SOME EXAMPLES OF BEST PRACTICES BY SMALLHOLDER FARMERS IN ETHIOPIA

1. INTRODUCTION

1.1 THE AIM OF THIS BOOKLET

This booklet collects together some of the many examples of best practices developed and used by smallholder farmers. These have emerged from within and alongside projects focused on solving problems in relation to natural resources management, crop production and food security. Many of these also address the challenges from climate change faced by these farmers. The aim of producing this booklet is to bring these best practices to the notice of development partners, local experts, researchers and other professionals so that they can understand and incorporate them into their local sustainable development and research programs.

Even though smallholder farmers in Ethiopia are highly challenged with land degradation, low soil fertility, climate change and food insecurity, they do not sit and wait. Instead they innovate coping strategies to overcome their problems at the local level. The importance and uptake of these different practices and innovations depends on the particular advantages gained and the problems they solve.

These farmer-developed innovations are localized solutions that are part of wider interventions being promoted by locally-based organizations through projects and programs. The Institute for Sustainable Development (ISD) is an Ethiopian NGO that has acknowledged and supported the enhancement of local knowledge and smallholder practices since 1996. This traditional wisdom has been combined with efforts to rehabilitate land, improve crop production and domestic animal management based on ecological principles through helping communities protect and use their natural resources sustainably supported by their own by-laws.

PROLINNOVA[1]–Ethiopia (PE) has a similar philosophy, building on the International Soil and Water Conservation (ISWC) project component that was started in Tigray in 1997. From 2003, the PROLINNOVA–Ethiopia platform has expanded to other parts of the country.

The Best Practice Association (BPA) was born in November 2011 from a deep desire to assess, document, promote and scale up/out some of the best practices that have been developed by farmers participating in the ISD and PE projects. The aim also includes creating awareness among agricultural specialists, researchers, academicians, policymakers and other stakeholders in the country about the effectiveness of the local practices and innovations for improving livelihoods in both rural and urban areas, with particular attention to the challenges raised by climate change.

This publication is made up as follows: Chapter 1 gives the general background; Chapter 2 describes examples of best practices for integrated watershed management; Chapter 3 focuses on innovative water management related technologies; Chapter 4 describes efforts by farmers to adapt to climate change; Chapter 5 highlights some best ecological practices used by farmers to bring about sustainable agricultural production for improved food security; while Chapter 6 shows the contribution of different institutions in environmental conservation which is essential for any other improvement to succeed and be sustainable.

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1 PROLINNOVA: PROmoting Local INNOVAtion in ecologically oriented agriculture and natural resource management, a Global Partnership Programme of the Global Forum on Agricultural Research (GFAR)

1.2 THE SOCIAL AND GOVERNMENT STRUCTURES IN ETHIOPIA

The key players in the projects are farmers and farming communities with their local experts and authorities. The social and government structures of Ethiopia and Ethiopians are as follows.

- Community members are tied to each other through shared social, economic and religious cultural norms. Every member of the community has the right to access and an obligation to protect all the local assets of their own holdings as well as the wider community. Households usually live within close proximity to each other to form a *kushet/got* in Tigrinya, *mender* in Amharic of around 20 and up to 90 households often associated closely with one or two centers of worship: a church and/or mosque. Hence they can be loosely equated with a village or parish.

- Politically the lowest level of administration is the *tabia* in Tigrinya, *kebele* in Amharic, of between 500 and 900 households which is governed by a Chairperson supported by a committee, all elected from and by the local community, and a paid manager.

- Each *kebele/tabia* has a team of at least 3 agriculture development agents (DAs) to help the farmers implement improvements to their activities. Each DAs has a defined area of work in either natural resources management, or animal science, or crop science—agronomy and irrigation. The DAs work under the direction of their respective wereda-based experts. They also manage the local Farmers' Training Centers (FTCs).

- The main development strategies of the government are implemented through the *wereda* (equivalent to a district) that is managed by a wereda council with a government appointed and paid administrator and his administrative and finance staff who support technical teams of experts. The administrator is supported by an elected advisory council. Each wereda also elects a representative to its Regional and Federal Houses of Representatives. Above the weredas are the Zones and then the Regional States.

1.3 THE ENVIRONMENTAL AND POLITICAL CHALLENGES FOR FARMERS

Droughts are recorded from throughout Ethiopian history through the official *Tarike Negest* "Chronicles of the Emperors". The *kremt* rains for the main growing season come from the Atlantic Ocean and hence are longest and heaviest in the south and west of the country, and shortest in the highlands of the east and north-east of the country: South and North Wollo in Amhara Region, and Central and Eastern Zones of Tigray Region. But the eastern and northern highlands are densely populated with smallholder farming households, and, because water is scarce, almost all have to depend only on rainfall to get a harvest to sustain them from one growing season to the next. Hence, any innovations that restore ecosystem services, particularly water as described in this booklet, can bring dramatic changes to the landscape and the livelihoods of the farmers.

Tigray and Wollo are well known for occurrences of disastrous droughts and accompanying famines. For example, in the two recent droughts of 1973/4 and 1984/5, Ethiopia lost hundreds of thousands of people and huge numbers of domestic animals. Both of these droughts and famines heralded dramatic changes in the political government of the country. That of 1973/4 was followed by the removal of the Emperor and many of the feudal lords to be replaced by the Military Government, the *derg*. The *derg* took up the slogan of "land to the tiller" with the granting of usuary rights to their land for the smallholder farmers and the organization of local communities into kebeles—the basis of local government. The 1984/5 drought triggered the start of the downfall of the *derg* and its replacement by the present government in 1991.

Despite the land reform instituted under the *derg*, until 1991, very little attention, let alone support, had been directed to the majority of Ethiopia's smallholder farmers. But over the last 20 years or so, this situation has been reversed. This local empowerment has made it possible for innovative farmers to bring about major changes to their environments, agricultural production and livelihoods. A few examples of these innovations are described in the following pages.

1.4 HOW THE BEST PRACTICES WERE SELECTED

The best practices described in this booklet were chosen after a study visit was organized for development workers of Ethiopian Evangelical Church Mekane Yesus, Development and Social Services Commission (EECMY-DASSC) and Lutheran World Federation, which are supported by The Church of Sweden. The aim was to convince and enhance the visitors' capacity in their development work by going to places known for their environmental vulnerability but which had been changed by the innovative efforts of their local communities, leaders and farmers. When the request for organizing the study trip came to BPA, it was decided that the right places to convince the visitors can be found in Tigray and Wollo. The other reason for the selection was that the leaders of the study visit are familiar with the farmers in these places, and the changes they have brought about.

The study visit went first to Dessie, the capital of the South Wollo Zone in Amhara Region in order to see and discuss with the farmers in Tehuledere and Ambassel weredas just north of Dessie.

Second, the group drove through Alamata-Korem in Southern Tigray. The wide valley beside Korem was where the relief feeding camp that hit the international headlines was set up during the 1984/5 drought.

Third was the visit to Wuqro, where Abreha we-Atsbeha is found in the Eastern Zone of Tigray. It is found in part of the rain-shadow region of the Ethiopian Highlands north-east of the Semien Mountains.

The study visit was concluded in Tahtai Maichew near Aksum as its surroundings are known for their ancient political and agricultural history. Since 1996, this area has been the main partner with ISD in its ecological agriculture and community development work.

Figure 1 shows the locations where the group visited and the best practices described in this book are found.

Figure 1: Ethiopia, the locations visited and where the examples of best practices described in this publication are found (1 – Tahtai Maichew, 2 – Abreha we-Atsbeha and Wuqro, 3 – Alamata-Kobo, 4 – Desse Zuria, 5 – Hitossa, 6 – Hosa'ena, 7 – Aleta Chuko, 8 – Armacheho)

2. INTEGRATED WATERSHED MANAGEMENT

Ethiopia is a mountainous country with 45% of the land above 1500 m asl. Most of the population are smallholder farmers who live between 1500 and 2500 m asl making their living from mixed animal and crop production cultivating their small fields with oxen. Extensive land degradation and soil erosion has greatly reduced the fertility of their soil resulting in low yields and a food-insecure society. But Ethiopia's smallholder farmers have been finding ways to cope with problems using their own practices and innovations, developed over millennia, with or without some external support.

The government of Ethiopia has encouraged local communities to mobilize themselves to improve their natural resources throughout the country but especially in the eastern and northern parts where land degradation is the most serious problem. For example, since the 1990s in Tigray, all the adults in a local community have been giving 20 days of free service each year to work on improving their environment, particularly in building structures for soil and water conservation, and improving local infrastructure such as local roads, schools and water collecting earth dams and ponds. Many communities have also included areas of degraded hillsides for natural rehabilitation and conservation by excluding grazing and preventing the cutting of woody vegetation. This enables grasses and herbs to grow so they can be harvested for animal feed. The areas are called enclosures or exclosures. As a result of this community work, there are now many hillsides where the natural vegetation has come back including plants useful for bee forage.

2.1 THE SURROUNDINGS OF 'HAYQ'[2]

Hayq is the Amharic word for lake. So this lake 30 km north of Dessie is just known as 'the lake' *Hayq*, and the town next to it has the same name. Dessie is the capital of South Wollo Zone of Amhara Region, just 400 km north from Addis Ababa.

[2] Pronounced 'haik'

Hayq is in an enclosed bowl surrounded by hills with steep, often almost vertical slopes. Farmers have been cultivating this area for centuries including having fields on the steep slopes. In the 1990s, much of *Hayq* and Dessie was surrounded by a highly degraded landscape with some of the steepest areas planted with eucalypts (different *Eucalyptus* species) and Mexican Cypress (*Cupressus lusitanica*), neither of which control erosion. There are small scattered patches of the indigenous juniper, olive and acacia forest usually associated with churches or mosques. Hence, when it rains the water runs off the slopes in torrents bringing much mud and stones with it.

By the late 1990s, the lake was suffering from silt accumulation. The uncontrolled grazing around the lake by domestic animals as well as their access to the lake to drink the water were destroying its shore and the protective vegetation. The farmers were also plowing right to the edge of the lake to make their fields. Overall, the local communities around the lake were not protecting their land.

As a consequence, the depth of the water in *Hayq* was getting shallower and the fish population was diminishing due to the lack of places to breed. The soil being removed from the hillsides was destroying everything so that crop and fish production was decreasing.

In 2007/8, the Tehuledere Wereda Agriculture Office and the local communities met and agreed to work together to restore their degraded landscape through integrated land management. They had also heard of the disappearance of the once highly productive Lake Alemaya near Harar due to the lack of integrated land management by the local people. The Tehuledere officials received support for this initiative from the Federal Environmental Protection Authority (FEPA) under its UNDP-supported Land Rehabilitation Project, the Environmental Protection and Land Use Administration (EPLUA) of Amhara Region together with ISD. Figure 2 shows the pattern of fields and homesteads in a part of the watershed adjacent to the lake in 2013 where good planning and control of grazing animals has been implemented.

Figure 2: Partial view of Hayq and its surroundings to the south-west direction showing the local road, the fields going down to the protected edge of the lake, houses in scattered farmsteads as well as the drainage channels from the hills. Also visible in the image are the contour bunds between the fields that provide soil and water conservation in the watersheds

Conservation work was started by treating the hillsides at the top of each watershed. The community members built physical soil and water harvesting structures, called "bunds", along the contours. The bunds were stabilized by planting them with useful trees and grasses. At the same time, the local community members agreed to control the movement of their grazing animals by using "cut and carry" of forage from the protected hillsides and keeping their animals tethered when taken out for grazing. A no-plow zone was identified along the shore of the lake with specific access places for the domestic animals to go and drink, see Figure 3.

Through advice and planting materials provided by the local experts, the farmers planned their homesteads to include live hedges, and quick growing trees, particularly eucalypt to provide wood for fuel and construction.

The most innovative development is the use of mixed planting of annual crops and perennial fruit trees in the cultivated zone between the protected lake shore and the homesteads and nearby road. The farming communities benefit from a well developed nursery near the town of Hayq from which they are able to get planting materials of banana, sugar cane, grafted sweet orange seedlings and other fruits. They also plant coffee in the shade of the trees.

The *Hayq* fishermen also met and agreed to a 'no fishing' season supported by a bylaw to be respected by the local people.

Figure 3: The intensely cultivated area leading down to the edge of Hayq: note the band of dark green sedges protecting the edge of the lake, and the protected borders between the fields planted with grasses

These integrated land management measures have given the local *Hayq* farming households and their communities the following improvements and advantages:

- Flooding and erosion from the top of the hills has stopped due to the improved permanent vegetation cover;
- The depth of the water in *Hayq* has increased and stabilized so that farmers can produce crops and fruits throughout the year with micro-irrigation from permanent streams and the lake;
- Animals are better fed because farmers make hay from the rehabilitated grazing areas and the vegetation from the protected hillsides;
- Farmers collect and use their animal dung to make and use compost and this has improved the structure and fertility of the soil so that the yields of their crops have increased;
- Farmers have increased their income through crop diversification; and
- The fish catch has increased tremendously also contributing to building up the local economy.

Farmers have seen and accept the need for good land use planning as a practical way to improve their livelihoods. The integrated conservation by farmers working with their local development agents has brought trust among the farmers with their experts and other local officials.

The farmers have built their confidence and are prepared to try other improvements to their agricultural management such as the use of the legume *Desmodium* and the forage grass *Bracharia* to help them control stem borer moths and the parasitic weed *Striga*. This system is known as ‘push-pull’ as the *Desmodium* produces a scent for the moths that pushes the female stem borer moths out of the field while the grass ‘pulls’ the moths to lay their eggs in it. The *Desmodium* also causes Striga seed to germinate but it dies before attaching itself to the roots of another plant.

Visitors (farmers, experts, officials and researchers) from many places are now coming to *Hayq* to get a better understanding of how an integrated and fully participatory approach to land management can bring multiple benefits for the local communities.

2.2 ABREHA WE-ATSBEHA

Abreha we-Atsbeha Kebele is 15 km to the northwest from Wuqro town found on the main road from Mekelle to Adigrat. Wuqro is 45 km north of Mekelle, the capital of Tigray Region. The Kebele is named for the ancient church established back in the twelfth century and dedicated to the first Christian emperors of Ethiopia, the brothers Abreha (meaning '*he illuminated*') and Atsbeha (meaning *'he brought the dawn'*).

The Abreha we-Atsbeha Kebele is in a long valley running approximately south to north between a sandstone ridge on the west and a basalt ridge on the east. Most of the soil is very sandy with poor water holding capacity but the water table can be reached by digging shallow hand dug wells. There is a central protected grazing area with a rich biodiversity that is also a wetland in the rainy season. The presence of the water table is indicated by the large fig and *momona* (*Acacia/Faidherbia albida*) trees scattered throughout the valley.

In the early 1990s, after the fall of the Military government (*Derg*), the Abreha we-Atsbeha area was so badly degraded that the local people asked the new government to find them a place where they could go and live. But then the community came together to discuss and find solutions for themselves. They said: "*We are born and grew up here; our fathers and mothers lived, died and are buried here. Leaving this place does not mean it is like selling or changing a house. It is like betraying our country, culture and religion*".

The whole community agreed that the problem was land degradation and water scarcity. They decided to heal their land through working to stop gullies and reclaim hill sides. They got some of the ideas for this through cross visits with other communities working with ISD, Mekelle University and the wereda administration. After one year they saw that the places with combined physical and biological soil and water conservation work held more moisture than the physical structures alone. This has encouraged them to try and reclaim more land every year. Now this Kebele is a model in the whole of Tigray for its exemplary restoration and conservation work. In June 2012, Abreha we-Atsbeha received The Equator Prize at the Rio+20 World Summit on Sustainable Development in Rio de Janeiro. This achievement can be put down to the dedication, innovation and leadership of one man, the Kebele Chairman, *Aba Hawi.*

2.2.1 Aba Hawi and The "Act First Principle"

Gebremikael Gidey is the name of the Kebele Chairman of Abreha we-Atsbeha. His name during his childhood was *Godefay* because he was an only child without either brothers or sisters. *Aba Hawi*, which means the Fire Man, is the name given to him later when many visitors from western Tigray came to see the community work of Abreha we-Atsbeha. They observed his active community mobilization and heard how he mobilized the people to start the conservation work, particularly the structures for water harvesting and recharging the water table at the slightly higher north end of the valley. Later another group came and suggested that it would be better to change his name from *Aba Hawi* to *Engineer*.

Then *Aba* Dula Gemeda (the present Speaker for the House of Representatives–the Parliament) visited Abreha we-Atsbeha and heard about the suggested change in name to *Engineer*. But *Aba* Dula Gemeda preferred the name *Aba Hawi*. According to *Aba* Dula, it means ***wish*** in Afan Oromo. *Aba* Dula pointed out that: "*Aba Hawi is implementing his own wish, his peoples' wish and our wish*." Later the name *Aba Hawi* was approved by the Kilte Awla'elo Wereda Council, which is the seat of local government for the area.

Many people from his own Kebele and elsewhere have confirmed that *Aba Hawi* is always active, getting things done, and that he is a self-taught landscape-designer, engineer, etc. He does not have the patience just to listen and stay in his office doing paper work. He and his people start acting even before the design and expert advice for a new improvement is brought to them. As soon as *Aba Hawi* has understood a plan for an improvement, he mobilizes his community members to put it into action.

Figure 4: Aba Hawi (Gebremikael Gidey) welcoming visitors to Abreha we-Atsbeha during their learning visit in October 2012

Aba Hawi is a proactive leader. He is always looking for different types of crops to plant and technologies to put in place. He is known as the risk-taker on behalf of the community using his own resources to buy and test these new technologies. This is to show other people when it works, but if it is not successful he takes the loss himself on behalf of the community. His is particularly good in scaling out any successful technology through encouraging farmers to do it themselves.

For example, he made a contract with some farmers who were reluctant to grow vegetables for a 50% share in the product whereby he provided all the seed while the farmers invested their labor. The farmers explained that *Aba Hawi* used his own money to buy the seed and show them that the plants would grow on their land. As a result, they said that they would continue this work in the next cropping season without his involvement.

One of his principles is "*Do not plant trees if the survival rate is going to be low*". He said: "*Why worry and spend a lot of time and labor while our mother nature [around us] is generous? We do not encourage anybody to plant if we are not sure that the survival rate will be high, over 90%, particularly for the seedlings of fruit trees. Our [tree] survival rate is higher than anywhere else in Ethiopia*", *Aba Hawi* says proudly.

By 2010, there was sufficient water in the water table in the valley for micro-irrigation throughout the year with many farmers developing vegetable gardens and fruit orchards.

Another success is the change from free range to zero and controlled grazing to support the natural resource conservation work. With the area rehabilitated, there is plenty of biomass with many farmers taking animal feed as they wish. This also gave a chance for other community members, particularly unemployed and landless youth, to develop beekeeping groups.

2.2.2 Lessons From Abreha we-Atsbeha

All the improved practices in Abreha we-Atsbeha Wereda are based on the principle of *Building the Community's Assets*. It is results-based work with an impact on improved food security for the whole community.

It started with the community members making different types of soil and water conservation structures in the catchment areas on the sloping sides of the valley starting from the top of the slopes and working towards the bottom of the hills.

Now, there is no erosion or violent run off in the whole valley. Water is retained by the physical structures so that it seeps into the ground and recharges the sub-surface ground water. There are even permanent streams and pools of water, see Figure 5

Figure 5: The impact of integrated watershed management in Abreha we-Atsbeha with the steep hills covered in vegetation and a large permanent pool along a river surrounded by trees and shrubs

The main activities implemented by the communities throughout the valley and the significant changes they have seen, are as follows:

- ❖ They start by convincing the members of the community about the importance of the conservation work. All members of the community invest their labor and time for the development without any payment. And there is no one assigned as a guard in any of the watershed catchments and protected areas.

- ❖ The working principle is the proper assignment of a limited number of people to work in a given activity, so that all members of the community can contribute effectively.

- ❖ The community accepted to change from their previous free range grazing culture into the new controlled and 'cut and carry' animal feeding system.

  During the study visit to the area in October 2012, no animal was observed outside their owners' houses. *Aba Hawi* and the community said that they give much attention to 'area closure' because it gives better results than the physical and biological conservation work by itself. This is because with free range grazing, the animals trample on and destroy many plants so that those that grow from the soil seed bank cannot establish. Now the fields have many young *momona* trees growing up without being planted.

- The Abreha we-Atsbeha Kebele is very wide so that the conservation work is still expanding. In the first half of 2012, 11 check dams were constructed in one community and by October they were full of water.
- All levels of the conservation work are linked to improved food security and income generating activities. The local town of Wuqro gets a steady supply of fruits and vegetables from the farmers of Abreha we-Atsbeha who have established micro-irrigation from hand dug wells.
- In October 2012, after the teff grown during the main rainy season had been harvested, *Aba Hawi* was planting teff to show the farmers that this crop can also be grown during the dry season using irrigation.

2.3 Ecological Farming Improves Livelihoods

Given the chance, farmers share their traditional knowledge and look for time-tested traditional and improved practices to solve their problems. Farmers have been working to maintain and improve the productivity of their soil through the use of local knowledge and technologies long before chemical fertilizer was discovered and promoted.

Even after the increased promotion of chemical fertilizer to Ethiopia's farmers in the 1990s, they soon realized that it is not cost effective because taking the chemical fertilizer through credit reduces their families' income and security at the end of each growing season. It also aggravates the problems associated with climate change, particularly the need for the soil to hold moisture during the dry gaps in the rainy season. Chemical fertilizer can only work well when there is enough moisture to dissolve and transport the nutrients to the plants. But even then, the structure and condition of the soil has to be maintained by providing humus—the most important ingredient in compost. Humus is a spongy material that can hold many times its own weight in water. It also sticks the soil particles together helping to prevent erosion.

When there are environmental challenges, farmers explain that it is not useful to arm them with expensive external technologies that destroy their local resources, particularly their seed and their soil, and put them into debt. But using an ecological approach backed up by sound professional advice, as the following example describes, can change the life of a farmer, his/her family and their neighbors from degrading dependent poverty into shared prosperity.

2.3.1 From Desperate Degradation to Prosperity

Farmer Wolde'amanuel Feleke lives in Doreba Kebele, Kachabira Wereda near Hosa'ena of Southern Nations, Nationalities and Peoples (SNNP) Region. He has 10 children who were by 2012 all economically self-reliant or studying. He has 1.5 ha of land. His land is on a steep slope. In the 1980s, there was high run off causing all types of soil erosion in his fields: all the nutrients including the chemical fertilizer he had applied to the field were washed out with the top soil. His land became highly degraded. The crop he got from the field was too small to feed his family.

Farmer Wolde'amanuel thought that this was a supernatural punishment. In response, he says, he was tempted to migrate from the area or join the army of the Military government, the *derg*, as an alternative means of getting a livelihood. Yet, his wife did not allow him to take this option when she came to know of his plan. She suggested to him that he should take another option and offer to plow the fields of other farmers who wanted to lease out their land. By plowing the land of these farmers, he could get a share of the harvest as payment for his labor.

As he described it, he started marching throughout his own and the neighboring kebeles to find land to plow. At one time he had rented land from over 10 farmers. Nevertheless, the share of the harvest he obtained from all these fields was not sufficient to feed his family because the soil in the fields he was leasing was degraded and its productivity was very low, similar to the situation in his own field. He was only getting mental satisfaction from plowing the fields of others for a share in their harvest.

In 2002, Farmer Wolde'amanuel was selected by the kebele administration to attend a training workshop on soil and water conservation, soil fertility enhancement through making and using compost, and forage development. The training was organized by EECMY DASSC South Central Synod branch.

The workshop lasted for three days. The topics were not new to him. He had attended similar workshops organized by other organization. What was different in this workshop was the approach of the trainers and the subsequent follow up from the project organizers that included contact persons called animators to help the farmers. The training was more practical and simple so that participants could understand it easily. Farmer Wolde'amanuel had the opportunity to observe and practice the techniques in the field.

As soon as he arrived back to his home, he visited his field. He observed and understood the bad effects of soil erosion in all its forms in the field. He was amazed to realize how much soil had been taken away from his field. He said: "*While I had been sleeping, erosion was taking lots of soil from my field*". He became very happy to realize that both understanding the problem and finding the solution were in his hands.

That same evening, he described the training and discussed how to use it with his family following what he had observed in his field. All the family members agreed to take part in soil conservation work and carry out fertility enhancement measures. They invited the animator of the project to help them in laying out the conservation structures along the contours of the steeply sloping field. It was suggested that they should use the 'fanyaju' system, which involves making grass strips along the contour to stabilize the soil. But

Farmer Wolde'amanuel wanted to try both fanyaju and raised bunds, which are embankments built of soil stabilized by planting grasses. The bunds hold back both water and soil so the level of the field is raised and more water is held in the soil.

The family working together was able to make these structures. Wolde'amanuel was given cuttings of elephant grass and "desho" (vetiver grass) for planting to stabilize bunds along the contours of the terraces and also provide feed for his livestock. The grasses he was given established and grew quickly. He also prepared compost to improve the fertility of his soil.

One night there was torrential rain. When Farmer Wolde'amanuel ran out the next morning to the field, he observed that some of the bunds had been broken by a big flood. But he did not give up. He decided to discuss this challenge with the animator in order to understand the cause of the destruction. He realized that there had been weak points in the construction of the bunds. He set about strengthening all the bunds. The next time there was a strong rain, the bunds were strong enough to withstand runoff and there was no soil erosion in the field.

With the conservation structures in place and compost added to the soil, he saw that all his crops were growing very well. He appreciated the technology. The grasses planted on the bunds also grew fast and became an additional source of feed for his animals. All these technologies were very much appreciated by him. At harvest time, Farmer Wolde'amanuel got double his previous grain yield as well as more straw for feeding his animals and putting mulch on the soil in his apple orchard, see Figure 6.

As in many parts of Ethiopia, it is becoming common for rain to start later and stop earlier than expected from the past experience of the farmers. But this is not a problem for Farmer Wolde'amanuel because he uses compost and also mulching which improves the water holding capacity of the soil. With the improved feed for his animals, the milk production of his cattle also increased and his oxen became stronger. Seeing this, he started fattening animals for sale when there are public holidays and other local social occasions. This has become an additional source of income for him and his family. He was also trained in highland fruit production and given 10 apple seedlings. He multiplied them and started grafting by himself to sell to his neighbors. This increased his income tremendously.

Figure 6: Farmer Wolde'amanuel showing his bund planted with "desho"and his apple orchard on the upper side with the soil covered with a grass mulch

The increased productivity of the land has increased his trust in the effectiveness of the project because of the way the techniques were taught and the good follow up from the animator. Seeing changes brought by the technologies introduced by Farmer Wolde'amanuel, his neighbors are also using them. Now Farmer Wolde'amanuel is no longer marching around his area to plow other people's fields for a share in the harvest, but being a role model for his community.

His production from his field is more than enough for his family and he has hired three people to work with him full time. During the peak seasons, the number of employees can be more than 10.

2.4 THE SOIL-MAKER IN THE SOILLESS LANDSCAPE

Farmer Araya Welde Aregay is a 58-year old farmer. He lives in Mai Siye Kebele of the Tahtai Maichew Wereda that is 20 km west of Aksum in the north central part of Tigray Region. Like many parts of the Region, this district has many rocky hill sides with very little vegetation. Farmers use any small area of land with soil to grow crops. But this farmer took up the challenge of building fields of soil on the rocky slope.

Farmer Araya is married living with his children and grandchildren who give him company and some little support. Every year he plants his fields with different crops and never rests them to restore some soil fertility even for a single year. Instead he makes and uses compost.

During the 1980s when the Tigray People's Liberation Front (TPLF) controlled most of Tigray, they re-distributed the land amongst the farmers and tried to share out both better more fertile land with poorer areas. But some of the farmers like Farmer Araya received only poor land. His was a steeply sloping rocky plot in a valley surrounded by a rocky landscape. This is the story of how Farmer Araya started to make his fields in this area and expand his cultivated area for his family to become food secure.

2.4.1 THE SOIL-MAKING PROCESS

The farm covers an area on steeply sloping land cut by one big gully with a small permanent river in the bottom. Farmer Araya had no option to go away from his place to find another fertile farm plot or work for someone else as there is a great shortage of farming land in the Central Zone of Tigray. His only alternative was to live with what he had been assigned to use. Then he started fighting the landscape to build terraces that would hold soil and grow his crops, see Figure 7.

Farmer Araya started to build terraces using the big and hard rocks. Then he needed to crush rocks to start making the soil. The rocks are very ancient sandstone and hard to crush. However, he never gave up when faced with this challenge from nature. Every day he dug the rock and crushed the boulders to make soil.

Figure 7: Farmer Araya and fields held by the stone terraces he has built from the bare rock behind him

After many years of struggle he now has fields in wide strips where he can plow by oxen; he digs the narrower strips with a hand tool. Some of the fields have been built on terraces that are taller than him, and he is nearly two meters tall!

After the fields are harvested, Farmer Araya continues building more terraces for more fields. He does this using the following steps that includes incorporating organic matter into the soil.

- First, he completes building each terrace with large rocks along the contour and then he crushes the smaller rocks to make the soil;

- Second, he cuts leafy branches from the local bushes and lays these down along the base of each terrace, see Figure 8;
- Third, he covers the leaves and branches with the crushed rocks mixed with some fertile soil. Sometimes he also adds some animal manure.

Figure 8: Farmer Araya showing how he makes his terraces to hold the soil for his fields: he includes branches from the locally abundant shrub to add organic matter

- Fourth, if there is no rain he waters the new soil to help the leaves and branches break down into organic matter in the soil.

He plants these small fields with a variety of crops. In 2011 he planted seven types of field crop including maize, teff, wheat, barley, and linseed. The crops looked good when the study group visited him in October 2012. He never uses chemical fertilizer because if the rain stops early he knows that the chemical fertilizer would cause his crops to dry up quickly.

The natural vegetation is also being restored around his fields so that he now has three modern beehives. He gets honey and earns some money from this every year.

2.4.2 FARMER ARAYA'S FUTURE DREAM

Farmer Araya said that if he continues to be healthy, he will build small dams to collect water in the river below his farm. Then, he will buy a water-pump to bring the water up to his farm. This will give him the opportunity to grow fruits and vegetables during the dry season as well as his field crops during the main rains.

He says: "*If man creates a friendly relationship with nature, the land can always be made fertile; i.e. it is our responsibility to [care for it] and make it fertile*".

3. WATER RELATED TECHNOLOGIES

Following are three stories of innovative farmers who have developed "best practices" in accessing and managing water. These examples have dramatically changed the lives of their families as well as those of their neighbors and others from different parts of Ethiopia who have visited them. These three farmers, one woman and two men, all live in Tahtai Maichew Wereda that is found about 20 km west of the historic town of Aksum in the northern part of the Central Zone of Tigray Region.

3.1 Sub-Surface Drainage: From Threat to Draining, Storing and Using Water

Farmer Abbadi Redhey is now a full-time farmer who completed fourth grade elementary school. He has been an army truck driver and worked in construction sites before coming back to farming. Like most farmers of the region he has less than one hectare of land for crop cultivation. This is the family's sole source of livelihood support. He and his wife have a family of 5 children.

Before Farmer Abbadi came to his present farm he had another farm area up the hill where he could only grow crops during the rainy season. The land he cultivates now was owned[3] by another farmer. The area was water logged and that farmer could not plow his fields during the rainy season. When Farmer Abbadi understood that the farmer did not want the land he asked the man to exchange it with his rainfed farm up the hill. The farmer was not sure if Abbadi knew about the water logging problem. However, they officially exchanged their farms.

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[3] Land in Ethiopia belongs to the State in the name of the people and cannot be bought, sold or used as collateral to raise a loan from a bank. However, both rural and urban dwellers have usuary rights for the land where they live, which are legally recognized as 'lease rights', and they own any structures, such as houses, they put on their land.

Farmer Abbadi did not find it as easy as he had expected to deal with the water logging problem in his fields. His family suffered before he started to create his innovative water drainage and storage system in his farm. Not only was the land difficult to use but he found that water came into his house covering the floor during the rainy season. To sustain his family, he had to find a way to solve the water drainage problem and make his land productive.

One day, when he was visiting the town of Aksum about 25 km away, Abbadi observed the water drainage system being installed alongside the roads. He saw that when it rained the water was carried away in open canals and did not stay on the soil surface as was happening on his farm. He began to think about how he could apply the same principle on his land. However, he did not want to build open canals because his children and animals could fall into them. His land is also very small, less than one hectare. Having worked previously as a laborer in building construction, he already had knowledge about leveling sloping areas and building methods. He applied this knowledge to solve the water-drainage problem on his land.

Farmer Abbadi made his first attempt by digging a deep and long canal diagonally across the slope of his land. He put long flat stones along the sides of the canal arranged to leave gaps so that the water, but not the soil, could pass easily between the stones. Then he put more flat stones on top of the canal and put the excavated soil on top of this stone cover. The excess water coming from the soil surface and water seeping up from deeper levels was "captured" by the canal and made its way by gravity along the gentle slope of the canal into a pit that Abbadi had dug out for this purpose. This became his first pond. Other canals and a second pond were made later.

His first aim in constructing the canals was to drain the water out of his fields so that he could plant and grow crops during the rainy season. When he saw how well the subsurface drainage canal system was functioning, he gradually expanded it throughout his entire farm, connecting the canals and leading the water to two collecting ponds, see Figure 9. The depth of the underground canals varies from 40 to 180 cm below the soil surface. During the rainy season he does not use the water. Instead, he lets it drain into the nearby small river.

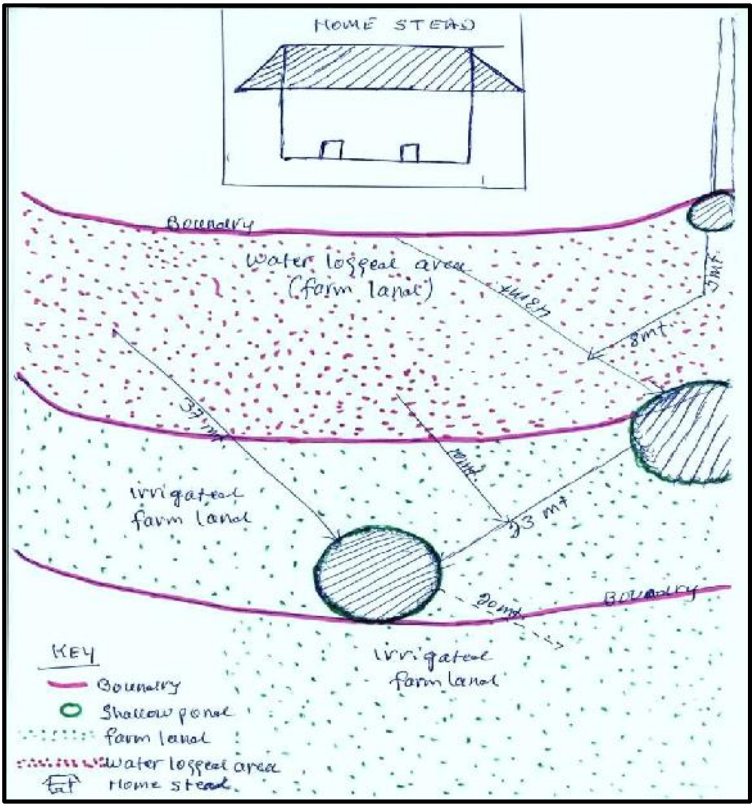

Figure 9: Sketch by Farmer Abbadi of his system of subsurface drainage canals and how he uses the water to irrigate his small fields

Soon Farmer Abbadi realized that the water being drained away was being wasted, and that it could be stored for use during the dry season. When it rains, the ponds fill up with water within 8 to 12 hours. During the dry season, he takes water from the ponds to the nearest fields using his treadle and motor pump, see Figure 10. The big pond is used to irrigate a bigger field while the smaller one is used for supplementary irrigation.

Through his innovation in water drainage, storage and use for supplementary irrigation, Farmer Abbadi not only solved his problem of water logging during the wet season but also his problem of water scarcity during the dry season. His motivation to innovate was to improve the situation for his family to survive and be healthy.

Figure 10: Farmer Abbadi with his water pump taking water from his large pond to irrigate his fruit tree orchard

During the first year of using stored water for irrigation in the dry season he managed to sell onions for 500 Birr. Farmer Abbadi is now able to get three harvests per year from his farm: a cereal crop during the wet season and one or two harvests of vegetables such as cabbage, onion, garlic, lettuce and tomato during the dry season. He also grows some coffee and fruits such as guava, orange, mango and lime (*lomi*) on his farm.

Although some of the neighboring farmers have not followed his example, many have done so and also improved their production. Like Abbadi, they have diversified their crops and sources of livelihood so that they now have food security and health for their families, see Figure 11. They have made their innovations using entirely their own resources in terms of materials and time.

Figure 11: Farmer Abbadi's wife and children of 3 boys and 2 girls, all healthy and going to school

Farmer Abbadi and three other farmers have recently formed a farmer research group to observe how effective their water innovations are in different farm settings, and provide training for other farmers in the Aksum area and elsewhere. For example, Abbadi went to Leku in Southern Ethiopia where he helped a self-organized youth group facing a problem of water logging in the land they had been assigned by the local authorities. He helped them establish a system to drain their land and make a tree nursery.

Abbadi expressed how proud and happy he is meeting district administrators, experts and farmers in workshops and exchange visits. "*I am happy and lucky because in addition to improving my life many people including officials and educated people respect me*" he said.

3.2 From Reclaiming a Gully into Water Reservoirs

Farmer Medhin Gereziher lives with her children in the Mai Siye Tabia. She is a widow with a family of five. Her cultivated land is less than one hectare. She lives beside a small river that runs along the bottom of a deep, wide and long gully that was developed by fierce flows of runoff water carrying soil, silt and stones.

Figure 12: Farmer Medhin in her farm in front of flowering maize and fruit trees

The gully started to develop in the rainy season following the Great Ethiopian Drought of 1984/5 GC. Every year it got deeper and wider eating into the fields. It was risky to cross not only during the rainy season but also during the dry season. Farmer Medhin and her neighbors sometimes had to help cattle and people get out who had fallen to the gully bottom.

Immediately after the main rainy season, the water in the gully bed disappeared. Then, in 2003 when the local community started building soil and water conservation structures in the upper catchment, she saw that the gully bottom remained wet and the water stayed flowing for longer than before.

Farmer Medhin wanted to plant vegetables, which have a good market in Aksum, by using this water for irrigation immediately after the main rainy season i.e. before the water course dried out. So, with her family, she started to hold back some of the water from flowing down by building a retention wall made of earth across the width of the gully. The vegetables she grew with the water gave her a good income from the first harvest. But, every year at the end of the rainy season, she had to rebuild the earthen retention wall because the force of the water in the rainy season would destroy it.

Farmer Medhin never gave up because of the good income from the sale of the vegetables. She increased the height of the retention wall so that the amount of water and the length of time it was available improved from year to year. At the same time she started planting fruit trees in her farm, and elephant grass on the sides and bottom of the gully. This stopped the gully from getting deeper and wider.

Some farmers in her neighborhood were copying what she was doing because they observed the advantage she was getting. The experts in the Tahtai Maichew Wereda Agriculture Office also realized that she was contributing to improved local agricultural production, food security and natural resource conservation: she could become an example for other farmers. They decided to support her efforts and those of the nearby farmers with cement, sand, stone, and expert labor to build a permanent dam across the gully, Figure 13. This support has improved the relationship among the farmers and extension workers in the Wereda with more farmers following their advice and offering their experiences.

For the last ten years, i.e. since 2002, the water held by the check dam has served not only Farmer Medhin but also another 27 farmers. The water way is now a small river with water flowing all year round and other farmers downstream have taken up irrigating at least some of their fields throughout the dry season.

Farmer Medhin has transformed her farming area into an integrated and diverse farming system with beekeeping, a better breed of dairy cow, and a productive fruit orchard on the land between her house and the gully, Figure 14. She also includes multi-purpose trees among the napier grass growing in the gully to get more feed for her animals. She has become one of the recognized food secure families and a model farmer in the Wereda.

Figure 13: The top of the cement dam that holds enough water for 27 farmers to irrigate their land in the dry season as well as provide a safe passage across the previously dangerous gully

She says: "*Now my interest is to get more knowledge by participating in experience sharing visits and farmers' exhibitions. ISD is supporting me to participate in such events as well as bringing visitors to my farm who can give me new ideas.*"

Figure 14: Looking across the rehabilitated gully to Farmer Medhin's fruit tree orchard and well constructed homestead

Figure 15: Farmer Medhin's youngest son with a basket of ripened guava fruits

3.3 INCREDIBLE INNOVATION: FROM DREAMING FOR WATER INTO WATER-LIFTING INNOVATIONS

Qeshi[4] Malede Abreha is a farmer-priest who lives in an area called Akab Se'at on the western side of Tahtai Maichew Wereda. In the 1980s, there was no water near his farm and the soil of his fields was poor and stony. Then he decided to try to make his family's life more secure by seeking for water under his stony land. He thought that if he could find water, then they could have a garden and a better living.

When he started digging down into the soil, his neighbors thought he was crazy but he was convinced he would succeed. He said: "*The land is like a human being. A human can't exist without blood, so if you cut the skin, there is blood. Likewise, if you dig into the ground, you will find water*".

Also his belief in the Bible gave him hope: "*The Bible says the earth floats on water; therefore, I was sure that I could find water no matter how deep*".

Qeshi Malede started to dig for water in September 1988. He wanted to find it before the end of June of the following year. This period is the long dry season after the main rains end. As he dug deeper and deeper, his neighbors ridiculed him more and more. They advised him to stop wasting his time and energy and to seek some daily labor in town in order to support his family. They even persuaded his wife, *Weyzero* (Ms) Abeba, to leave him and move with the children to relatives in the nearby town of Aksum. But *Qeshi* Malede kept digging. At home he only had his dog, called *Shambel*[5] for company. He said: "*this dog is not a dog but behaves as a man because he eats roasted grain like me*".

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[4] Qeshi or Kes is the title 'Priest'

[5] Shambel is the name for a Captain in the Army. Unfortunately the dog died before *Qeshi* Malede became one of the successful farmers in his area.

Finally, at a depth of 12 meters, he did find water. Luckily it was in December, not in June. It was surprising for everybody. He felt he had really succeeded when his wife came back to live with him and they started thinking together about ways to lift the water out of the deep hole. They wanted to use the water for their household needs as well as develop a fruit and vegetable garden.

Since they found water and started to use it effectively, everything around *Qeshi* Malede and *Weyzero* Abeba has changed including the thinking of their neighbors, the people in the Wereda as well as the many visitors who come and see and talk with them. But the change was not immediate. It has taken a lot of experimentation, discussion and visiting for this husband and wife team to become successful.

3.3.1 Devising a Way to Lift The Water

The next problem was how to lift the water up out of the 12 meter deep hole. Pulling a 20 or 25 liter jerry can of water upwards from such a depth was very hard work. When *Qeshi* Malede and *Weyzero* Abeba had pulled up several containers of water for their household and garden, their hands had become chafed and their fingers became stiff. So they discussed how to make it easier to lift up the water. *Qeshi* Malede had been to a monastery in western Tigray and seen the Shadouf system using a long pole with a pulley and a weight at one end that lifts a bucket with water out of a well or canal.

Qeshi Malede erected two pairs of long parallel poles on opposite sides of the well shaft. On one pair of the poles, he nailed a horizontal piece of wood that supported two more long poles that had a heavy weight on one end and a bucket to hold water on the other end. These buckets dipped into the well alternately to pull up water. There was only one rope attached to the poles with a rotating gear attached to the poles. Whenever the rope was pulled down, one bucket came up filled with water and the other empty one went down. The same cycle repeated itself when the rope was pulled down again. Figure 16 shows *Qeshi* Maleda with a model of the first water lifting device that he constructed explaining how it works to a meeting of farmers and experts in Tahtai Maichew

Wereda. This lifting device helped to reduce the hard work of drawing water up out of the deep well, but it also had problems.

Figure 16: Qeshi Maleda with a model of his first water lifting device explaining how it works to a meeting of farmers and experts

The family saw that this device could only be operated by an adult as it required a lot of rope and wood, and it was dangerous because the well opening had to be wide enough for the double poles and buckets to go up and down. If children were to help in lifting up the water, then the well opening should not be so wide.

Qeshi Malede then built a small wooden model of a modified water lifting system to see how it could work before making the full-sized one. This model had a wooden stand on a horizontal log over the well opening so it was more compact but with a more complicated pulley system. It, too, operated with two containers: as one container full of water came up, the empty one on the other side of the log went down into the well. When the containers were moving up and down, the rope moved very fast through their hands but when they tried to hold the rope to slow down the speed, it cut into their fingers. The system was energy-efficient with respect to pulling up the water, but it still could not be operated by children. In order to slow down the speed of the rope and prevent their hands from being cut, he thought of and tested still further modifications, described later.

3.3.2 Watering the Garden Made Easy for All

But having pulled up the water, there was still the tiresome work of carrying the water from the well to the trees and vegetables in their garden, which they were doing by hand. They started to focus on this problem only after they were satisfied with the pulley and lifting design. Once they had an easy way to move water vertically, they started to think of ways to move water more easily horizontally.

First, in order to hold the water brought up from the well, *Qeshi* Malede used cement to build a small open reservoir about 3 meters away from the well. Energy and time were still needed first to carry the bucket from the well to empty the water into the reservoir and then again, after the reservoir was full, to carry the water to the plants.

Husband and wife thought of digging a canal for the water to flow from the reservoir to the garden, but they feared that too much of the precious water would be lost. Then *Qeshi* Malede made a hole slightly above the lowest point in the bowl-shaped reservoir and fixed beneath it a small metal tube that led underground to the garden. Where this tube came out of the ground, he attached a plastic hose long enough to reach all parts of the garden. He inserted a plug in the hole where the tube led out of the reservoir, so they could stop or start the flow of water whenever they wanted.

This made it possible for one person on his or her own to do the work of drawing water out of the well and then watering the garden. Most of the time, however, *Qeshi* Malede operated the pulley while *Weyzero* Abeba and/or the children used the hose to water the garden. But sometimes, if both parents had a lot of other work to do, the children filled the reservoir with water and then watered the garden, which was not hard work using the plastic hose. This has been maintained as the system for watering the garden (Figure 17).

Figure 17: Two of Qeshi Maleda's and Weyzero Abeba's children watering an orange tree in their fruit garden in 2006

3.3.3 Adapting and Testing Different Designs

In 2005, *Qeshi* Malede visited and took part in the Annual Mekelle Region Farmers' Exhibition. There he saw different designs of water lifting devices. He decided to try one kind of pulley system based on a rope or chain with rubber or wooden discs that went round a wheel at the top and then passed through a pipe the same diameter as the discs. At the bottom, the water enters the pipe and is drawn up to the surface because the discs stop the water draining back into the well. The operator pulls the water up by turning a handle on the wheel at the top.

At first, *Qeshi* Malede made a small model to test and see how it might function with water in a bowl to represent the bottom of the well. Then he built a full size model and put it over the well. He and his wife tested this innovation, and kept on thinking of ways to improve it because at first a lot of the water drained back into the well before it could be caught in a bucket. Then *Qeshi* Malede made his next small model, tested it, identified its problems and looked for how to make more improvements. The process of testing and improving his novel water pump continued for eight months before he finally got a functioning pump with which he was satisfied.

Eventually *Qeshi* Malede and *Weyzero* Abeba developed a device with which either of them working alone could lift water very quickly and easily. He called this innovation "*Abeba Tigray*" after his wife, because she continuously encouraged him, and after his home region, Tigray. In Figure 18 he is demonstrating and explaining to a group of farmers how *Abeba Tigray* works, while Figure 19 shows Weyzero Abeba operating the water pump.

From being one of the poorest families in the community, the family of *Qeshi* Malede has now become relatively rich. Their garden is full of different trees: guava, coffee, lime (*lomi*), orange, citron (*tringo*), *gesho* (equivalent to hops), banana, *enset* (false banana), papaya and grapefruit. Underneath the trees, they grow vegetables such as carrot, cabbage, red and white onion, lettuce and various spices.

Weyzero Abeba and her daughters are responsible for buying the seeds and seedlings and for selling the fruits and vegetables in the nearby market after they have kept some of the produce for their own use. *Weyzero* Abeba is also an expert in keeping local chickens healthy and in looking after their bees. The family has some cattle and sheep, which they care for together and they have planted fodder trees to be able to feed them better.

3.3.4 How the Community and Others have Benefited from the Innovation

Qeshi Malede and *Weyzero* Abeba have not only transformed their own lives; they have also helped to transform the lives of many of the other families in their local community as well as elsewhere. Their innovations are obvious for all to see. They often receive visitors (Figure 20). When her husband is absent, *Weyzero* Abeba explains their water pump and other innovations to both men and women who come to see the results of their work. The couple says that, in return, they learn something new every time a visitor comes and comments on what they are doing. This gives them new ideas to try out—and they always seem to be trying out something new.

Figure 18: Qeshi Malede explaining his latest water lifting model called Abeba Tigray in front of farmers. The yellow arrow show how the water lifting rope with its washers moves up through the pipe and then drains out of the tube on the side so it can be collected in a bucket or jerry can

Figure 19: Weyzero Abeba showing how to operate the water lifting pump named after her

Qeshi Malede is now widely recognized as a local expert in groundwater harvesting. He is contracted by other farmers to dig wells, and he gives advice about efficient use of water. The innovations in knowing where to find water and how to lift it easily out of the ground have greatly reduced the work load on local people—particularly women—who previously had to fetch water from distant places to their homes and gardens.

Often, *Weyzero* Abeba works together with him also outside their own farm. At the same time, she gives the people advice about how to improve their families' lives, based on her own experience. It is striking how much more the women are convinced by the advice when it is given by a woman.

The neighbors have also been closely following the various improvements in water-lifting technology that *Qeshi* Malede has been making. Many farmers have adopted water lifting devices. For example, one close neighbor asked *Qeshi* Malede to help him make a similar water-lifting device for his hand-dug well. They were able to do it very quickly. *Qeshi* Malede said: "*The difference is, it took me eight months to develop my Abeba Tigray, but we did it at his place in only one week. I am always busy in advising and modifying my technologies.*"

Figure 20: Swedish visitors hearing about Qeshi Maleda's water lifting pump during their visit to Tigray in 2007

There are now over 600 wells in the area, all of them built after *Qeshi* Malede showed how important water is for an improved income. Most of them are built with the couple's advice, either directly or indirectly through informal farmer-to-farmer extension. Almost all other families that have learned from the example of this innovative family have managed to achieve household food security within a few years. The village is now well known for its wells supporting vegetable and fruit production.

4. ADAPTING TO CLIMATE CHANGE

The effects of climate change are well understood by smallholder farmers because the risks to their survival are increasing. This is especially true for those farming families that have to depend solely on rainfall for their crop production. Rain water is the most critical resource as most farmers do not have access to alternative sources of water for irrigation. The negative impacts of unreliable and violent rainfall are also increased where the land has been eroded, the vegetation cover destroyed and hence the water holding capacity and infiltration of water into the soil and underlying water table reduced.

For these farmers, their productivity is very low and their families are very poor. When the rainy season comes late, the moisture constraints become more serious, and farmers have to shift from crops needing a long growing-season of 3 to 5 months to those that can mature in 2 months or less and/or even survive on the residual moisture in the soil. For example, sorghum and finger millet require 4-5 months to mature, while wheat and barley can ripen in about 3 months, some varieties of teff only need 45 days to be ready for harvest and chick pea can grow on residual moisture. But, this solution creates problems as shifting from one crop to another is costly in kind and cash, and farmers become more likely to have to sell their assets or to get into debt. Also, the farmers prefer to grow the long growing season crops and varieties because they give better grain yields than the short-growing season ones as well as providing much needed animal feed, construction material and even fuel.

4.1 THE SYSTEM OF CROP INTENSIFICATION (SCI)

In Ethiopia, the System of Crop Intensification (SCI) is a new field management (agronomic) technique that is now being adapted for a wide range of crops from the more widely known System of Rice Intensification (SRI).

SRI was developed in the 1980s in Madagascar by a French Jesuit Priest, Father Henri de Laulaniè, and the local farmers to increase rice production without having to clear more of the forest for growing rice. SRI is now being used in over 60 rice growing countries of the world and some, such as Cambodia, have incorporated SRI into their main rice growing strategy.

Both SRI and SCI are based on an integrated use of improved field management practices that use fewer inputs in relation to seed and seedlings, as well as water for irrigation where this is available. But when the work is well coordinated, the farmers use less labor for weeding and harvesting and get higher yields and economic returns.

ISD has been working together with farmers and local agricultural experts in order to find out how SCI can be best applied in the drought prone regions of Tigray and South Wollo, which crops give the best responses, and how farmers can integrate SCI into their farming system practices.

Basically SCI consists of either directly sowing seeds or transplanting young seedlings in rows along with compost with or without a small amount of chemical fertilizer. The seeds or seedlings are put with wider spacing than usual between the rows and seeds or plants within the row. Farmers in Ethiopia call this "planting with space". Weed control is done with simple implements that cut through the roots of the weeds and also disturb the soil enough to make it better aerated as well as letting rainwater easily enter the soil.

4.1.1 Introducing SCI to Farmers in Ethiopia

Back in 2002, some staff members from ISD discussed with Mr Aregawi Abay, then head of the Agricultural Bureau of Tigray Region, to find ways to overcome crop failure due to unreliable rainfall. Knowing that Ethiopia is a country where droughts are frequent, we started to look for those farmers' practices in the project areas of Tigray that had helped minimize the risk of crop failure.

When we reached the community of Sherafo near Wuqro Kilte Awla'elo, we heard that its entire crop production had been lost during the Great Drought of 1984/85—except for the crop of *Qeshi* Haregot. He had taken the unusual action of up-rooting his young finger millet plants from his field and re-planting them in a river bed where some moisture still remained. By doing this, he obtained a sufficient crop to have finger millet seed for the next rainy season. This introduced the idea of transplanting young seedlings to take advantage of moist soil.

At the same time, the leaders in ISD had been encouraging ISD's extension officer to raise seedlings of long season crops, particularly finger millet and sorghum, in nursery beds at the time the small rains should come in April so that they could be planted out in the field when the main rains started at the end of June.

4.1.2 Successes with SCI

In 2003, ISD met with a group of agricultural experts in Tahtai Maichew Wereda who decided to try solving the problem of a delayed rainy season by raising seedlings of finger millet for 30 days in a near-by nursery and then distributing these to 3 farmers, 2 men and 1 woman, in Mai Berazio village area.

Only the elderly woman called Mama Yehanusu Atsbeha had a good result. She planted the seedlings in a 5 x 5 m area in a field leaving a hand-space of 25 to 30 cm between plants. She also broadcast seed of the same finger millet variety directly into the rest of her field. She had applied compost to all of the field.

The results were impressive. At an early stage, the plot of transplanted crop looked sparse; but later on the plants became dense with many tillers, each having longer, denser fingers (panicles) than on the seed-sown plants in the rest of the field. Mama Yehanusu got a yield equivalent to 7.6 t/ha from the transplanted crop, while the rest of the field gave her a yield equivalent to 2.8 t/ha.

Figure 21: Young farmer, Leul, in Kewanit, Tahtai Maichew, holding a finger millet plant with over 30 productive tillers supported by the large root mass developed through using SCI during 2012

The agricultural experts and many neighboring farmers were present when Mama Yehanusu harvested her crop. Not surprisingly, many farmers began adopting “her” way of raising finger millet seedlings before the start of the main rainy season. They have shown that Mama Yehanusu’s field was not a “one-time” success. The average yield from fields of transplanted finger millet is 4.5 t/ha while with conventional broadcast sowing, average yields remain around 2 t/ha.

Building on this experience, ISD and its partners decided to look for ways that would help farmers grow other crops that need a longer time to grow than that provided by the rain and the moisture held by the soil in their fields during the main rainy season.

Farmers traditionally broadcast their seed by randomly throwing them over marked-out sections of their field when the rains start. This type of sowing, though quick, is not always efficient as it uses a high sowing rate and management of the growing crop can be labor-intensive, especially for weeding and harvesting. It also results in an inefficient use of moisture, with competition between the crop plants for water and nutrients. When other inputs, such as chemical fertilizer and/or compost are added, there is not a good spatial relation between where the seed is sown and the input thrown. As a result, resources and time are poorly repaid, and the productivity levels remain low. But with the use of SCI management, yields of many crops can be dramatically increased.

4.1.3 A Leading Farmer Extends SCI for his Community

Farmer Teklu Berhe lives in Adi Guara in the southern part of Tahtai Maichew Wereda, which is the driest part of the district. In 2005, he raised seedlings of sorghum one month before any other crop was being sown and transplanted them into his field when the rain started. As has become usual, the rainfall was badly distributed in that year and crops, especially sorghum and finger millet, failed to mature in all his neighbors' fields but the sorghum transplanted by Farmer Teklu was the only one to produce grain. But, birds came to his field and ate up almost all the seed. However, the local farmers saw that the raising and transplanting of the seedlings gave the farmer an advantage in managing his crop and guaranteed that the sorghum would mature, and this stimulated them to also take up the practice of raising and transplanting seedlings. In 2009, Farmer Teklu raised seedlings of finger millet and transplanted them into his 0.25 ha field from which he harvested 11 sacks weighing 1.1 tons. This is equivalent to 4.4 t/ha. Through his active demonstration, this farmer has helped convince many of his neighbors to start using SCI for sorghum and finger millet.

4.1.4 Research Testing and Scaling Out of SCI

In September 2009, one of us met Prof Norman Uphoff of Cornell University in the United States and learnt about the SRI practices developed in Madagascar in the 1980s as well as experiences with other crops such as wheat in India. Between 2009 and 2010, with support from Oxfam America, ISD collaborated with the researchers, Dr Tareke Berhe and Mr Zewde Gebretsadik, to apply SCI to teff. The experiments on teff were carried out in Debre Zeit Agriculture Research Center side by side with farmers in Ada'a around Debre Zeit near Addis Ababa, and in Tigray in Aksum Agriculture Research Center, Tigray Agriculture Research Institute, Kalamino Special School, Mekelle University, Aksum University and with the farmers already familiar with SCI for finger millet near Aksum. Results in nearly all the places were very encouraging but especially in Debre Zeit Agriculture Research Center and neighboring Ada'a farmers as well as researchers, extension experts and farmers in the Aksum area of Tigray.

Teff is Ethiopia's iconic and most popular cereal, but as grown with traditional methods, it has the lowest yield with an average grain yield across the country of only one ton per hectare. Teff has responded dramatically to SCI, i.e. being transplanted or planted directly in rows with a spacing of 20 cm between the rows as well as 15-20 cm between plants in the row. Transplanting with spacing is not difficult for the farmers to manage because the small teff seedlings are robust and not easily damaged by handling. But it takes time and labor. Hence, the farmers' preference is for sowing in rows, but the very small seeds of teff need to be spaced out along the row. Farmers have developed different innovations for the row planting including mixing teff seed with sand or dry crumbled compost at a ratio of 1 part teff seed to 3 or 4 parts of compost or sand. Farmer Shume of Ada'a has develop a drill using the empty case of a ball point pen called "bic" because the hole at the end of the case allows one seed of teff to pass through at a time.

Figure 22: Trial with row planting of teff in Debre Zeit during the dry season, April 2010

Through using SCI for teff, farmers are getting yields of 2.5 t/ha or more, while over 6 t/ha has recorded under research conditions. Teff grown with traditional management absorbs the bulk of household labor for land preparation, sowing, weeding and harvesting. But with SCI, weeding and harvesting is much easier and quicker. Improving teff production based on SCI principles is now a major program of the Ethiopian government's Agricultural Transformation Agency (ATA). In 2012, more than 50,000 farmers and 1,200 Farmers' Training Centers were using SCI for growing teff.

Farmers are rapidly adopting and adapting SCI ideas and practices with a range of crops by trying them first on small plots before applying SCI to their fields. This is becoming the "normal" way of growing finger millet in their fields in some areas. In 2011, there were 118 farmers using SCI for finger millet in Tahtai Maichew wereda alone.

Figure 23: Researcher Eyob and Senior Extension Expert Hailu Legesse examining SCI teff on a farmers' field day in Tigray, October 2010

These practices have spread through farmer-to-farmer contact from a few in the Tahtai Maichew and La'elai Maichew weredas near Aksum to other districts in Tigray and South Wollo. Many farmers are now regularly growing and transplanting seedlings of other crops as well. In addition to finger millet, ISD has found farmers using SCI methods for several cereals, barley, bread and durum wheat, maize, sorghum, and for the pulses chick pea, faba bean and lentil. When applying quality compost to the soil, farmers with their own best varieties can get yields equivalent to the improved varieties that are dependent on the use of chemical fertilizer. The farmers, and particularly the housewives, prefer the local varieties because of their good flavor. They say: "*When my husband and children eat the food made with our own varieties and grown with compost, they do not get hungry quickly and can work longer*".

Apart from avoiding the now high cost of chemical fertilizer, this alternative management system helps Ethiopia's farmers maintain and even increase the varietal diversity in their crops, which is important for dealing with the risks associated with climate change. Globally, this is also important because Ethiopia is one of the eight Vavilov centers of crop genetic diversity, and SCI supports farmers to continue their traditional *in situ* conservation of their own varieties for their own survival as well as contribute to the global gene pool for future generations of farmers.

4.1.5 Combining SCI and Water Harvesting

Like many other farmers *Qeshi* Hagos Wolde Mariam of Hawesta in the south eastern part of Tahtai Maichew was suffering from the late onset and early stopping of the rainy season so that he could not grow maize in his homestead farm. His farm is on a slope and there were no structures to retain moisture in his fields. 2011 was a particularly bad year when the rainfall stopped very early and all crops were going to dry up before maturing. The extension people told the farmers to water their fields, but this was tiresome. Even so the farmers tried to follow the instructions. *Qeshi* Hagos realized that watering his field was good but the water soon ran down the slope. Then he built small soil bunds between his rows of maize to make micro-basins in his field to retain the water. He was able to capture the water from the last rains in these structures. He saw that the water stayed longer in these basins while the other parts of his field dried up.

After that, *Qeshi* Hagos built the micro-basins between the rows throughout his field, and this has become his standard good practice. When the rainfall is good he opens the basins to prevent water logging of his crop. This is until the middle of August. This is because rainfall is generally reliable until the middle of August but farmers are not sure about its frequency and amount afterwards. After the middle of August, he closes the micro basins so they hold back the water and his maize can mature.

Qeshi Hagos' maize grows with deep roots and strong stems each plant of which produces more than one cob. He is one of the model farmers with good practices in his village and the wereda.

Figure 24: The local journalist, Demoz Heshe, standing beside Qeshi Hagos' maize field showing the micro-basins he had built and the remains of his harvested maize

Figure 25: Qeshi Hagos explaining his micro-basin system to local farmers, experts and researchers in a meeting in Aksum University

4.1.6 Lessons Learned From SCI

In addition to increasing production, transplanting seedlings of finger millet, sorghum and other crops has shown various advantages for adapting to climate change.

- Using SCI, crops become more tolerant of extreme weather events such as dry spells during the rainy season and even to water-logging when there are storms;
- Labor is reduced while crop performance improves, because:
  - transplanting makes inter-row and inter-plant weed control easier so that farmers can use simple weeding tools to cut the roots of the weeds so they form a mulch over the soil and decompose to boost fertility, or
  - the weeds are collected for animal feed which is much needed while the movement of animals for grazing is restricted during the growing season;
  - when the soil is aerated, this stimulates the growth of plant roots and benefits aerobic soil organisms;

  - harvesting by sickle is easier as plant growth is more uniform and the mature panicles do not get tangled up as in a broadcast sown field;
- Establishing the crop in rows allows for a more efficient use of inputs (compost, fertilizers, etc.), which are placed alongside the seed or in the hole with the seedling rather than being spread randomly over the whole field;

These changes in agronomic practices help farmers mitigate or adapt to changes in climate because seedlings can be raised in small protected areas with an efficient use of available water about one month before the main rainy season is expected. Then, when the main rains have started and the soil is moistened, the seedlings are transplanted to a field clean from weeds. As clearly seen in Figure 21, when transplanted, the roots grow bigger and deeper, making better use of the moisture at lower soil depths; and there are more strong productive shoots, the tillers.

The main challenges for scaling out this innovation are that all the experts and development agents in extension as well as the lead farmers require regular training backed up by exchange visits and follow-up. There are also many farmers that do not feel comfortable with the wider spacing left between the young plants, and some farmers have commented on the increase in weeds in these spaces although these provide important animal forage and material to make compost. However, the general aims of the SCI technology are to enable farmers to improve their productivity while also adapting to climate change.

4.2 Bee-Keeping for Improved Survival and Coping with Climate Change

Ethiopian farmers have a very long tradition in bee keeping and the indigenous races they keep are not very aggressive with hives often kept near or even built into the walls of their houses.

Many smallholder farmers keep bees because the honey, beeswax and bee colonies are a good source of income. These products have a high demand and the prices stay high throughout the year. This contributes significantly to the household's food security especially in moisture stressed and degraded farming areas. Combining bee keeping with natural resource conservation also adds value to the conserved natural resources as this provides income generating opportunities for otherwise unemployed youth, women and other institutions such as monasteries that need good sources of income.

Recently beekeeping is facing serious problems: a major one is that the bee colonies are abandoning their hives. This is thought to be because the bee forage is drying up faster than before as there is insufficient water in the environment so the bee forage stops flowering quickly. Sometimes the beehives sold in the market are not made from wood suitable for bees because they contain chemicals that irritate the bees. Also, the modern wooden beehives are not well insulated with the bees getting over-heated by the strong sunshine during the day and cold during the night unless they are kept under shade. Bees need an even temperature inside their hives to be active and productive.

There are two basic types of beehives in farmers' hands. These are the traditional and modern types. Compared to a modern beehive, the traditional beehive has a smaller internal capacity and the honey storage area is not always well separated from the brood area where the queen lays her eggs and the larvae (grubs) are reared so that many bees and larvae are killed when the honey combs are removed for harvest. The modern beehive has more internal space than the traditional hive with good separation of the honey storage and brood areas of the hive, and the honey combs are in frames that can be taken out without disturbing and destroying the brood.

4.2.1 Traditional Beehives

There are different designs of traditional beehive that are cheap and easy to produce or buy and manage. One type looks like a large log, circular in cross-section with a diameter of about 30 cm and about 1-1.5 m long. It is made from wood, even a hollow branch, or sticks tied together and plastered with cow dung and/or mud. Farmers use this design of beehive to put their bee colonies up in the branches of trees when they are flowering and also in trees next to their flowering crops. They also hang up these types of beehives in trees to catch swarming bee colonies.

A second type is circular and hollow with a diameter of between 50-60 cm and about 1-1.2 m long. It is made from cattle dung mixed with tef straw plastered onto a wooden frame. This is kept in the home compound under shade.

Temporary beehives for carrying colonies from one place to another are made from gourds, but these are never large enough to house an active honey-producing colony.

4.2.2 Farmer-Adapted Modern Beehives

Modern beehives are made from wood or polystyrene and consist of square sections that can be stacked one on top of the other. The brood chamber with the queen is in the bottom section while the top section(s) are where the worker bees store the honey. A metal grid, the queen excluder, is placed between the bottom section and the next one to prevent the queen getting into the honey storage area. The slits in the grid are wide enough for the workers to pass through but not the queen.

Farmers are interested to have modern beehives as they can harvest more honey without destroying the bee colony, but they are expensive. Hence to improve their incomes many farmers have become creative in developing their own innovations to improve beekeeping. These innovations include ways to improve the making and management of traditional and modern beehives to be able to harvest better quality honey and multiply bee colonies.

The farmers started their innovations in 2007/08 by combining components of the traditional and modern hives working individually. The resulting improved endogenous beehives are far cheaper and easy to make and to manage. They are also better insulated against both heat and cold, and bring higher net returns than either the traditional beehive, or the modern commercially produced beehive.

According to the evaluation by the farmers, the bee colonies in the "adapted" hives are stronger than those kept in the modern ones. The "adapted" hive has created a comfortable environment for the bees to easily regulate the temperature inside their hives during cold and warm seasons, and even between day and night. The farmers also commented that the bee colonies live longer and make honey faster. The honey can be harvested twice a year: once just after the start of the main growing season in July when crops and many other herbaceous plants come into flower, and the other at the end of the growing season around November.

Outstanding farmer innovators who have shared their improvements include Farmer Abbadi Redhey, Farmer Gebre Michael Beza, *Haleka*[6] Giday Hagos and *Weyzero* Yibeyin Assefa. In 2010, they formed a beekeepers research group in Tahtai Maichew Wereda under the PE Axum Platform.

Weyzero Yibeyin and *Haleka* Gidey from Tahtai Maichew District near Aksum told us that: "*In farmer innovation, there is neither penalty for failure or credit for success if someone wants to try an experiment or copy from another person. Therefore, we always try to understand what needs to be done and then practice it*".

These farmers came together in 2010 to train local unemployed youth, women and monks in improved beekeeping. This was in a project supported by the Danish Ministry of Foreign Affairs channeled through UNEP and UNDP under the title of CCDARE (Climate Change and Development – Adapting by Reducing Vulnerability).

[6] *Haleka* is a title in the church indicating that the person has completed some parts of the traditional church education, but did not become a priest.

The following Figures 26 and 27 show youth, women and monks learning how to make modern wooden beehives, and the end result, a modern hive with 3 sections, in seen in Figure 28. Figures 29 and 30 show *Weyzero* Yibeyin making a square beehive section using a wooden frame covered with cow dung plaster and the resulting completed beehive section.

4.2.3 Rearing Honeybee Queens and Bee Colony Multiplication

The hive used for queen rearing is of a special design and smaller in size than the normal beehive, see Figure 31. The farmers follow the development of the three types of cells for drones (males), workers (non-fertile females) and queens (fertile females) on the brood frames. Each of these cell types are easily identified by their color and shape. Splitting of a colony becomes possible if all three types of cells are found. A young queen also produces a high pitched sound, called piping like a flute or *washint*, just before she emerges from her cell. This is the signal for the drones to get ready to fly off with her on her mating / nuptial flight.

The farmers prepare 2 or 3 queen rearing beehives which are traditionally made from gourds, see Figure 32. The combs with the three types of cells are divided among these special beehives: each colony is focused around its egg-laying queen with her workers. But before a queen can establish herself with a colony, she has to take a mating / nuptial flight as soon as she emerges from her cell. During the flight she mates with a drone and then returns to her colony where she is cared for by her workers and lays the eggs from which the new colony is built up.

During the colony splitting process, the farmer leaves one of the new bee colonies in the old site and puts the hive with the old colony some distance away. Each of the colonies are about 50 to100 meters apart from each other.

Figure 26: Youth and a monk learning how to construct a modern beehive in 2010

Figure 27: A woman closely following the making of a modern beehive section in wood

Figure 28: A completed modern beehive with 3 sections made by youth, women and monks

Figure 29: Weyzero Yebeyin applying cow dung plaster to her modern-shaped beehive section

Figure 30: Completed bottom section, the brood chamber, of Weyzero Yebeyin's cow dung plaster hive – note the entrance into the hive at the bottom of the wall of the section

Figure 31: Small hives used to encourage bee colonies to rear new queens for bee colony splitting: note the grid over the entrance of the hive to prevent a virgin queen flying out immediately after she has emerged from her cell

Figure 32: The bee colony spitting apiary of Farmer Gebre Michael Beza with the small hives and large gourds prepared to receive the new bee colonies

Sometimes the bee colony prepares to replace an old queen. This is often done when a bee colony has lost its queen, for one reason or another, such as death, or if the queen is no longer functional in the colony.

The establishment of new bee colonies is usually done at the beginning of the main rainy season from about the end of June to the middle of July or from the end of August to the first week of September. But the honey is not taken from the new colony because it needs to be left to develop its strength in numbers and stored honey to take it through the dry season. However, sometimes honey can be harvested at the end of the harvest seasons from a new colony set up at the beginning of the rainy season.

As well as training in making bee hives, the expert farmer bee keepers also train other innovator farmers on how to split their own bee colonies so that can increase the number of hives, particularly in areas where beekeeping has not previously been practiced, or the first colonies have escaped. This is helping their bees to adapt to their new environment. Therefore, many farmers are seeking training skills on bee colony splitting.

4.2.4 Planting Different Bee Forage to Complete the Feed Gap

The farmers working with ISD and PE have identified many of the plants preferred by bees as forage including when they flower – see Annex B. This is in order to support the farmers and other interested beekeeping groups establish strong bee colonies. With support from the CCDARE Project, color photos of some 30 of these plants have been printed by ISD on A4 size paper and laminated so that the local development agents can have them in their Farmer Training Centers to build awareness of the importance of bee forage.

The most important bee forage plants are those that flower during the dry season as this is the feed shortage period for keeping bees. Moreover, farmers have identified those plants that give the best quality honey. These include the herbs and shrubs called *girbiya* (*Hypoestes forskolei*), *siwa qarni* (*Leucas abyssinica*) and *tebeb* (*Becium grandiflorum*) and the widespread small acacia tree *lahai* (*Acacia lahai*). Fruit trees, such as banana (*Musa sapientum*), citron/*tringo (Citrus medica)* and sweet orange (*Citrus simensis*), are also important sources of bee forage – Figure 33. Farmers have been shown how to collect seeds, raise seedlings and plant them in individual farms as well as community land and enclosures. A group of youth and women in Tahtai Maichew Wereda have established a nursery especially for growing seedlings of bee forage.

Lahaie – Acacia lahai

Girbiya – Hypoestes forskolei

Tebeb – Becium grandiflorum

Siwa Qarni – Leucas abyssinica

Sweet Orange – Citrus simensis

Banana / Muz – Musa sapientum

Figure 33: A few examples of important bee forage plants

Having local experts and innovator farmers taking the lead in the expansion of bee keeping is helping more farmers increase and diversify their source of income and family nutrition. Apart from the farmers, there are other groups, such as landless youth and monasteries, as shown above, interested to take up beekeeping to make a living for themselves. For all of these groups, being able to buy queen and bee colonies is very important. It is also bringing back and helping conserve the local biodiversity.

4.3 GROWING APPLES AS A CLIMATE CHANGE ADAPTATION PRACTICE

Weyzero Yeshi Gobaw is a 60 years old model farmer living in Ambezo Kebele of Lay Armacheho Wereda in Gojam, see Figure 1. Previously, she only produced annual crops but her farm land had become highly degraded due soil erosion: she could not produce enough grain for even 6 months to feed her family. In 2008/09, she received training in apple production by the Armacheho Development Association and was given 13 seedlings. This project is supported by the EECMY-DASSD, North Gondar Synod. The staff gave her continous follow-up. In 2011, she earned a total of Birr 24,000 from the sale of the fruits to local and Gondar town markets.

Figure 34 shows Weyzero Yeshi showing her fruit laden apple trees to visiting farmers. She explained to the visitors: "*Now I'm able to cover all expenses of my two childern attending preparatory and high school in Gondar town. Likewise, I'm engaged in sheep rearing to diversify my livelihood in order to adapt to the climate change and economic situation. I have 4 sheep and 2 of them will give birth to offsprings very soon.*"

Weyzero Yeshi also commented: "*Now I'm relieved from socio-economic problems of being poor by becoming empowered and confident to participate in any social and regilious event because I am respected. I give thanks to the project and Norwegian Church Aid (NCA) that supports EECMY-DASSC for their efforts and contribution in improving my livelihood".*

It is seen that the project has brought appropriate agricultural innovations that can be easily adapted and adopted by the committed farmers. The introduction of highland fruit production in the area has brought significant changes to the livelihoods of the target community. In 2012, the project was supporting 131 farmers in a similar program where many of them have been able to improve their livelihoods and adapt to climate change in their area.

In general, all project components are designed to improve the livelihoods and help farmers combat the adverse effects of climate change in the Armacheho area.

Figure 34: Farmers visiting Weyzero Yeshi's apple production in Armacheho for experience sharing in 2012

5. Using Compost gives Improved Livelihoods with Food Security

The first population census in Ethiopia was carried out in 1984. It recorded an estimated total population of 34 million. By the 2007 population census, the number of people living in the country was estimated at 73.8 million of whom 84% were found in rural areas. Now, in 2013, the population is probably around 84 million making Ethiopia the second most populated country in Sub-Saharan Africa after Nigeria. The majority of the rural population is smallholder farmers with an average of less than one hectare of cultivated land per household. With rainfall becoming more unpredictable, every year there are several million people in the rural areas of Ethiopia needing food aid assistance to survive as they cannot grow sufficient food crops to sustain themselves from one growing season to the next. These rural households mostly live in the degraded and water-stressed areas of the northeast and eastern parts of the country. Because of their low production, they also lack the purchasing power to buy the food that they need.

Traditionally, Ethiopian farmers have used a range of management methods for restoring and maintaining the fertility of their soil. These used to include periodically resting the soil as fallow fields where animals could graze and the natural fertility of the soil could be built up. Farmers also used the rotation of crops with cereals planted on the most fertile soils followed by pulses and oil crops. Some aspects of crop rotation are still practiced to a limited extent but the use of fallow has virtually disappeared. Farmers also collect and apply animal dung, sometimes stored and fermented in pits, as well as ash for adding to the soil of particularly important crops such as traditional vegetables, particularly garlic, faba bean and *enset* (false banana–*Ensete ventricosa*).

However, unlike India and China, both countries like Ethiopia with a long agricultural history, Ethiopian farmers were not making and using compost to help restore fertility to the soil of their crop growing areas. This has now changed after the Ministry of

Agriculture recognized the work of ISD and incorporated the making and using of compost into the standard extension package for smallholder farmers in all crop growing parts of the country.

5.1 "COMPOST MAKES US EQUAL"

Starting in 1996/97 in Tigray, ISD trained farmers and development agents in four local communities on how to make compost in pits and use it to improve the fertility of the soil in their fields. Many people, including farmers, local agricultural experts and higher officials, were not convinced that there was sufficient organic material available locally to make enough compost to be applied to the fields. There was also apprehension that locally available organic waste materials, generally considered to be unhealthy, would be useful for their crops after it was converted into compost. There is still a general perception that there is not enough organic waste material available for farmers to make good quantities of quality compost. Moreover, the farmers were afraid of getting *mich* (a headache or sudden sickness) and other health problems from the smell coming from handling these materials.

In 1996/97, ISD convinced some of the farmers in four communities in central, eastern and southern Tigray to make compost and then take it to their fields to add to the soil to grow their crops. The farmers, development agents and ISD saw that the crops grown on the compost treated soil grew better that those in other fields where no compost had been used. Hence in 1998, ISD arranged with the farmers and development agents to cut and weigh the grain and straw from one meter square plots in the fields at harvest time. The farmers were soon convinced that compost was useful for them after they observed that there was a consistent yield increment, mostly for cereals but also for faba bean and field pea. And from 2002, the Tigray Bureau of Agriculture and Rural Development included the making and use of compost in its strategic plan for the Region.

The first area where farmers started making and using compost consistently and in good amounts was in the Adi Abo Mosa community around Lake Hashenge in Ofla Wereda of southern Tigray. Some of these farmers had already started to use chemical fertilizer, but they were not happy with the price, or with the increase in the growth of weeds, especially wild oats (*Avena vaviloviana*) when they used urea and DAP.

5.1.1 Farmer Ararsa Hamdi Tells How Use of Compost Changed His Life

Farmer Ararsa Hamdi is a farmer married with 3 children who lives in the Adi Abo Mossa village. In 1998, he was very poor without any plow oxen. By 2004, he had been able to buy two oxen, three sheep and one donkey. He told his story as follows.

ISD: What was the feeling about compost and the condition of the community back in 1997?

Farmer Ararsa: *I was one of the members selected to be trained to make and use compost. At the beginning of the project we were not interested in preparing compost because previously we used to add cow dung to our soil and then we were told to use chemical fertilizer. We did not know of any advantage from using compost.*

ISD told us how to prepare compost by putting leaves, crop residues, home garbage, cow dung, urine and the like together to be decomposed in a pit. We thought that it was a waste of time, but we were obliged to join in.

We were also afraid of the "mich" *when handling the materials. It was not easy for the experts to convince us at the beginning. We used* nech shinkurt *(garlic),* feto *(cress) and other herbs to protect ourselves when we turned over the compost material or transferred it from one pit to another. At this time, we refused to work during the daytime because the* mich *may kill us.*

We discussed about it again and again for a long time. Then we came to a decision that turning or transferring of the composting material should to be done at night instead of in the daytime i.e. after 6 pm. To facilitate the work we all agreed to bring our own lights for the night. During that *time I remember the working place was like a town decorated by lights. Then we started to turn over the composting materials in the night.*

But now, we work at any time as we understand that there is no mich *problem. We also understand how to prepare and use the compost: even we distinguish the quality and maturity of compost by its smell. Now we are attracted by the smell and we are happy to prepare and use it.*

ISD: At the beginning what were your neighbors saying about compost?

Farmer Ararsa: *They were saying that we had become mad, we did not want to listen to anybody's advice; we didn't want to live and raise our children, etc.*

ISD: Do you know why they were saying so?

Farmer Ararsa: *Traditionally the society sees the problem of* "mich" *coming from open pits and people coming into contact with rubbish with a strong smell during the daytime.*

We refused to work individually. Instead, we organized ourselves into groups to work together. That is why we prepare compost in groups of around 10 households until now.

ISD: Now, are you working to make compost in the daytime?

Farmer Ararsa: *Here I want to mention two points: The first is that we soon saw the importance of using compost in the improved growth and productivity of our crops, as well as the reduction in the weeds. The second is that we put all of our compost pits under the big trees, i.e. to reduce the problem. By putting the pits in the shade of the trees we are able to work at any time during the day without fear* (see Figure 35).

ISD: What is the change in your life?

Farmer Ararsa: *At the start of the project I was* "malto" *(very poor, having nothing) but now I am changed.*

For many years before the project started in 1997, each growing season I lent my land to another farmer who had plow oxen. We had an agreement of sharing to buy the seed and inputs (DAP and urea), and *also sharing the yield. But there was always a debt to pay for the chemical fertilizer.*

Figure 35: Farmers and ISD in 2000 looking at the compost pit prepared by Adi Abo Mossa farmers under the shade of 'leul' – Ekebergia capensis

Farmer Ararsa continued explaining that: *I told him to use compost rather than buying chemical fertilizer, or pay the full cost for the chemical fertilizer himself. Finally, even though my idea did not convince him, he accepted to use compost rather than buying the fertilizer by himself. That year in 1998, I got a good yield without any debt for the chemical fertilizer and I was able to buy one ox with 350 birr. We had the same arrangement the following year, i.e. to only use compost. With the money I saved I was able to buy a second ox. Now I can plow my own land and do not have to lend or share it. This is my change through using compost. Now I am a new man and my family has also benefitted.*

ISD: How do you evaluate the use of compost?

Farmer Ararsa: *As you can see, we have deep black clay soil. Generally it is hard to work because it is cracked open during the dry season, and sticky and heavy to plow when it rains. Using chemical fertilizer, it gives a* *high yield but the fertilizer needs to be applied every year and it is hard to repay its cost after harvest time. Even the crop was not germinating well without using the chemical fertilizer.*

After the introduction and use of compost, the change in the soil and in the yield is surprising. When you hold the soil in your hands and walk over it, it is spongy and it holds more moisture for a longer time after the rains stop. It has increased the infiltration of water down into the soil. The plants grown in the composted soil are deep green, deep rooted, with heavy seeds; they make more and good tasting injera.

Moreover, we can use the same field the next year without applying compost. We are lucky to be able to use compost.

When I look back at our condition and resistance not to accept compost I laugh at myself about our low awareness about the importance of compost. Today compost is important not only for our land but also because it is saving us from taking financial credit. It simply requires labor and follow-up. If anybody starts using it, for sure he and she will like it.

5.1.2 Other Farmers' Experiences with Compost

Many other farmers have confirmed the positive experience of Farmer Ararsa of Adi Abo Mossa in Ofla near Hashenge in making and using compost to improve the yields of their crops and their livelihoods.

Weyzero Ijigu is a widow with 4 children also living in Adi Abo Mossa. Like Farmer Ararsa, she was *malto* (destitute) when the project started in 1997. Her children could not go to school because they had no shoes or exercise books, and *Weyzero* Ijigu could not participate in the community social affairs as she did not have a change of dress, nor could she contribute the customary jug of flour to make the food.

She joined one of the groups making compost and contributed her labor to collect compost making materials as well as help carry compost to the fields. When she got her share of the compost from the communal pit, she used it on a field where she planted *dimblal* (coriander).

Figure 36: A farmer from Adi Abo Mossa in 2003 holding a maize cob grown with composted soil in his right hand, and one grown without any input in his other hand

This is a high value spice and she got such a good income from the sale of her coriander crop that she was able to buy shoes and exercise books for her children so they could go to school. And for herself, she got a change of dress and was able to participate in the social gatherings of her community. For *Weyzero* Ijigu, the use of compost has changed her life and that of her family.

Farmer Awel Seyid in the Haiq Area of Tehledere Woreda in South Wollo is one of the best farmers in his area who produces and uses compost in his farm. Now all his neighbors are also making and using compost, and the whole environment is being changed (see Section 2.1 on Integrated Watershed Management).

5.1.3 Land Rehabilitation and Use of Compost in Zeban Sas

Ziban Sas village in Sa'esi'e Tsa'eda Imba Wereda of Eastern Tigray is on the top of an almost vertical cliff with very thin infertile sandy soil 4–10 cm deep that does not hold water. In 1996, the vegetation cover was highly degraded with very few trees and bushes and very poor grazing for animals. The rainfall in the area is also scanty and unreliable. The only crops the farmers could produce were barley mixed with some wheat and a little teff. The barley-wheat mixture is called *hanfets* with the seed being sown and the crops harvested together. Even the food is prepared from the two grains together. This was a very challenging situation for ISD.

In 1996, when ISD started working with the Ziban Sas community the water table had dropped to 20 meters below the soil level. Before the area was degraded the women were able to collect the water for their homes from a well next to the local church. However, by 1996 they had to walk down to a spring below the cliff to collect water for their homes and then carry the 20–25 liter jerry cans on their backs up the steep cliff to their houses.

After the community was convinced to work with ISD, the farmers, and particularly the women, of Ziban Sas put in soil and water conservation structures (Figure 37), stopped their animals from free range grazing so that the amount of biomass increased, and prepared and started to use compost on their fields. The result 2 years later is shown in Figure 38. After 4 years the water table in the area had come up to 8–10 m and the women started to again use the well beside the church to collect water.

Figure 37: Women of Ziban Sas carrying the stones to make soil and water protection structures on the communal grazing area in 1996

Figure 38: The protected and rehabilitated grazing area in Zebansas two years later in 1998

The local development agents (DAs) and community leaders, Farmers Birhane Hagos and Yemane Gelagay, described what happened in the life of the local community after they started the project's activities. They said that one of the early successes of the project came from the use of compost with both women and men making compost in pits, see Figure 39.

According to them, at the beginning they did not accept the idea of improving their crop production using only their own resources, and especially composting. They said: "*We didn't want the closure of the farm land, and the labor needed to collect the composting material. We were not convinced that the compost could be as good as what we knew about taking and using the cow dung from our homesteads*".

Figure 39: A model woman farmer in Zeban Sas with her compost pit in 2002

Farmers Birhane and Yemane went on to say: "*What we still wonder about is the residual effect of compost*". They told us that: "*Compost is not like chemical fertilizer* [which needs to be added each year]. *Compost has its own lasting effect on the soil. If enough compost is applied this year its effect will be seen the following year without applying more compost.*"

Figure 40: A Ziban Sas farmer standing in a field of 'hanfets' wheat / barley mixture grown without compost added to the soil

Figure 41: The same Ziban Sas farmer standing in a field of 'hanfets' wheat / barley mixture grown with compost added to the soil

There was one farmer called Gebre Selassie whose farm was on very poor land. He was growing teff every year because the land could not grow any other crop. Then he made compost, applied it to his field and sowed it with *hanfets* (barley and wheat mixture).

The growth and yield was very good. The next year he broadcast the same field with teff without another compost application. It was a very good crop, better than any other time before.

From this experience, everybody in the village understood about the effect of using compost by looking at the good harvests from Gebre Selassie's land – see Figures 40 and 41.

It has also been seen that use of compost helps farmers adapt to climate change. This is because compost helps the soil to hold moisture for about 2 weeks longer than fields without compost.

5.2 EXTENDING A BIOGAS PROJECT FROM ENERGY TO FOOD SECURITY AND HEALING THE SOIL

The National Biogas Project of Ethiopia (NBPE) is being implemented in the four main crop growing regions of Amhara, Oromiya, Southern Nations, Nationalities and Peoples (SNNP), and Tigray. It is hosted in the Ministry of Water & Energy with the support of SNV (The Netherlands Development Agency) and the Ethiopian government. The project started in 2009 and had the aim to have 14,000 biodigesters built and functioning by the end of 2013.

The biodigesters are being constructed so that rural households can generate and collect methane gas from the decomposition of animal dung to use the gas for cooking and lighting. When the biodigesters are fed with a mixture of water and animal dung, an equivalent volume of bioslurry is produced that is pushed out of the digester into a collecting pit. The bioslurry is rich in nutrients. Hence, the bioslurry collecting pit is connected to 2 pits where compost can be made. The flow of bioslurry from the collecting pit to the compost pits is controlled through 2 shallow channels.

ISD is a partner in the NBPE with the mandate to work as a Local Capacity Builder for the use of bioslurry as an organic fertilizer. ISD provides training in the use of bioslurry to make high quality compost and also monitors the impact of the use of bioslurry compost on crop yields in demonstration plots and farmers' fields.

The training is supported with manuals in the main local languages and other types of promotion materials including reporting on the impacts of using bioslurry on crop yields locally and internationally.

When the NBPE was initiated in 2009, the main focus was the production of energy for cooking and lighting. But by 2012, it was bringing another big advantage in improving soil fertility and agricultural productivity. ISD now has a network of innovator farmers who have improved the quantity and quality of compost they produce as well as making and handling of bioslurry compost more efficient and effective.

5.2.1 Farmer Beyene Tadesse

Farmer Beyene Tadesse is one outstanding example who has shared his experiences and innovations in making and using bioslurry compost with many other farmers and visitors from both within and outside Ethiopia, Figure 42.

Figure 42: Farmer Beyene explaining his compost making process using bioslurry to visitors from SNV

Farmer Beyene Tadesse and his wife *Weizero* Shallo Alemu have 3 children who live in a well managed compound next to the main road between Nazret and Assella, 145 km from Addis Ababa. This is in Hitossa Wereda of West Arsi Zone in Oromiya Region only 10 km from Kulumsa Agricultural Research Station. They have six cattle, all of which are mixed Friesian-Holstein with the local breed. They also keep improved breeds of chicken. He started farming after he had completed 10^{th} grade education. Now his wife is also completing her 10^{th} grade education.

However, he does not have his own farm land; only his homestead. He leases farm land from neighboring farmers every year at a cost of 1,600 ETB per hectare.

The dominant crop in the area is bread wheat followed by maize and then some pulses. Most of the farmers are using improved varieties that have been bred to need and make use of chemical fertilizer, urea and DAP.

5.2.2 Improving Compost Preparation from Bioslurry

Farmer Beyene's biodigester was built in 2009. He states that his knowledge about compost came from an ISD training workshop in 2010. He is particularly grateful to Dr Hailu Araya who explained all the steps needed to make compost in a simple way. He says that the training was open and practical: it gave him the opportunity to think about and try different approaches rather than stick to a strict recipe. He has now fine-tuned his compost making process so that it is ready in 30 to 40 days, as compared to 4 to 6 months from the pit composting process used by other farmers.

Farmer Beyene and his family are well organized with clearly defined duties and responsibilities for every day, including feeding their biodigester, preparing the materials to add to the bioslurry and managing their compost pits that receive the bioslurry. There are 2 compost pits which are filled alternatively, i.e. when one pit is full, it is covered with soil and the second pit is prepared to receive the bioslurry and make compost. Both pits are covered with a roof to stop the sun breaking down the nutrients in the compost and the rain getting in.

The steps in his compost preparation process are as follows:

- First he cleans the empty pit and checks that no water is leaking into the pit through the walls;
- Second, he and his wife break up and lay some dry plant materials such as maize stalks as a bedding on the floor of the pit. This layer allows air to circulate in the compost pit;
- Third, he opens the channel between the bioslurry collecting pit and the compost pit so that the bioslurry flows over the layer of composting materials. Bioslurry is a thick liquid that flows slowly so it can be left flowing even over night. Then he and/or his wife spread the bioslurry evenly over the whole pit;
- Fourth, they both immediately cover the bioslurry with already collected materials for composting. Most of this is dry material such as straw from animal bedding and left over animal feed, but it also includes some soil, ash, any weeds and kitchen waste plus some soil. The proportion of bioslurry to other materials is 1:2-3, i.e. 1 cm of bioslurry and 2-3 cm of other materials. This proportion of dry material put on top of the bioslurry helps in absorbing the moisture in the bioslurry so that the mixture is firm enough to stand on;
- Fifth, the next day, after the biodigester has been fed with cow dung mixed with an equal amount of water, an equivalent volume of bioslurry flows out of the bioslurry collecting pit and over the already layered composting materials. Then it is immediately covered with a layer of dry materials and soil as described above;
- Sixth, the process of adding a layer of bioslurry followed by a layer of dry materials and soil is continued day by day until the compost making pit is full. Normally it takes about

30 days to fill one pit which is 1 meter deep, 2 meters long and 1 meter wide;

❖ When the compost pit is full it is covered with a deeper layer of soil, wide leaves, thatching grass, etc so it will get hot and the decomposition of all the materials will go fast without losing nutrients such as nitrogen to the air.

Some points to remember.

The materials for making the compost, particularly dry ones such animal bedding, old straw and other crop residues like empty maize cobs, need to be collected every day in proportion to the amount of bioslurry allowed to flow into the pit.

Figure 43: Beyene's bioslurry compost pit with a pile of straw beside it ready to put on top of the layer of bioslurry. Next to the open pit is a filled compost pit covered with straw.

Everybody in the farm has to know how to take care of the compost pits. They need to be under a shade and protected from sun, rain and flood water. Otherwise the pit will face drying out or getting too much moisture, both of which stop the compost making process.

After the first pit is full, it is time to empty and prepare the second pit for filling using the same layering process as described above. The second pit needs about one month (30 days) to be filled. At the same time it will be the second month for the first pit, and materials in it will have decomposed to make mature good quality compost. Farmer Beyene tests the compost making process from time to time by opening the cover and taking out a sample to test its heat and smell it.

When the compost is mature, it has to be taken out of the pit and stored in a protected place away from sunlight and rain. In fact, the mature compost may continue to lose moisture so it becomes lighter and easier to handle when the time comes to take it to the field.

According to Farmer Beyene this type of compost making is easy even for children to do if you show them the different steps and explain so that they understand.

Farmer Beyene explains how he teaches his children. "***First**, I show and tell them to collect composting making materials such as house cleanings, grass or straw left over from animals, chicken droppings, some ash, etc. **Second,** I show them how they make the bioslurry flow uniformly into the pit before adding the other composting material. **Third,** we mix all the composting materials together and add them uniformly over the bioslurry making this layer deeper than that of the bioslurry. **Fourth,** I show them how to properly cover the pit.*

As there are two compost pits in Ato Beyene's house he prepares 10-12 batches (one batch per month) of compost in one year which gives him around 25-30 tons of compost in a year. Most of the compost he uses, but he also sells to his neighbors at ETB 100 a sack. In 2010, he sold 80 sacks bringing him an income of ETB 8,000.

5.2.3 Farmer Beyene's Extension Approach

Before he got training in compost preparation, Farmer Beyene and his wife used the bioslurry in a liquid form for their vegetables and maize grown in their garden. The results were good, so he wanted to show these to his neighbors. He invited his neighbors to see and drink coffee boiled by biogas and eat boiled maize. They both tasted very good. Afterwards, he offered to show them his biodigester unit and the effects of using bioslurry. He explained to them the whole process of the biodigester and the bioslurry. He told them that it is useful for light, cooking and soil improvement.

Later Farmer Beyene gave each of his invitees a 5-liter jerry can of bioslurry for free to apply on their vegetables in their own gardens. They started to come back to take more of the bioslurry, but the demand was too high for him to accommodate and he reduced the amount of bioslurry given.

As a result of Farmer Beyene's advocacy, many of the farmers applied to be part of the biogas project in order to improve their homes and soils like Beyene. Now the number of farmers in his area has increased tremendously.

Farmer Beyene then went on to build a small open-sided hut, Figure 44, where he could meet with visitors and discuss the advantages of having a biodigester providing both biogas and bioslurry compost. He keeps different brochures and manuals there to share with his visitors. In 2012, he estimated that he taught and discussed with an average of 250 people monthly coming from surrounding areas and other locations, even from other countries.

He asks his visitors to record their views in a large book. The views of two of his visitors are as follows:

- Ato Seifu Atnafe from SNNPR Agriculture Bureau said "*I am very much convinced about the importance of bioslurry from the presentation and field visits. To extend these practices to many areas, policy makers should have been included in the program*."

Figure 44: Beyene's extension hut with visitors looking at the materials on display

- Ato Gebre Tsadik from Tigray Agriculture Bureau said "*The compost preparation process and the effect of compost on crop yield I observed is visible at field level. In our region, compost preparation and using it is one of the top priorities of the local government's interventions. Hence I will try to work with my colleagues to give much attention to incorporate use of bioslurry in our annual development plan*."

5.3 Socio-Economic Advantages of Bioslurry Compost

For each farmer with a biodigester, the size of the two compost pits needs to be in proportion to the size of the biodigester. The biodigesters built by the majority of farmers range from 6 to 10 m^3, and the amount of compost produced per year depends on whether or not a farmer is able and willing to make compost from the bioslurry. The potential amount varies from 30 to 50 m^3 over 10 months and from 36 to 60 m^3 over 12 months. The majority of farmers have 6 m^3 biodigesters so they could produce 30 to 36 m^3 a year in 10 and 12 months respectively.

From the farmers' point of view, biogas and bioslurry have the following advantages.

5.3.1 Biogas and Bioslurry Help Farmers Save

Farmer Shume Deyas from Ada'a calculated that his expenses for buying fuel wood, kerosene and charcoal were around ETB 10,000 a year. As he explained, using biogas has helped him reduce all these costs. Both Farmer Shume in Ada'a and Farmer Beyene in Hitossa say that they can produce enough compost from their bioslurry to be free from purchasing chemical fertilizer. Having biogas also reduces the competition for dung to be used as a fuel.

5.3.2 Spreads labor demand for making compost

As a biodigester needs to be fed with animal dung and water throughout the year, bioslurry compost can also be prepared throughout the year, but particularly when the labor demand for other agricultural work is reduced such as in the dry season. There is also no need to collect additional water when making compost, i.e. the bioslurry contains more than enough water for the compost making process.

5.3.3 Impacts on yields

Only a few records of the impacts of the use of bioslurry compost on crop yields have been collected. However, the results indicate that there is a significant yield increment both in grain and straw even when there are problems from pests and diseases.

The NBPE pilot weredas and villages from Tigray in 2010 were Hintalo Wejerat, villages Adi Gudum and Waza, and Ofla, villages Hashenge and Mankere. The data were taken from fields growing either wheat or barley, as these are the dominant crops in these villages. The climate in Hintalo Wejerat is semi arid and the soils are thin and stony. Rainfall in the Ofla area is higher, soils are deeper, and farmers have become used to using some chemical fertilizer as well as normal compost from pits.

Tables 1 and 2 give the grain and straw yields converted to kilograms per hectare for wheat and barley from Hintalo Wejerat in 2010.

Table 1: Grain and straw yield of wheat in Hintalo Wejerat, 2010

Treatment	Farmer's name	Grain average kg/ha	Straw average kg/ha	Grain increase over check
With bioslurry compost	Abreha Moges	2,800	3,961	164%
	Berhanu G/Selassie			
	Belay Mores			
Check - nothing added to the soil	Senay Teklu	1,711	3,072	
	Selemawit G/Mariam			
	Embaye Desta			

Table 2 - Grain and straw yield of barley in Hintalo Wejerat, 2012

Treatment	Farmer's name	Grain average kg/ha	Straw average kg/ha	Grain increase over check
Compost	Gidey Tekaye	2,628	4,056	172%
	Hindeya Muez			
	Felege Tsegaye			
Check	Kinfe Nuriyu	1,528	2,417	
	K/Mariam Haile			
	Dagnew Melew			

The response from applying bioslurry compost to their fields was large: average wheat grain yield increased by 64% and that for barley increased by 72% over the 'check', i.e. a field without any inputs where neither compost nor chemical fertilizer had been used. Even the farmers with poorer fields benefitted from the use of bioslurry compost. For wheat the average yield for a poor field more than doubled from 1170 to 2450 kg/ha, while that for barley increased from 1150 to 2270 kg/ha.

In the village of Waza, farmers growing barley had included the use of chemical fertilizer in their treatments, see Figure 45.

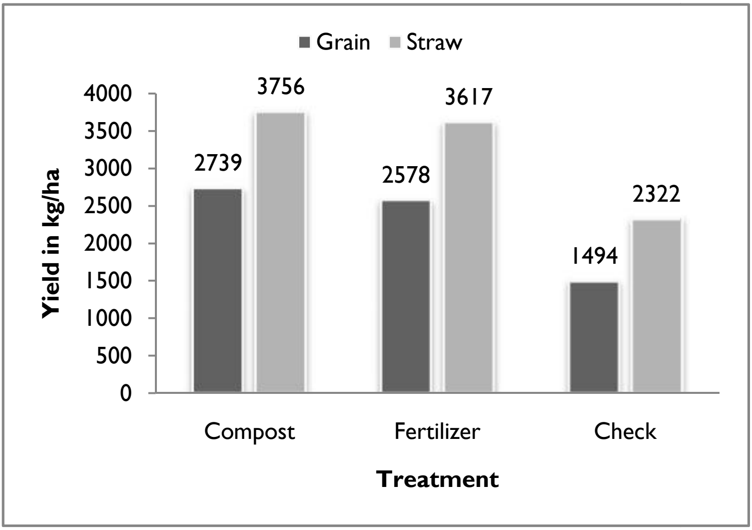

Figure 45: Comparison of the effects of bioslurry compost, chemical fertilizer and no inputs (check) on grain yields of barley in Waza, Hintalo Wejerat, 2010

The graph shows that the application of either bioslurry compost or chemical fertilizer almost doubled the yield of grain compared to the check. Similar results were found when ISD started to monitor the impact of adding compost from pits to the soil on crop yields in 1998.

In Ofla, the bioslurry development agents focused on collecting crop yield data from farmers growing wheat. In Mankere, six farmers who had used all three treatments, compost, chemical fertilizer and check cooperated with the development agent who took data from a total of 54 plots each 1 m^2. The average grain yields were 4,500 kg/ha from the use of bioslurry compost, 4,600 kg/ha from chemical fertilizer and 3,600 kg/ha where no input was used. In Hashenge, farmers were using an improved wheat variety, HAR 1685. The average grain yields were 4600 kg/ha from both the check and the use of bioslurry compost, and 5300 kg/ha from the use of chemical fertilizer. Hashenge farmers have been making and using compost since 1997/98 (see Section 5.1.1) and the overall fertility of the soil in the area is good.

5.3.4 IMPACT ON DISEASE RESISTANCE

Bioslurry compost has been found to increase the resistance of crops to disease and pest attacks. For instance, in 2010 due to a prolonged rainy season, the condition was favorable for the occurrence of stripe rust (*bicha wag*). The disease infested wide areas of wheat: for example, 135 ha in Ada'a and nearly all of Hitosa weredas of Oromiya region. NBPE received reports that wheat in Hitosa grown on compost treated soil was resisting the disease. A team from SNV, ISD, EPA (Environmental Protection Authority) and Kulumsa Research Station of EIAR (Ethiopian Institute of Agricultural Research) visited Hitosa on 28 October 2010. There was a clear difference between the wheat crop of the same variety grown on two fields on either side of a path between the two fields. In one field chemical fertilizer had been used but the other field had received bioslurry compost. The wheat in the compost treated field resisted the stripe rust (Figure 46) while that grown with chemical fertilizers was heavily infected (Figure 47) and had had to be sprayed twice with fungicide. The wheat grain yield from the heavily infested field was 2.2 t/ha while that from the field where compost had been applied was 5.2 t/ha.

Following this visit, the bread wheat research team from the neighboring Kulumsa Agricultural Research Station started working with Farmer Beyene providing him with seed of improved varieties to assess their performance and yield when grown on compost treated soil. This collaboration can identify improved varieties that are suitable for an organic agriculture system.

Figure 46: Bread wheat grown with composted soil and resisting the stripe rust

Figure 47: Bread wheat grown with chemical fertilizer and heavily infested with stripe rust

5.3.5 HEALING THE SOIL

Farmer Beyene conducts his own research by planning and observing the effects of bioslurry and bioslurry compost. In 2011 he applied bioslurry to half of a small field inside his compound where he planted maize. The maize grown on the bioslurry treated soil was good. Then, in 2012, he applied bioslurry to the half of the field where he had not applied it in 2011 but he did not apply anything to the other half. He wanted to see if there was a residual effect from the application of the bioslurry in the previous year. He saw that the maize in the area that had received bioslurry in 2011 was better than the crop where he had applied the bioslurry in the 2012. This showed him that the beneficial effects of compost were stronger in the second year than in the first year when he had added compost to the soil.

This residual effect of compost has also been recognized by many other people, experts and researchers, but particularly by farmers.

Many farmers are now realizing the advantages of using compost for improved soil fertility. But in areas such as Hitossa, their soil has become poor through the continued use of chemical fertilizer. By 2012, Farmer Beyene told us that farmers are asking him to use their land and add compost to the soil to grow his own crops for one or two growing seasons. They say that Farmer Beyene's use of compost and crop management is helping to heal the soil. When the fertility of the soil has been improved through the addition of compost, the farmers take back their land from Beyene. But Beyene says that he always has 5 or more hectares to grow his crops.

5.4 ONE MODEL FARMER'S USE OF CROP DIVERSIFICATION AND INTEGRATED SOIL FERTILITY IMPROVEMENT

Aleta Chuko wereda is found in Sidama Zone of SNNPR. It is 70 km south from Hawassa, capital city of Sidama Zone and SNNPR. The Development and Social Services Commission (DSSC) of EECMY, South Central Ethiopia Synod, has been carrying out the Chuko Food Security Development Project since 2008.

Farmer Berihanu Rikiwa, 50 years old, is one of the model farmers supported by the project. He lives in Dibicha kebele. He is married with 9 children (3 male, 6 female). His land holding is only 0.52 ha and it was not producing enough to feed 11 family members. Because of this he was given training to diversify the crops he grew and use organic farming practices to improve their production.

Farmer Berihanu explained: "*I got trained in organic farming technology in 2011, and benefited with agricultural hand tools such as wheelbarrow, watering can, fork and spade for preparation of compost and to dig the land. I used local materials to prepare vegetation compost, basket compost, mulching and plant tea (liquid manure) to improve soil fertility. I used these inputs to compare and contrast between crops grown on composted and non-composted soil, and fields where compost and chemical fertilizer had been applied separately. With the compost the yield increased in both quantity and quality.*

He continued: *I have shown these demonstration trials to farmers, government officials, and other civil society organization members. I saved money that I would have used to pay for chemical fertilizer year after year. Once you apply compost to a field, it can be enough for two years of crop production.*

He says: *"All my family members participate in compost making practices and I have six farmers who have followed my system to convey the knowledge to other farmers."*

Ato Birhanu Rikiwa describes the good practices that he and his wife and children have adopted after starting to use compost as follows:

- *Since 2011, we have planted 500 good yielding varieties of enset seedlings in rows. We used compost and mulching techniques to improve soil fertility. The growth of the enset plants with compost added to the soil is very fast and vigorous compared to those on non-composted soil. In a short time it is ready for harvest providing food needed at household level.*
- *For a long period, we had old coffee trees with low yielding capacity. Then I got training on coffee management such as stumping, pruning, thinning and organic fertilizer application. The project also supported me with farm tools to stump the old coffee trees. Now through improved management, our coffee is high yielding.*

Figure 48: Farmer Berihanu showing visitors his compost making pit

- *We planted 1000 improved pineapple seedlings, called Smooth Cayenne, on a small plot of land* (Figure 49). *With the technical and material support of the project I established a demonstration plot to compare the local pineapple with the* *improved variety for showing to other farmers as part of the Project's extension approach. The new agronomic methods such as land preparation, row planting, organic fertilizer application, and mulching have improved production of pineapple. I have six follower farmers whom I have trained and transferred the new technology to them.*

Figure 49: Farmer Birhanu's improved pineapple production field

- *I have got knowledge on the grafting of fruit trees to improve their production and I have planted seedlings of sweet orange.*
- *The project has introduced a good yielding variety of ginger that was not known before in the area. I have planted it on a small plot using new techniques.*
- *Our vegetables include carrot, Swiss chard, beetroot, cabbage, tomato, lettuce and onion. During the dry seasons we fetch water for irrigation. In 2011/12 our vegetable production increased significantly and we earned birr 3000 from their sale. This has helped us to buy clothes and food for the family, and to send our children to school. Moreover, we use some of the vegetables for household consumption and this has improved the dietary complement for our family. Both our food consumption and income have increased.*

Farmer Berihanu went on the explain about seeds. He said: "*For the last many years, the government has introduced hybrid seeds without giving any attention to local seeds that are good yielding and disease resistant. The price of hybrid seeds has continued to increase so that they are no longer affordable. To keep the biodiversity of the crops, I have started to collect, multiply and distribute indigenous seeds through my demonstration site. Chuko Food Security Development Project has supported me with trainings and provision of farm tools. The project has given value to the traditional knowledge of the community. My observation from demonstration plots so far is that the local seeds are drought and disease resistant, as well as comparatively good yielding. We have stored the seeds using traditional preservation methods for planting in the next season and to distribute them to other farmers who ask for them.*"

He said proudly: "*I am the owner of my own seed*."

Farmer Berihanu concluded by saying: "*Our land holding is very small compared to our family size. We always try to use our land intensively. Thanks to the project, through crop diversification and integrated soil fertility practices my family has become food secure and the living standard has improved. We will continue these practices without external inputs as we have the knowledge and skills to do so.*"

6. Environmental Conservation by Local Organizations in Tigray

As the population and the demand for cultivated land increases, the natural resources in general and woody vegetation in particular are diminishing. It is now estimated that less than 3% of Ethiopia is covered by forest, both natural and as plantations, in the highlands above 1500 m asl. There is still an extensive cover of woodlands at lower altitudes, but even these are disappearing fast with clearance for agriculture and the demand for fuel wood and charcoal from both rural and urban households: 93% of the energy needs of Ethiopia are provided from woody biomass.

Many publications report that Ethiopia had a forest cover of about 40% in the 19th century, but this is based on a study done by the forester, Brietenbach, and published in the Ethiopian Forestry Review in 1962. Brietenbach had used altitude zonation to identify that 40% of Ethiopia had a climate suitable for forest if there was no human interference. Written records by travelers to Ethiopia from the 16th century onwards report that the Ethiopian highlands were densely populated and cultivated with many isolated trees and sacred groves, but not with forests. Shortly after Brietenbach's study was published, FAO quoted his finding as though in the 19th century, Ethiopia had a standing forest cover of 40%. This figure was also quoted as a 'fact' by McCann in his book *From poverty to famine in Northeast Ethiopia: a rural history–1900-1935*. The history of land management, and hence also forest, in Ethiopia was studied and published in 1990 in Volume 2 of *Ethiopia's National Conservation Strategy* in the paper by Tewolde Berhan Gebre Egziabher, "*Ethiopia's future conservation strategy must take cognizance of that of its past*".

The remnants of old natural forest in the northern parts of the country are in sacred places where they are protected by strong traditional beliefs (Figure 50). However, due to the pro-active cooperation among members of local communities to identify enclosures, as described previously, as well as around many new churches, Muslim grave-yards, army bases, and schools, the woodlands and forests are being restored.

Figure 50: Diwo Mariam, a very old church surrounded by dense natural forest

6.1 THE ROLE OF SACRED PLACES

Ethiopians believe that the land associated with churches and mosques is sacred and should be covered with good vegetation. Many of these places include springs with holy water (*tsebel*) that are used medicinally and spiritually as they are where clean water can be found. These are the places where people can get rest and quench their thirst with confidence. But now conditions in these forest holdings are changing both positively and negatively because peoples' belief in their religion is declining and churches no longer have the same power over the behavior of their associated communities. Where the traditional beliefs are still strong, these can guide positive changes.

6.1.1 ORTHODOX CHURCH FORESTS, NEW AND OLD

Saint Kidane Mihret of Adwa town and Saint Mikael of Axum are two examples where the local congregation have planted indigenous trees in their compounds. The survival rate of these trees is unbelievably high. They are two of the youngest churches in these towns but their compounds are now densely covered with trees despite the stony soil. Saint Mikael church was established 7 years ago, i.e. in 2005.

According to *Aba*[7] Teklehaimanot Asayehegn at the beginning there was only one building and there was not a single tree in the compound. Hence, there was no shade for the congregation to protect them from heat and rain, because the majority of the church members do not enter the church building during services, but follow from the compound. Priests also go to the outside veranda of the church to preach and teach their followers.

Aba Teklehaimanot is the head of the church and his responsibilities include planting trees as *atsed*–providing shade in a church compound. He consulted with his believers on what trees to plant and how to care for them. Members of the church obtained seedlings of different species and planted them as a community work together. Then they shared a number of trees to different groups so that each group would water and care for the trees.

The church took responsibility to recruit a guard to watch over the trees day and night and prevent animals entering to graze on them. After only 3 years the church compound became greener than that of the surrounding community.

When *Aba* Teklehaimanot was asked how he got the commitment to conserve nature, he told us that his teacher, *Aba* Gebregziabher, was his role model. His teacher never ordered his students to undertake a task. Instead, they learnt by following his example. Whenever, he was free he always spent his time caring for the local

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[7] *Aba* meaning 'father' is a title of respect for the head of the church.

vegetation. Then his students also became involved. This is how he became committed to conservation.

Despite this positive example, many old churches and monasteries are seeing the forests around them shrinking. There are many examples with dying forests throughout the country and church elders and leaders are fighting for their survival. The break down in traditional beliefs combined with the demand for quality wood for building new houses is driving many people, particular the younger ones and landless youth, to encroach into these previously sacred places.

Some of the churches are becoming pro-active in planting buffer zones of quick growing tree species, even eucalyptus, around their compounds. The church leaders hope that these buffer zones will prevent people from cutting the older trees inside the church area. The churches are still very strong local institutions which can teach their congregation members about local natural resource conservation and respect for nature.

6.1.2 Muslim Grave Yards

Ethiopia has a very long tradition of peaceful relations among Christians and Muslims. This dates from the 7^{th} century when Mohammed was being persecuted in Arabia. He sent a group of 7 converts to Aksum where they were given hospitality by the Emperor saying: "*We worship the same God, and have the same food eating rules.*"

One of the princes converted to Islam with the name Negash, and he built the first Mosque in Ethiopia in a place named after him. However, after he was converted the woman in the royal household to whom he was betrothed refused to marry him. Instead she became a nun and built a church near to but down the hill and out of sight of Negash's Mosque.

Muslims have a strong tradition of conserving and protecting natural vegetation, particularly in their graveyards. It is not only that they are fenced but also people believe that entering and cutting trees from these places are sinful. We have seen that these places, even though recently established, have better vegetation cover as compared to the ongoing encroachments in the areas around the churches.

The examples we have seen are in the towns of Wuqro Marai, Adwa, Negash and Wuqro Kilte Awla'elo. They all are well protected by fences. No one gets into these places, even to graze their animals. The vegetation cover in all of them is amazing, especially the one in Adwa town which has a good acacia tree canopy (Figure 51). Many people told us that when the graveyard was established, there was no tree in it.

Figure 51: Muslim graveyard in Adwa with good growth of acacia trees

The areas around the Mosques are also considered as sacred, as seen in Negash and Wuqro Marai. There are two Mosques in Raya Azebo. All have good plant cover inside their compounds. The best cover is in the Mosques in Raya Azebo because the Muslim community believes that anyone who lives by selling wood always stays poor, and second, anybody who is a son of Allah should love a tree. It is generally seen that when a Muslim community is established, the density and height of the vegetation in that place is improved.

6.2 THE ROLE OF ARMY BASES

The history of the behavior of the present Ethiopian army is very different from what was happening during the time of the Military government–the *derg*. Many people in Ethiopia, especially in the northern parts of the country, remember the destruction of trees during the civil war between the army of the *derg* and the local people. There was no way to prevent the *derg* army from cutting trees, even in the sacred places.

However, since the 1990s, the Ethiopian army has been behaving in a completely different way. In many places they are the leaders in forest and woody vegetation recovery. They cooperate with the local communities providing labor and trucks for many weredas, especially in Tigray, to transport seedlings.

Figure 52: Arato forest improved and protected by the army

Arato Military Base near Adwa is one example. The base has an enclosure area of about 1200 ha that local people would previously enter to graze their animals and cut trees, even though there were guards. When the area was assigned to be managed by the Arato Military Base, the wereda agriculture and the local administration were afraid that there would be even more destruction. But the opposite has happened. Now the area is under the control of the military base, the forest has recovered (Figure 52).

6.3 SCHOOL ENVIRONMENTAL CLUBS

All elementary schools include environmental conservation and protection in their curricula and are encouraged to form environmental protection clubs made up from interested students led by concerned teachers. Some of these school environmental clubs are also working with their local communities to bridge the intergenerational gap between the knowledge of the farmers and the modern knowledge of the students. One of the activities carried out by school environment clubs is to protect and improve the environment in the school compound.

Megabit 30 Elementary School in Wuqro is a long-established school that was built in the 1950's. In the 1990s, there was hardly a tree around it except 2-3 *aku'y, awhi* (*Cordia africana*) and some eucalyptus trees. ISD helped the school environment club establish a tree nursery and get seedlings of useful trees, particularly for fruits. Now the compound is full of guava, avocado, papaya, and banana. There are also many Cordia trees in the compound. Other examples of elementary schools built in the 1990s are Enda Maino and Abreha We-Atsbeha, both also near Wuqro. When the schools were built, there were no trees in their compounds, but when visited in 2012 more than half of their compounds had Cordia and fruit trees growing in them. These schools have become models for other elementary schools in the Tigray Region.

Figure 53: Enda Maino elementary school compound in 2008

ANNEX A

A1: COMPOST PREPARATION TRAINING PROCESS[8]

INTRODUCTION

Composting is a process where waste organic materials derived from plants and/or animals are decomposed by microbial action under aeration to produce a friable homogenous product that is added to soil. The product is used to provide plant nutrients, enhance soil structure and aid water retention. It has been used for millennia in agricultural crop production.

Compost is important because it:

- Contains the main nutrients useful for plant growth – nitrogen (N), phosphorous (P) and potassium (K), often written as NPK;
- Improves the organic matter in the soil by providing humus;
- Helps the soil hold both water and air for plants; and
- Unlike chemical fertilizer, it also gives trace elements or micronutrients needed by plants.

There are two major methods of making compost. These are:

Pit method: compost preparation in a pit. This is the preferred way in moisture stress and mountainous (cold) areas. This is because in moisture stress areas the pit keeps the available moisture for a longer time while in the cold area it keeps the inside temperature high enough for the decomposition process to continue.

Heap method: compost preparation by piling on the ground. It is an appropriate method for areas where there is excess moisture through high rain and irrigation. If the compost making here is in a

[8] This can be used with the manual "Natural Ferilizer" by Sue Edwards and Hailu Araya and published by the Institute for Sustainable Development, also available at www.isd.org.et

pit, excess moisture may enter into the pit and retard the decomposition of the compost from a good smelling aerated process into a sour or ammonia-smelling process.

SOME PRINCIPLES TO BE FOLLOWED

For effective compost making, there are some principles, which have been identified from the trainings ISD has conducted and farmers have practiced for more than 12 years. These are:

- ❖ The training should provide the space for free dialogue among the trainees and the trainers. This will allow for the sharing of experiences and develop trust.
- ❖ Farmers develop confidence and are convinced when they see and participate directly in the training by practicing what they learn because most farmers are convinced by what they see rather than what they hear. Therefore, training has to be practical.
- ❖ To get an effective and sustainable result out of the training, the trainees should be a mixture of different social groups such as farmers, women, youth, development agents, experts, local leaders such as priests, etc. This will create trust among these social groups with the extension professionals.
- ❖ The number of trainees should be limited to a maximum of 30 people that can be divided into 2 or 3 groups during practicing so all participants can be active and not just passive listeners.
- ❖ Use one easily understood language – training should be in a simple straightforward language that can be readily understood by all the trainees, especially the farmers; i.e. there should not be a mix of languages, and technical terms should be avoided or clearly explained.
- ❖ Give a simple manual – each participant should get a copy of a manual for making and using compost in their local

language. The discussions should allow for trainees to forward their comments on the manual.

- All comments should be collected and analyzed so they can be used in the next training and to update the manual.

A2: Steps to Use in Making Compost

Choosing a Compost Pit Location

Selection of a site for a compost pit is very important for a better compost making process. A compost pit should be under a shade to protect it from sun, and protected from flooding.

Trainees should be taken for outdoor practice in selecting compost pit sites. They should work in their groups to discuss where to place the pit among themselves, and then report back to the whole trainees. However, if they do not find a good place with shade and appropriate slope, the question is: "*are they going to stop preparing compost?*" The answer is: "*No*". A compost pit can be dug and provided with some safeguards. These are, **first**, to make a shade with plastic sheets, grasses, old sacks, etc similar to the shade used in a tree seedling nursery, and **second**, make structures to divert possible flood water from entering into the pit. Both these safeguards should be put in place after the pit has been completely filled with composting materials.

Digging a Compost Pit

Compost can be prepared using one pit, two pits or three pits. This depends on the farmers' need and/or capacity to prepare compost. But if there is only one pit, the amount of compost that can be prepared will be less than the amount in three pits. The width and length of a compost pit is not limited except its depth, which should not be deeper than 1.5m. This is because it is difficult to control the temperature in a deeper pit; it may be too hot and therefore, it can easily loose moisture, and this affects the decomposition process.

However, in Ethiopia, it is recommended that the pit for the training exercise should be dug in the compound of a Farmers' Training

Center (FTC) or the home compound of a disadvantaged family (elderly, sick, poor women-headed) so they can benefit from the compost after the training is completed.

PREPARING BIOMASS FOR MAKING COMPOST

Any and all organic waste materials can be used for compost making. But listing all the possibilities for trainees does not help; it even confuses them. It is best if the composting materials are grouped into four categories, and then the trainees can suggest materials they know that fit for each category. The categories are:

Dry stalks (stover) – it includes maize, sorghum, grasses with thicker stems, or thin branches from trees, which could not decompose easily. These are put in the bottom of the compost pit to make sure there is a good circulation of air and moisture inside the pit. But this is not a must to have.

Dry biomass – this is all kinds of dry biomass such as straw from field crops, all kinds of weeds that have dried out, grasses, etc. It is the main source of carbon. It is preferred if these materials are left-over from animal feed and bedding. This is because there is no need to compete with clean straw and grass needed for animal feed. These leftovers have extra advantage of already being mixed with urine and fresh animal dung produced by animals while they are in the pen. The urine and dung are very good for improving decomposition of the straw; enhance compost nutrients and the establishment of compost making micro-organisms.

Green biomass – this includes all kinds of green plant materials such as leaves and soft branches, weeds, grasses, etc. It can and should also include damaged fruits and vegetables that cannot be sold or eaten, and kitchen wastes from preparing food. It is the main source of nitrogen in the compost.

Starter material, the "spices" called "qmemaqmem" by farmers – a mixture of dry and wet compost already partly or completely decomposed biomass. Farmers called it "*qmemaqmem*" because it is used at each level/step of compost making. **Dry**

qmemaqmem is a dry starter, which includes any dry animal manure (*figh*), bird and chicken droppings, ash, fertile soil, etc mixed all together; and **wet** *qmemaqmem* that is a fresh or wet starter including fresh animal dung, urine (human and animal) and water mixed all together. This mixture contains the micro-organisms (worms, beetles, etc) as well as fungi and bacteria that do the work of turning the plant and animal materials into compost.

Testing stick – this is used to test the condition of the composting materials inside a pit or a pile.

In order to involve all the trainees, they should be divided into groups to collect these different materials, and then bring them beside the pit or pile. A jerry can should be placed in a toilet to collect human urine. To minimize the time required to collect all the required material it is recommended that the trainer also arranges for a good quantity of compost materials to be collected 1 or 2 days before the training is to take place. It is important to make sure there are enough materials to properly fill the pit or make a good pile about 1 meter high.

MATERIALS NOT TO BE INCLUDED IN THE COMPOST

In any part of a training program and/or follow-up, the trainer should make it possible for all the participants to forward their comments, questions and concerns. This should include what materials to keep out of the compost making process. As these vary from one place to another, the trainer's recommendations in listing materials not to be included in the compost making should be based on his/her knowledge and experience. He/she should only make comments and/or statements in which he/she is fully confident, and also invite the farmers already making compost to forward their own experiences. Farmers are innovative and may disprove comments from trainers based on their own practices.

However, the following materials should definitely **not** be part of the compost: fuel (kerosene, diesel, petrol), engine oil, stones, pieces of iron, broken glass, plastic materials, any pieces of clothes (especially nylon or plastic cloth), hyena / dog / other pet droppings, any type of wax, any type of fat, hide/skin, hair, etc.

COMPOST LAYERING PROCESS

PREPARING THE COMPOST PIT

The next step is preparing the compost pit before filling it with the available materials. All sides of a pit must be dry i.e., there should not be any moisture (e.g. a small spring) leaking into the compost pit. Then the sides need to be wetted with a mixture of fresh animal dung and urine mixed thoroughly with water. If there is a shortage of fresh animal dung using only water to moisten the sides is another option. This helps macro- and micro-organisms (the decomposers) to work faster.

FILLING A COMPOST PIT

During the filling of the compost pit, trainees should be grouped into 3-5 groups, i.e. according to the available materials and work. Each group should be a mixture of experts, development agents and farmers regardless of background and/or qualifications. The groups are:

1. Compost pit preparation group;
2. Stalk group;
3. Dry composting material group;
4. Green composting material group;
5. Dry *Qmemaqmem* group; and
6. Wet *qmemaqmem*.

This grouping helps in minimizing a mix-up of the work, ensures full participation of all the trainees, and opens up discussion during training on whose turn comes next and why. All groups should be asked to estimate the amount of biomass available for the compost pit. The following steps are used to fill a compost pit:

Preparing compost pit is the first step The sides are wetted with a mixture of fresh manure, urine and water.

Filling a compost pit needs time and care.

1. First, all the dry stalks are put to cover the bottom of the compost pit. The layer should not be thicker than one hand deep (15-20 cm).

   The bottom layer is sprayed with water and a mixture of fresh animal dung and water i.e. according to farmers this is a mixture of wet *qmemaqmem*. If possible, also put in some dry *qmemaqmem* – a mixture of dry animal dung, ash, bird and chicken droppings, fertile soil, and even crushed and burnt bones if possible. Then spray well with water.

2. The next layer to be added is a mixture of all available dry plant material: straw and hay from animal bedding, all kinds of dry weeds, grasses, etc. The layer should not be thicker than one hand deep (15-20 cm).

3. Then spray with sufficient water, and a mixture of fresh animal dung and water i.e. wet *qmemaqmem*. If possible, also put in some dry *qmemaqmem*. Then spray well with water.

4. The next layer to be added is green plant material. It should not be thicker than one hand deep (15-20 cm).

5. This layer does not need to be sprayed with water or a mixture of cow dung and water because it is moist. However, if possible, add some dry *qmemaqmem* over the top of the layer. Then spray with a small amount of water.

This sequence, steps 2-5, completes one round of layering. But the pit will not be filled in one round.

The addition of this set of layers (2-5) is repeated till the pit is completely filled and has a raised, dome-shaped top, nearly 50 cm above the ground level next to the pit.

Put in a testing stick by pushing a straight stick, which is about half a meter above the completed dome, down into and through the layers in the pit. This is useful for follow-up on the compost making process. It is used to test the moisture and temperature of the inside part of the compost pit. It is better if it is not perpendicular because nobody should stand on the pit when pulling it up. It is preferable to put in the stick when the pit is half full.

Filling the compost pit is completed by sealing the top with cow dung, mud or a mixture of soil and cow dung (*chika*) and then protected with large wide leaves such as those of enset and banana. If large leaves are not available, the top can be covered with sacks, cardboard, cloth etc.

If the pit is in a place where there is no shade, a shade is made and ditches dug to prevent flood water getting into the pit.

<u>N.B.</u> – to make the piling easy we can mix the dry and green composting materials in equal proportion before starting filling the pit.

FOLLOW UP AND TURNING OVER

Follow-up with the compost making process needs to be given strong emphasis, as it is often weak. If the compost pit has been filled correctly and it is shaded and protected from floods, usually the farmer can find good compost without turning over when he opens the pit 3-6 months later. However, regular follow-up is important to identify problems quickly (e.g. compost too dry or too wet) and deal with the problem promptly. In reality most farmers do not turn-over their compost, but all farmers should test the progress in the decomposition process.

The testing stick tests the moisture and temperature of the inside part of the compost pit. About 3 weeks after filling the compost pit, the testing stick is pulled out, the material on the stick is smelled and it is then put on the back of the hand.

If the stick is watery and cold, and the material smells **sour** or like ammonia it shows that there is excess water in the compost.

Therefore, the materials should be taken out and more dry matter added while turning-over the compost materials back into the pit.

If the stick is dry without any sign of moisture, it shows that more moisture and/or green matter should be added to the materials.

STORING COMPOST

Matured compost should be stored either in its original compost pit or taken out and put under shade and covered until it is taken and used in a field. A sunny and windy place is not good for storing compost because many of the nutrients, particularly nitrogen, will be lost. Some farmers put in a small house until they use the compost.

COMPOST APPLICATION

There are different views about how and when to apply compost. It is true that the nutrients in compost are released to plants slowly. However, if compost is applied earlier than the crop is planted the available nutrients will escape to the air. As soon as the compost is added to the soil, small amounts of nutrients are available to the germinating/growing plants. Therefore, compost application should be during planting time. This is because when applied at the same time the releasing process will start with the already available nutrients immediately.

If compost is applied before planting, it should not lie on the surface of the soil. **It has to be ploughed or dug into the soil**. If farmers use row planting, the compost should be put in the row with the seeds and then be covered.

IMPORTANT POINTS TO BE CONSIDERED

Many farmers are afraid of *mich* (sickness when they open the compost pit during the day time). Therefore, the suggestion is to turn-over the compost in the evening or during the night. No need of trying to convince farmers by saying there is no *mich*.

Many people are not convinced about the availability of sufficient biomass but the farmers preferred time for making compost is immediately after the main rainy season before they start harvesting. It can be prepared the year round in irrigated areas, and particularly where vegetables are grown, and also by any farmer that has a functioning biodigester.

If the materials are not decomposed well enough there is high probability that weed seeds will be put back into the field with the compost. Therefore, it is important to make sure the compost process has been completed with a temperature high enough to kill weed seeds, diseases (pathogens) and other pests.

ANNEX B
PLANTS FOR BEES IN TAHTAI MAICHEW WEREDA, TIGRAY

Sources: Information from farmers, *Honeybee Flora of Ethiopia,* and *Useful Trees and Shrubs for Ethiopia*

B1: HERBS, SPICES AND CROPS

Amharic/Tigrinya names	***Scientific name***	**Economic Use**	**Use for bees**
Adey Abeba/ Gelgel Meskel	*Bidens (Coreopsis) spp.*	-	Important bee forage, flowers in Sept-Oct
Ater/Ayn Ater	*Pisum sativum*	Good source of food supplement and income	Important bee forage in the growing season
Bakela/ balonga (Alkuwai)	*Vicia faba*	Good source of food supplement and income	Important bee forage in the growing season
Beso-bla / Sesseg	*Ocimum basilicum*	Important spice	Flowers all year round
Damakese/ --	*Ocimum lamiifolium*	Local medicinal plant	Good honey source, all year
Dmbilal (all)	*Coricendrum sativum*	Important spice	Important honey source
Girbiya (Tigrinya)	*Hypoestes forskolei*	-	Important source of white honey, flowers all year
Guaya/ Sebere, Enguaya	*Vicia sativa*	Good source of food supplement	Important bee forage at end of growing season
Habesha Gomen (all) / Hamle	*Brassica carinata*	leafy vegetable and oil crop	long flowering through dry season

Amharic/Tigrinya names	***Scientific name***	**Economic Use**	**Use for bees**
Inselal/Shilan	*Anethum graveolens*	local medicinal uses	Flowers almost all year round
Misir/ Birsin	*Lens culinaris*	Good source of food supplement and income	Important bee forage at end of growing season
Nech-azmud / Tsa'eda-azmud	*Trachyspermum ammi*	Important spice	Important honey source
Nug / Nihug	*Guizotia abyssinica*	Oil crop	Very important honey source
Suf (all)	*Carthamus tinctorius*	Oil crop	Flowering Nov-Feb, important for bees
Telba/ Entati'e	*Linum ussitassimum*	oil crop	Important honey source end of growing season
Tena-Adam / Chena-Adam	*Ruta chalepensis*	Important spice	Good for pollen and nectar
Tikur-azmud / Tselim-azmud	*Nigella sativa*	Important spice	Good for pollen and nectar
Yeferenj Suf (all)	*Helianthus annuus*	Oil crop, fodder	Source of honey and pollen, Stems and leaves used for smoking hives

B2: PLANTS TO INCLUDE IN HEDGES AROUND COMPOUNDS

Amharic/Tigrinya names	***Scientific name***	**Economic Use**	**Use for bees**
Anfar /	*Buddleja polytachya*	Cleaning pots and fodder	Good for pollen and nectar
Koshim / Mongolhats	*Dovyalis caffra*	Good hedging plant	Important honey source

B3: FRUIT TREES GROWN IN IRRIGATED AREAS AND HOMESTEADS

Amharic/Tigrinya names	***Scientific name***	**Economic Use**	**Use for bees**
Apple/pom (all)	*Malus domestica*	Food and income	Bee forage when flowering
Birtukan/Aranshi	*Citrus sinensis*	Food, drink and income	Good bee forage throughout the year when irrigated
Gesho/ Gesho	*Rhamnus prinoides*	Important flavouring for talla and tej	Pollen for colony maintenance in dry periods
Lomi (all)	*Citrus aurantifolia*	Flavoring for drinks and bread, medicinal	Good bee forage throughout the year when irrigated
Muz (all)	*Musa sapientum*	Food and income	Good bee forage throughout the year when irrigated
Papaya (all)	*Carica papaya*	Food and income	Good bee forage throughout the year when irrigated and urea is added
Trungo (all)	*Citrus medica*	Food, medicinal and income	Good bee forage throughout the year when irrigated

B4: SOME OTHER TREES AND SHRUBS

Amharic/Tigrinya names	***Scientific name***	**Economic Use**	**Use for bees**
Akacha (all)	*Acacia saligna*	Firewood	Good pollen and useful to strengthen bee colonies during dry season
Bazra Girar / Che'a, Tsatsi	*Acacia abyssinica*	Wood has many uses	Increases honey production in dry season
Bsanna / Tambukh	*Croton macrostachys*	Leaves are good fertilizer	Helps increase honey production
Geme / Karewah, Kurruak	*Ehretia cymosa*	Firewood, construction, medicinal	Bee forage
Gerbi / Momona, Aqba, Garsha	*Acacia/Faidherbia albida*	Important agro-forestry on black soil, animal feed	Increase honey production end of growing season
Swa qarni (Tigrinya)	*Leucas abyssinica*	Firewood and animal forage	Valuable nectar and pollen source, source of white honey and during dry season
Tebeb (Tigrinya)	*Becium grandiflorum*	Firewood	Valuable nectar and pollen source during rainy season - source of white honey
Tqur Berbere / Selim Berbere	*Schinus molle*	Wood termite resistant	Good pollen and useful to strengthen bee colonies
Tree Lucerne (English)	*Chamaecytisus proliferus*	Firewood and animal	Bee forage in the higher areas

Amharic/Tigrinya names	***Scientific name***	**Economic Use**	**Use for bees**
		forage	
Tult/Hohot (Hakot)	*Rumex nervosus*	Wood termite resistant	Good pollen source for honey bee during dry season
Wanza / Aku'y, Awhi	*Cordia africana*	Very valuable timber tree	Excellent bee forage; crushed seeds dissolved in water to feed bees in dry times
Warka / D'ahro	*Ficus vasta*	Shade, leaves are good for compost	Crushed fruits with water makes valuable bee food in dry times
Wttie, Cheba / Lahai	*Acacia lahai*	Firewood and animal feed especially for goats	Good pollen and useful to strengthen bee colonies during dry season