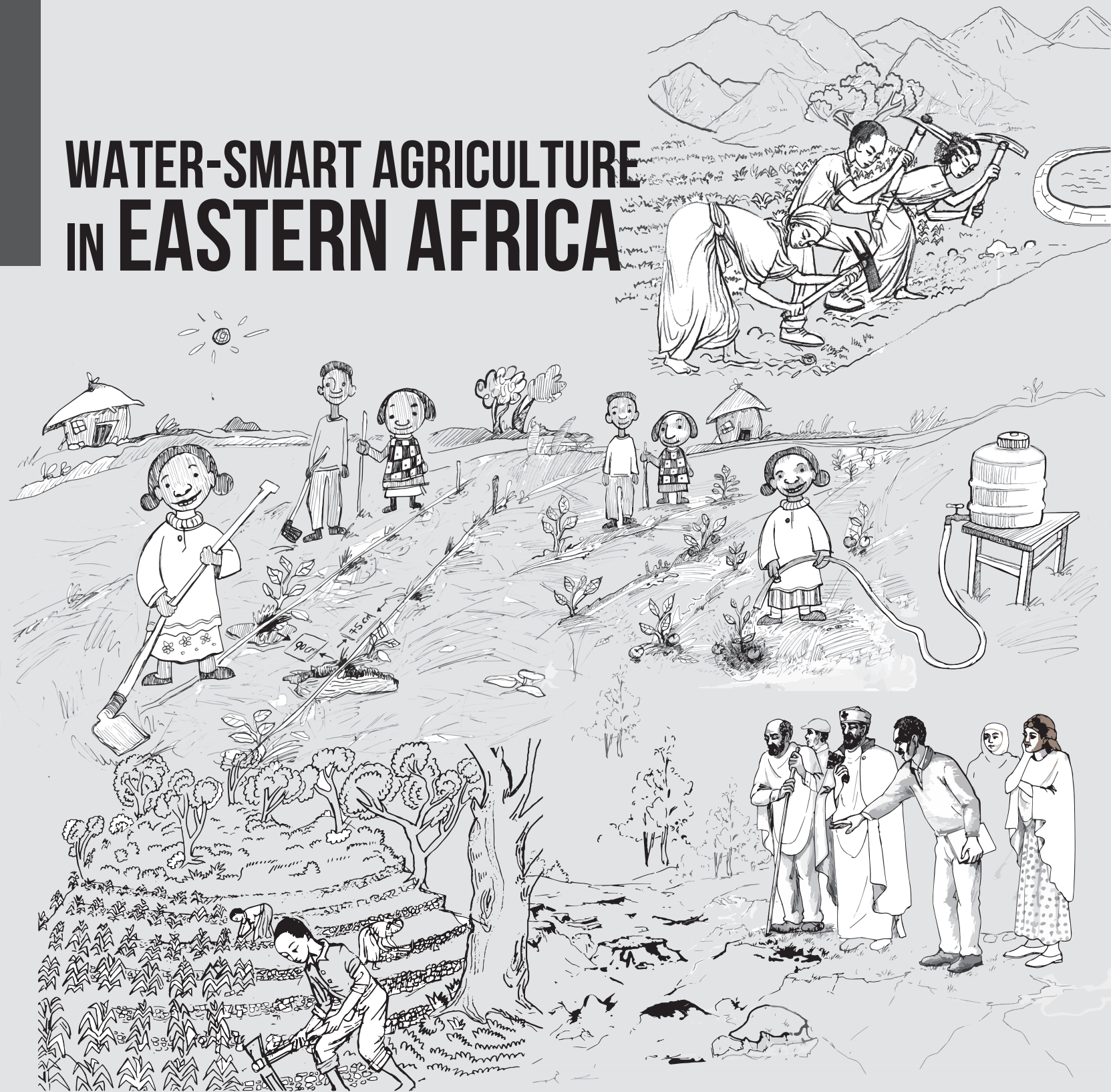


WATER-SMART AGRICULTURE IN EASTERN AFRICA

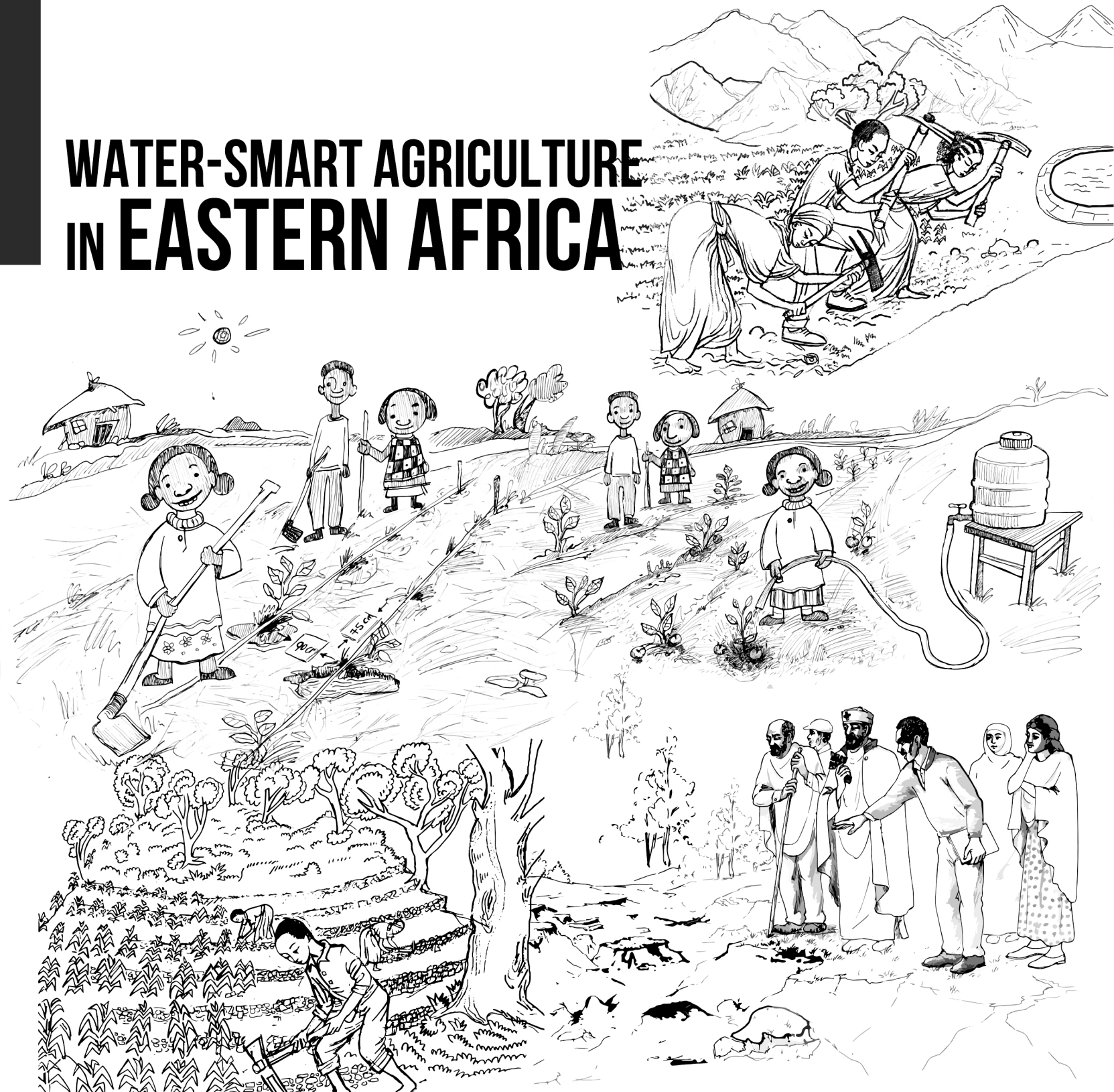


RESEARCH
PROGRAM ON
Water, Land and
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WATER-SMART AGRICULTURE IN EASTERN AFRICA



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Content

Appropriate Conservation Tillage for Smallholder Farmers in Ethiopia	3
Disadvantages of cross plowing	4
Development of appropriate conservation tillage system for smallholder farmers in Ethiopia	5
Results and discussion	6
Conclusion	7
Reference	8
Exploring Groundwater Source for Sustainable Smallholder Agricultural Production in Northern Uganda:THE CASE OF AGAGO DISTRICT	12
Implementation	13
Results	15
Challenges	15
Lessons learnt	15
Conclusion and recommendations	15
Bibliography	17
Abreha We-Atsbeha:A SHOWCASE FOR SUCCESSFUL INTEGRATED LANDSCAPE RESTORATION	20
Livelihood and Landscape Situation Prior to 2003	21
Interventions and approaches adopted for landscape restoration	21
Impacts of the interventions	23
Increase in vegetation cover	23
Expansion of irrigation	23
Increased frequency of production,diversification and resulting livelihood changes	24
Improved community self-reliance	24
Conclusion	24
Lesson learnt	25
References	26
Participatory Community-based Gully Rehabilitation on the Ethiopian Highlands:THE CASE OF BIR WATERSHED	31
Intervention approach	32
Results	34
Conclusion	35
References	36

HILLSIDE CONSERVATION AGRICULTURE FOR IMPROVING LAND AND WATER PRODUCTIVITY IN TANZANIA	39
Why Conservation Agriculture?	41
Approach followed	41
Key results	42
Challenges and limitations of Conservation Agriculture	43
Conclusions	43
References	44
Evaluating permanent planting basin for optimum plant population for maize and beans	49
Methodology	50
Results	51
Recommendation for maize	51
Recommendation for beans	51
References	52
TOT WRITESHOP PARTICIPANTS	53

Preface

This publication is the product of the Training of Trainers (ToT) on the Writeshop held in Addis Ababa, Ethiopia from 11-15 August 2014. The ToT writeshop is meant to contribute to the process of developing a sourcebook on Water Smart Agriculture. It was a golden opportunity for the experts/authors and facilitators from Ethiopia, Tanzania and Uganda to acquire the necessary skills on how to conduct a writeshop to develop user-friendly materials written in the shortest possible time.

Capitalizing on the central role that agricultural transformation has, participants have shared successful interventions/practices from the three countries in this ToT product. It covers a range of opportunities, challenges and lessons learned in different areas and countries from water and food security, to community participation and environment smart agriculture.

The publication is neither prescriptive nor exhaustive. As many of the examples show, there is no one right way of dealing with projects compatible with water smart agriculture. Something that works in one area, or at a certain time, may be inappropriate somewhere else or in a slightly different set of circumstances. The publication simply shares and reflects the experiences of six experts/authors from the three countries on water smart agriculture.

Acknowledgements

This ToT writeshop product is produced with the support of the CGIAR research program on Water Land and Ecosystem (WLE), the International Water Management Institute (IWMI) and the Global Water Management Initiative (GWI) East Africa project of CARE International.

The organizers would like to express their deepest appreciation to the International Institute of Rural Reconstruction (IIRR) team, Firew Kefyalew and Mary Ann Llanza who carried out the ToT on the writeshop and Desalegne Tadesse from IWMI/NILE who facilitated the logistics in the writeshop. In addition, we would like thank Julian Gonsalves, Michael Victor, Alan Nicol and Abby Waldorf who provided guidance for the training of trainers.

Our sincere thanks also goes to:

- Members of the writeshop and steering committee: GWI East Africa team members and their partners
- The writeshop participants, authors and other contributors (see annex list of participants)
- Artists (Workneh Bezu, Dawit Tilahun, Asrat Geleta), editor (Anmaw Anteneh) and layout designer (Dawit Bahre), whose inputs were essential for the completion of the sourcebook

ACRONYMS

AEZ	Agro-Ecological Zone
ANOVA	Analysis of Variance
ARI	Agricultural Research Institute
CA	Conservation Agriculture
CLUSA	Cooperative League of the United States of America
DAP	Di-Ammonium Phosphate
FAO	Food and Agriculture Organization
FFS	Farmers' Field Schools
IPM	Integrated Pest Management
MATI	Ministry of Agriculture Training Institute
NARL	National Agricultural Research Laboratories
NgeZARDI	Ngetta Zonal Agricultural Research and Development Institute
PFG	Participatory Farmer Group
PPB	Permanent Planting Basins
SIMLESA	Sustainable Intensification of Maize Legume cropping system for food security in East and Southern Africa
SSA	Sub-Saharan Africa
t/ha	tones/hectare
l/ha	Litres/hectare

INTRODUCTION

The agricultural sector in Africa is faced with diminishing water resources, threats of climate change, volatility of agro-input commodity prices, regional conflicts, policy shocks and the adverse effects of globalization. These complex interactions increase the risk, exposure and vulnerability of smallholder farmers to emerging shocks, thereby negating efforts aimed at reducing the sectors vulnerability and enhancing agriculture sector contribution to food security, employment creation, poverty reduction, and overall economic development (IPCC, 2007).

Africa's population is projected to double in the next 20 years. To feed these people, an increase of over 100% of agricultural productivity is a must. Given the current trends in agricultural growth and the findings of the recent World Bank (WDR, 2008), this is a formidable challenge. Sub-Saharan Africa is the only region in the world where crop yields have stagnated over the years leading to a decline in per capita food production, especially in the East Africa region. Cereal yields rarely exceed 1.5 t ha⁻¹, less than half of those realized in other parts of the world (NEPAD, 2003; Rockstrom et al., 2007). Thus, about 30% of EA population is chronically hungry and over 40% live below absolute poverty.

The low per capita food production is mainly due to reliance on rain-fed agriculture, which is vulnerable to climate variability and change; low investment in the sector; limited access to technology; and poor rural infrastructure among other reasons (NEPAD, 2003). Accelerated agricultural growth rate through water-smart technologies and practices is key if the region is to fight widespread poverty, malnutrition and food insecurity.

Multiple factors such as rainfall uncertainty, changing growing seasons, soil exhaustion and land competition leave many African farmers highly vulnerable and risk-prone. There is therefore a need to make transformations in the way the diminishing land and water resources are managed, conserved, and utilized so that smallholder farmers can continue producing more food to feed the increasing population while conserving both the land and water resources. Scientists and other stakeholders are called upon to think and act more systematically in dealing with the water security challenges faced by smallholder farmers.

The need for water smart agriculture

In May 2014, the Global Water Initiative East Africa together with IWMI / WLE convened a regional workshop on Transformations in Water for Smallholder Farmers in East Africa – towards a Water-Smart Agriculture. The aim was to build a common understanding on water-smart agriculture, and come up with modalities on how to pioneer this concept

and make it understandable to both policy and decision-makers on one end, and farmers, extensionists, and other stakeholders at grassroots level.

The concept of Water-Smart Agriculture is useful for bringing together different areas of agriculture water management.

What is water smart agriculture?

Water-Smart Agriculture explains how smallholder farmers can manage the little water resources they have to cope with the uncertainties associated with the rainfed production systems. It builds farmers' resilience to deal with the growing uncertainty in rainfed production system, combining rain-fed farming with sustainable small-scale irrigation from surface and ground sources.

The need for a sourcebook on water-smart agriculture

This resource will hopefully serve as a starting point in the development of a larger system of knowledge sharing. In particular, the process it has undergone and the papers presented here supports the production of the sourcebook in the coming months. The sourcebook will address the need to bring together knowledge and experience in the region, increase support to practitioners (and, where possible, policy makers) and provide a core for the development of a modular 'Learning Hub' on best practice and knowledge that can continually be developed through a web-based platform.

Key concepts on water-smart agriculture

Water-smart agriculture initiatives need not stop at smart agricultural water use techniques and practices. It should cover the entire agricultural value chain from production, even up to changes in government policies and plans. Examples of issues and evidences to be documented could be smart water technologies, smart agronomic practices, smart natural resources management, smart agricultural water management policies, smart catchment conservation techniques, etc.

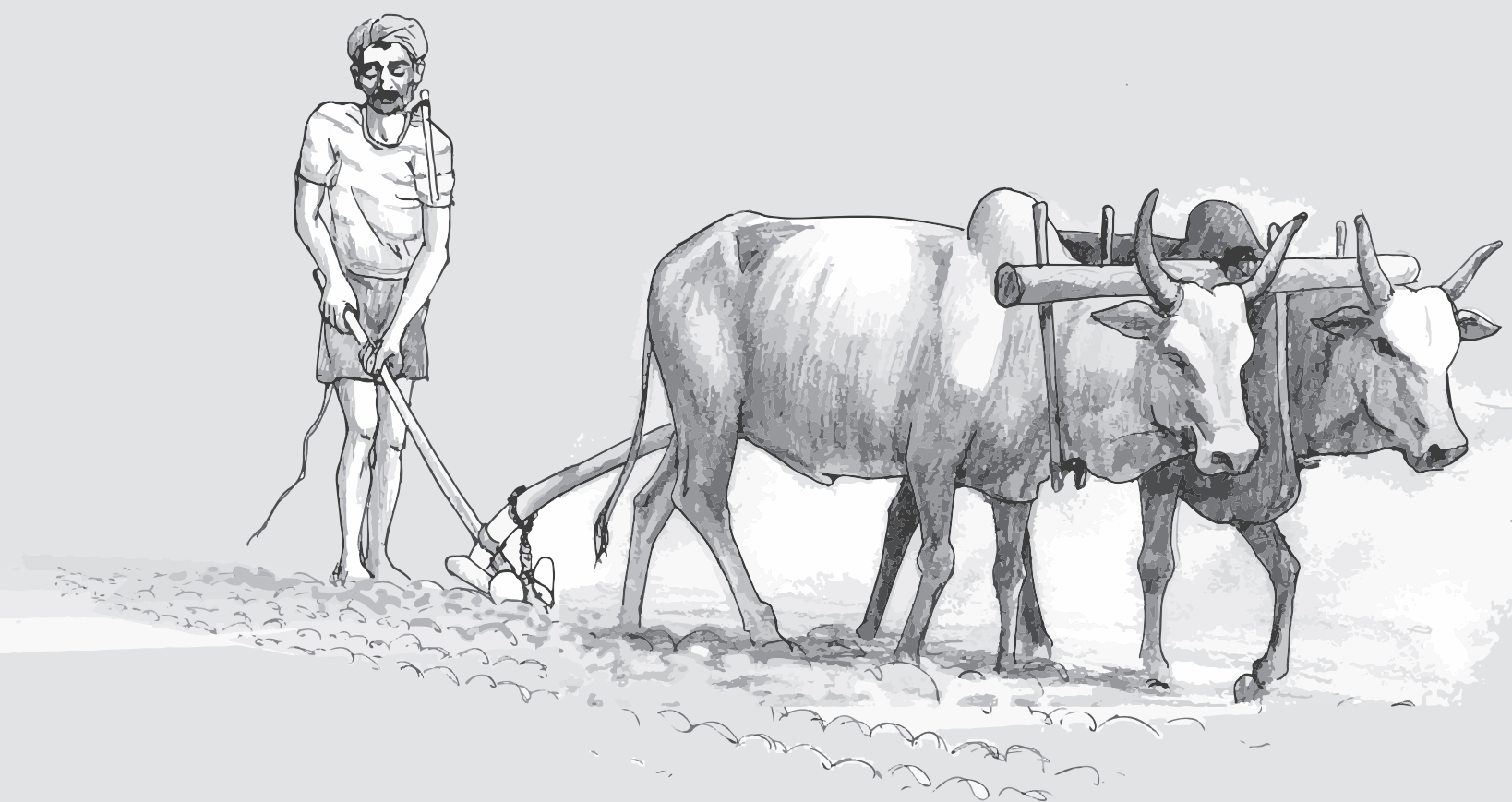
The core areas of Water-Smart Agriculture that have been addressed in this publication are:

- Water-smart conservation agriculture practices
- Smart agronomic and crop husbandry practices that conserves water at field level
- Participatory soil and water conservation practices
- Smart/participatory catchment restoration and gullies restoration initiatives

- Alternative and smart/sustainable water sources for sustainable agricultural production

The publication provides examples of water-smart agriculture initiatives to help farmers realize more returns from the land and water resources. The book can be used to build the capacity of those supporting farmers, including extension agents, researchers and the private sector.

APPROPRIATE CONSERVATION TILLAGE FOR SMALLHOLDER FARMERS IN ETHIOPIA

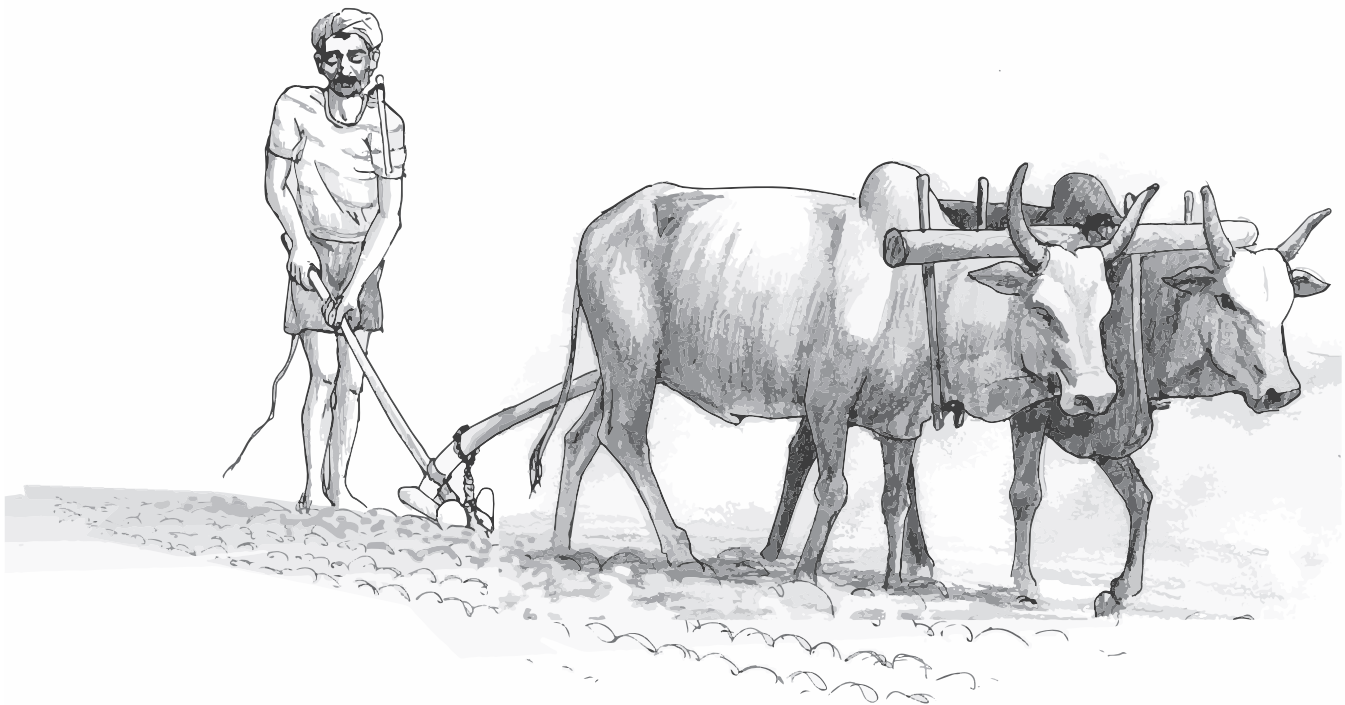


Author:
Melesse Temesgen

Appropriate Conservation Tillage for Smallholder Farmers in Ethiopia

Melesse Temesgen

School of Civil and Environmental Engineering, Addis Ababa Institute of Technology



Conservation tillage is a tillage practice that involves minimum soil disturbance aimed at conserving soil, water, and labor and traction requirements (Rockstrom et al., 2009). Conservation tillage is practiced to reduce and reverse land degradation, which was caused by intensive and improper tillage. No till or zero tillage has been widely used in high rainfall and high temperature areas like those of South America. Out of the total land under no till, about 96% is found

in South America, parts of North America, and Australia. The other continents - Asia, Europe and Africa - share the remaining 4% (Giller, 2009). This shows that there are climatic and socio-economic factors affecting the adoption of conservation agriculture.

One of the purposes of tillage is weed control. The high weed infestation that comes along zero tillage has to be offset by the use of herbicides, which may

not be friendly to the environment in addition to health concerns. Besides, fear of adulteration of chemicals and the policy of the Ethiopian government that prioritizes labor-intensive technologies have not in favored chemical weed control over the rather cheap animal-powered mechanical weed control. This, coupled with other socio-economic factors such as the challenge of leaving crop residues in the field where communal grazing is practiced, calls for a locally adapted conservation tillage system that can achieve the main objectives of conservation agriculture (Giller, 2009).

Conservation tillage was introduced to tackle the problem of land degradation that came as a result of intensive tillage. In commercial farms the main cause of land degradation is soil inversion with tractor-drawn mouldboard and disc plows. In addition to soil inversion, movement of soil at higher speeds with tractors causes too much soil pulverization. Such tillage practices speed up soil organic carbon losses. Loss of soil organic carbon causes land degradation. Besides, use of tractors for tillage as a mechanical means of weed control has been found to be less economical compared to the use of herbicides. These factors and the fact that higher soil temperatures caused by intensive tillage jeopardize seed viability led to the abandoning of tillage as has been widely witnessed in South America and other parts of the world.

When it comes to Ethiopia, the main reason for land degradation is soil erosion, which is caused by repeated cross plowing. Cross plowing is the practice of orienting the directions of two consecutive tillage operations perpendicular to each other. Farmers in

Ethiopia are forced to undertake cross plowing because of the geometry of the traditional tillage implement, **Maresha** (Figure 1). **Maresha** creates V-shaped furrows (Temesgen et al., 2008), which leave strips of unplowed land between consecutive passes (Figure 2). During the next tillage, farmers cannot easily access the unplowed strips without resorting to cross plowing.

Disadvantages of cross plowing

- **Cross plowing wastes too much time and energy.** During the second plowing, the plow is run across the already plowed furrows in order to access the unplowed strips of land. This wastes close to 50% of the time and energy of both the oxen and the farmer. Even after the second tillage, we find spots of unplowed land left between pairs of crossing furrows. These spots of land still carry weeds that have to be controlled. Additional tillage operations are required to fully disturb these spots during which the plow has to spend most of the time running over the already plowed land. This is the main reason why farmers in Ethiopia have to plow so many times.

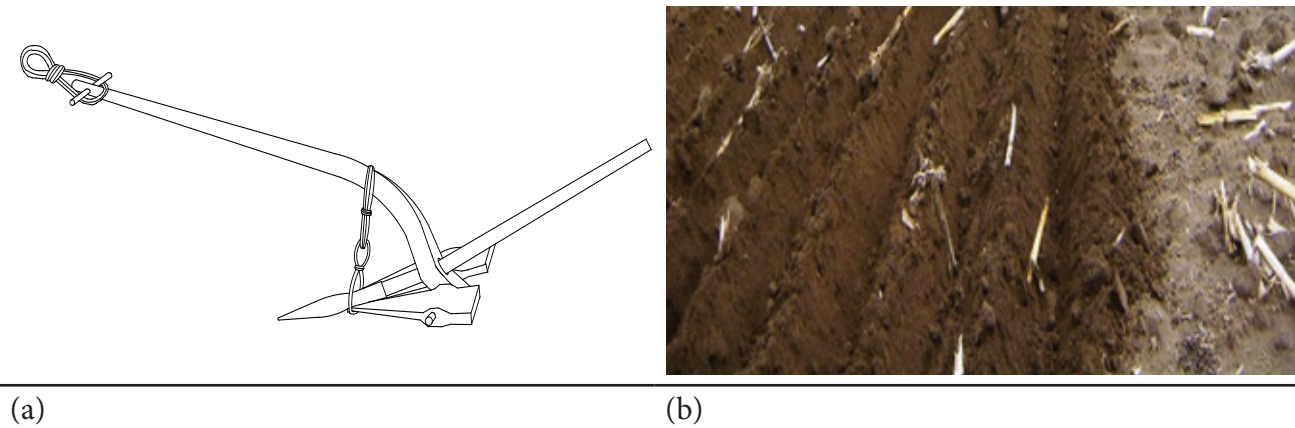


Figure 1. (a) The traditional tillage implement in Ethiopia, Maresha (b) V-shaped furrows left after plowing by Maresha. The land between passes can only be disturbed through repeated cross plowing, which is the main cause of soil erosion and high tillage frequency in Ethiopia.

- **Cross plowing causes high surface runoff and soil erosion.** Cross plowing rules out contour tillage, which is highly recommended in moderate to steep slopes. With cross plowing, one of any two consecutive tillage operations falls along or nearly along the slope. Orientation of tillage directions along the slope provides channels for rapid flow of water, which causes higher surface runoff. Consequently, in addition to loss of soil moisture in dry areas, higher surface runoff is generally associated with higher soil erosion. Soil erosion is the main cause of land degradation in Ethiopia.
- **Cross plowing is inconvenient in fields treated with soil conservation structures.**
- On moderate to steep slopes, much of the land is treated with soil conservation structures. However, farmers usually destroy the soil conserva-

tion structures due to the difficulty of undertaking cross plowing between the structures, which are usually constructed in short intervals. Some farmers plow the field parallel to the structures but they have to employ more labor to manually dig the strips of land left between two consecutive passes.

Development of appropriate conservation tillage system for smallholder farmers in Ethiopia

Field experiments were carried out using improved tillage implements that avoid cross plowing. One of the field experiments was conducted at a site known as Enerata in the upper Blue Nile Basin (Temesgen et al., 2012). The experiment compared conventional tillage with conservation tillage on fields treated with soil conservation structures. Data collected include the labor and time required for tillage, soil moisture distribution between consecutive soil conservation structures, and crop yields. Following comments of

farmers concerning the high draft power requirement of the tillage implement, another model known as Arashogel has been developed. The two implements are similar in terms of avoiding cross plowing but Arashogel is made simpler and easier for the oxen to pull. Another field experiment has thus been carried out, using Arashogel, in Minjar Shenkora woreda of Semen Shoa zone. Data has been collected on surface runoff, time required for tillage, soil erosion and crop yields. Test crops are maize and tef. At the moment, Arashogel is being demonstrated on farmers' fields in Semen Achefer and Gonder Zuria woredas of the Amhara Regional Administration.

Results and discussion

The results show that surface runoff can be minimized by using conservation tillage systems that avoid cross plowing (Figure 3). The improved tillage implement allows farmers to cut the strips of land left between consecutive furrows of Maresha. Hence, farmers can practice contour tillage. The results of the field experiment carried out in Minjar Shenkora woreda with the support of Stockholm Resilience Center of Stockholm University showed significant reduction in surface runoff and soil erosion while improving crop yields (Laike Kebede, unpublished data). In Gonder Zuria woreda, Germany's Nature Conservation Alliance (Naturschutzbund Deutschland; NABU) is demonstrating conservation agriculture on farmers' fields. Farmers reported that the application of Arashogel-based tillage saves time and energy by reducing tillage frequency by at least 50%. According to farmers, the quality of seedbed after the second tillage using Arashogel is similar to that prepared after 4 or 5 passes with Maresha.

Reduced tillage reduces loss of soil organic carbon, and reducing the loss of soil organic carbon is one of the main objectives of CA. Tillage with Arashogel creates invisible barriers along the contour (Figure 4) that retard movement of water along the slope, thereby significantly reducing soil erosion and conserving water through increased infiltration. Moreover, Arashogel makes it more convenient to plow between soil conservation structures. The invisible barriers left between passes allow more infiltration by reducing surface runoff towards the soil conservation structures. It also prevents water logging behind the soil conservation structures and possible damages to the structures that would have had detrimental effects downstream. The results of the field experiments have shown that crop yields and life span of the soil conservation structures can be increased by the application of such a tillage system (Temesgen et al., 2012).



Figure 2. The Arashogel designed to avoid the traditional cross-plowing during consecutive tillage operations due to its wings, which cut the unplowed strips of land left by Maresha.

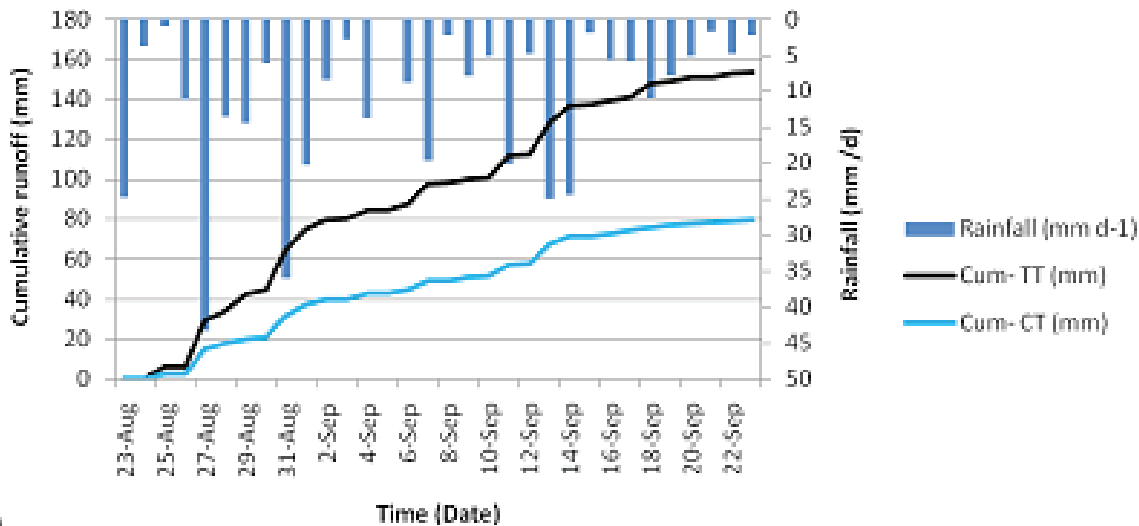


Figure 3. Surface runoff from fields treated with a conservation tillage system (CT) that avoids cross plowing and a traditional tillage system (TT) at Enerata, in the upper Blue Nile Basin (Source: Temesgen et al. 2012)

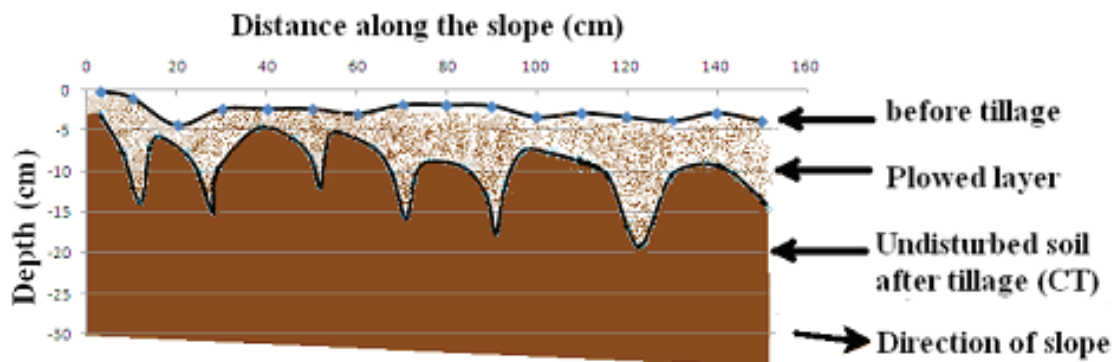


Figure 4. Invisible barriers created by avoiding cross plowing while fully controlling weeds with reduced tillage retard water movement along the slope, thereby conserving soil and water

Conclusion

Conservation tillage, based on the use of Arashogel to avoid cross plowing, has been found to be the most effective and appropriate system to achieve the objectives of conservation agriculture by reducing soil and water losses while reducing labor and traction requirements for tillage, which is the immediate benefit that attracts smallholder farmers. In moisture stress areas, the tillage system has been found to conserve soil water, thereby increasing crop yields, which is another factor to motivate farmers. Unlike other types of conservation agriculture that focus on long-term benefits, the Arashogel-based conservation tillage achieves both short-term and long-term benefits while being simple and of low cost.

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EXPLORING GROUNDWATER SOURCE FOR SUSTAINABLE SMALLHOLDER AGRICULTURAL PRODUCTION IN NORTHERN UGANDA: THE CASE OF AGAGO DISTRICT

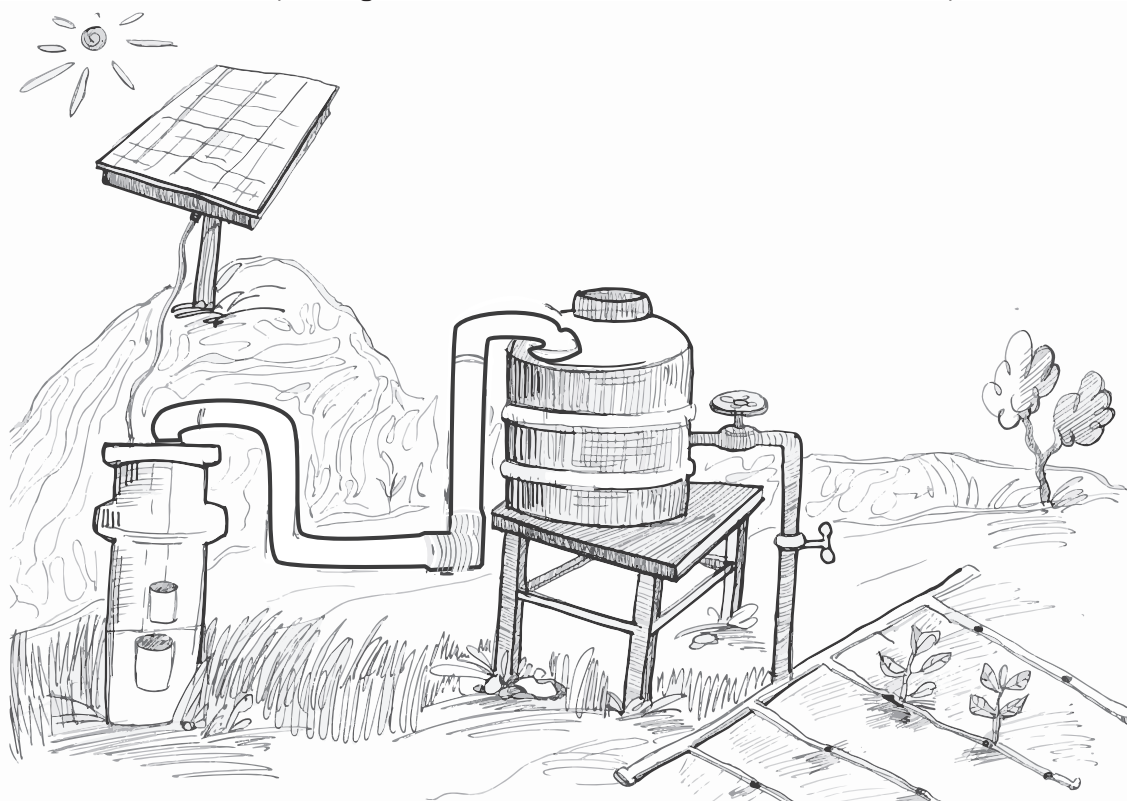


Author:

Okwir Gustavo, Department of Biosystems Engineering, Faculty of Agriculture
and Environment, Gulu University

Exploring Groundwater Source for Sustainable Smallholder Agricultural Production in Northern Uganda: The Case of Agago District

Okwir Gustavo, Department of Biosystems Engineering,
Faculty of Agriculture and Environment, Gulu University



When Lord Resistance Army insurgency in Northern Uganda ended, relative peace returned and the Internally Displaced Persons (IDPs) camps had to be closed down but the people resisted returning home because they were destitute. They had no means of livelihood after two decades in camps. Forty percent of IDPs living in Kalongo camp were extremely vulnerable, with no means of livelihood and mostly depending on direct aid (GOAL, 2009). The food production in the district was very low with only 28% of the population in Agago district accessing food from their own produce, 63% from the market and 9%

from other sources (Kalebbo & C, 2010).

After closing Kalongo IDPs camps, the majority of returnees settled in Pakol Parish in Parabongo Sub-county, and started growing millet, potatoes, beans and simsim for consumption. They also produced cotton and vegetables such as cabbage, onions and tomatoes for sale. The community already had experience in vegetable production, mainly growing cabbage and tomatoes in the swamps during the dry seasons. The agricultural work was primarily done by women and children, who sold their produce in Kalongo Market (GOAL, 2009)

The returnees had no other sources of income and depended entirely on the sale of their produce, but their productions were characteristically low because of the erratic rainfall distribution and severe drought periods. Pakol parish is in the northern agro-ecological zone with a less pronounced bimodal rainfall pattern. The rainfall is often erratic with occasional dry spells and cannot guarantee a satisfactory crop production under rain-fed agriculture.

Goal International, a Non –Governmental Organization initiated an Irrigation project to help small holders farmers during dry spells and long drought. The project objective was to enhance the returnees livelihoods and strengthen the community's capacity through provision of supplemental water for increased agricultural production. It targeted to benefit 100 households by piloting a vegetable production under irrigation on 14 acres of land.

Implementation

In delivering the project objectives, the need to increase water availability and maximize water use to produce more with less water were key considerations at design and implementation levels. The following tasks were accomplished.

- **Community mobilization and problem identification**

The intended beneficiaries were mobilized for a brainstorming session so as to identify problems and propose interventions. The community proposed provision of irrigation water to overcome water stress on crops that result from dry spells and unreliable

rainfall patterns.

- **Assessment of crop water requirement**

The calculation of the net irrigation water requirement was based on 80% dependable rainfall to cater for long droughts. The crop water requirement for cabbage and tomatoes, as analyzed using AquaCrop tool (FAO, 2012), was 5mm per day. Considering drip irrigation method for the project because of its high efficiency of water application, it was considered that only 20% of the area would be irrigated. Therefore, the net crop water requirement would be 1mm per day, thus translating to 56m³ of water per day for the 14 acres of land under the project.

- **Assessment of water sources**

The project analyzed the options of rainwater harvesting, river damming, and groundwater abstraction for feasibility, but the surface water option was immediately ruled out because there were only seasonal streams that also dry up during dry seasons.

Roof-top catchment of rainwater was not feasible because most of the houses in the project neighborhood were grass-thatched. Whereas the runoff catchment was feasible and had a potential to yield more water, the topography of the project area limited its successful exploration. Fortunately, assessment of groundwater revealed a huge potential and was, therefore, adopted for the project.

Empirical assessments of groundwater parameters found the aquifer potential and yield adequate for the project. The drilled well had a sustainable yield of 7.5m³/day.

- **Power sources to operate groundwater pumps**

The project area had no supply of electricity from the National grid and the options of diesel engine to run the pumps was not appropriate because its running costs would overburden the already poverty-stricken returnees. In the light of sustainability, a solar-powered pump was installed but because its performance is tied to sunshine, it would only be effective for at most 10 hours daily. The capacity of the available solar-powered pump from the local market was limiting, too. So, two pumps with a capacity of $2.4\text{m}^3/\text{hr}$ each against a head of 65m were installed at depths of 40m and 45m below the ground

level.

- **Storage reservoirs**

The total capacity of the reservoir tanks was chosen to match the capacity of the installed pumps. It was estimated that the solar-powered pumps would effectively work for a maximum of 10 hours on a good sunny day, thus delivering a total of $4.8\text{m}^3/\text{hr}$. To achieve an adequate head (water pressure) to distribute water to the drippers, the 14 acres of land were divided into 5 sub-plots of equal size and each had a 10,000-litre capacity reservoir tank installed near it. The reservoirs were all raised 2m above the ground so as to provide the necessary water head to run the drip irrigation system.



- **Water application methods**

Considering the cost involved in water abstraction and water as a limiting

factor in production, it is prudent to use methods which are efficient in application. The farmers, however, were trained on all irrigation methods including furrow

irrigation, drip irrigation, and sprinkler irrigation methods and how to reduce water loss during application (see Figure 2 and Figure 3 below). However, drip irrigation method was recommended for use because of its high water application efficiency. Five sets of drippers were installed but farmers were also provided with garden hoses to complement the drippers or in cases where they would fail. Garden-hose method of water application is a cheaper alternative to drippers but extreme caution is required when irrigating young and delicate crops. On farm methods of water management such as mulching (see Figure 4) was encouraged to reduce evaporative water loss.

Results

The irrigation project gave returnees hope and a new beginning. It encouraged all the persons in the Internally Displaced Persons camps to return home and the Kalongo camps have since been closed.

The beneficiaries of the Pakol irrigation project are no longer depending on direct aid. They are able to buy the seeds in the subsequent seasons and have now diversified their production, growing maize and beans on larger scales for the market. The farmers have also upgraded their group to establish a village savings scheme where they pool proceeds from their productions and loan it to members with interests. This has played a vital role of financing small-scale farmers who have no collateral to access loans from the financial institutions.

The technology of supplemental irrigation is now spreading with some households excavating small ponds near swamps to collect water for use during dry spells.

From the ponds, they use treadle pumps to draw water and apply on their crops, owing to the training and experience gained from the demonstration plots.

Challenges

The communities were IDP returnees expecting handouts in the form of money, farm inputs, and in kind (in the form of food), which was beyond project deliverables.

The adoption of the technology is slower than anticipated. Many households are still depending on the demonstration field for production. The initial cost of the system is prohibitively high for returnees who have just started rebuilding their lives.

Lessons learnt

Managing community expectations is very important to ensure delivery of project goals. This can best be achieved through effective engagement of communities, which allows meaningful participation. Communities should be involved right from problem identification, proposal generation and implementation, up until monitoring and evaluation. More importantly, during implementation, the community must be made aware about contributing some resources to enhance a sense of ownership of the project for project sustainability.

Conclusion and recommendations

With all the benefits of restoring livelihoods of a destitute community as was in Pakol

and the potential of doubling proceeds of small holder farmers, irrigated agriculture is one most important tool for fighting food insecurity. At all instances, the yield and returns from irrigated agriculture are higher than those from rain-fed agriculture. In Ethiopia, Fitsum et. al. (2009) have shown that the returns on irrigated agriculture by a smallholder farmer can be up to 200% higher than the returns from rain-fed agriculture. With good agronomic practices, such as soil and water conservation, the economic returns of irrigated farming can transform farmers from peasantry to commercial production within a short time.

Harnessing groundwater for supplemental irrigation takes away the fear of erratic rainfall. Many times, people have considered groundwater as a pure source of water that must be reserved for domestic purposes only, but it is high time we overcame the hurdle and explore all sources of water including groundwater to improve agricultural production. For a sustainable and successful harnessing of groundwater for irrigation for a community of smallholder farmers, the following are recommended:

- Formation of water users (beneficiaries) into groups with a management team: The management team would liaise with governmental agencies and development partners with a bid to mobilizing resources and technical support. This approach has successfully been applied for management of rural community water supply and sanitation systems in Uganda.

- The management team would not only be in charge of operation but will also work out an agreeable formula for charging farmers for the services rendered. A formula for charging can be based on the volume of water applied, the area irrigated or a fraction of the final produce. This, however, has to be agreeable to all.
- The beneficiary community needs to be adequately sensitized on the project benefits. The beneficiaries need to be made aware of their responsibilities and contributions to the project.

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ABREHA WE-ATSBEHA:

A SHOWCASE FOR SUCCESSFUL INTEGRATED LANDSCAPE RESTORATION



Author:

Niguse Hagazi, Kiros Meles Hadgu, Aklilu Negussie

Abreha We-Atsbeha: A Showcase for Successful Integrated Landscape Restoration

Niguse Hagazi, ^a Kiros Meles Hadgu^b, Aklilu Negussie^c

^{a, b, c} World Agroforestry Centre, /ICRAF/ Ethiopia



Poor management of soil, water and vegetation in the northern parts of Ethiopia has led to land degradation, nutrition depletion in the soil, and loss of farm land. It has also led to accumulation of silt in downstream water resources, affecting existing and future water resource development activities.

Abreha we-Atsbeha, a village located in the Tigray region of northern Ethiopia, was a typical example of severely degraded, drought-prone areas in northern Ethiopia one and half decades ago. Prior to 2003, the government considered relocating the inhabitants of the area for resettlement as the land was infertile and the farmers living there depended on year-round food

aid. Given the option of either resettling or working on rehabilitating the land, the community decided to work on reversing the situation of their degraded lands with some technical and material support from development practitioners. This article provides a review of the interventions made in Abreha we-Atsebeha and the results achieved as an input to the body of knowledge on “water-smart agriculture”. The article is developed through literature review of different studies conducted on the village in the past as well as those that are being carried out now, grey reports, and personal experiences/ observations of the author.

Livelihood and Landscape Situation Prior to 2003

The people of *Abreha we-Atsebeha* are pre-dominantly engaged in crop and livestock production, mainly practicing rain-fed subsistence farming. Water was scarce due to inadequate and erratic rainfall. In addition, deforestation, overgrazing and severe soil erosion affected agricultural productivity. Ground water declined sharply and the watersources like springs and rivers dried across the landscape of the watershed. Farmlands were washed away by erosion, and large gullies were formed. As a result, most of the land was unproductive before 2003. Efforts to address the problem by introducing soil and water conservation (SWC) endeavors through food-for-work programs were not successful mainly because they were undertaken in top-

down approaches without adequately involving the community.

Interventions and approaches adopted for landscape restoration

In 2003, the village of *Abreha We-Atsebeha* was selected as a project site of the Managing Environmental Resources to Enable Transition to more sustainable livelihood (MERET) implemented by the government with the support of WFP. Since then, massive integrated soil and water conservation work has been done in the watershed with the active participation of the community and the strong commitment and support of the local leadership. Numerous water harvesting and physical conservation structures¹ have been constructed. Supportive biological measures² have been undertaken to conserve soil and water in conjunction with grazing land management.

The activities are undertaken by involving the community starting from planning to monitoring and evaluation and by putting in place a principle of sharing the benefits of direct and indirect products of the restoration efforts, such as grass from the enclosures. Community members contributed from 20 to 40 days of free labor in a year to undertake the activities. The safety-net public works³ program was also made to focus on these conservation activities. Finally, a combination of the

¹ Constructed structures include stone-faced trenches, trenches, stone bunds, hillside terraces, check dams, cut-off drains, semi-circle terraces, a series of ponds, gully reshaping and pitting, digging of shallow hand dug wells, construction of roof water harvesting, river diversions

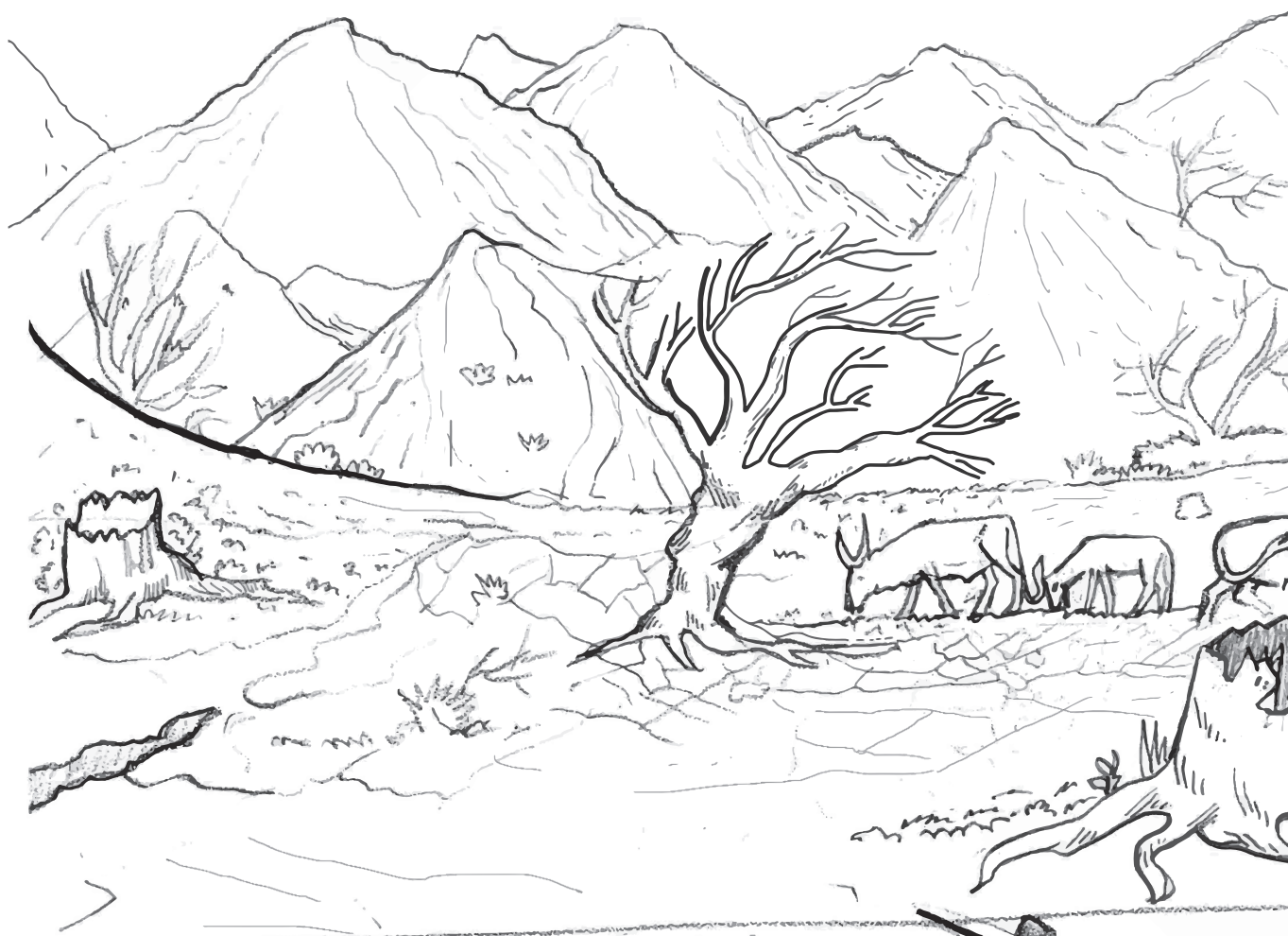
² This refers to measures that assist natural regeneration and enrichment planting.

³ Safety net public works program is a food security program where food insecure households in food insecure communities contribute labor to build community based assets in exchange for money

participatory approach employed, the community free labor contribution, and the mobilization of resources from various programs and projects implemented in the area to address the land degradation problem were instrumental in bringing about change.

Moreover, government agricultural extension and administrative bodies, the community, and other concerned development actors operating in the

area reached at a consensus that the agricultural extension system should employ a holistic approach. They agreed that water security should be the central point of focus for food security. This meant that, extension activities were directed towards supporting farmers to restore the whole landscape in order to increase water availability by increasing ground water recharge. The community adopted the motto that 'every household of the watershed community should have one or more alternative water sources, locally named a *water bank*'.



Impacts of the interventions

The overall comprehensive effort exerted on the watershed had a range of significant positive impacts. Degraded land has been restored as the community adopted sustainable natural resource management practices. The community livelihood has improved. A favorable microclimate has been created. Ground water table has increased. Crop production has increased and the variety of crops produced has also been diversified.

Increase in vegetation cover

Survey results in 2013 indicated that 24 woody species were grown by 378 individuals in enclosures, 20 species by 327 individuals in the physical conservation supported with enclosures, and 25 species by 167 individuals in physical and biological conservation with enclosures. In contrast, in the open access land management, only two woody shrubs with 4 individuals each were recorded, which indicates how huge the difference the community-based integrated watershed management makes in vegetation cover is. The increased vegetation cover has contributed to the improved recharge of ground water in the whole landscape in general and in the bottom lands or down slopes in particular.

Expansion of irrigation

The development of shallow hand-dug wells was very limited before 2003 in Abreha we-Atsbeha. Since 2004, the construction of shallow hand-dug wells rapidly has increased as the demand for water for irrigation has increased. Survey results of 2010 indicate that more than 650

shallow wells have been developed in the village and small-scale irrigation activities have expanded. (The water table has increased and enough water that can be used for irrigation is obtained within the range of 3 to 7 meters depth.) More recently, the community has reached a consensus to construct and use shallow hand-dug wells in groups so as to use single and large shallow hand-dug wells for two or more neighboring farms rather than individual farms. This helps to avoid competition for ground water and unsustainable abstraction of ground water by individual farmers. As a result of the different water harvesting structures constructed and conservation methods adopted, 450 ha of land is under irrigation in the village. Irrigable area increased nine fold (from 32 ha in 2004 to 285 ha in 2011) and 12 fold in production (from 328 tons in 2004 to 3965 tons in 2011).

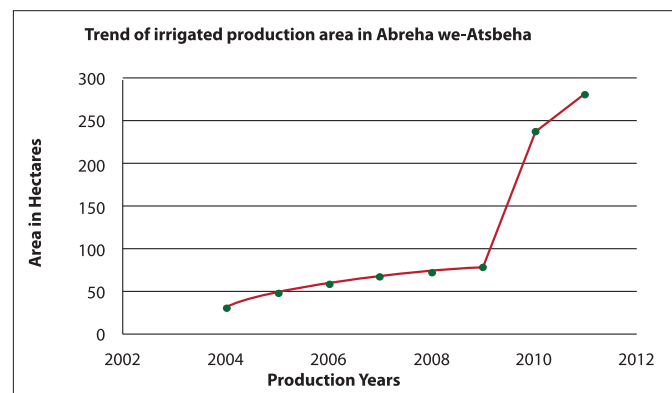


Figure 1: Increasing trend of irrigation area (ha) in years after intervention by Integrated Soil and Water Conservation in Abreha we-Atsbeha (Haileselassie, 2013)

Increased frequency of production, diversification and resulting livelihood changes

Irrigation enabled farmers to diversify the crops they produce and to increase the frequency of production per year, reducing dependence on rain-fed agriculture. As a result of “water banking”, i.e., construction of hand-dug wells for groundwater harvesting, currently, farmers of Abreha we-Atsebeha are changing their cereal-crop-based subsistence production system to market-oriented vegetable, fruit, and spice production. Crop diversification adopted by the community has also reduced risks caused by drought and pests and other natural hazards. Diversification has provided the farmers insurance against crop failure. In the village today, more than 10 types of fruit are cultivated and the number of fruit trees has increased from 1506 prior to the intervention to 77,977 in 2011.

Vegetable production (e.g. tomato, pepper, onion, cabbage, lettuce and potato) improved farmers’ income greatly. Farmers’ income from vegetable production grew from 29,070 USD in 2004 to 574,417.5 USD in 2011 (Haileselassie, 2013). Because farmers own hand-dug wells, they have become food-secure at household level and changed their feeding style in terms of both frequency and quality.

Improved community self-reliance

One of the impacts of the interventions is a change in the communities’ consciousness about their own potential. They used to believe poverty is the will of God,

something they are powerless to escape from. Their collective action after the intervention convinced them that poverty can be overcome if they work together, while their dependence on external aid is greatly reduced.

The communities have established strong local bylaws about benefit distribution from the rehabilitation efforts and fines to sanction those who go against the communities’ adopted principles of sustainable management of natural resources. The bylaws are also used to address issues of equity among different wealth groups and gender equity. The bylaws helped the village win a certificate of recognition for achievements in ensuring gender equity from the Ministry of Women’s Affairs of the Federal Democratic Republic of Ethiopia in 2009.

UNDP provided the Equator Prize 2012 Award to the community under the prize “in recognition of outstanding success in promoting local sustainable development solutions for people, nature, and resilient communities” .

Conclusion

The landscape restoration efforts aimed at increasing water availability through ground water recharge has brought a significant positive change in Abreha we-Atsebeha that can be expressed in terms of ecological, economic and social aspects. The efforts have been targeted on water smart agriculture practices and integrated natural resource management for improved livelihoods and climate change adaptation and mitigation endeavors. Other localities, districts, regions and countries can adopt the experiences,

approaches and strategies practiced by the community and local leaders of Abreha we-Atsbeha in order to attain the sustainable water smart agricultural practices for improved livelihoods, while adapting and mitigating the changing climate.

the focus of the extension approach from crop and livestock extension system to integrated natural resources management

Lesson learnt

- The change in the communities' mindset from viewing poverty as being God-sent to believing that humans can determine their own fate through hard work
- The importance of starting from the planning stage in a participatory approach all the way to the monitoring and evaluation levels
- The commitment of the local leaders in mobilizing and organizing the community at all levels of intervention
- Development and implementation of bylaws by the community
- The readiness of the community to adopt new technologies and practices
- Collaboration and integration of development actors
- The strong linkage between development practitioners working in the village
- The decision of the agricultural extension and other actors to shift

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PARTICIPATORY COMMUNITY-BASED GULLY REHABILITATION ON THE ETHIOPIAN HIGHLANDS: THE CASE OF BIR WATERSHED



Author:

Getaneh K. Ayele, Seifu A. Tilahun, Daregot B. Tenessa, Charles F. Nicholson,
Tammo S. Steenhuis

Participatory Community-based Gully Rehabilitation on the Ethiopian Highlands: The case of Bir Watershed

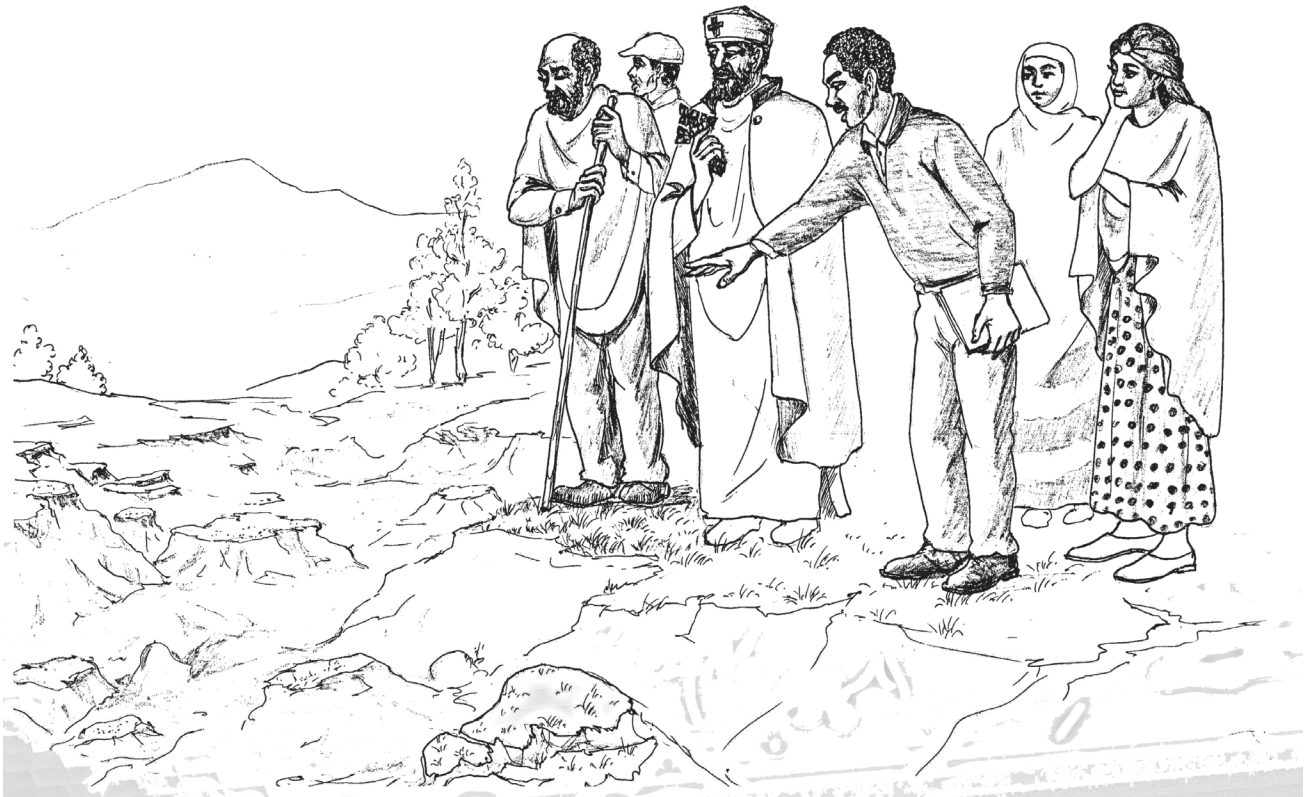
Getaneh K. Ayele¹, Seifu A. Tilahun¹, Daregot B. Tenessa³, Charles F. Nicholson⁴, Tammo S. Steenhuis^{1,2}

¹PhD program in Integrated Water Management, School of Civil and Water Resources Engineering, Bahir Dar University, Bahir Dar, Ethiopia

²Department of Biological and Environmental Engineering, Cornell University, Ithaca, NY

³College of Business and Economics, Department of Economics, Bahir Dar University, Ethiopia

⁴Department of Supply Chain and Information Systems, Smeal College of Business, Penn State University, USA



Soil erosion by water is a major problem in Ethiopia. The forms of erosion identified on the highlands are sheet erosion, rill erosion, and gully erosion. The Ethiopian highlands have undergone substantial land use/cover changes that resulted in changes in the hydrological processes of the landscape

of the highlands (Tesemma et al., 2010). More surface and sub-surface water flow is produced, which in turn leads to the creation of gullies that carry off this excess water.

Gullies are a major threat to food security by swallowing fertile land, endangering

environmental sustainability, and diminishing prospects for water resources development on the Ethiopian highlands (Teshome et al, 2013; Tebebu et al., 2010). In addition to its direct biophysical effects, gully erosion negatively affects community social and economic activities (Poessen et al. 2003; Frankl et al. 2011).

The soil and water conservation practices so far on the highland have usually targeted the steep slope areas through a top-down approach (Bewket and Sterk, 2002) by not giving enough attention to gullies. For example, the new soil and water conservation campaign initiated by the government in 2012 focused only on putting bunds on the hill slopes and cultivated lands. However, gully erosion removed soil with an equivalent depth of 4 cm per year over these highlands (Tilahun et al., 2013; Tebebu et al., 2010).

Bir watershed on the Adama highland is one of the hotspot areas affected by gullies swallowing agricultural and cultivated land (Ayele et al., 2014). The bottom part of a particular sub-watershed (called Enchilala) in Bir is dominated by active gullies on the grazing and cultivated land. However, the communities have been mobilized through a top-down approach to dig deep infiltration furrows in the uplands since 2012.

The overall objective of this paper is, therefore, to describe the effect of a participatory gully rehabilitation work in Enchilala sub-watershed of Bir area. The study was carried out through the Partnership for Enhanced Engagement in Research (PEER) science program funded by USAID to show the potential outcomes of a community mobilization

for gully rehabilitation on the highland. A participatory gully rehabilitation process included discussions with religious leaders and local elders, followed by meetings with local village farmers to assess the acceptability of gully rehabilitation approaches.

Intervention approach

To start the community mobilization process, the researcher first discussed with religious leaders and local elders (Figure 1), and then with local village farmers about the potential to rehabilitate the gully. At first the religious leaders, local elders and farmers were of the opinion that it was impossible to rehabilitate a gully once it is created because they believed that gullies were created by God to punish them for acts against His will.

After these leaders viewed photos of other rehabilitated gullies and after two farmers visited a rehabilitated gully site in another watershed, the religious leaders and elders agreed to rehabilitate one gully as a trial. A consensus was reached to undertake the trial on a large upland gully which has an area of 0.71 ha. The area of land that drains to this gully is 25.8 ha.

After an agreement with the farmers was reached, the researcher identified twenty-two farmers who had grazing land. He then organized a meeting with the local community, religious leaders, administrators, extension workers, and Wereda natural resource experts to involve them in the gully rehabilitation plans so that they feel they share the responsibility for the outcome. The Wereda office of Agriculture provided seedlings of *Sesbania Sesban* and locally available

grasses. This type of grass has a dual purpose: as a biological conservation and as fodder. One objective of the rehabilitation activities was to increase fodder yield to fatten oxen, particularly when combined with supplementary feeds.

The twenty-two farmers identified to conserve the gully promised each other to contribute labor and wood to fence the gully and to equally share the grass at the end of the rainy season. A challenge arose in this implementation process. Most of the twenty-two participating households who live near the gully were not eager to begin the conservation work because they did not expect the gully to recover. They believed that grass could not grow on such a damaged gully, so they did not want to contribute labor and wood to fence it unless the neighboring communities helped them. The researcher

mobilized other farmers living in adjacent villages (20 in number) to contribute labor and wood, and then the twenty-two farmers promised to share grass and any other benefits from the rehabilitation efforts with all who contributed their labor and wood.

After overcoming this challenge, the twenty-two farmers installed biological and physical conservation measures in their gully in cooperation with other additional twenty local farmers and the researcher (Figure 2). They made check dams from wood and stone within the gully. They, then, planted local grass species and 214 *Sesbania Sesban* in a mixed pattern. They also set 50 ETB/animal as a fee for anyone who allowed his animal into the enclosed gully.



The amount of sediment deposited in and around the gully was measured using 15 sticks installed in the gully and along the right and the left sides of the shallow sub gullies. Cross-sectional measurements were taken before and after the rainy season on the studied gully and two other control gullies located near the rehabilitation gully. The measurements were taken on 23 April 2013 and on 3 September 2013.

Results

The conservation practice was able to reduce soil loss with the harvest of soil water in the gully. The measurements of cross-sectional change revealed that the cross-section of the studied gully was reduced in depth by 0.68 m and 0.55 m in the lower and middle areas of the gully, respectively. The width of the gully in the lower and middle areas of the gully was unchanged. On average, the total depth of sediment trapped throughout the gully by both physical and biological conservation was 0.26 meters, and the total amount of soil trapped in one rainy season was approximately 2,323 tons.

The two control gullies showed high gully erosion expansion rates. The length, depth, and width of one of the control gullies expanded by 23m, 1.9m and 13 m, respectively, between 15 June and 3 September 2013. The total soil loss from this gully was 710 tons. The other control gully developed during the study with a length, depth and width of 19, 0.9 and 40 meters, respectively. The total soil loss from this gully was only 585 tons. Both of the control gullies are expanding at alarming rates.

The most significant accomplishment of the project was that the rehabilitation

process motivated by the religious leaders and elders modified the belief of farmers that God created gullies as a means of punishing them for their wrongful acts. The study showed that it is possible to alter the erosion dynamics of gullies. In addition, farmers as a group negotiated with the local Wereda Office to use their mandatory labor contribution for installing soil and water conservation practices to rehabilitate gullies and get an economic benefit. The harvest of grass indicated 10,000 Ethiopian *birr* was obtained from 0.7 ha area of gully rehabilitated only in one rainy season. The estimated forage yield in the gully after closure during the rainy season was 8.36 tons.

But this economic benefit resulted in a conflict among the communities. The twenty-two farmers whose lands surround the rehabilitated gully were reluctant to share the grass with the other twenty farmers who assisted with rehabilitation activities. In addition, they argued that they had not been allowed to graze their cows on this land as would have been the case if the rehabilitation had not been there and, therefore, demanded a greater share of the benefits. On the day that the twenty-two farmers began to harvest the grass, the farmers from the other villages stopped them from harvesting additional grass. This conflict was resolved by the elders in the village who made the twenty-two farmers apologize and sign a promissory note to contribute labor and wood in the next program (2014 rainy period) to rehabilitate a gully in a second village.

The outcome of this conservation was an uptake by the general community in the Encilala area of the Bir Watershed. In the 2014 rainy period, the communities from

different villages of the watershed are taking their own initiatives to rehabilitate five more gullies. The use of labor in gully rehabilitation can markedly increase the economic benefit of communities, decrease sediment concentration in rivers, and slow the siltation rate for downstream reservoirs.

Conclusion

This case study showed that:

- For effective implementation of community mobilization and conflict resolution, the role of religious leaders and elders is paramount.
- Farmers can be empowered to negotiate with authorities about the kind of land rehabilitation work they should be doing.
- Farmers benefit from the participatory gully rehabilitation work and such work leads to the mobilization of the general community to do soil conservation to other gullies.
- A hotspot erosion area can be rehabilitated and such work can become a learning case for Woreda experts.
- Such gully rehabilitation project can change farmers' perceptions about causes of land degradation.

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HILLSIDE CONSERVATION AGRICULTURE FOR IMPROVING LAND AND WATER PRODUCTIVITY IN TANZANIA



Author:

Juma Omary Mdeke, Dosteus Lopa and Fredrick Kahimba

HILLSIDE CONSERVATION AGRICULTURE FOR IMPROVING LAND AND WATER PRODUCTIVITY IN TANZANIA

¹Juma Omary Mdeke*, ²Dosteus Lopa and ³Fredrick Kahimba

¹Kilimanjaro Zonal Irrigation Office, Ministry of Agriculture Food Security and Cooperative,

²CARE International in Tanzania, Dar es salaam, Tanzania

³Sokoine University of Agriculture, Morogoro, Tanzania



Tanzania has a total area of 945,000 km² (MARI, 2006). Its inland lakes cover 59,000 km² (6% of the total area) and the remaining land covers 886,000 km² (94% of the total area). Despite its complex climatic and topographic setting, the country has sufficient land to allow substantial growth in agricultural production. However, land degradation

due to soil erosion and decline in soil fertility due to continuous cropping with no attempt to replenish the soil with mineral and organic manure are the major setbacks to agricultural production in Tanzania. Any attempt to improve and expand agriculture in Tanzania should invest in the betterment of land and crop husbandry practices.

On the other hand, there is shortage of water for agricultural production in the country due to inadequate rainfall in various parts of the country (Mutabazi et al. Undated). In general, nearly two-thirds of Tanzania, which covers a total area of 939,701 km², can be described as semi-arid on the basis of having a less-than-25% probability of receiving 750 mm of rainfall per year (Mascarenhas, 1995; Bourn and Blench, 1999). Such areas, including Same district, are always noted to be less productive in agriculture. As Mutabazi et al, (Undated) indicate, this is the reason why semi-arid areas of Sub-Saharan Africa (SSA), including Tanzania, where water is the most critical constraint to development, critical manifestations of poverty such as food and income insecurity are apparent. The question is: 'How can agriculture continue under such situations of soil degradation and insufficient water for agricultural production?' Answering this question becomes even more difficult given the fact that some attempts by

smallholder farmers in various places are strictly constrained by lack of efficient technology and capital. This, therefore, calls for a new, inexpensive approach that smallholder farmers can easily use. Conservation agriculture (CA) is, thus, considered for improving land and water productivity in Tanzania.

Conservation agriculture is any system or practice which aims to conserve soil and water by using minimum soil disturbance (conservation tillage) and crop rotation/association to minimize soil evaporation, which reduce runoff and erosion, and improve the conditions for plant establishment and growth. It involves planting crops and pastures directly into land, which is protected by mulch using minimum or no-tillage techniques. CA is also used to increase organic matter levels by improving soil structure and fertility, to reduce reliance on cultivation, and to achieve viable and sustainable productivity (Fig. 1(a)).



Figure 1(a): Conservation Agriculture (CA)

Other components and practices of CA comprise agro-forestry, trap cropping, cover and green manure cropping,



Figure 1(b): Degraded hillside landscape

alley cropping, contour farming and strip cropping, organic and biodynamic farming, stubble mulching, integrated

pest management (IPM), and crop and pasture rotation.

Conventional tillage, on the other hand, which is most commonly practiced in the country, involves the use of hand hoes, ox-drawn mould-board ploughs, tractor-drawn disc ploughs and harrows combined with straw collection and burning during land preparation (Fig. 1 b). During the operation the soils are cut, inverted and pulverized while most of the residues are buried underneath. The practice frequently causes soil compaction, affects soil physical properties, provokes biological degradation, and results in lower crop yields. With fine dust on the surface and compaction below, a lot of soil is washed away by the first rains. Soil losses of up to 30 tons/ha have been reported in Kilimanjaro region in conventional flat-cultivated fields at a slope of 5% (Kaihura et al., 1998).

Why Conservation Agriculture?

Land degradation has been a growing problem in Tanzania because of increased human activity and the growing demand for land as the population grows. Deforestation, over-grazing and inappropriate tillage practices are contributing heavily to land degradation. It has been observed that the rate of soil losses in some parts of the country have increased from 1.4 tons/ha/year in 1960 to 224 tons/ha/year in 1980 (MTNRE, 1994). With the increased population pressure, the fallow periods, which were commonly used, have become shorter for the soils to recover, perpetuating the "soil mining" of nutrients. The replenishment of nutrients is low because of inadequate application of manure and inorganic fertilizers. This has

led to a further decline in soil fertility, which is manifested in lower crop yields.

Therefore, CA can help to improve, conserve and use natural resources in a more efficient way through integrated management of available soil, water and biological resources, in combination with external inputs (FAO, 2005). This in turn can help improve the productivity of agricultural land and water. The impacts of CA have been marked positive in agricultural, environmental, economic and social terms (Garcia-Torres et al., 2003; Bishop-Sambrook et al., 2004).

While millions of hectares of farmland are already under zero tillage in Latin America, conservation tillage in Africa, which is one of the practices of CA, was restricted mainly to larger estates. There are, however, enough examples demonstrating that conservation tillage can be practiced successfully by smallholder farmers, too, as it has been done in northern and north-eastern parts of Tanzania (Babati, Same and Lushoto districts) and central and eastern parts (Chamwino, Morogoro, Kilosa and Mvomero districts). This paper reviews the CA practices in various case study sites in the country which have also shown positive impacts of land and water management as a strategy towards water smart agriculture.

Approach followed

The CA practices in Tanzania generally started with the sensitization of district authorities and farmers to create awareness on the CA initiative. Inception workshops were also conducted for all participating district authorities, technicians, manufacturers, researchers

and other stakeholders.

A total of 30 Participatory Farmer Groups (PFGs), each consisting of 25 individuals, 10 in each district, were organized on the basis of common interests and similar constraints and were encouraged to work together. Each participating farmer was asked to set aside an area equivalent to 0.4 ha as a management training plot. The area was divided into two equal parts (of 0.2 ha each). One part was to be used for conservation agriculture practices, where the farmer use inputs provided by the project. These included high-yielding varieties of maize crop as recommended by the District Agriculture Office for that particular area, and basal and top dressing fertilizer as a soil fertility improvement measure prior to the establishment of cover crops and cover crop seeds.

Farmers were trained on the use of the better tools like hand jab planters and direct seeders to reduce labor requirements for various agricultural operations. Training of farmers was conducted by trained Village Extension Officers. Under their guidance farmers also kept records of timing of activities, costs involved and outputs to facilitate the analysis of cost/benefit derived from the adoption or adaptation of CA practices. In this way the farmers were able to see the differences between their practices and the proposed CA interventions.

Various methods were used to impart CA knowledge to farmers. Examples are Farmers' Field Schools (FFS), Exchange Visits, Farmers' Field Discussions, Open Day Exhibitions, Farmer-to-Farmer Contacts, and Para-professionals/Contact Farmers/ just to mention a few. The Ministry of

Agriculture Training Institutes (MATIs) and Agricultural Research Institutes (ARIs) have played a big role in showcasing the importance of CA and many other agricultural techniques that made a difference through training farmers.

Key results

CA has created a huge positive impact in improving soil properties and structures, soil fertility, and soil and water conservation. It has also reduced soil erosion, increased infiltration of rain and surface water, enhanced retention of soil moisture, and shown resilience to the effects of drought. Regularly flowing streams have increased crop yields at lower production costs, mainly due to reduced labour inputs. This time-saving practice often allows diversification into other agricultural production or rural income-generating activities.

The impact of CA on livelihood is significant as it has brought positive changes on all areas where it has been practiced. The improved production of agricultural produce in various parts of the country is evidence for the positive impacts in the communities concerned. This is also reflected in the amount of harvest from the CA plots for the main crop (maize) and cover crop seed production. In Mvomero District, for example, maize harvests for all groups from the CA plots were 4870kg/ha, compared to 3216kg/ha realized from the farmer practice plots. In villages where the rains were better the harvest from the CA plots was also higher.

CA practices in all the selected districts and villages in Tanzania have been remarkably successful in those areas.

Success stories include reduced erosion and improved soil structure; improved infiltration and moisture efficiency; improved soil health and nutrient retention; lower soil temperatures and better establishment; increased planting opportunities and flexibility; lower machinery, labour and maintenance costs; and more reliable yields. All these increased the interests of the local manufacturers to produce direct seeding equipment and sell them to the farmers. They also increased willingness of district/local government authorities to introduce CA as an important approach to reverse land degradation. This requires a change in mindset on the part of the farmers, who have used conventional tillage as the correct approach in crop production for many years. Also, links have been strengthened with local research institutions on suitable cover crops and proper crop rotation recommendations for adoption by the farmers.

Challenges and limitations of Conservation Agriculture

No single farming system or technique is perfect for all applications, and conservation farming is no exception. Conservation farming involves more planning, management and a commitment to sustainability. Trade-offs are necessary and extra costs may be incurred in the initial years.

Conservation farming will not always result in higher yields, especially in seasons where rainfall is ample and well distributed. The effectiveness of some herbicides is reduced by mulch on the surface as high rates of organic matter 'tie up' many chemicals. Fertilizers such as

nitrate and herbicides may leach more readily through the soil due to higher infiltration rates under conservation tillage; however, runoff losses will be reduced. These aspects are being addressed through improvements in fertilizer and herbicide formulation, application technology and better management practices.

Conservation farming systems are dynamic and call for innovation and continual improvement. Grazing, weed, insect and fertilizer management are required for successful conservation farming, and it takes time and experience to develop these skills. A good understanding of the interaction between plants, animals, the soil and the environment is necessary. Conservation farming systems are intended to be flexible and responsive, and to work within the constraints of the environment.

Some of the challenges that have not been resolved yet include lack of adequate funding to reach more farmers, shortage of locally available direct seeding implements, inadequate awareness-creation campaigns among all stakeholders, and poor integration of crop and livestock farming systems whereby several conflicts between pastoralists and farmers have been experienced.

Conclusions

CA consists of easily and readily available practices that can be used in every part of the world. It is a scalable, effective, cheap and manageable practice which can be transferred from one place to another.

CA has helped to improve land and

water productivity, thereby changing the livelihood of the smallholder farmers in various areas in Tanzania as it:

- increases farm production and/or stabilizes it;
- has no adverse environmental effects;
- prevents erosion and improves soil fertility;
- is easy for farmers to adopt the technology; and
- is easy to provide institutional support, and outreach and

technology transfer from one area to another.

More efforts are needed to ensure that the concept of CA and, hence, Water Smart Agriculture is taken up by Government and adoption by communities to the majority of smallholder farmers in Tanzania. This will help to increase income at household level and hence improve livelihood.

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EVALUATING PERMANENT PLANTING BASIN FOR OPTIMUM PLANT POPULATION FOR MAIZE AND BEANS



Author:

Drake N. Mubiru, Godfrey A. Otim, James Lwasa, Jalia Namakula, William
Nanyeenya, John Elem

Evaluating permanent planting basin for optimum plant population for maize and beans

Drake N. Mubiru¹, Godfrey A. Otim², James Lwasa¹, Jalia Namakula¹, William Nanyeenya³, John Elem⁴

¹National Agricultural Research Laboratories, ²Ngetta Zonal Agricultural Research and development Institute, ³National Livestock Resources Research Institute, ⁴Cooperative League of the United States of America



Permanent planting basins (PPBs), as used in conservation farming, is a minimum tillage method. It is easily practiced by small scale farmers. “You do not need special equipment to start conservation farming; all you need is a hoe and a piece of string” (IIRR and ACT, 2005). It enhances the capture and

storage of rainwater and allows precise nutrient application of limited nutrient resources. The method is widely used in southern Africa (Zambia and Zimbabwe) to reduce the risk of crop failure due to erratic rainfall. PPB, in combination with improved seed and crop residues, creates a mulch cover that reduces evaporation

losses and has consistently increased average yields (Twonlow *et al.*, 2006). This technology contributes to efficient and effective use of available water resources, which is important in promoting water smart agriculture.

This crop management method was introduced to Uganda from southern Africa and there was a need to understand how the technology responds to the different agro-ecological zones. This was intended to build practical evidence on how farmers in Uganda could apply the technology for optimum yields. The National Agricultural Research Organization, with financial support from Sustainable Intensification of Maize-Legume cropping system for food security in Eastern and Southern Africa (SIMLESA) and Cooperative League of the United States of America (CLUSA), undertook a study aimed at establishing the optimum plant populations for both maize and beans in the agro-ecological zones of Lake Victoria Crescent and Northeastern Savannah Grassland.

Methodology

The studies were located at the National Agricultural Research Laboratories (NARL) – Kawanda in the Lake Victoria Crescent agro-ecological zone (AEZ) and Ngetta Zonal Agricultural Research and Development Institute (NgeZARDI), as shown in the map below. Kawanda receives an average annual rainfall of 1,200 mm while the figure for Lira is 1305.3 mm. The experimental design was a randomized complete block with 3 replications for Longe5 maize variety and NABE 15 bean variety. The treatments were 3, 4, and 5 plants per PPB for maize and 6, 8, and 10 plants per PPB for beans.

The 3 and 6 plants/ basin for maize and beans, respectively, were the control treatments.

Map of Uganda showing location of study sites



Before field preparations, baseline soil analysis was done to establish the status of soil fertility so as to apply the right quantity of fertilizers. Fields were slashed; weeds were allowed to sprout and they were sprayed with glyphosate at a rate of 7.5 l/ha. Basins of 35 cm (long) × 15 cm (width) × 15 cm (deep), with spacing of 90 cm between rows and 75 cm within rows from centre to centre of the PPB, were marked out using strings and dug before the onset of rains. Available crop residues were used as mulch. Organic manure at a rate of 1 mug per planting basin was applied. In addition, fertilizer Diamonium phosphate (DAP) measured in a leveled soda bottle cap was applied at a rate of 2caps per pit. The pits were covered with top soil before the seeds were planted. When the maize reached knee height, a mineral water bottle -top of nitrogen

was applied per basin. The trials were done in two cropping seasons in 2013 and data was collected from a total of 24 plots and analyzed using Analysis of variance (ANOVA) to determine optimum yield based on the plant population per PPB. The outcomes of the study were disseminated and are being tried by 8 farmer groups in Nakasongola and Lira districts. Below is the summary of the results.

Results

- There was a 27% increase in grain yield by using 4 plants per basin compared to 3 plants per basin currently practiced for the Lake Victoria crescent agro-ecological zone at NARL for season 2013A.
- For the Northeastern savannah agro-ecological zone at NgeZARDI, there was no significant difference in grain yield between 3, 4 and 5 plants per basin for both seasons (2013A and 2013B).
- Notwithstanding the differences in the plants per basin, the bean grain yield at both NARL-Kawanda and NgeZARDI was much lower than the potential yield of 2.5 tons/ha. Also, there was no significant difference between 6, 8 and 10 plants per basin for both agro-ecologies.

Recommendation for maize

- The plant population of 59,259 plants/ha (4 plants per PPB) was

the optimum number in areas with relatively high soil moisture such as the Lake Victoria Crescent agro-ecological zone.

- A plant population of 44,444 plants/ha (3 plants per PPB) was the optimum number for the Northeastern savannah grassland where there is low soil moisture.

Recommendation for beans

- There was no significant difference in the bean plant population per basin. In light of this result, it was recommended that the spacing of the PPB be reduced from (90X75) cm to (60X60) cm so as to increase the optimum plant population closer to the conventional practice of sowing 200,000 plants/ha. The implication is that in each basin a farmer can plant 6 seeds.

In line with the principle of crop rotation in conservation agriculture, the study further recommended the optimum plant population for maize as follows: 3 plants per basin at (60 x 60) cm of basin spacing or 83,333 plants/ha for Lake Victoria Crescent agro-ecological zone; and 2 plants per basin at (60x60) cm of basin spacing or 55,555 plants/ha for the Northeastern savannah grassland agro-ecology.

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TOT WRITESHOP PARTICIPANTS

IN ADDIS ABABA, ETHIOPIA (AUGUST 10-15, 2014)



Name: Animaw Anteneh (PhD)

Organization: Addis Ababa University

Position: Instructor

Email: animawant@gmail.com

Brief Bio: Animaw has been teaching at Addis Ababa University for more than two decades. He is a professional editor, translator and interpreter. He also has two children, a boy and girl.



Name: Asrat Geleta

Organization: Private Animation Studio

Position: Professional Animator and Illustrator

Email: asua255@gmail.com

Brief Bio: Asrat has graduated from Addis Ababa University School of Fine Art and Design. He has 5 years of experience working on 2D animation and illustration. He is also a painter and exhibited his works in Ethiopia and abroad. He loves watching movies, reading and participating in different community based services.



Name: Bethel Terefe

Organization: CARE International in Ethiopia

Position: Programme Policy Adviser, GWI EA

Email: bethelt@care.org.et

Brief Bio: Bethel comes from a social sciences background and has worked in the Ethiopian Development sector for 10 years on gender and water issues. She enjoys writing.



Name: Daniel Otim

Organization: Busitema University

Position: Lecturer in Agriculture Mechanisation and Irrigation Engineering Department

Email: danotim@gmail.com

Brief Bio: For over 8 years, Daniel has handled an array of civil engineering projects, involving feasibility studies, site investigations, material testing and analysis, design and construction specifications, construction supervision and management. He loves playing chess because it sharpens his mind.



Name: Dawit Bahre
Organization: BlueHat Graphics and Printing
Position: IT and Graphics Expert (General Manager)
Email: birshd@gmail.com
Brief Bio: Dawit graduated in Software Engineering in 2006 and certified in graphics (online) in 2007. He owns the Blue Hat Graphics and Printing Company. He always likes doing graphics design, motion graphics and animation based arts.



Name: Dawit Tilahun
Organization: Freelance
Position: Professional Artist
Phone: 0911660005
Brief Bio: Dawit is an artist who does canvas painting, landscape, the human figure and abstract art. He fell in love with art at the age of 5 years. He loves music and listens to it every day on the radio while he paints. He also loves traveling out of the city to get new ideas.



Name: Desalegne Tadesse
Organization: International Water Management Institute (IWMI)
Position: Communications Officer
Email: d.tadesse@cgiar.org
Brief Bio: Desalegne is a communicator who is struggling for the sustainable land and water management. His background is Political Science and International Relations as well as Journalism and Communications who did many jobs in this regard for the past 8 years. He loves watching football and playing tennis table.



Name: Dosteus Mtinde Lopa
Organization: CARE International in Tanzania
Position: National Policy and Advocacy Manager
Email: Dosteus.Lopa@co.care.org, doslopa@gmail.com
Brief Bio: Dosteus works as an expert in linking social development and natural resource management by applying integrated pro-poor approaches for over 10 years now. He also loves physical work such as digging with a hand-held hoe.



Name: Elizabeth Agiro

Organization: CARE International in Uganda

Position: Communications Coordinator, GWI EA

Email: Eagiro@co.care.org

Brief Bio: Liz is a seasoned journalist with 10 years experience in journalism and public relations. She has skills in communications strategy, digital communications and media relations among other attributes. She is also passionate about playing pool and has won at competitive level.



Name: Firew Kefyalew

Organization: International Institute of Rural Reconstruction

Position: Country Director (Ethiopia) & Programmes Advisor for Africa Region

Email: firew.kefyalew@iirr.org

Brief Bio: Firew Kefyalew is trained in educational psychology (psychometry) and is also a certified organization development professional. Firew comes with hands-on experience working in different countries in Africa. He loves reading and spending time with his family.



Name: Frederick Kahimba (PhD, PE)

Organization: Sokoine University of Agriculture

Position: Senior Lecturer

Email: fredkahimba@suanet.ac.tz

Brief Bio: Frederick holds a PhD in Biosystems Engineering, specialized in soil water management. His current research focus is on Conservation Agriculture, Water Harvesting Technologies, smallholders irrigation technologies and climate change. Fred loves physical exercises and playing with children.



Name: Godfrey Otim Anyoni

Organization: National Agricultural Research Organisation

Position: Crop Agronomist

Email: otimgw@yahoo.com, otimgw@gmail.com

Brief Bio: Godfrey loves innovation, new ways of doing things. He finds it exciting to work with farmers and appreciates the day to day challenges they face. He also finds it trendy to conserve nature and particularly likes sightseeing and appreciating natural endowments.



Name: Gustavo Okwir
Organization: Gulu University
Position: Lecturer, Department of Biosystems Engineering
Email: gustavio@gmail.com
Brief Bio: Gustavo is a trained water resources and agricultural engineer with research interest in agricultural water management, irrigation, design and management and modelling of water systems. He is also an ardent follower of political issues the world over and movies.



Name: Juma Omary Mdeke (Eng.)
Organization: Ministry of Agriculture Food Security and Cooperatives
Position: Zonal Land Use Planning and Management Incharge – Kilimanjaro Zone
Email: mdekeoj@gmail.com, mdekeoj@yahoo.com
Brief Bio: Juma is an agricultural/irrigation engineer and expert on design and construction of irrigation systems and infrastructure. He believes in change and knows that he will win, not immediately, but definitely.



Name: Mary Ann Lianza
Organization: IIRR Regional Centre for Asia
Position: Programme Specialist for Development Communications
Email: maeanne.lianza@iirr.org, maeanne.lianza@gmail.com
Brief Bio: Mary Ann has been working on communications in the development field for as long as she can remember. Gender issues are her professional and personal advocacy. She likes alternative music.



Name: Melesse Temesgen (PhD)
Organisation: Aybar Engineering
Position: Researcher
Email: melesse_tem@yahoo.com
Brief Bio: Melesse (PhD, MSc, BSc) is an agricultural engineer by training specialising in farm implements and their linkages to hydrology. He has 30 years of experience in research and teaching in the field of farm implements and hydrology.



Name: Niguse Hagazi
Organization: World Agroforestry Centre (ICRAF) Ethiopia
Position: Consultant
Email: niguse.hagazi@yahoo.com
Brief Bio: Niguse has expertise in forestry, agroforestry, conservation agriculture, tropical land resources management, climate change and development of extension materials and guidelines. He enjoys working on farms and landscape restoration.



Name: Seifu Admassu Tilahun (PhD)
Organization: Institute of Technology, Bahir Dar University
Position: Director, School of Civil and Water Resources Engineering. Also, Assistant Professor and Chair of Hydrology in the School of Civil and Water Resources Engineering
Email: satadm86@gmail.com
Brief Bio: Seifu graduated from Bahir Dar University with a BSc degree in Civil Engineering. He joined Cornell University to do his PhD and finishing an MSc from Addis Ababa University. He thanks his wife (Eleni) for giving him extra time to work.



Name: Violet Alinda
Organization: CARE International in Uganda
Position: Programme Advocacy Manager, GWI EA
Email: Valinda@co.care.org
Brief Bio: Violet holds a Masters of Science in Development Economics with 15 years experience of working with community development projects. She spends her 'me' time reading biographies.



Name: Workneh Bezu
Organization: Habesha Art Studio
Position: Artist, Puppet designer and illustrator
Email: workye2002@gmail.com
Brief Bio: Workneh is a full time studio artist and painter. He does children's puppet movies, books and animation and also illustrates books for the visually impaired. (www.yesicansee.org, www.ethiopianpuppetfest.org)

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For further information, please contact:

Global Water Initiative (GWI) East Africa

Bethel Terefe

Email: bethelt@care.org.et

Dosteus Lopa

Email: Dosteus.Lopa@co.care.org

Violet Alinda

Email: Valinda@co.care.org

International Water Management Institute (IWMI)

Desalegne Tadesse

Email: d.tadesse@cgiar.org