farmers access to water for their livestock deeper into the dry season (img.7). Others accessed the groundwater by investing in pumps to irrigate dry-season cash crops with good market prices due to low general supply. The greater volume of water and biodiversity throughout the landscape strengthened resilience by enabling alternative income streams such as apiculture, which is a lucrative livelihood option because of low labor requirement and a high local demand for honey. Historically, farmers in Tigray only kept traditional beehives to produce honey for personal consumption, but in 2016 alone beekeeping farmers in Abreha we Atsbeha harvested 40 tons of honey (field notes, 2016). Moreover, the social capital is further strengthened by the leadership of Abu Hawi, the council chairman, who has the drive and charisma to mobilize and motivate the community to work towards a focused goal. Strong social capital emerged from the restoration efforts and is evident in the systems of trust that the community members have in collective labor and adherence to local bylaws. The zero-grazing bylaw also enables other interventions to be successful, like integrating fodder-trees into the landscape. If it was free grazing, then the planted seedlings would have a higher change of not surviving until adulthood (key-informant interviews, 2016). Most of the studied households believed that the zero-grazing rule was better for their livestock, except for household-7 (food insecure) who means that during dry years when their production is low, their animals struggle, she went on to say that when the animals were free to graze, all households always had enough milk. In addition, all the case farmers spent some of their income on buying extra fodder for their livestock. As such, not

enough extension work has been done in parallel with the landscape restoration (water works) to develop pasture land and improve the quality and availability of forage (key-informant interviews, 2016).

Image 7: Livestock watering in the Suluh river with the spillway leading water to fields out of picture for irrigation. Note the stands of eucalyptus trees planted for soil consolidation of waterways as part of the landscape restoration efforts.

3.3.2 The influence of government and institutional support on resilience

The lowest unit of local government in Ethiopia is the *baito,* (*kebele* in Tigray) that manifests the state's agendas at the landscape level, and makes decisions regarding the allocation of food aid, agricultural inputs and extension services. Because the government of Ethiopia is run by the Ethiopian People's Revolutionary Democratic Front (EPRDF), a coalition in which the Tigrayan People's Liberation Front (TPLF) is a majority member, Tigrayans have enjoyed two decades of favorable support from government programs aimed at improving the livelihood situation in Tigray. However, the political status quo might change in the future as resistance to the current regime has been gaining momentum recently (field notes, 2016). Farmers have access to financial information in the form of market trends and commodity prices that are broadcasted by the state on radio and television (field notes; expert interviews, 2016). Agricultural extension services provide access to information, improved seed varieties,

transport of fertilizer, herbicide and pesticide (case interviews, 2016). Household-10, mentioned above for benefiting from the improved natural endowment (raised water table), could not have accessed it without the support that he received from the government institutions that were designed to increase agricultural production; a micro-loan from a financial institution to purchase a water pump and knowledge regarding irrigation and agricultural input from the extension services. In addition, foreign investment and non-governmental organizations (NGO's) contribute to the households' endowments by installing infrastructure and providing food aid (img.8). For example, a South Korean NGO started construction in December 2016 to extend the school (physical capita) to include grades 10-12, which means that families no longer need to pay to send their children to boarding schools in the regional towns and cities, which eliminates an expense (financial capital) and increase the labor power (human capital), as the children can still perform farming tasks when not at school (field notes, 2016). Furthermore, scientific interest in the region's adaptive strategies, like the climate smart agriculture project in the Horn of Africa that partly funded this research, provide insights to their progress and adaptive capacity through experimentation, knowledge and financial assistance.

Adaptation projects and interventions that are well-intended sometimes fail to have the desired effects, or reach the target demographic that they were designed for. A Mekelle University project with the goal of teaching good composting practices often encountered ineffective knowledge flow when villages sent representatives to participate in a compost workshop, as they often sent the farmer in the village with the most experience and success with composting, so that the honor of the community he/she comes from is maintained, instead of sending those in need of new knowledge. Furthermore, the research team was eager to return to the study site to monitor progress and provide specific feedback, but they did not receive grants to continue the study. Despite the provincial government's goal to increase apiculture (key-informant interview, 2016), a general reason given by the farmers for not keeping bees is that the colony abandoned the hive because the farm's location is not suited for bees. However, experiences in Tigray have shown that limited access to basic information on good hive maintenance is the reason for colonies absconding (key-informant interviews, 2016). Finally, the national government's strategy for alleviating poverty in rural Ethiopia includes the use of mineral fertilizer, pesticides, herbicides and new crop varieties to increase yields, and to achieve this, extension agents are incentivized to optimize its dissemination.

Image 8: The bulk of food aid, in the form of wheat and vegetable oil, show how far the community is from sustaining themselves entirely from the landscape.

3.3.3 The influence of culture on overall resilience

The farming practices, and thus livelihood strategies in Abreha we Atsbeha are based on traditions and customs that are embedded in the peoples' belief systems. The patriarchal society give men the power to make the final decisions regarding how the endowments are combined to create a livelihood, especially regarding how the household's income is spent. The male lead of household-3 could rent out the field next to his well as he cannot meet the labor requirement of cultivating it, but refuses to do so because the farmer who wants to rent it wants to use the water in his well to irrigate the field (case interviews, 2016). His wife, in casual conversation when her husband was not present, said that she would rent it out if the decision was hers (field notes, 2016). An unwritten rule of the culture dictates that only men may plough the fields and women who do, run the risk of being shunned out of the community. The Tigrayans have a very strong custom of ploughing their fields multiple times before planting. and the farmers in Abreha we Atsbeha traditionally plough their fields six times for *E. teff*, and three times for other cereal crops (field notes, 2016). The use of oxen for ploughing means that oxen are kept for as long as they can provide draft power, before they are sold cheaply on the meat market as old animals with low condition (key-informant interviews, 2016; field notes, 2016). An interview question that asked about the possibility of not ploughing was received with great skepticism and the idea was deemed ludicrous (field notes, 2016).

Moreover, Tigray has a favorable geographical location with access to an established international market for beef and mutton products. The demand for meat from China and countries on the Arabic peninsula and in northern Africa are increasing as their populations expand and their economies grow (field notes, 2016). The Chinese market that the abattoir in Mekelle is already exporting to, recently also started to demand the genital of the animals (field notes, 2016). This market place exists on the proverbial doorstep of the farmers who are currently managing the endowment of livestock in line with their culture, not in a way that is optimized for livestock fattening and profit optimization. The infrastructure to access these markets exist; local buyers purchase animals from the farmers and walk them to Wukro (from up to 50km away) where they are sold and transported to the region's abattoir in Mekelle. Here, the animals are slaughtered, after which both fresh and frozen carcasses are transported by truck to Addis Ababa and the port of Djibouti, from where they are shipped to foreign buyers who are eager to pay more for animals in a better condition than those they are currently receiving from Tigray (personal conversation, 2016). However, in Tigray's crop—livestock farming culture, the conditioning of cattle is not prioritized, as oxen are first and foremost used for their draft power. Livestock's conditioning is further limited by the custom that prioritizes quantity over quality, or conditioning of animals. Farmers keep as many heads of animals as possible, for financial security and social status, rather than optimizing resource use to have less animals in the best possible condition (key-informant interviews, 2016). Finally, the custom of using fire to cook *injera* with nearly every meal creates competition for biomass-resources, that limit the return of biomass to the soil (fig.9).

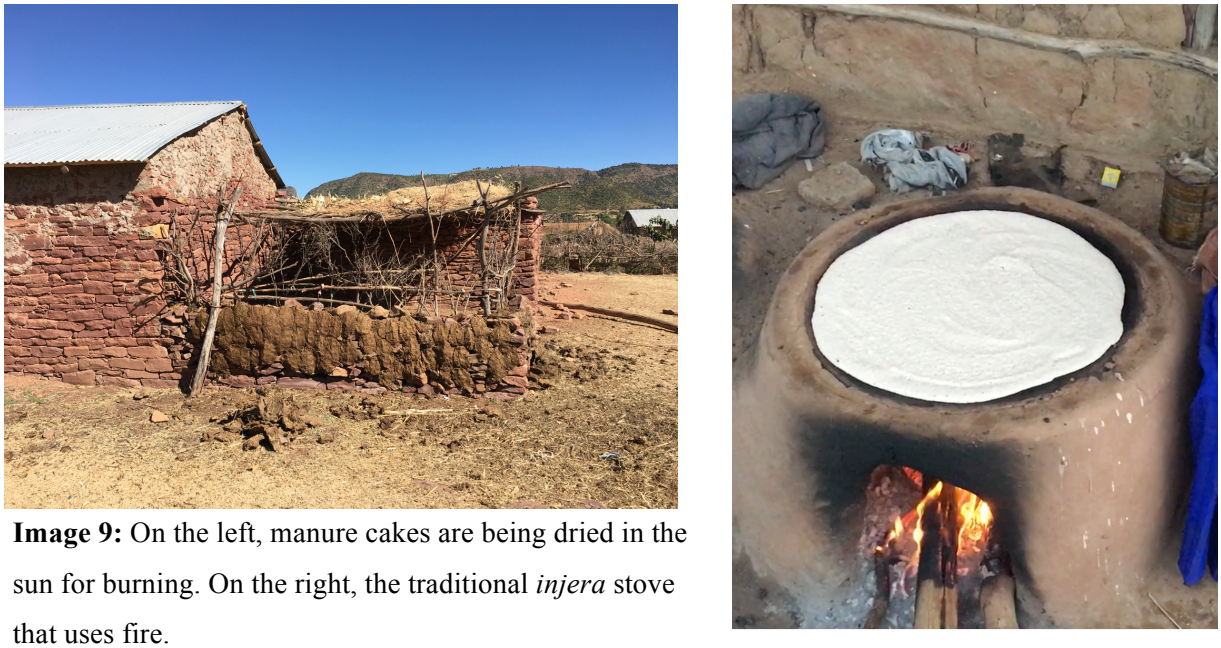

Image 9: On the left, manure cakes are being dried in the sun for burning. On the right, the traditional *injera* stove that uses fire.

4. Analysis

4.1 Sustainable Livelihood Analysis

4.1.1 Factors that limit resilience for some more than others (contrasts)

4.1.1.1 Land and water

The value of owning land in a subsistence farming society is illustrated by the example of the household who does not own any. Household-9 in this case, gets half of the production that the other households get from the same area of land, but for the same amount of labor and other inputs. It comes as little surprise then, that this household chronically relies on food aid to meet the family's caloric requirements. Among those who own land, factors such as size, the age and location of the farm further influence its value and utility. The relationship between the location of a household's fields and access to groundwater has a significant effect on the household's resilience. The households on the mountain valley with access to the spring water, or households who own fields next to the river, can generate income from a dry-season harvest, or from a permanent fruit orchard, something that the households who rely only on rain had no access to. The significance of this difference might place stress on the community in the future if climate change causes the amount of rainfall in the area to decrease, or if rainfall becomes more erratic. The bigger a household's total land area is, the more crops they can produce on it. A large volume of produce increases the households' resilience in three ways; more food for household consumption, more income from selling the surplus in the market, and more crop residue to feed to their livestock. In the rare case that a household does not have access to all the inputs demanded by their large field size, like household-4 whose owners are too old to meet the labor requirements, they can rent out a field to a landless farmer and passively receive 50% of that land's produce. Finally, owners of land have more space to plant fodder trees and cacti, a source of fodder that increases the resilience of their livestock herds during periods of drought or low productivity.

4.1.1.2 Labor

The contrasts between the labor forces of the study's households illustrate how factors such as age, gender and family size, combine to influence its potency. The family demographic of household-3, that has 4 adults, allow them the opportunity, by their personal capacity to adapt to changes in the community level governance, to access livestock fodder that is not available to households with only two adults. Old-age affects resilience as farming tasks become too taxing on the individual's bodies, like when household-4 had to part with some of their saving to rent a laborer when the male lead was too ill to work. When a female farmer is pregnant or breastfeeding, her mobility and personal labor contribution is reduced, and the toddlers who require care and attention further limits her labor availability for farming practices. Thus, labor is a vital component of the farming system, and lack of access to labor has a limiting effect on a households' resilience.

4.1.1.3 Diversified income streams

The more endowments a household has access to, the more opportunities they have, to grow those endowments and create a livelihood that strengthens their resilience. The households with diversified sources of income, such as fruit trees and honey, generate an income that can be saved for times of stress or invested to further strengthen their existing endowments. Households-3 and -6, with their relatively big livestock herds can sell animals to create financial flexibility during times of stress. Furthermore, available financial capital makes it possible to negate risk by paying for climate insurance, while poor farmers are less likely to afford climate insurance, and are skeptical of investment in general out of fear for overall poverty should it fail. Thus, achievements with restoring general ecosystem services does not rule out the vulnerability of those that have the least access to, or the lowest quality endowments. Attempts to strengthen overall resilience should not overlook the importance of striving for equity in the society through providing the fragile and the poor with means to cope with inevitable mishaps, such as access to insurance schemes or social contracts that compensate for losses.

4.1.2 Factors that affect resilience for both groups (similarities)

4.1.2.1 Household livelihood strategies supporting resilience

In Abreha we Atsbeha certain livelihood strategies are practiced by all the households to the extent that they have become unanimous features of the landscape. Each strategy contributes to the households' overall resilience, albeit some more than others. The general practice of multi-cropping with several different grain species, integrated with livestock, spreads the risk of pests or disease causing the failure of entire season's harvest. The practice of saving seed preserves the genetic resources of the local crop varieties, and the selection of the best seeds from the strongest plants ensures the crops' natural adaptation to incremental changes or slow trends in the climate. The planting of cacti serves as a multi-functional element on the farms, as it consolidates soil, protects crops from grazing by passing animals, and it provides emergency fodder during desperate times, such as droughts. In a semi-arid landscape, access to an emergency fodder supplement such as cacti, might just be the difference between an animal dying or surviving until the next rains come. Lastly, the application of mineral fertilizer is an effective short-term strategy for augmenting available soil nutrients to optimize crop production.

4.1.2.2 Household livelihood strategies limiting resilience

As mentioned above, land is possibly the most important endowment that a subsistence farmer owns, and if that land's soil is eroded away and the nutrients are mined out of it, the farmer's resilience reduces because he/she can no longer provide for their families without having to pay for external inputs. Plots have become smaller as they have been subdivided and redistributed onto a growing population. The continuous cultivation of a field depletes the soil of nitrogen which eventually results in a dependence on mineral fertilizer. If fields could be left fallow, or even better, be planted with a nitrogen-fixing (cover) crop, soil erosion would be restricted and the nitrogen content of the soil would improve. However, farmers that live so close to the line between food security and food insecurity cannot afford to miss out on a season's harvest. This is an important issue for African landscapes, as the growing population will remain a constant threat to their vulnerability context. Nutrient mining would be less of an issue if as much as possible of the organic matter that the soil produced, was

returned to it. Unfortunately, the opposite is true in Abreha we Atsbeha, where most of the manure is dried, and burnt as a fuel source for cooking fires. All the households, including those with electricity and that of the chairman of the village who has a working biogas burner, made fire to cook *injera* almost every day, sometimes more than once a day. As the cutting down of trees and woody shrubs for firewood is restricted by a community bylaw, the women sometimes use charcoal and firewood that they buy from further afield, dead sticks and branches, crop residue, and dried manure to fuel their fires. Although the ash from the fires is returned to the soil, most of the organic matter and nutrients leave the farming system.

4.1.2.3 Household endowments factors that strengthen resilience (similarities)

Like the livelihood strategies above that are commonplace throughout the landscape, so too are there shared endowments that further strengthen resilience. The ecosystem services provided by pollinating insects and the presence of pests' natural predators contribute to the crop yield, even though the exact amount is difficult to accurately quantify. The value of community assistance is another factor that is hard to measure, but that is vitally important to the functioning of the farming system. For example, the plough used in Tigray requires two oxen to operate and the threshing process involves oxen and cows walking around in circles on the harvested grains. Thus, a farmer with only one ox is stranded without a good relationship with a neighbor that is willing to lend him/her an ox in exchange for some or the other favor in return. Finally, the farmers' access to mineral fertilizer, herbicide and pesticide, in addition to advice on its application, is a vital contribution to resilience as it closes the gap between actual and potential yield, and provides a means for farmers in a landscape under restoration to turn their farms into virtuous production systems. This strategy also allows for the intensification of land already under cultivation, and in so doing, curbs the need to clear more land for cultivation. However, not all aspects of the extension services in Abreha we Atsbeha contribute to resilience, as will be discussed below.

4.2 The position of the cases relative to the landscape

4.2.1 Landscape restoration's supportive effect on resilience

It is obvious that the level of resilience in Abreha we Atsbeha would not be as positive as it is today if they did not start to rehabilitate their landscape in 2004. The changes lead to a strengthening of resilience, because as households' access to water and ecosystem services improved, the productivity of their land and livestock increased. The inhabitants of the village had to change their traditional practices of animal husbandry, an integral part of their crop—livestock system, and devote their labor (free of charge) to a long-term project with speculated results. In this way, the landscape restoration also enhanced their social capital. For example, despite the households producing much less milk now than when they were grazing freely, the fact that the bylaw is respected and maintained shows that the villagers trust their social system, and that they understand the concept of sacrificing one part of their livelihood for the sake of the greater resilience of the landscape. This presence of this aspect of the social capital might be of value in the future if further bold transformations are undertaken, and is an important factor to consider for other landscapes planning to undertake landscape-scale changes.

4.2.2 Landscape restoration's limiting effect on resilience

Although most of the changes associated with the landscape restoration are positive, there are certain factors that limit further progress towards building resilience. The Tigray project's compost initiative falls short of its target of sustainable resource use when one considers the small amount of biomass that is returned to the soil. Soil with high levels of soil organic carbon (SOC), from manure, crop residue and other biomass will improve the soil's structural stability, water holding capacity, aeration and fertility factors that could be contributing to the value of farmer's important land-resources. Aside from the fact that nutrients and biomass are not returned to the soil, if the price for the main source of nutrient-input is market dependent, the farmers' resilience against market fluctuations decreases. Furthermore, not all the benefits of the landscape restoration are equally distributed, yet everyone must adhere to the rules and provide labor to construction projects. Lastly, the limited development of pasture land and improved quality and availability of forage, in parallel with the zero-grazing rule, directly

affects households' access to food in the form of milk. Knock-on effects have either not been anticipated, or are not given due attention, but other landscapes should be mindful to combine forage/fodder improvements with rules such as zero-grazing. Thus, despite the community's progress with landscape restoration, opportunities exist to further increase resilience in the landscape.

4.2.3 Other externalities that influence resilience

The farmers of Abreha we Atsbeha's limited access to information and education, or human capital, regarding best practices for composting and apiculture is reducing their adaptive capacity. Even though they have access to information from the extension agents that enables more effective livelihood creation, agricultural inputs, fertilizer application rates, improved seed varieties, and planting strategies, there is ample opportunity to further improve the quality of their endowments and strengthen their resilience. Not only does organic fertilizer reduce the need to pay for mineral fertilizer, but it also increases the soil's porosity and water-holding capacity. Thus, access to knowledge and feedback on good compost management is vital in a region where rainfall is scarce, and precipitation patterns are predicted to become more erratic. The current bottle-neck regarding effective distribution of awareness and knowledge on good composting and nutrient cycling practices seems to be the extension agents who focus on mineral fertilizer dissemination. Other landscapes should learn from this and make sure to avoid it during the planning phases of restoration projects, and should instead focus on making nutrient cycling a priority. In Abreha we Atsbeha, alternatives should be explored that attempt to establish an alternative way to disseminate composting skills and create awareness on the importance of nutrient cycling. If successful, the benefits experienced by the early adopters of compost-enriched soils, might cause the intervention to gain enough momentum to affect the desired change on the landscape scale. However, the low adoption rate of composting is not only due to a lack of awareness and training, but also due to a combination of other factors; the labor-intensive nature of composting, the high moisture demand and the competition for biomass as a fuel and fodder resource.

Apiculture training and information from extension services, the local university and NGOs are enabling many farmers to create an alternative income from honey sales, but their scope and resources are not reaching far and wide enough. Those farmers who invested in apiculture based on recommendations from extension agents or evidence from a neighbor's successes,

but whose enterprise failed due to suboptimal hive management, would have benefited from more focused feedback and assistance. The fact that so many farmers tried and failed shows that there are limits to the efficacy with which knowledge reaches its intended targets. Furthermore, limited access to best beekeeping practices prevents farmers from maintaining their bee hives, as incorrectly managed hives lead to colonies absconding, which in turn discourages other farmers from risking the investment. Training on beekeeping has been given and some farmers have become successful beekeepers, but many poor farmers who are striving to diversify their income, require frequent training that includes practical demonstrations and personal feedback.

5. Discussion

As expected, the results of a livelihood analysis confirm existing knowledge in discourses about adaptation, transformation and landscape restoration. The results of the positive effects that water conservation strategies, yield augmentation through chemical inputs, diversified income streams, and access to land and labor have on the farmers' livelihood-outcomes agree with previous studies on the site (Tafere et al., 2013, Wolde-Georgis et al., 2010, Edwards et al., 2012, UNDP, 2013, Lamond, 2012, Barral et al., 2015, Speranza, 2013). Further afield, studies of the restoration of China's Loess Plateau for example, also indicate increases in crop production and ecosystem services resulting from strategies that integrated water and soil conservation, carbon sequestration and yield augmentation of grain production, albeit with a different approach regarding governance (Su and Fu, 2013, Lü et al., 2012). There, the villagers were given ownership of the terraces they built to consolidate the sandy hillsides, in comparison with Abreha we Atsbeha, where the villagers are obliged by law to perform work on hillside terracing. In this way, the continuation of the landscape restoration in Abreha we Atsbeha depends on the stability of the government and their agendas, instead of building social capital that will self-govern the use of local resources and encourage the natural adaptive capacity of the people. The results did not necessarily provide new insight to the mechanics of how factors such as farmers' knowledge, resource use, and access to land and labor restrict resilience (Pretty et al., 2011, Wade et al., 2008, IAASTD, 2008, Morton, 2007, Demeke et al., 2011, Carter and Wiebe, 1990), but was a necessary inclusion to be able to identify the ways that these restrictive effects can be reduced.

5.1 Insights and nuanced examples

5.1.1 Strengthening social capital for adaptive capacity

The results of this study recognizes the mobilizing power that Abu Hawi, the council chairman's charismatic and motivational leadership has on the progress of the physical transformation of the agro-ecosystem, as discussed by Tafere et al. (2013), but goes further to describe the way it creates new social capital in the landscape through establishing structures of trust between the farmers and the collective, and between the collective and its leadership. Farmers learn to support Abu Hawi's ideas when claims that he made about the future effects of long-term investments come to fruition. The farmers' adaptive capacity strengthens as their skepticism to adopt new practices and/or technologies is reduced by their trust in the leader's visions and opinions. However, this is a fragile supportive force, because if his absence is not succeeded by a similar intensity of leadership, a void will be created that causes the landscape restoration efforts to seize or lose potency, or he can lose reverence and support if he backs a strategy that ends up failing. This insight also provides evidence for the importance of convincing the local leadership of the importance of any long-term restoration effort, and involving them in the planning phases of the interventions so that they have a sense of ownership of the strategy.

5.1.2 Interventions that cause unanticipated, resilience-reducing effects in other parts of the system

The results also provide an example of how well-intended changes to one part of a system, or subsystem, can have unanticipated effects elsewhere in the system. "A change in any one input (or, indeed, any part of a system) may affect any other part of the system, including its outputs and its resulting changed needs for other inputs." (Spedding, 1995, cited in Schiere et al., 1999). The zero-grazing rule that improves resilience through contributing to the raised water-table, also causes a decrease in resilience by causing both reduced milk production for household consumption and by forcing farmers to pay for supplement livestock fodder. Similarly, the community bylaw that prevents farmers from cutting down trees for firewood causes the consolidation of soils and an increase in biodiversity, but it also creates a demand for manure and crop residue as fuel sources. Stakeholders working with interventions aimed

at landscape restoration, who are attempting to anticipate such unforeseen effects, could find value in these results when attempting to anticipate changes to other parts of the systems they plan to change. This awareness of the influence that relationships between parts of the system have on one another, and the appreciation that these could change over time, could be used to identify opportunities to utilize internal resources in the system that are currently underutilized. As time passes, this ability to sustainably extract the maximize resources from the landscape will become a vital prerequisite for utilizing the benefit of ecosystem services to create resilience, especially considering the expected doubling of Eastern and Middle Africa's population size by 2050, that is only projected to start declining after 2100 (UN, 2004)

5.1.3 Traditional diet's role in competition for biomass

The study explains the causal relationship between an element of a society's culture, such as a certain part of the diet, and its effect on the community's overall resilience. A root cause of ineffective nutrient cycling in the landscape is the habit of eating *injera,* and because the cheapest, easiest and most reliable way to prepare it is through fire, farmers have formed the habit that prioritizes the use of any biomass they have access to, to fuel the fire. This insight is supported by the fact that even farmers with access to electricity still use fire to cook *injera.* "Culture influences action … by shaping a repertoire or 'tool kit' of habits, skills, and styles from which people construct 'strategies of action'" (Swidler, 1986). Thus, a society's underlying cultural framework, that governs day-to-day actions and decisions, should be included in qualitative investigations and analyses of landscapes in need of change. The influential power of the underlying framework that dictates the actions of the collective, is a factor that could be the cause of unsustainable resource-use, while simultaneously being the gateway to transformation with far-reaching potential. Despite the value of an objective and un-biased perspective for analyzing cultural limitations, internal processes of analysis and recommendation, such as farmer field schools, are more effective because community members themselves realize and formulate the limitation, and then use their knowledge of the locality and their natural adaptive capacity to create the most suitable action strategy (Davis et al., 2012, Braun and Duveskog, 2011). As such, this insight is particularly applicable for African landscapes that are characterized by large heterogeneity of tribal cultures and landscapes with low agricultural productivity and where high portions of the growing population is occupied with agriculture as their primary livelihood strategy.

5.1.4 Landscape restoration vs. ecological landscape restoration

The findings of this study that describe the low amount of effective nutrient cycling, due to biomass burning and ineffective composting, contradicts literature describing AwA as an example of a landscape where farmers use composting to improve their soil's structure and nutrient-uptake (Lamond, 2012, Araya and Edwards, 2006, Wolde-Georgis et al., 2010). Possible explanations for this could be that locally based researchers are wary of criticizing the government extension agency out of fear for repercussions on their future opportunities to conduct research on agriculture in Tigray. Furthermore, the use of the blanket statement of "composting" for everything that involves the return of biomass to the soil limits the ability to describe the exact level of compost management that is happening. The perceived relative value of organic matter for different purposes is an important factor in determining how the farmers strategizes its use. The relative value might decline when a household considers the labor they must spend to make compost, in addition to the indirect price the they will pay in the form of loss of other extensions services, should they choose to switch to an organic-fertilizer-only livelihood strategy. Furthermore, farmers' perceived value and low prioritization of composting might be a result of insufficient knowledge about the long-term benefits regarding soil structure and water-holding capability (not only the nutritional benefits) associated with recycling of organic matter. Nutrient cycling enjoys little priority when compared to the precedence of the landscape restoration efforts that focuses primarily on water conservation efforts, and the regional government's extension support that favor the dissemination of industrial inputs over nutrient cycling. Ecological landscape restoration aims to increase biodiversity, SOC and nutrient cycling in a degraded landscape, while simultaneously maintaining, or intensifying agricultural productivity (Barral et al., 2015, Wade et al., 2008). Similarly, an agroecosystem is more likely to be sustainable (and resilient), the more it resembles the structure and function of the area's natural ecosystems (Gliessman et al., 1998), which, in Abreha we Atsbeha is SOC and biodiversity rich as seen in the church yard where the religious customs have always forbidden the use of the biomass or the soil. However, the current agroecosystem does not yet resemble a natural ecosystem, because hardly any biomass returns to the soil. As such, Abreha we Atsbeha should use the momentum of transformation from the last years to create a renewed awareness and energy among the people regarding their, and their offspring's alarming vulnerability context considering climate change and population growth, so that they become eager to make the belief system changes needed to move towards a mature and functioning ecosystem.

Landscape restoration should not be regarded as a project with a finish date, but rather an indefinite endeavor.

5.2 Reliability and limitations of the findings

The primary limitation of this study was the inexperience of the researcher with conducting case study research, in particular the ability to identify when bias had influenced observations, or to realize when systematic procedures had not been followed accurately. The effectiveness of the semi-structured interviews as a technique for gathering qualitative household-data was limited by the inexperience and basic command of English of the translator that was used for some of the interviews. An experience researcher might have understood early on that another translator should have been found, that could have led to more spontaneous insight during the case interviews. Effective translation would have allowed for more conversational interactions between researcher and farmer, that could have resulted in more robust data about farmers' lived experiences.

A limitation of the construct validity of the phenomena taking place in the landscape was the omission of interviews with the agricultural extension agents and their supervisors. Their perspective on the experience of working to improve resilience in the landscape would have been particularly useful for understanding the drivers of their actions. Perhaps background would have been provided that informed the study about the agenda of the people in power positions who motivated the dissemination of mineral fertilizer use.

Because all the observational data was based on the observations of one researcher, the objectivity of the observations could not be triangulated by another researcher performing the same protocol on similar sample of households. However, as the researcher was aware of the threat that potential subjectivity and bias had on the reliability of the study, observations were triangulated with other data sources to look for rival explanations of the witnessed phenomena. Previous studies of agricultural practices and landscape restoration in the village and key-informant interviews with researcher from the regional university, were the main sources of data for triangulation. For example, an interview with a key-informant regarding his experience of working with farmers on a compost dissemination workshop, confirmed the researcher's observations of the lack of composting and nutrient cycling in the village. Thus, ensuring that the claims made regarding the lack of compost-heap management, was not

unreliable due to any bias that the researcher might have had regarding the importance of nutrient cycling.

5.3 Recommendations based on findings

The main implication of the study for Abreha we Atsbeha is that nutrient cycling should be improved if the community is going to establish long-term resilience against climate change and population increase. There is an urgent need to recover the natural adaptive capacity of the farming land as soon as possible, so that future opportunities that arise as the ecosystem matures can be seized to increase resilience for the growing population. In addition, further interventions with potential to increase productivity and resilience in the landscape, such as conservation agriculture, promotion of horticulture production, livestock fattening and better irrigation will all be more effective if they take place on soil with improved SOC, and if they are integrated with existing soil rehabilitation activities. In this sense, the landscape still offers much improvement potential. Soil with high levels of SOC, due to the application of composted manure, crop residue and other biomass will improve the soil's structural stability, water holding capacity, aeration and fertility (Kassie et al., 2009, Twarog, 2006, Pagliai et al., 2004, Edwards, 2007), and good soil porosity improves infiltration and thus limits runoff during floods, and holds moisture during times of drought (Evanylo et al., 2008). Organic fertilizer must be promoted alongside the use of mineral fertilizer and other inputs, as an integrated strategy that synergizes the benefits of both soil augmentation approaches. Considering long-term trends of continuous population growth, such integrated fertilizer strategies are required to ensure maximum crop production in places, such as Tigray, where the nutrient content of the crop residues and manure content is low (Vanlauwe and Giller, 2006, Tedla, 2010). However, it is not a sustainable livelihood strategy in terms of creating resilience if a household's annual crop production relies on inputs that are subject to fluctuations in the market, and return on investments become more unpredictable as the climate's instability increases. In addition, the availability of inorganic fertilizer reduces the relative value of organic matter for fertilizer, so farmers favor mineral fertilizer, which limits the restoration of much needed soil rehabilitation. Complex problems such as these have no single solution or quick-fix. As such, a strategy is recommended that integrates the major insights gleaned from the case study into a hypothetical transformation project with the long-

term goal of mainstreaming nutrient-cycling in Abreha we Atsbeha, and comparable landscapes.

First, research is needed on the most energy-efficient and affordable alternatives to fire-powered *injera*-stoves. The new stoves must be durable, simple to use, produce the same standard of *injera*, and be as reliable as a wood fire. In addition, they must be particularly affordable for it to have any realistic chance of replacing the fire-stoves, because the poorest of subsistence farmers in Ethiopia are least likely to adopt new technologies or practices, out of fear of failure of the investment leaving them destitute or resulting in them being jailed, or forced to sell their available assets (Tafere et al., 2013, Wolde-Georgis et al., 2010). Electricity's potential as an alternative energy source for cooking is debatable; ~60% of households already have access to electricity (Lamond, 2012), the resource is relatively cheap to use, and an electric stove would allow for indoor and night-time cooking. However, electricity supply to the village is not reliable and the long-term electricity use from a coal-fired power grid is counter-productive from a climate adaptation perspective. Currently, electric *injera* ovens are manufactured by the Ethiopian Electrical Power Corporation and is sold for 4000birr (~US$150), but is not optimized for energy-use efficiency. Nevertheless, the development of new *injera* cooking methods is underway in Ethiopia, with experimental development including indirect solar baking (Tesfay et al., 2014a), storage of solar energy to combine with steam to enable night-time and indoor cooking (Tesfay et al., 2014b), and increasing energy-use efficiency of electric *injera* stoves, or *mitads* (Jones, 2015). The use of solar power for *injera* cooking is a promising development because the region receives consistent solar radiation, the technology utilizes renewable energy, it can be used by the poorest households who are often those without access to electricity who stand to benefit the most from having their resilience increased. An alternative to solar-powered *injera* stoves that have the added benefit of creating organic fertilizer, are biogas-reactors that can more effectively captures the energy that is dissipated during composting of biomass.

However, just because an intervention makes sense theoretically, does not mean that it would be a practical success. An earlier attempt to solve the problem of biomass burning was the proposed use of biogas reactors wherein the decomposition of manure (and other organic material) into organic fertilizer yields methane gas to cook with (Abadi et al., 2017). The use of this technology would, theoretically, result in a triple win scenario; the soil's structure and fertility improves, substantial nitrogen loss associated with composting is very limited in

biogas production under anaerobic conditions, and the prevalence among women of airway diseases associated with cooking on open fires are reduced (Pratt et al., 2015, Abadi et al., 2017). However, dissemination of the technology was slow, due to (among others) a combination of socio-economic factors operating at different scales; poor farmers were reluctant to invest in an unknown technology, and Ethiopia experienced a cement shortage on a national level during 2010 and 2011 (Kamp and Forn, 2015). Thus, the National Biogas Program of Ethiopia did not achieve its target of installing 14 000 biogas reactors by 2013 (Abadi et al., 2017), nor did the project gather any momentum in Abreha we Atsbeha. Most of the reactors that was installed as part of the first phase of the project, are in disuse, and those that still work, are seldom used and operate well below optimal capacity (field notes, 2016). A study by Abadi et al. (2017) elsewhere in Tigray suggests that the primary reason for not adopting the technology is that the ~7000birr (~US$260) investment was too high, while secondary reasons were limited access to water and labor. Moreover, a lack of knowledge and expertise regarding the of use biogas has been found to be a general limiting factor for biogas adoption in rural landscapes (Surendra et al., 2014). Advancements in the development of biogas technologies are attempting to address these shortcomings by developing more affordable and practical flexi-biogas digesters as an alternative to the fixed dome design (IFAD, 2012), steady-state digesters that reduce the high water requirement, and by developing *injera* stoves that are exclusively designed to work with biogas. Thus, the first phase of a hypothetical transformation project would be participatory research that involve farmers in the testing of the most practical, affordable and reliable new biogas solutions in a participatory way that gives them a sense of ownership and loyalty to the project.

Secondly, volunteering female-farmers[5] that represent both sides of the food-secure—food-insecure scale would be selected for participation in long-term (1-2 years) study. Participatory development projects in which the new technology is adapted internally and the adoption program is developed locally, instead of being imposed on the villagers from the outside and being regarded as something that will inevitably fail sooner or later, might cause the villagers to feel responsible for maintaining it to ensure its long-term success. This form of development integrates the development of important social capital, as discussed above, into programs that aim to transform the agroecosystem. The new technology will be installed in their households to test its practical use, but more importantly, to measure the amount of

[5] as they make the fires and cook the *injera*

organic fertilizer (bio-slurry) the average household can produce when biomass is decomposed in the biogas digester. The suggested project would have to be several years long, so that the researchers are eventually able to test if crop yields improve under the new management strategy. Farmer field schools and participatory workshops that record the farmers' experience with managing the digesters and cooking with the new ovens will be used to further optimize the technology's effectiveness. The long-term feasibility of the project could be improved if individuals who live in the village are trained to perform maintenance on the new installations.

The third element of the project would make use of participatory research to design a program that activates the landless, idle youth into an enterprise that meets the increased labor demands associated with operating a biogas digester. The youth, as the future of the landscapes, should be included in change processes and given a sense of ownership of something valuable. Interested individuals from the village would be trained in biogas maintenance, and will regularly service and monitor the participating households' digesters. During the planting season, they could also assist with transport and application of the bio-slurry to the fields. Pretty et al. (2011) describes a comparable example from Burkina Faso, of the potential of a landscape's unemployed labor to meet increased labor demands caused by a new intervention. There, groups of men spontaneously formed themselves into working groups to build soil conservation constructions for payment. Thus, labor constraints do not necessarily have to limit the dissemination of new technologies. An incentive to encourage the youth in Abreha we Atsbeha to participate could be an arrangement that transfers the 20 days of government work that they must do on water conservation projects every year, to work on this project instead. Another alternative could be to pay them small monetary rewards for good performance, which is monitored and administrated by the researchers. Either way, they would receive vocational training and it would be an effective way to spread awareness and begin to change the community's belief system. Should the research's data show that farmers' long term livelihood outcomes improve, and the demand for biogas increases, a system might arise wherein the farmers pay the local enterprise for their specialized labor. Social capital will strengthen, as "… reciprocity and exchange [will be used] to build relationships in order to achieve collective and mutually beneficial outcomes" (Pretty et al., 2011). Conway and Schipper (2011) foresaw the need for such changes when they stated that "…climate change is likely to require gradual shift of livelihoods and economic activity into other activities that are less climate sensitive alongside measures to

reduce the exposure and climate sensitivity of agricultural production."

Transformation would take place in both the practical-, and the personal spheres, and with enough momentum, could eventually result in change in the political sphere. For that to happen, awareness (personal sphere) of the beneficial long-term effects of nutrient cycling must serve as the foundation that motivates the farmers' choice-making when it comes to burning manure, or composting it. The individuals who have internalized the importance of sustained soil amendment and nutrient cycling for future resilience, will want to use organic fertilizer. In general, people tend to reject concepts that do not align with their worldviews, or that require them to change their usual habits of performing tasks (Stoknes, 2014). However, "traditional communities define themselves by their culture … and their overall worldviews and actions are built around their traditions. Therefore, it is excessively difficult to expect fast changes in attitudes." (Tafere et al., 2013). For that reason, this suggested strategy would use 2-3 years to accumulate tangible evidence to prove to other farmers that this is a feasible and worthwhile livelihood strategy, because Tigrayans are most likely to adopt a new strategy or project when they see and hear about successes of other farmers in their locality (Tafere et al., 2013). In Africa, subsistence farmers who adopt new practices tend to do so in response to current, or short term motivations, rather than long-term investments based on future projections (IPCC, 2014). Thus, the cultivation of a new belief system will be a major driver for success, because "norms of behavior … help to shape the behavior of individuals, thereby encouraging collective action and cooperation for the common good" (Pretty et al., 2011). Without a change to the norms, the farmer will go back to burning biomass the moment the new technology fails. If such a project would turn out to be a success or failure, valuable information will result from the process that would benefit other landscapes in countries where *injera* cooking on fires are also reducing resilience.

6. Conclusion

Landscape restoration efforts that restrict practices that degrade the land and replace them with activities that restore natural features of the ecosystem, improves the efficacy of peoples' livelihood strategies of creating resilience-outcomes. Natural capital improvements, such as access to groundwater and ecosystem services increase the value of existing farming enterprises, but it also provides farmers with the opportunity to diversify their income streams by investing in ventures such as apiculture or dry-season irrigation of cash crops. In regions where droughts and floods are likely to increase as the climate continues to change, it is vital for long-term resilience of the inhabitants that the soil's filtration and water-holding capacity is maximized. As such, the improvement of soil structure and natural fertility through the recycling of biomass should be a critical component of any landscape restoration project. However, changes to other parts of the system that have a shorter, more tactile return might enjoy preference over long-term soil rehabilitation efforts.

In the case of Abreha we Atsbeha, three factors combine to limit nutrient cycling, two of which are due to changes to other parts of the agroecosystem. The first is the community bylaws that restrict access to wood collection for fuel and free grazing of animals on hillsides, which lead to crop-residue being used primarily for fodder and secondly for fuel, and manure being dried and burned. The result is that very little organic matter is returned to the soil. Moreover, the little biomass that is returned, is handled in a sub-optimal manner due to the influence of the second limiting factor. The agricultural extension services' preference to focus on increasing yield through industrial inputs cause the dissemination of good composting services to be neglected. The third factor that limit nutrient cycling, is the cultural tradition of eating *injera* that increases the need to make cooking fires. Although it is the *injera* that creates the necessity for fire, it is more the lack of affordable, energy-efficient alternatives to replace the wood fires that effectively limits the amount of biomass available for soil rehabilitation.

A rural society's cultural habits guide the daily choices and decisions individuals make regarding the ways they use their resources. Over time, these collective cultural habits have a transforming effect on the landscape, be they negative or positive. As such, it can be of great value to a landscape if cultural habits with a negative effect could be reversed to become

cultural habits with a positive effect. Attempts to establish new belief systems are often met with blind opposition, as people are naturally resistant and skeptical of changes to their culture. However, social capital and trust in the collective society could be combined with participatory research and/or farmer field schools to counteract this, so that the locals themselves create the pathways to change their belief systems and strategize new ways to use their landscapes' resources.

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8. Appendix

8.1 Case study protocol

8.1.1 Operational procedures

The daily operational brief will be; immersion in the village to be able to identify and understand as many as possible of the relationships and delicate nuances at work in the systems. All the farms in the study will be visited at least once a week, to facilitate this, I plan to offer a few of hours of my labor to each farmer, every week. By rotating between the methods used and the farms being studied, movement is created between the different stages of transition that the farms are in, which should add validity to comparisons between them. The walks between the homestead, the farms, and the mountains will be treated as transect walks and important observation opportunities, any informal conversations will be attempted as much as possible, despite the language barrier. Regular contact between myself and the farmers will be encouraged, which should make discussions more candid and fruitful, and limit the 'reflexive threat'. Hopefully, this intimacy will show rare nuances that would otherwise be missed. Each night I will reflect on how the data gathered that day, answered the questions of the research. Data separated from reflections, will be meticulously recorded in a case study data base, for future researchers to be able to track the chain of evidence. Lastly, an audio-visual record of the experience, compiled with camera and drone footage, will be an additional medium to communicate the reality of the farmers' transition. I will do transect walks, hillside sits with binoculars, zoom camera and notepad, conduct semi-structured interviews and participate in community life as much as I can.

8.1.2 Qualitative interview structure

(based on "InterViews: Learning the Craft of Qualitative Research Interviewing by Svend Brinkmann and Steinar Kvale")

1. Introduce the theme of the interview with the first question.
2. Follow up questions: Keep theme in focus and get clarification on subject's interpretation of the theme (sometimes have to depart from subject's answers).
3. The interview guides are not a script, remain flexible
4. Phenomenology: interest in understanding phenomenon from the actor's point of view

Describe the world as experienced by the subjects.

OBJECTIVITY – SUSPENDED JUDGEMENT – UNPREJUDICED

8.1.3 Interview guides

8.1.3.1 Guide for 1st round of case interviews

1. Enterprise diversity

Research question:

What is the extent of enterprise diversity on the farm?

Interview questions:

What crops do they produce on the farm now?

What crops do they produce on the farm during the other seasons?

What is produced for consumption and what are the crops they sell?

What proportion of what is produced is eaten, and what is sold?

Which crop is most valuable to them, and why? (Income, ability to store, nutritional value..)

What animals do they have on the farm? Do the animals generate an income for them? How?

Which animals are most valuable to them, and why?

2. Livestock management practices

Research question:

To what extent do the farmers practice "sustainable" livestock management practices? Feed (input) and manure (output)?

Interview questions:

What do the animals eat now? And during other seasons?

Are animals kept on the farm, or do they take them out to graze?

What is done with the animals' manure?

3. Irrigation/well?

Research/Interview questions:

Is there an irrigation well?

If yes, what do they irrigate with it?

4. Income

Could be a sensitive subject, so tell them that they don't have to answer anything if they don't feel like it.

Research question:

Where does the income of the family come from?

Interview questions:

Do they get money for their labour?

Do they get money from renting out oxen for ploughing on neighbour's farm?

Do they get money from a relative working in the city?

Do they get money from selling their farm's products?

Do they get money from selling animals?

6. Vision and goal

Research question:

What is the farmer's vision for the farm?

Interview questions:

What would the farmer like to have in addition to what he/she already have?

Other crops or animals?

How many animals would he/she like to have, ideally?

8.1.3.2 Guide for 2nd round of case interviews

This is the guide of general questions that was asked during this round, in addition, unique questions were also asked to individual households to elaborate on phenomena that was missed during the first round and/or that emerged during observations.

1. Household demographics

Research question

What is the nature of the labor force of the household?

Interview questions:

How many members in the family?
How many male vs female?
Their age?

2. Crop—livestock

Research questions

Livestock feeding strategy
Further questions specific to each household, regarding information that was lacking from 1st round.

Interview questions

When do they feed cactus to the animals?
Do they feed sua leftovers to the animals?
Do they buy commercial feed for their animals?

3. Household water

Research question

Where do they get their daily water from?

Interview questions

Who collects the water they use in the house?
How far away is it?

4. Manure

Research question

How and where is manure sourced, other than that which is picked up around the tethered animals?

Interview questions

Is manure collected from the field after livestock has eaten on it after the harvest?
Is manure collected from the communal field where the oxen graze?

5. Biogas

Research question

Of those who have biogas infrastructure on their farm, find out why they don't use it?

Interview questions

Do you use the biogas digester?
Why not?

6. Labor

Research question

What is the households' labor situation

Interview questions

Do they ever pay for day laborers?
Do they ever rent themselves out as day laborers?
Who does what farming tasks in the household?

7. Planting strategy

Research question

Seeing as though I cannot observe the planting practices, I will try to learn about it from the farmers themselves

Interview questions

How much compost do they apply to the field before planting?
When do they apply it?
How much mineral fertilizer do they apply?
When do they apply that?

How many times do they plough the fields?

8.1.3.3 Guide for 3rd round of case interviews

1. Pests

Research question:

What is the extent of pesticide use on the farm

Interview questions:

Do they use Pesticide?
If yes,
How many times in one growing season do they apply it?
How much does each application cost?
On what do they apply it?
Who applies it?

If no,
Are there any pests on their crops?
Why don't they use pesticide?
Have they ever lost a harvest due to a pest outbreak?

2. Seeds

Research question:

Where do seed input come from?

Interview questions:

Do they ever save seeds for next planting season?
If yes,
Which plants?
Why?
If no,
Why not? (are the commercial seeds better? In what way?)
How much seeds do they buy?
How much does it cost?

3. Livelihood strategies

Research questions:

What are the farmers' perception of improvements in the landscape?
How have improvements affected their livelihood creation?

Interview questions:

If farming easier now, than it was 10 years ago?
What are positive aspects of farming here? What helps farmers to do well?
What are the most important decisions they must consider every year (or season?)
For the household, crops, livestock?
What investments did they make for their household? (well, oxen, other animals, buildings, water pump)
What input did they spend the most money on?
What is preventing them from producing more food/income?
How has the climate changed since they had the farm?

4. Fodder

Research question:

How has the increased biomass affected livelihood creation?

Interview questions:

Do they feed the leaves of trees to their animals?
If yes,
Which trees? (sesbania/momona?)
When?
In one month, how much would they feed trees to the animals?
Are the trees on their property?
Do they pay to rent a tree from other farmers sometimes?

Do they rent out a tree to other farmers?
If no,
Why not?

5. Apiculture

Research/interview question:
Why don't they keep bees?

6. Livestock

Research question:
*What are farmers' experience with the cut-and-carry community bylaw**?***
Interview questions:
How was it before there was a rule that animals had to be kept tied up?
Since that rule came, how did their farm change?
Since that rule came, how did the landscape around AwA change?
Would they prefer it if their animals could graze freely?
Why?
How many liters of cow's milk does the household consume in a week?
What happens to the skin when the cow is slaughtered?

7. Labor

Research question:
What are the labor requirements during other (not harvesting season) times of the year?
Interview questions:
How do they decide WHEN to plant?
How much time does it take to plough one field?
Are only men allowed to plough the fields?
How do they prepare the field for planting?
How much fertilizer/compost to use?
How long time does this take?
How do they get rid of weeds? How many days do they need to weed one field?
How many days does it take to harvest one field?
What do they do during the dry season? Are there any farming activities?

8. Compost

Research question:
What is the general attitude towards composting?
How do they prepare their compost?
What plant material do they add to the heap?
Do they put manure in there?
How often?
Do things grow better when they use compost?
Is it worth the effort?
Where is it kept?
And for how long before it is used?
Can you show it to me please (at farms where I haven't seen it yet?)

8.1.3.4 Key-informant interview guide

Focus on getting facts, not opinions.

1. Apiculture

Mohammed Tilahun – *Apiculture researcher at the University of Mekele.*

What are the trends of farmers adopting beekeeping over the last decade?
Is honey production increasing or decreasing?
What is the demand for honey products like? Where does the value chain end?
What are the factors that cause hive abandonment?

What are other limiting factors regarding honey production?
Why aren't more farmers keeping bees?
Prices of boxes and colonies? How does the price of honey compare from farmer to consumer?
Carrying capacity of the land i.t.o opportunity for expanding apiculture?

2. Compost
Mohammed ?????

What are limiting the production AND use of compost?
Do they do follow up visits to sites where they taught about compost?
How much compost does a farmer need for a hectare of land?

3. Livestock
Dr. Solomon Bariagabre: *Head of department of animal production, MU*

What are the obstacles that a villager who wanted to upscale their cattle production face?
How, in his experience, has zero grazing of livestock affected the nutrient cycling, and on-farm productivity of the region?
What opportunities and challenges exist for intensification of livestock production?
Prevalence of disease in the region, and farmers' access to veterinarian services?

4. Ecology of farming systems
Dr. Sarah Tewolde-Berhan – *Ecological Organic Agriculture Project, College of Agriculture, MU*

How is a change to zero-grazing affecting the rest of the farm's productivity? Do farmers understand the benefit of landscape restoration?
Is it realistic to suggest the fattening of animals instead of only focusing on using them for labor?
Limiting factors for improving soil fertility?
What are the factors that are preventing farmers from achieving food security?
Any knowledge/experience of farmers who have escaped the "poverty trap"? By what mechanisms did they achieve it?

5. General questions that could be used in any of the interviews:

-What are the major challenges facing poor farmers?
-What are the most important steps that a food insecure farmer must take to start the process of escaping the poverty trap?
-Do they know of farmers that have recently moved from being food insecure to being food secure? Yes. *Where? What was their environment like? How did they escape the poverty trap?*
-What are the most important first steps that farmers who are trying to escape the poverty trap have to undertake?
-Which interventions on behalf of the government have been successful in the past? What lead to their success?
-Which interventions on behalf of the government have not been successful. Why?

8.2 Case report

8.2.1 Field notes

Introduction
I spent the first week walking around and sitting at different locations throughout the village and its farms. At times, I managed to communicate to the farmers that I would like to help with farming activities, but this was mostly difficult due to the language barrier. Some of the young (18-25) men of the village could speak some English, so I often spent time with them in the late afternoon. On some days, familiar farmers invited me into their homes to share meals with them. This document is a summary of every week's notable observations, followed by reflections on how these tied into the aim of the research.

8/10:

First transect walk throughout the landscape

- All households are drying **manure cakes for burning**, even Aba Hawi (the village leader) who has a biogas installation. Manure cakes are drying on the walls of all houses.
- There are different species of livestock grazing in the communal grazing area. Cows, sheep, goats, donkeys, horses. Yet in some places the animals were tethered or caged.
- The rule states that only oxen are allowed to graze on the communal field. But I have seen sheep and donkey there too.
- Chickpeas planted in integrated acacia—chickpea field. Makes use of the residual moisture. And it's a pulse. Anyone of the case farms doing this? If not, why? *Yes, some are. Farm 4 for example, is doing the same and also has acacia and other trees on their field.*

REFLECTION
It surprised me to see the extent of manure being burned as a source of energy. I expected to see an emphasis on nutrient cycling, based on the reputation of the village as one that is breaking ground in landscape restoration and climate adaptation. Perhaps people will prioritize their daily needs over long term strategies.
The landscape restoration rule that prevents trees being cut down for firewood forces people to look to manure for fuel. Watershed restoration vs SOC restoration.

10/10:

- Today was the first round of interviews of the households in the case study. Farms ranged from being so food insecure that they relied on the government for food aid, to having so much that they annually sold surplus of all their produce at market. Even the affluent farms were drying **manure cakes for burning,** though. So no contrast there.
- All farmers across the board said that **oxen were their most valuable animal** on the farm. Answers regarding **most valuable crop varied between teff and millet**. The disease that effects millet for which there is no cure was mentioned by many farmers.
- All farmers in this village are bound by village rules to practice zero grazing and not chop down trees, so animals are tethered around the homestead. Very few farmers had goats. Oxen could go to the communal pasture to graze. The poorest of the poor farmer (Tsehay (farm 7), who relies on government help) sends her daughters to collect the manure from this communal field.
- Although the farmers came across as friendly and polite, I sensed an annoyance/irritation towards the interviews from some of the older farmers.

REFLECTION
If the aim of this study is to assess how landscape restoration efforts are affecting farmers' transition towards food security, then 2 main goals should be prominent:
1. What can be learned from the village as an agro-ecological community, that can serve as a template for other villages striving to achieve food security.
For example, there need to be a concerted effort initially to restore the hydrological system, and restrict land degradation. Then sets of rules that maintain communal resource use.
2. What can the food insecure farms of this village learn from the food secure farms, to enable them to catch up?
A blatant example is Tsehay's farm (farm 7) that is not far from two food secure farms. What are those farms doing differently to her? Why are they food secure and she is not?
Access to water, the age and number of her children, the size of her land?

16/10:

Landscape/community observations over the last week:

- An old lady that invited us in for sua when I had my translator with me:
    - Lives alone: rents out land and gets 30% of yield. *Contrasted by the ability of a vibrant male farmer who has the ability to work the extra land and produce extra food. =labor limitation is holding back women (and old) farmers?*
    - Has no animals (because she is alone and old), so breaks the' law' and cuts trees for firewood.
- The wholesale burning of manure, and its relationship to the landscape restoration's rule of 'no cutting for firewood'. 'CSA' *Livestock management practice vs watershed conservation practice*
- Some farmers have several beehives, while their neighbours have none. *Why?*

- The evidence of grazing pressure on the communal land as contrasted by the high grasses in the fenced-off school yard that borders it.
- Cut-and-carry is only allowed for grasses.
- Saw one farmer on the rocky hill, who had made a small patch of tomatos between the rocks next to his home. He had mixed manure with the sandy soil and carried water to the place in 2-litre soda bottles.

REFLECTIONS:

Female led households are often the poorest of the poor. They cannot meet the labor requirements of a properly functioning farm. Especially the older ladies. Added to that, the cultural norms and strict division of labor between male and female. If a female farmer ploughed her lands by herself, she would be discriminated against by her fellow villagers.

The cycle of 'wealthy' getting wealthier: Farmers who are generating an income are able to buy more chemical fertilizer, and thus produce more yield* than poor farmers. (*contested = does it really produce more yield/ it is a seasonal solution vs long term benefits of organic composted fertilizer/ dependent on good rains) *If poor farmers had a biogas installation they could produce their own compost and thus catch up.*

Opportunities?

- **Biogas** installation for the food insecure (poor) → manure that is usually for fire into biogas slurry → high water requirement which can justifiably be met because they are not cutting down trees → compost to grow more crops. (*Crops like millet that has high feeding and market value, and that stores well)*
- Is there scope for a farmer to focus on livestock intensification? What would the economics be of a farm that grows mostly fodder crops to fatten and sell animals to market. With the income, the farmer could then buy the crops that he/she would usually grow?

22/10

Transect walks and visits to case study farms in mountain-, and church valley

- Several farms with **biogas installations**, but many seemingly not in use. (pipes not connected, weeds growing out of the pits)
- Children collect water. Carry it themselves, others used donkeys.
- Less crops growing on edge of fields where eucalyptus trees are planted.
- The old lady of farm 3 harvesting prickly pears from cactus 'fence', and consuming them on the spot. Uses a long stick to harvest them from the top of the plants.
- Farm 4: rotten guavas fed to the cows who eat it with vigour. On another day cows were fed on recently harvested finger-millet field.
- Farm 6: intercropping on one field of wheat, finger-millet, and teff, separated with wild shrub growth.
- Children herd the animals to the different water holes on a daily basis, mostly in the late afternoon, but throughout all daylight hours.
- Whole families assist with reaping and harvesting.

REFLECTION

Possible reasons for the disuse of biogas installations:

Custom of cooking with fire, and a reluctance to adopt the new technology?
Labor intensity of 'feeding' the biogas digester?
Unsuitability for the *injeera* oven?
Lack of knowledge?
Lack of backup and advice from biogas experts?

Conundrum of the children:
If children are sent to towns to get good education, then they could potentially get a good career and then assist their family financially. But, in the short term, the children fulfill a big part of the labor requirement of running the household. They help with herding animals, collecting water, market activities, harvesting and reaping, etc.

31/10

Transect walks and visits to all case study farms.

- Sheep grazing in recently harvested field preferred the cactus on the fringes to the crop residues.
- Fields are eaten bare of crop residue, **very little organic material left** after harvesting and grazing of animals. Only the stalks of the plants.
- Donkeys are a crucial part of the farming system. They are used to transport crops, grass, water, flour, and even water pumps.
- Groups of neighboring farmers use one location where the ground is cleared and hardened to stack their harvests. They then combine their oxen to trample the harvest to separate the grains from the stalks. This process takes most of 2 days, depending on the amount of harvest and number of oxen.
- The **young adults** seemed to have very little to occupy themselves with when they are not helping their families with harvesting. I often saw them playing *karambula* (a game played on a pool table, but without cues) before midday, with crowds of them just sitting and watching the others play.
- A very strong sense of community exists here. Families help each other with farming tasks, share equipment, food and knowledge. The benefits of social capital
- Even though the village has good 3G mobile phone network, the government has restricted access to social media in an attempt to supress the uprising and unrest with the current state of affairs.

REFLECTION:

Donkeys seems like a more valuable animal to the farming system than the ox, yet all farmers stated that the ox is more valuable. The reason for that is that the ox is used of ploughing and reaping. *Is it possible to get the farmers to change from ploughing to a zero-tillage approach*.?
Opportunity: Seize ploughing; possible "conservation agriculture" benefits like increased carbon sequestration, less strain on animals → fatten, higher price at market?
(donkeys and cows can be used for reaping)

6/11

Transect walks and visits to all case study farms.

- Not all children go to school every day. The children are quick to throw rocks at each other and at animals (for no reason). They are often seen beating animals with sticks, seemingly just for the heck of it.
- Dogs are only kept to protect poultry and other livestock against attack by marauding hyenas. The dogs are not given names like in western society, they are just another animal that are kept to serve a specific purpose.
- Heterogeneous maize yields, one farmer had uniform cobs with even coloration, while his neighbour had a great variety of cob sizes and kernel colours. Hybrid seeds and saved seeds.
- All people eat the insides of corn stalks, it is very sweet and juicy.
- Oxen do not graze in the communal area any longer
- Ongoing planting of eucalyptus stands. Plantations at different levels of maturity throughout the village. Some specifically on riverbanks and enclosed with thorny branches that fence them in.
- I have been focusing on compost heaps. I have not seen any heaps that resemble a well managed system of compost; most are heaps of manure that are exposed to the elements, and never turned.

REFLECTION:

Do the benefits of planting eucalyptus (consolidating the soil, fast growing and providing timber for market and building) actually outweigh the disadvantages (unpalatable leaves, high water demand)?
Between the consumption of people and the animals, very little biomass is wasted. At the same time, very little is placed back into the soil. Some farmers rely quite heavily on chemical fertilizer to maintain yields.
There exists an opportunity to improve nutrient cycling, both at farm, and landscape level. Why is it not being done? Is it because there is a top-down emphasis on the use of fertilizer?

13/11

Transect walks and visits to all case study farms.

- Much activity around the village as people harvest their crops, and then process them with their teams of oxen.
- Only women take the grains to the mill to get processed into flour. Only men plough the fields.
- Animals often seen grazing on the hillside on the outer extremes of the village. This is against the rules
- South Korean delegation came to plan the expansion of the school to include grades 9-12.
- Agricultural extension agent working with bee-keeping told me that the total honey harvest in the village during 2016 was 40 tonnes (400 kuntal)
- One of the springs on the Southern side of the mountain valley (N-slope of the buttress) dried up this week.
- The children who drive the animals to water are carefree with regards to what the animals graze on after drinking. Some sheep made a beeline for the sycamore fig seeds pods.

REFLECTION:

The rules of the village regarding where animals are allowed to graze, seems to be broken on a daily basis. How can they be policed? Is it necessary for a strict enforcement of these rules? During my stay it is the harvesting season, so there should be enough crop residue for the animals to eat, so what is free grazing like towards the end of the dry season?

Honey fetches a high price at market and the village has good conditions for apiculture (flowering plants, water and mild temperature), yet farmers are reluctant to keep bees. Most say that they are scared that if they spend money (5000birr) to buy a box with a colony, the bees would soon move away. Yet, those who keep bees make a good return on initial investment, as beekeeping requires very little external input.

20/11

Transect walks and visits to all case study farms.

- In the mountain valley there is a spring halfway up the hillside. A channel has been dug and lined with concrete (for most parts) and is directed with a series of gates. There are two collection dams, one was completely dry, and the other was filled with water and covered with a film of algae. The farmers with contact to the different diverted streams were irrigating a maize field, chili and tomatoes, and guava and orange trees.
- Around the homestead of Abu Hawi sticks of wood are used daily for making fire. Sometimes it is bought from outside the village, but other times it is obvious that it is just collected from around the countryside.
- By spending time with and getting to know some of the young adults of the village, I learnt that many of them did not complete high school. They are worried about their prospects for the future, and several of them explicitly stated that they have no interest in farming.
- In conversation with an agricultural extension agent whose trust I had earned, I learned that the extension agents receive cash-incentivizes to sell fertilizer and pesticides to the farmers. In a casual conversation, I asked if it was a rule/law that farmers had to buy fertilizer. He answered that it wasn't, but that his colleagues withheld other extension services from fathers who did not buy fertilizer. These are the same extension agents who are supposed to give guidance and support on best practices for composting.
- Two of the farmers in the case-study did not want to participate in the final round of interviews. Both wanted to know about the purpose of the study. Once this was explained to them, they said that there had been many researchers there over the years, but that they never got anything from it.

REFLECTION:

Why would an extension agent promote good composting practices, if he knows that a farmer would require less chemical fertilizer when he/she is producing good compost. The knowledge and importance for improving SOC exists, but the channels for that information to reach the farmer have been severed. No wonder some of the farmers feel like they never see the benefit of any of the research that is done in their village

28/11

Transect walks and visits to all case study farms.

- Approximately 50 head of cattle are driven into the village square every Wednesday night. They are from a series of villages further West. They are driven by cattle merchants who buy them from villagers along the way (from as far away as 20km), who then herd them all the way to the town of Wikro. They rest up for a while, and then continue to Wikro after midnight to complete the 16km to Wikro, in order to arrive there for the market, where the slaughterhouse representative buys them from the cattle herders and transport them to the abattoir in Mekele.
- Unsupervised herd of 4 cattle were destroying someone's chili field
- One household (apparently, part of Abu Hawi's extended family) has two wells on their property and are thus able to irrigate a relatively big orchard of orange and guava trees.
- Much of the grass that was cut from the area that was cleared to expand the school was delivered to Abu Hawi's house, and then added to the pile of fodder for his cattle.
- Visit to abattoir in Mekelle, Daniel spoke about the growing demand for meat products from emerging markets, especially the Arabian Gulf and China. He also mentioned the constant requests they receive for carcasses in better condition.

REFLECTION

The grass that was cut from the school and brought to the village leader's house for his animals. What are other ways in which the exercise of power over access to resources affect poor farmers striving for food security? Are the rich getting richer, (because of authority and influence), while the poor is getting poorer?

5/12

- During the last 8 weeks, the community members had built an irrigation channel that diverts water from the river to a strip of fields situated next to it. They completed roughly 1,5km of channel in this time.
- A delegation (all men) from Somalialand were given a tour of the watershed restoration work going on in the village.
- Young acacia bushes are cut down to fortify outer fences to "protect against dogs and hyenas who kill the chickens.
- Various small heaps of ash on a recently ploughed field
- Members of several other families were helping 'farmer 9' to sift and pack teff grains
- An old man on the rocky hill had made a small vegetable garden, using manure and ash with water that he carried there in 2 x 2.25l plastic cans.
- Letrebrehan (the girl living on farm 4) sold 1kg of guavas to one of the small kiosks
- At the weekly market, there is a guy who comes by buys from Wukro to sell eggs. He only has chickens, and he buys concentrate feed for them. He represents strong competition to the local farmers who are also trying to sell a few eggs.

REFLECTION

Not all community members who participated on the irrigation project will directly benefit from the work. Access to resources like land and water plays a significant role in individual households' ability to achieve food security. Is it possible to share the benefits of a new irrigation scheme evenly throughout the community's members?

→Themes

SOC depletion

- strong tradition of ploughing
- very little organic matter returned to the soil

Lack of knowledge regarding best practices

- bee keeping
- composting
- biogas

Benefits of landscape restoration

- Biodiversity
- Water table

Landscape restoration vs soil rehabilitation

- In Abreha we Atsbeha, there soil rehabilitation does not feature prominently in landscape restoration
- Manure burning vs compost
- exploitation of positions of power (by agricultural extension agents)

For the sake of 'outscaling' this evidence, other landscapes and villages can learn from successful practices of Abreha we Atsbeha's recent past (last decade), but also from the shortcomings in management on both the farm, and landscape level. It could be that the emphasis on restoring the hydrological system is causing a neglect of SOC restoration. Analysis must explore the factors that influence the above themes.

8.2.2 Summary of case farms

Introduction
This document is a summary of information that was collected for 10 farms, based on 3 rounds of interviews and random observations over a 10-week period between October and December 2016. The farms were selected, and are categorized based on the households' relative level of financial flexibility. For the sake of simplicity, three categories, 'food insecure', 'food secure', and 'transition' are used are used to categorize the households' level of affluence, relative to one another, and within the context of the specific landscape. To determine which category best suited each individual household, factors such as their annual reliance on food aid, yearly expenditure, size of land and herds, access to electricity and visual indicators of prosperity or poverty were considered. For personal reference, different areas of the village were given simple names that represent a specific natural feature of the landscape; Church Valley, Mountain Valley, Rocky Hill, and Acacia Hill.

Food insecure:

Households that annually relied on food aid to meet the family's nutritional demands, and who did not have any surplus production for market, or financial capital for investment.

Farm 7:
Church Valley, NW edge
-Male led household; husband and wife with 7 children.
-Children help with collecting manure, grass and water after school.
-Owners of the farm for 19 years.
Farming components
Teff, finger-millet, maize and wheat on a rotational system.
Planting in April, Nov-Apr fields left fallow.
1 ox, 1 cow, 1 calve, 5 sheep and 10 chickens
Most valuable crops; teff and wheat in dry years, millet and maize in wet years.
Most valuable animal; ox.
Livestock
Fodder: Cut and carried grass, crop residue, commercial feed (50kg @ 500birr, 1st time last season. Would buy again. "can feed one cow on 400kg of feed in a year"), ox on communal pasture, sua leftover when they have (holidays), cactus during drought when there is not enough crop residue
Does not feed trees to animals, but would feed sycamore leaves if they had access to any.
Manure is collected from the homestead and the young girls collect it from the communal grazing area, before it is used for burning and fertilizer (compost).
Could consume 5l milk a week, but at the time they didn't have any.
The hide of slaughtered cattle is disposed of, but before they used it for sitting and sleeping material.
External input

150kg of fertilizer at 1500birr. (cooperative brings to a storage twice a year, they have to transport it from there)
Herbicide on wheat and teff, once a season. When there are lots of weeds they use 2 cups, 1 cup = 60 birr. Husband does the spraying.
Doesn't use pesticide, "generally don't have a problem with pests"
Teff, finger-millet and maize seeds are saved, but wheat seeds are bought every planting season because "they are better when bought". The price of the seeds vary, and is most expensive around the first rains.
Their annual expenses are +/- 8000birr, but a lot of that is also for education of their children.

Management

Finger-millet, maize and sorghum is weeded manually before the rains.
Does government work during the dry season, working on water conservation infrastructure. They start ploughing while it is still dry (before the first rains).
They add manure, ash, and leftover fodder onto the 'compost' heap and then put all the 'compost' they accumulate onto their fields before planting.

Income

Sells some of the sheep, hens and eggs. Mostly livestock income from selling sheep during the holidays.
Says she sells total 150kg of the crops each year, but also receive wheat from the state because the income from the farm is not enough.

Water

Collected from a hand pump not far away. <500m

Biogas

None

Personal opinion

Believe it is easier to farm now than **10 years earlier**, because the rainfall is more stable and they can get seeds in the community market.
They believe they could **produce more** if they had mechanized ploughing.
Does not keep **bees**, because they do not know how to manage them. They had one box, but the colony left.
Zero grazing rule; half good, half bad: If they do not have enough fodder at home, the animals struggle more, whereas before, when they were free to graze around, all households had enough milk.
Things grow better when they use **compost**, and chemical fertilizer is too expensive to use continuously. Uses chemical fertilizer when the rainfall is excessive because they believe it absorbs more of the water and thus creates a moisture balance in the field.

Future vision

If given money to invest in the farm:
Would increase livestock heard indefinitely (cows and sheep), and would like one more ox.
Would like a horse and cart for transport.

Farm 8:

Rocky hill (An area of unfavorable land for cultivation, where the most recent households to settle in the village are located. Large plates of sandstone near, or above the surface of the soil.)
Male led household with husband, wife, 20y-old daughter, and 4 children
House away from 3 fields in the distance (~1,5km)
Had the farm for 25 years, it was given to them by the community and it has always been the same size.
No electricity

Farming components

Teff, wheat, maize and finger-millet grown on field away from home (soil requires a lot of fertilizer and workload rotated with neighbor + coffee, grapes, guava, cabbage, tomato, pumpkin around house
1 ox, 1 cow, 7 chickens (saw 2 sheep there on a visit)
Most valuable crop is teff (because of high market value)
Most valuable animal is cow.

Livestock

Fodder: Buy and collect grass, and crop residue from far away field. Ox in communal grazing when it is allowed. Sua leftovers, and 3 jerry cans of feed a month "because they can't find enough" and cactus in the autumn (feed animals straw and sua-leftovers from Jan→April). Does not feed tree leaves to animals, because "it is forbidden to cut down trees".
Big pieces of manure for fire, small pieces for fertilizer around the house.
Manure collected around house and from ox when eating in communal area.
Cow produces 2-3l of milk per week.
Usually disposes of the cow-hides, but before it was used for sitting and sleeping material, and for making rope.

External inputs

150kg of fertilizer per season
One application of pesticide is usually enough to get rid of pests, but if they re-appear, then they spray again. It is mostly applied to teff, tomato and cabbage. The husband gets information on the pesticide from the extension agents, and then applies it himself.
Applies herbicide when there are excess weeds, but the farmer prefers to do manual weeding, because he believes the herbicides decreases the harvest.
Seeds; always buys wheat seeds, as it is "more specialized", and saves the seeds of the other crops during normal (weather) seasons. Following seasons of drought, they buy all the seeds for the next planting season.

Management

If the family had access to funds, they would invest in irrigation and bee-keeping. Honey production happens "only once a year", so one needs to have enough financial capital to back up the investment.
For planting; first they decide which crop will best suit the particular field, then they plough it 3 times before planting. The farmer adds fertilizer with the seeds when planting.
The farmer would like to produce, and use, more compost.
The farmer has two compost holes; he adds everything except eucalyptus to the one, and when it is full, turns it over into the other hole. The ground is very rocky, so he was not able to dig deep enough, but was (slowly) busy to build up structures to contain compost above ground.
He believes compost is better for both irrigated and rain-fed fields.
During the dry season the farmer does day laborer's work some days, masonry and irrigation if they are able to rent a field near the river.

Income

Some years have a bit extra crop to sell
Sell some eggs to buy coffee with
Make bricks but don't sell them. Market price is 10birr a brick, but they only make them to build additions to their house.
Sells some eggs and surplus crops, but not enough, so they get food aid in the form of wheat.
Family members sometimes work in town as masons, or day laborers.

Water

Collected from a communal tap which is "near" (+/- 300m)

Biogas

None

Personal opinion

Believes farming is harder now than before, because things are more expensive. The farmer does not think the weather has changed over the last 5 years. "Mostly it is good, except in 2008 when there was a big drought".
Supportive forces; enough straw available for their cattle, opportunity to work in construction as an alternative form of income, and the possibility for irrigation exists now that there is more water (raised water table).
Hindering forces; lack of finances.
Zero grazing; believes it is better when the animals "stay at home", because when they are allowed to graze freely, they would cause total overgrazing, eat the irrigated crops of neighboring farmers, and sometimes a cow might get separated from the herd and get lost.

Future vision

Would like to have more teff and wheat
Would like to have minimum 2 hybrid cows because they give more milk
They are going to build an animal house with the bricks they made

Farm 9:

Rocky hill
Male led household with 2 adults and 5 children (1 with mental disability)
Bought the house 7 years ago after living with family "nearby".
No electricity

Farming components:

Don't have land, so work on other farmers' fields and gets 50% of the harvest.
Tomatos and chilli garden for own consumption.
1 ox, 1 cow, 1 chicken, 1 donkey

Livestock

Crop residue, collected grass, and ox grazed in communal area, sometimes commercial feed depending on the amount of land they are renting that season. If they have many fields they have much crop residue to use as feed. Sometimes they buy cactus that is fed to the animals in combination with straw. Never uses tree-leaves, because they don't own any land with trees on it.

Manure is collected from around the house and communal areas, and then burned.
Depending on fodder availability, they produce and consume 2-3l of cow's milk per week.
Discards the hide of slaughtered cattle.
External inputs
Never pays for labor
50kg to 100kg of fertilizer, depending on the size of the land that they can rent.
Uses pesticides when pest breakouts occur. One application on teff per season, if any.
Applies herbicide to teff, and occasionally finger-millet and barley. The rest of the weeding is done manually. If there are many weeds, it takes two laborers, 5 days to weed one field.
Management
Does not save seeds because they do not own any fields. Therefore, "they don't know which seeds they will need the next season."
Does not keep bees, because they don't have money to buy any.
Does not know if the climate has changed.
During the dry season, they only do government work.
Adds manure, straw leaves and weeds to a 'compost' heap, sometimes daily, other times every 3rd day. Crops perform well when they use compost, but they only apply compost when the field that they rent is not too far away.
Income
Husband works as causal labor around village. Mostly with reaping
Nothing left for selling
Work as day laborer
Water
From communal tap
Biogas
None
Personal opinion
"There is no positive aspects regarding farming here". They cannot produce enough/more because they don't have enough farmland.
Believes it is better without zero-grazing, because sometimes they don't have enough fodder to feed the animals at home.
Future vision
Would like to have land, and more of everything

Food secure

Households that produced enough crops to feed their family annually without relying on food aid, and that produced enough to have surplus to sell in the market after their family's food requirements were met. Due to the difficulty of measuring food security accurately, and the fact that it changes over time, even these food secure farms sometimes relies on food aid. They also had varying degrees of resilience; (varying financial flexibility to maintain food security during droughts/disasters and to make investments for the farm), but for the sake of simplicity they were all categorized as food secure for the sake of this study's comparison..

Farm 1
Church valley
Male-led household with 5 members (father, mother and 3 children)
Had farm for 6 years, was given to him by community because he doesn't have parents. Used to do day work in the community before that.

Farming components
Finger-millet, teff, sorghum, maize, beans, potatoes, chili's.
Practices crop rotation (never fallow, he doesn't have enough land)
Plants nothing after autumn harvest because there is no rain.
1 ox, 2 cows, 1 lamb, 6 chickens
Finger-millet is most valuable during good rains, and when using inorganic fertilizer (double the yield of teff)
Ox is most valuable animal
Livestock
Feed: grass collected from the mountain, crop residue, *sua* leftovers, cactus during the dry season. During autumn and winter (Nov-Feb) commercial feed worth 600 birr and leaves from the *Sesbania* trees on the edge of his property.

Manure burned and used for composting.
Manure left in field after animals graze post-harvest
If fodder quality is good, they consume 5-6l of cow's milk a week, if it is poor then 2-3l
Skins thrown away after slaughtering.
External input
Spends +/- 3000 birr/year on external inputs
50kg fertilizer per season
Pesticide; 1 cup (75 birr) per field teff field, applied personally once a season.
Herbicide; To all crops, except sorghum and maize
Seeds: Saves seeds for all the crops he plants. If a new hybrid is released, he will buy that, because he knows how good it is for the next season.
Never pays for labor
Management
Takes half a day to plough one field. Only men are allowed to plough the fields.
Applies fertilizer to every field, every year.
Manual weeding in addition to spraying, "it is much better now with herbicides".
During dry season (Dec-June) he works on the government's watershed rehabilitation program.
Compost applied sporadically, as he doesn't have enough to cover all his fields.
Adds material to his compost heap every 2-3 days; manure, straw residue, leaves, ash ("the ash is very good")

Income
Potatoes and chili's directly to market, most of sorghum and some of the rest (66% own consumption, 33% to market)
Some of the excess crop residue is sold
Helps his neighbor to reap, but then gets help for his fields in return.
Sometimes rents out *Sesbania t*rees on the edge of his field as livestock fodder @ 400-500birr/season
Water
Has a well on field away from home. Neighbor has pump, so they share the water.
Irrigate maize, potato and chili with it.
Household water collected from pump near Eastern edge of communal area. (+/-400m)
Biogas
None
Personal opinions
Believes farming is easier now than 10 years ago; due to **access to new seed varieties**. During excess rainfall, he plants finger-millet and maize, and during low rainfall seasons he plants wheat. 10 years ago, that was not an option, because they did not have access to wheat seeds.
Natural diseases (especially close to harvest time), and a shortage of land is preventing him from **producing more food**/income.
Doesn't keep **bees** because he believes the conditions around his homestead is not good for bees, i.t.o weather and the availability of flowering plants.
Farmer supports **zero grazing** rule; it limits overgrazing, prevents conflict with neighbours, and the animals can't get sick from drinking dirty water.
Weather is better now than it was before; 10 years ago, there were lots of pests due to bad weather, now it is more stable so they can grow more crop varieties.
Chemical fertilizer is better than compost. He planted one field with fertilizer and one with compost, the composted field tends to have more pests, like termites.
Future vision
Would like more land to expand his enterprises. Increase production
Would not like to have fruit trees, they take too much space and water (mango)
Before he gets more land, he cannot get more animals, but he would like more ox.

Farm 2
Church valley
Male-led household with 6 members (father, mother, adult son, and 3 children)
Declined participation in the final round of interviews (research fatigue – asked what he would get out of it)

Farming components
Maize, teff, millet
4 ox, 1 hybrid cow, 5 sheep, 11 chickens
Maize and teff most valuable to them

Ox most valuable animal
Mostly eat injeera. Also eats prickly pears during the winter.
Livestock
Grass cut-and-carried, crop residue, sua leftover, cactus during dry season.
Manure collected from around homestead.
Mostly burned, some 'composted'
External input
250kg fertilizer per season
Income
Sell some millet, but maize better for income, seldom when they have surplus.
Sometimes buy skinny ox, fatten, and then sell
Sometimes sell sheep
Sometimes sell some surplus crop residue as fodder
Mostly generates income as a mason.
Water
Dug a well but collapsed.
Household water collected from a well +-70m away
Everyone in the family collects water
Biogas
Not being used because:
"Don't have enough to put in it"
"The fire is too weak"
"It flooded with the rain"
Future vision
More land to plant more of whatever suits this place best. Not interested in increasing livestock production, only crops.

Farm 10
acacia valley
Male led household, 4 pax; 3 adults of which grandmother, son, and daughter, and 1 child.

NO zero-grazing in this village
Had the farm for 43 years

Farming components
Millet, wheat, teff, maize, tomato, chili (onion next season)
1 ox, 1 cow, 3 calves, 1 donkey, (used to have sheep but leopard killed them)
Teff most valuble (market value and crop residue is good fodder)
Ox most valuable (because of ploughing)
Livestock
Feed mostly on teff residue, and graze freely (he doesn't have time to collect grass), also feed them cactus from Sept→April, even though they don't have their own, they go looking for it or buy it and feed it to them mixed with straw. They buy straw (spent 2000birr on straw last year). During the dry season they feed leaves (mixed with straw) from the acacia trees "far away". They collect branches from this tree approximately once a month (during the dry season). Sometimes they borrow/beg leaves from their neighbors.
Manure is collected from where animals feed around house and from fields after harvest, and is then burnt and used for fertilizer. Doesn't have enough livestock for fertilizer, so has to buy inorganic. Puts the ashes from the fire on the compost heap.
Animals are grazing freely, so manure needs to be collected from where they are/go.
Because they do not have enough fodder, they only produce about 2l of milk per week.
They use the skin of the slaughtered cattle for sleeping material and ropes.
External input
400kg of fertilizer
Labor. During busy time (harvest and irrigation if they have land to rent close to water) they will get a laborer 3 times a month
Pesticide on all crops, applied with their own hand-sprayer.
Herbicide only on grains, vegetables are weeded by hand throughout growing cycle.
Save seeds when they have enough and when it was a good yield, otherwise they buy it from the market. Buy the new wheat-hybrid for every season.
Management

Don't have money to expand their bee hive. They only have one traditional box.
They add compost to the field during the dry season, before ploughing and planting.
During the dry season, they work on government projects, rent themselves out as labor, irrigate their vegetable fields, and do maintenance on their house.
They add manure, household waste, fodder residue, chicken manure and ash to their 'compost'. Once they have enough, they would put it on the field.

Income

Harvests twice a year. Surplus is what he lives on.
Sold 2,5 kuntal last season, but believes he will have more this season because of good summer rains.

Water

Rents some land next to the river where there is water
Household water from 500m away
If they had a well close to their field, they would grow maize, chili, tomato and potato.

Biogas

None

Personal opinion

Believes it is **easier to farm now**, than 10 years ago, because they have access to knowledge in the form of information about herbicides, pesticides and plant breeds.
Their limited access to land **prevents them from producing** more.
Zero grazing; it is better, because sometimes the animals would eat the neighbor's crops, and then they would quarrel and argue, and that is bad for the neighborhood. Even though his animals are not always tethered.
The farmer's opinion is that the **weather has not changed** over the last 10 years.
Crops grow better when they use **compost**.

Future vision

He has some land that is far away from water, so he would like a well on it.
He would like some more land.

Farm 5

Mountain valley
Male led-household, husband, wife and 2 children. (I never saw the husband)
Had the farm for 43 years, but it has become smaller "because after the DERG-regime it was divided and distributed to others".

Farming components

Wheat, teff, millet, maize, sorghum, beans. Guava, mango, geisho, coffee, banana (but struggling because planted last year during drought)
2 ox, 3 cows, 2 calves, 4 donkey, 7 chicken, 25 sheep
4 of 5 hives with colonies. Says less bees now than before. Harvests twice a year, 3 times if it is a good season. Average yield is 6/7kg, but can go up to 15kg. $1/6^{th}$ is consumed, the rest is sold. She has kept bees for the last 6 years.
Teff and wheat most valuable. Good food and good at market
Ox for ploughing, cows for milk = most valuable.

Livestock

Fodder: Cut-and-carried grass, crop residue, leftover sua, commercial feed (3 jerry cans of sua leftover weekly), cactus during the dry season (fed in addition to straw and crop residue). Does not feed any trees to the animals because they do not have fodder trees on their property.
Tethered, ox to communal area when it is allowed.
Manure collected in the yard, those in the fields when animals graze after harvest is left there.
Has a heap of manure and also makes manure cakes to burn.
When there is enough fodder, they produce 2l of milk per day.
Sometimes uses the hides to make rope.

External input

200kg of fertilizer per year.
Sometimes get dayworker (otherwise it is only the husband who works on the farm)
Applies pesticide to the teff field, once a season
Applies herbicide to all crops except finger millet, maize and sorghum. The rest are weeded by hand. Sometimes spray the fruit trees, but because they are still so immature, not much yet.

Management

Saves seeds if the yield was good, otherwise buys seeds for the next season.
Added a fruit tree orchard to their property in the last 4 years.

Don't have a specific plan as to when to plant, they "just do as usual".
For every crop they follow a different system of ploughing; finger millet requires repeated ploughing.
Adds compost before the seeding process, and fertilizer after the seeding process.
During the dry season, they get ready for the growing season by starting to plough early.
Add manure from all animals to a 'compost' heap, in addition to kitchen and fodder waste. This is added every day in the summer, and twice a week during winter.

Income

33% eaten, 33% saved, 33% sold of all crop production.
5/6ths of honey is sold @ 200birr/kg. 4 active hives @ 2 harvests a year averaging 7kg-1kg for eating = **+/- 10 000birr/year income from honey.**
Milk from cows, mostly male sheep, chickens and eggs sold.

Water

Small well on Eastern end of farm, irrigates geisha and guava with it.
Water for well from a communal well higher up (which is fed from a spring running quite strongly out of the mountain). Last year's drought the water dried up.
Upper well's water is used directly by farmers living in the vicinity of it. When they have finished using it, this family gets water.
Trees are watered every 5/6 days, and only the trees are irrigated.

Biogas

None

Personal opinion

Farmer believes it is easier to farm now than 10 years ago, because of **fertilizer and information** sharing by the government extension agents. Also thinks it is better now that they have herbicide and pesticide that does the work that required human labor in the past. Shortage of water and land is preventing them from **producing more food**/income
Believes it is better with the **zero-grazing** system, because if there is a shortage of fodder, the farmer can control the amount that the animals consume on a daily basis. Now that the animals stay at home, they stress less and rest more; they not exposed to dangers such as pests and too much sun.
"In the dry season there is more sun and the **temperature is higher**."
"Compost by itself is not good enough, because the farm has adapted to the artificial fertilizer." They put the available compost onto one field until it "has enough", and if there is any left they would put it onto the next field. They "estimate by eye" when the field has enough compost.

Future vision

Would like to have more of all components, and as many animals as possible
A bigger well
Maybe biogas (leading question by Efrem)

Farm 3

Mountain valley
Male led household with 6 members (grandfather, grandmother, son and his wife, and 2 children)
Had the farm for 43 years, decreased in size because he gave some land to his children.

Farming components

Teff, millet, maize, wheat, beans, cactus
2 ox, 4 cow, 11 sheep, 11 chicken, 1 donkey
Teff is most valuable, good price at market
Ox most valuable, for ploughing and selling (financial security)

Livestock

Sheep taken away by son to graze elsewhere every day. He comes back at 4pm
Cut-and-carried grass, ox in communal area, crop residue, sua leftovers, cactus during droughts, acacia leaves to small ruminants (fruits to cattle in May) and *momona* leaves to cattle
Manure collected from tethered animals around homestead, not from harvested field grazing. Used for burning, fertilizer.
2-3l of cow's milk/week
Throw away cow's hide after slaughtering. 10 years ago they used it for making bedding.

External inputs

5000-6000 p/y (more if they require extra labor)
200kg of fertilizer every year
Never rents labor, they do everything themselves.
Pesticide and herbicide, applied twice a year.

Sometimes experience pest problems, especially during drought periods.
Management
Save all crops' seeds, except wheat, which they buy every season.
Used some money to extend the house over the last couple of years.
Buy some cattle, but sell them again the next year.
Doesn't rent out trees for fodder, because they are "too small".
Don't keep **bees**, because there are too many predators; lizards, ants, termites.
They apply all the 'compost' they have, but it is not enough, so they have to buy chemical fertilizer.
Weeding is done manually and with herbicides. Takes 5 laborers +/- one day to weed a field of 0.25 ha.
During the dry season, they plough for finger-millet and work on the government projects.
Compost is made by adding leftover cattle feed, kitchen leftovers, manure, weeds. During the dry season, they burn all the manure, but during the wet season they add manure to the compost on a daily basis.
Income
Sells surplus crops every season, mostly teff, millet and wheat
Sell hens and lambs
Water
There is a rainwater pond in the corner for some light irrigation and a communal handpump 100m from the farm.
Biogas
Has biogas but doesn't use it. "It takes a great effort" and "doesn't have enough land to use it".
His brother has biogas too, and says it doesn't give enough energy.
Government asked who wanted it, then "experts" came and installed it for those who showed interest in it.
Personal opinions
It is easier to get help from extension agents now than 10 years ago. The **government provides** transport of fertilizer to the village, and provide knowledge and new products.
The harvest is decreasing now though, because the **rain is inconsistent** and farmers have to spend some of their time working on government projects.
High price of fertilizer and fluctuations in weather limits them from **producing more food/income**
Does not agree with the zero-grazing; when the animals are tethered at home, it costs them more to provide fodder for them.
Compost is better than artificial fertilizer; AF is expensive and natural fertilizer contains no toxins.
Future vision
Would like to have more sheep and teff.
Would like to have some fruit trees
Would like to have as much animals as possible

Farm 4
Intersection between mountain and church valley
Male-led household (80y), 3 pax (2 children at university in city)
Had the farm for 43 years, in which time they gave 3 plots to their children.
Declined the final round of interviews. (research fatigue)

Farming components
Teff, millet, maize (away from village), guava, mango, avo, papaya, cotton, geisho,
4 ox, 1 cow, 1 donkey, some chickens (having difficulty securing them) (used to have sheep but children to school so no more shepherds)
Finger-millet most valuable to them, (even when considering disease susceptibility)
Ox is most valuable
Has an extra field (between orchard and house) where nothing is being planted. Because "they can't afford a worker". Also, they don't want to rent it out, because "the others wants them to irrigate it" (the well is 20m from the field) and "they want more than 50% of the yield."
Livestock
Cut-and-carried grass (10 donkey loads lasts 4 months), crop residue "collected", leftover from sua, cactus when there is no straw. This only happens during drought. No commercial feed.
Manure collected from night room of the cow, from tethered animals, and from fields around homestead where animals graze after harvesting. Wet manure is used for the trees, dry manure for fire.
For burning and composting
External inputs
200kg of fertilizer a year
Labor – "they are getting older and older". When interviewed there was a dayworker harvesting and bringing their teff to them, it was his 3rd day at 100birr/day.

Income
Guavas directly to market and surplus of other products sold after having enough for themselves to eat. They always have enough to eat.
Letrebrehan (the child) was selling guavas on a Thursday in the main street. She was the only vendor. (*are they that desperate for money, or is it because the guavas are ripe and they need to sell them?)*
No income generated by animals.
Water
Has a great deep and clean well, says he irrigates all his crops with it. There is a motorized pump. Wife says they only irrigate fruit trees because they don't have laborers to do irrigate more.
Biogas
None
Future vision
Would like to have vegetables and tomatos for the market

Farm 6
mountain valley
Male headed household, 5/7 pax (1st interv: man said 5 pax, 2nd interv: lady said 7; 2 adults, 5 children of which 3 males and 4 females)
Had the farm for 43 years, it became smaller because "it was divided and distributed to others"
Farming components
Teff, millet, wheat, maize, sorghum, geisha, orange, will plant cabbage and other veg after harvested millet. (said the man during interview 1), the lady said they didn't grow any vegetables and will not plant anything after the harvest because there is not water. (interview 2)
They store and eat the crops, the fruit (95%) and veg is for market
4 ox, 10 sheep, 1 cow, 15 chicken (7 hybrid)
Finger-millet is most valuable crop, because of high yield/sq.m. and market value (but it is disease prone, used to have enough to sell some, now not enough any more)
Ox is most valuable to them.
Livestock
Eat collected grass, crop residue, leftover from sua, cactus mixed with straw, and a bit of free grazing around his land. "If it wasn't for the cactus last winter, the cattle would have died". Cattle are not fed tree leaves because their momona tree does not have enough leaves, but the small ruminants eat it some years.
Oxen to communal area between January and August
Burns (less now with electricity and electric stoves) and compost manure collected from around the homestead.
Left in field after post-harvest grazing.
Size of the herd stayed stable over the last 10 years, despite buying and selling of animals periodically.
If they have enough fodder, then the cows produce 10l milk/week

Hide is sold in the market for 40birr
External inputs
150kg of fertilizer a year
Pesticide; especially on teff
Herbicide; wheat and teff
Save some seeds, buy wheat seeds @ 700birr for 0.5 kuntal
Sometimes buy commercial feed, when the crop residue gets finished.
Management
Wait for the rainfall before planting
Makes 'compost' by putting manure, weeds, leftover straw and kitchen waste in a pile. They apply compost every year to all fields, although they rather use fertilizer because the government "forces them" to use it. If this was not they situation, they would use more compost.
In the summer, they add manure to the heap every day, but in the dry season they burn it all.
During the dry season, they raise their cattle, do government work and start ploughing the finger-millet fields.
Income
Sell calves once they are grown and sheep at 1000birr, hens and eggs.
He gets additional income from being a builder
Water
Pool on in-laws neighboring farm where rainwater collects (*it looks like a well)*, water is diverted to their farm with dug channels.
Irrigates orange and geisha with it.
Biogas

None
Personal opinions
Access to water is holding back **increased production**. They would like to irrigate a field in the dry season, but they don't have money for a water pump. The "high price" of fertilizer is preventing them from attaining maximum yield.
Does not keep **bees**, because they do not have money to buy them and believe that the colony would not stay long before moving away.
Climate has become warmer in the dry season, but the conditions for growing wheat have improved. The rainfall is more moderate now, in the past there used to be more floods.
Future goals
Less animals, he doesn't have time to manage them all
Wants machinery for ploughing, because then he can fatten his ox and thus sell them at a higher price in the market.

8.2.3 Transcribed key-informant interviews

8.2.3.1 Ecology of farming

Dr. Sarah Tewolde-Berhan – *Ecological Organic Agriculture Project, College of Agriculture, MU*

Researcher: Is it correct to assume that zero-grazing is beneficial for the landscape, but that its benefits for on-farm productivity and subsequent food security is limited?

Interviewee: Yes and no. There are a lot more benefits at a landscape level, I agree. If zero grazing is possible to introduce, then interventions like pasture management, pasture improvement, planting of perennial fodder crops would be possible. There is a direct link between the farmer and the animal if that is possible to do. Thus far, a lot of agroforestry interventions, including fodder improvement, have failed because of free grazing. Even your farmland is not your own, because at the end of every harvest season everybody's animals go everywhere and graze everything. So, if you plant a seedling (with the hope of growing a fodder tree) there is no guarantee that it will be able to grow fodder in the future. ***So, I think it (zero grazing) has direct benefits to the farmer, but not on its own, in combination with other interventions.*** *Because if you just have zero grazing and you don't even manage the landscape itself, there is no benefit to the landscape. Like for example in Abreha we Atsbeha; there is a lot of soil conservation at the landscape level, construction going on all over the place, water conservation interventions. That is all at the landscape level, but if you ask the farmers today, 20 years ago they could only produce once a year with the rains and people did not even have drinking water. If it was a drought year they couldn't produce anything, now they are producing throughout the year.* ***So there is a direct benefit to the farmer aswell when the landscape is restored****, even to the animals. Overall I think it is a good thing, and the biggest challenge for them is something like the hen and the egg scenario; if you introduce zero grazing there is not enough fodder volume left in the landscape to harvest and bring back to feed to the animals, so that is the biggest bottleneck to overcome. Also, children usually took the animals out to pasture, and when they stay at home, someone has to go and harvest fodder. I think what is needed is just a change of mentality and seeing how it can work for them.*

R: In your experience, do you think the farmers recognize that link, seeing that the actions they take is causing the landscape to be more productive for their farms, or do they not grasp that concept?

It depends, in special case, like Abreha we Atsbeha, where the aquifer is quite shallow and impacts can be seen in a short period of time, the farmers grasp the concept. Even in areas where it is not like that, like the rest of Tigray where there are a lot of area closures set up, springs that have been dry for generations are returning and people are appreciative of that, and they make the link between ***the protection of the environment and access to water.*** *Where they are facing a problem, as with animal feed and improved grazing, I think* ***enough extension work hasn't been done to develop pasture land and improving forage and fodder availability.***

R: Do you think there is an opportunity to grow specific fodder crops to facilitate a paradigm shift to fatten animals for the export market, or do the households' nutritional demands not allow for that?
I: In each community there is a grazing area where the animals are going and degrading it further. Those areas can be used for fodder crop growing to some extent. I don't think Tigray is ready for feeding wheat and maize to cattle for fattening. But producing fodder by growing legumous plants like Sesbania, Alfalfa and so on

is a very good option. There is a study that was done on the fodder quality of the indigenous grasses of Ethiopia that showed that there is more nutritional value when the grass is left to grow and accumulate biomass, than when it is eaten in its infancy and there, so that the environment is degrading as biomass buildup is prevented. In that case the palatable species reach a point where they cant even propogate because they are continuously being grazed on. That's a serious problem that can be addressed by going from number of cattle to how fat the ox is or how much meat the animal can have on its body or how much milk is the cow producing. This is something we have to work on, so far in many African countries cattle are security and status and in times of crisis they are the ones that are sold first, and in terms of status people are valued for the number of cattle that they keep. There are places, like in the south of Tigray, where if a man can own 1000 heads he can bathe in milk, so it's all a status thing. So, ***not to disrespect culture or our heritage, but we have to move beyond status*** *and actually come to hard facts that the farmers can see. I mean, an ox that is skinny and bony will sell for much less than a healthy beast. The same with milk production, if you get enough milk, you have enough for your children and also some to sell in the market.*

R: I perceive that the burning of animal manure is limiting the potential of soil fertility in Abreha we Atsbeha, what do you think are limiting factors for soil improvement?

I: The first of course is biomass, and the second is the dry environment. If you want to make good organic fertilizer you need a certain level of moisture there so that micro-organisms can grow and things like earthworms can survive. We have 9 months of very dry conditions and getting an organic system going is quite a challenge. But, I agree that it would be beneficial to put as much as possible of the manure back into the soil.

R: Do you think that biogas digesters have the potential to solve that problem?

I: With biogas, as with other technological implementations, culture plays a major role. Cooking of bread and injeera is not possible on a biogas stove and we are not used to a European style oven, which you can actually use the gas with. So there is a need for technology to catch up somehow.

R: Even though water is limited in Abreha we Atsbeha, it is still possible for a farmer to take, for example, one donkey load of water put on his/her compost heap once a week. But they are not motivated to build compost, do you know what the reasons for that is?

I: Compost is very labor intensive, it needs to be turned over a couple of times, you need to collect all the material to put into the pit, and you need to keep it moist. There are many aspects to it, so farmers maybe don't like all the labor and they are not weighing it against the potential benefit they can get out of it. ***They would have to be really convinced to want to do it.*** *There are a few farmers who really love making compost, but not everyone is like that. Farming as a whole is already a very labor intensive thing, and farmers are used to expending labor, but they prioritize and that doesn't fall on their priority list.*

R: How can one go around improving that scenario, is it through using extension, or showing off model farms, or is there another good way of promoting?

I: Two ways, one is extension and the other is raising awareness. Organic farming has the advantage of being sustainable, healthy and climate appropriate. So, it's good to create awareness that the farmers are actually doing something for the next generation, that they leave behind healthy soils for their children to plough, and also that they are going to be eating healthier foods because they produce organically. A lot of the farmers around here understand what drought is and the threat that climate change pose. ***So, there is a need to create awareness in addition to the extension work that is needed****.*
Compost is one of the packages that the bureau of agriculture is actually promoting, and the extension agents are supposed to help the farmers to work on that, but when it comes to evaluation, ***the extension agents are not being evaluated on how many farmers are making compost and how much compost and organic fertilizer has been produced, but they are being evaluated as to how much chemical fertilizer they have convinced the farmers to take, and how much improved seeds, pesticides and herbicides have been used.*** *I think there is a flaw or a glitch somewhere in the* ***policy*** *of the country and they need to change that somehow. The government states that it is in favor of a Green Economic Development Pathway, of which large-scale compost use forms a big part, but the decision from the top is not making its way effectively to the farms. Extension agents are trained on compost making, but they are not evaluated on it, and if one is not evaluated on something then it is naturally neglected and not followed up on.*

R: In your experience, have you come across any households or farmers that have managed to escape the poverty trap? What were the mechanisms that they used to achieve that?

I: Institute of Sustainable Development (NGO) that was one of key players in getting compost introduced as a national package for agriculture. Lot of work in W-Tigray. Introduced land restoration through zero grazing, compost and improved seed varieties. Study on FAO about this, they found that through using compost for consecutive years, production kept increasing whereas with chemical fertilizer production reached a climax. There one farmer who is very good, he made a hand dug well and innovatively made a pump to get out water. He escaped the poverty trap, he has 6/7 children that all went to school and are now very successful. There is another farmer in the East who has even installed and is using biogas. He uses bioslurry instead of compost and is producing well.

Poverty is also relative. As long as the family is fed and you are doing better than your neighbors, then you are not poor…

8.2.3.2 Apiculture

Mohammed Tilahun – Apiculture researcher in Tigray.

R: What trends do you experience overall in honey production in recent history?

I: It is not a progressive trend showing, but at different years we do survey and experimental research at sites.
The transition from traditional to modern boxes has increased honey production. 7/8kg per year with traditional hives, and more than 25kg a year with modern hives. Some exceptional cases even up to 70kg per colony per year (2 harvests). The average is between 25 and 30kg

R: After the introduction of the modern hives, has there been any cases of decline in production.

I: Sometimes it happens, when they use improved box hive with the same management as they were using before they might sometimes lose their colonies. The boxes are very wide so there is a lot of space, if the bees are not multiplying enough, it creates a room for other parasites. Like wax-moth is the most common one. Many families lost their colonies at the beginning, but have learned that they need improved management, especially cleaning. Inspection is also necessary periodically. Some started feeding their bees with supplement feed like sugar syrup. Powder from peas or beans, or any kind of legumes is also used as a supplement feed. If they don't do this, they see a decline in production. Another reason for decline is because of wax. When we increase box hive adoption, the wax production is lower (because of the design of the box hive). In the traditional hive they remove all the comb together with the honey, but this is not the case with the box hives. They have to uncup the combs, they extract the honey and replace it back. Because of that we also observed a decline in the adoption and production.

R: It sounds to me like it has a lot to do with a lack of knowledge of the best management practices.

I: Yes, lack of knowledge, but also integration. If we also depend on importing beeswax that is dangerous, because then we may be importing pests and diseases. They can come with the wax. Therefore we have to integrate wax production and honey production together. We couldn't make it at the same time because of the technology of the improved box hive. Nowadays in highland areas farmers keep traditional hives for supplement wax.

R: Has the land reached its carrying capacity for bees, or are there still opportunity for more hives?

I: It can happen that the area might be overloaded with colonies, but I think the major problem is with management, because they could supply with supplement food for the bees so that they survive and stay. If they don't produce they could still survive. But the major problem that I observed is that if they don't manage it properly, if they don't inspect and clean the hives periodically, pests and parasites enter the hives. Especially waxmoth is a big challenge

R: What is being done from an extension point of to teach and demonstrate and share knowledge to the farmers.

I: Yes, we work with giving training to the agents who are helping the farmers. We also give training directly to the farmers. There are also other organizations that work with that.

R: Do you experience that in those areas the production improves?

I: Those farmers who manage according to the recommendations are very successful. In Wukro there are very rich people (in local context). Some farmers prefer to keep bees instead of small ruminants.

R: If it is such a lucrative business, why aren't more farmers keeping bees?

I: One thing is the experience, those that are inexperienced fear bees and their stings. They can also kill poultry and dogs. The other is that they need to place the hive a distance away from their home, and then there is the risk that it might get stolen. If they place it close to the home it affects their family and the relationship with the neighbours. Sometimes in villages chemicals (pesticides) are sprayed for different reasons, and this also kills the bees. But despite these challenges, there are still many farmers who are adopting beekeeping. That's why the gov is also giving exclosures for the landless to keep bee boxes. Only cut and carry and bees.

R: Where is the end of the supply chain of the honey, where is the end product sold?

I: Most of the honey from modern boxes is sold in the local market for domestic consumption. Those from traditional boxes are used to make a local alcoholic drink, which creates a livelihood for some people. Genrerally, most of the honey is consumed in the country, very little is exported.

R: Is the domestic demand for it still high, or has it reached a saturation point?

I: Not yet, there is still a very high demand. The price is very high, even when compared to international prices. Because of this honey can't be exported, as the price is not competitive (it is too high for a distributer to make a profit)

R: What is the price that the farmer gets for honey?

I: It depends on the color of the honey, if it is red honey then they get 80-100birr, white honey is 150-200birr a kg. Now it is actually 300.

R: And if it is sold here in Mekele to the consumer, what is the price?

I: 350birr/kg

R: How much does a modern box cost?

I: It was 1300birr 2 years ago (subsidized), but now this year I don't have the exact price. But it should be more than 2000 if privately bought.

R: If they can sell it for 200birr/kg, then they only have to sell 10kg to buy another box?

I: Yes, economically it is very profitable, but the biggest challenge is the risk. Because they cannot be sure that the colony will remain until it can produce for the first time.

R: If you say 2000birr for a box, does that include the box?

I: No, the colony itself cost about 2300birr. But this is still a good investment, because in one year they can multiply to up to 10 colonies.

R: Do they always harvest twice a year?

I: If it the climate is normal or in areas with irrigation, they can harvest twice a year. Otherwise it is only once a year.

R: So keeping bees contributes to food security?

I: Yes. Because it contributes to financial flexibility and it increases ecosystem services.

8.2.3.3 Compost

Mohammed Kebede

R: What is your experience with farmers adopting composting practices?

*I: **Farmers say they are doing compost but it is not, it is basically just farmland manure, bedding material, and crop residue on a heap**. Compost means the decomposing material is monitored, turned and watered. They got complaints that the farmers say that their compost is not working and that it harbors pests and diseases.*

R: What does the teaching program look like when you go and teach farmers about composting?

I: We teach them about organic farming in general: intercropping, animal manure, green manure (growing highly vegetative crops and then discing them into the soil), and also about composting. We also show them the difference between 'lazy' farmers and 'model' farmers. Then they all say they do like the lazy farmers, who only put dung. They are supposed to start with putting a stick in the heap, and feeling the temperature; if it is hot, they should put holes and water because the micro-organisms could die. If it is cold, decomposition is not happening. If there is white coloration on the stick, there is likely fungus in the heap.

R: Do you make follow-up visits to those farmers?

I: That is our plan, we told them that we would return. We write a proposal for that, but it was not approved by the university so we don't have resources to follow up.

R: Are these training successful?

I: Yes, because they learn that they have to manage the heap, and also that they can put the kitchen waste on the heap. Currently they sometimes throw it away, because they believe that is what bring the pests.

R: So would you say that lack of knowledge is a limiting factor for effective composting?

*I: **Yes, lack of awareness. Especially about the materials, management and time. They don't know how long time it should decompose before it is good to use. They also don't add soil, or pay attention to layering.***

R: How long time is a good period?

I: It is depending on the heat, the amount of water and the number of micro-organisms. They can increase the number of micro-organisms by adding topsoil, but they don't know that. But in genera,l it takes about 3-6 months.

R: So, ideally start composting after harvest and then it is ready before the next planting season?

I: Yes, then they apply it during the ploughing. Which is good because if it is only applied some material might leach out.

R: What else prevents the teaching of composting practices from being effective?

*I: Sometimes when they advertise that there will be a teaching program, **then the Woredas would send their best farmers, or 'model' farmers to represent**. **So, the information doesn't get through to the people who need it most.** And we also don't know what the knowledge level is at grass root level. We have also found that the distribution of the 'compost' to the field is very sporadic and uneven.*

R: How much compost do you need for one hectare of land?

*I: 10-20 tonnes, depending on the quality of the compost, the nutrient content. The quality of the compost is dependent on the material. For horticulture it is about 30-50 tonnes. That is only about 2 or 3 pits. **If they***

utilize all the available material they can produce enough. Especially farmers with cattle can produce big enough amounts. Also, most farmers have smaller fields than 1 hectare.

R: Some farmers that I interviewed said that they didn't have enough plant material, what is your response to that?

I: This is the lack of the knowledge about composting materials. They don't use the crop residue, the weeds, kitchen waste, ash (potassium and calcium) and other random material.

R: Do you have any experience with farmers who use biogas?

I: Very rich farmers use biogas. They need lot of animals. The government installed them and they are using it for light and cooking, but the farmers we work with don't have them.

R: What are your thoughts on farmers who burn manure?

I: It is a big problem. ***The same as when they burn sorghum and maize stovers for fire instead of the compost heap. If they place those at the bottom of the pit it provides aeration, and thus accelerates decomposition. Then they would also have enough material, even those without animals can make compost.***

Also if they had electricity they would not have to burn so much organic material, but the farmers in those areas do not have electricity.

R: Are there extension agents who teach about composting?

I: In every Kebele there are, but they are just working for the government, and so ***they are just concerned with how many farmers are using nitrogen fertilizer or urea treatment. They don't care about the compost. They give 'medals' (or accolades) to those agents who sell the most fertilizer, and they are most likely to get promoted.***

8.2.3.4 Livestock

Dr. Solomon Bariagabre: *Head of department of animal production.*

R: Any evidence that points to how whole farm productivity has been effected by changes in grazing regimes?
I: Of course as a strategy the gov has tried to introduce the zero grazing system. Actually not only by the gov, in some areas the traditional practice is to not allow grazing in the lower valleys. There are merits and demerits; in areas where the livestock populations are high, it is hard to implement zero grazing; because you need watering, fodder. Carrying capacity is around 10 animal units per household. Farmers are forced to retain few animals in the crop—livestock system. In the lowlands areas of the Southern zone there is vast areas of land, so animals are allowed to graze freely. ***The limiting factor is feed availability***. ***Livestock production in the region is limited by*** *4 factors; 1.* ***Feed,*** *2. Health, 3. Marketing network, 4.* ***Breed characterization***. *Zebu (Bosindicus) is the local breed, and they are trying to introduce more of the high yielding milk producing exotic varieties like, Gurnsey, Bosmaris, Halstead.*

R: Is there causation with zero grazing effecting crop productivity?

I: From a landscape point of view it is beneficial: it limits overgrazing, overstocking, and over utilization. From a ***nutrient cycling point of view, there is the disadvantage that urine is lost which would otherwise be deposited to the soils.*** *However, the government looks at it from the point of view of area rehabilitation.*

R: What are the prevalence of diseases among livestock in the region?
I: We have different internal and external parasites in the region. Also some bacterial diseases; anthrax, bovine pastrolisis. Also ticks, flies and lice that effect the productivity of the animals.

R: Is there a gov program that provide farmers with access to a veterinary scientist?
I: ***Vaccination program is free****. climate insurance programs* ***REST****; if you lose your crops or animals because of drought or disease, flooding****. Credit loans*** *can help with paying for the insurance.*

R: Do farmers have to pay for veterinary services?
*I: Vaccination is free, but **treatment is subsidized based on the income of the farmers**. Some **imported medicine** is very expensive, so gov **subsidizes** that expense. The government says there is no such thing as free handouts, they want the farmers to **pay for the services, so that they are not only reliant on handouts**, in a way they are teaching them financial management.*

R: What are the opportunities for a small-scale farmer to get access to the livestock export market? Is it a realistic proposition for a farmer to upscale his/her production for that?
***I:** **Marketing infrastructure is not well developed**, but information to market has become accessible recently. We **have agricultural product marketing information agency in the region, they survey the market and broadcasts info on radio and tv programs**.*
*The abbatoir (Mekelle Meat Export Center) collects animals at central market places. Farmers send their animals to Wikro market, then the abbatoir collects them from there. The **problem is not access to market, but rather the quality of animals**. The ox is sent to market after being utilized on the farm. So the quality of the meat is lower than what is demanded by the international importers. After consultation with the import agencies, we learned that they prefer lean and tender meat, but the worked ox comes with tough muscles. But the government is popularizing and promoting the animal product market.*

R: Maybe a shift is needed to mechanize ploughing and fattening animals?
I: Small ruminant and cattle fattening is one of the packages in the department of agriculture's development strategy. Government aims to reduce the reliance of the mixed crop farming systems on large ruminants to reduce GHG emissions. That's where small mechanization practice will be introduced. So far the oxen driven practice is culturally driven.

After the official interview was discussed, the converstion continued some more:

"Green climate resilient governing policy of the environment"
The scope of food security goes beyond the scope of food, so therefore it is hard to measure.
Benefits of beekeeping: (Dr. Solomon)
- Don't need land
- No GHG emissions
- Ecosystems services of pollinators
- Good market value of honey

Colonies leave because:
- Enemies; insects and parasites.
- Climate; availability of water
- Access to flora

Land belongs to the government… land distribution is no longer in practice. **Scattered and fragmented nature of the land atm**. Can't be subdivided even more. Land belongs to the household, who is allowed to endow it onto future generations. Challenge, because population is increasing but the land is fixed. Have to increase land use efficiency and industrialize the economy to create employment opportunities for the future generations. – Dr. Solomon

8.3 Extras

8.3.1 Quantitative survey

During the last three weeks of the fieldwork, a structured survey of 100 randomly selected households was designed, tested and conducted in the community, as a supplement to the primary case data. The aim of the survey was to gain additional insight into some of the perceived phenomena within the system, for example; the prevalence of using energy sources other than fire for cooking, the reason why more farmers did not keep bees, and how often farmers generally relied on food aid to supplement household nutrition. However, the qualitative data above was deemed sufficient to answer the research questions.

Mekelle University
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QUESTIONNAIRE: FARM MANAGEMENT FOR FOOD SECURITY

Explain the purpose of the study: To illustrate the relationship between farm management, and food security.
Inform the respondent that the study will be used to advice policy, extension and research interventions that could favor the respondent.

The respondent's identity will not be shared with anyone, and the information that he/she gives will only be handled by the researcher, CJ van Blerk. After the report is finalized in June 2017, the information will be destroyed. The respondent has the right to refuse to answer any question/s.

Ask if the respondent is willing to be interviewed, if he/she agrees, start the interview

1 **Is the leader of the household male or female?**
Circle the correct choice Male | Female

2 **How old is the head of the household?** _____(years)

3 **How many able-bodied and adult family members are there? Older than 14 years**

_____(number)

4 **What is the total size of the cultivated land?** _____(ha)

5 **How long have they lived here on this farm?** _____(years)

6 **Do they have a well?** *Circle correct option* Yes | No

7 **Do they have a biogas installation?**
Circle the correct option Yes | No

If no, go to question 10

If yes…
8 **How long have they had it?**

1 2 3 4 5 6+ years?

9 In one week, how many times do they cook with it?

Never | a few times | every day

10 Do they have electricity? Yes | No

If no, go to question 12

If yes…

11 In a week, how many days do they use the electricity for cooking?

Circle the appropriate number of days

1 | 2 | 3 | 4 | 5 | 6 | 7

12 Do they have a compost pit, heap or nothing at all?

Circle the correct option Pit | Heap | Nothing

13 How many of each animal do they have?

Ask about every animal, don't just accept their first answer

Type of animal	*Number*
Ox	
Cow	
Donkey	
Horse	
Sheep	
Goat	
Chicken	

14 In the last 5 years, have the amount of animals that they have changed?

Circle the appropriate answer

decreased | stayed the same | increased

15 Do they have to buy extra feed for their animals?

Circle the appropriate answer Yes | No

16 Do they have bees?

Circle the correct response Yes | No

If yes, go to question 18

If no…

17 Why not?

Write in English please

---

18 How many hives?

Circle the correct response

1 | 2 | 3 | 4 | 5+

19 In the last year, how much income did they produce from selling honey? _____birr

20 Where do the family's income come from?

Mark each response with an X

Selling crops
Selling animals
Working as labor on farms
From family member working in the city/abroad
From doing other work
Other
(*write in English)*

……

21 If someone gave them money to invest in their farm, what would they spend it on?

Just ask the question, and then put a X next to what they answer.

More animals
More land
Water pump
Fertilizer
Labor
Bees
Biogas
Other
(*write in English)*

…….

22 In the last 5 years, how many years did they rely on food aid to feed the family?

Circle the correct response

0 | 1 | 2 | 3 | 4 | 5+