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Department of Urban and Rural Development
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Crop production upgrading strategies and their role for household food security in Chamwino District, Tanzania

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Cover picture: A smallholder farmer on her tied ridged Pearl millet plot near her house in Idifu village. By Charles Ndimbwa.

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Abstract.

Food insecurity is still a challenge affecting many people in the world, whereby the majority live in developing countries in Southern Asia and Sub-Saharan Africa. In Sub-Saharan Africa, many who are food insecure are poor smallholder farmers in rural areas who depend on rain-fed agriculture for food and income. In Tanzania, the Trans-SEC project was implemented from the year 2014-2018 to promote site-specific and adapted upgrading strategies (UPS) in crop production to improve rural agricultural systems along the food value chains for enhancing smallholder farmers' food security. This study assesses the roles of such strategies for food security among smallholder farmers relying on rain-fed agriculture in two villages in semi-arid Chamwino district in Dodoma region, Tanzania. I draw on data from four gender-segregated focus group discussions as well as 54 interviews with both women and men in 33 purposively selected households that have adopted UPS for enhancing soil water management and crop production. The two UPS considered in this paper are rainwater harvesting using tied-ridges as well as kitchen gardens. My findings show that farmers are still food insecure although they report improvements in terms of food stocks on average now lasting for eight months instead of six months, enhanced consumption of vegetables, and little incomes. The limited impact on food security from tied-ridge can be traced to low and erratic rainfall, especially during the sowing period in December, as well as limited expansion of the tied-ridges beyond the testing plots due to the heavy work involved in making the ridges using hand hoes. I argue that these upgrading strategies would have had a more positive impact on the food security of these households if rainfall had been enough for crops to mature. To achieve long-term successes in semi-arid areas, upgrading strategies like tied-ridge should integrate irrigation practices using additional water sources than rainwater.

Key words: Food security, Upgrading strategies, Smallholder farmers, Food Value Chain, Agriculture- nutrition pathway.

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Abbreviations

FAO	Food and Agriculture Organization of the United Nations
FL	Flat cultivation
FVC	Food Value Chain
IFPRI	International Food Policy Research Institute
MDG	Millennium Development Goal
RWH	Rain Water Harvesting
SDG	Sustainable Development Goals
SSA	Sub-Saharan Africa
TR	Tied ridges
UNEP	United Nation Environmental program.
UPS	Upgrading Strategies
URT	United Republic of Tanzania

1. Introduction.

Food insecurity is still a challenge affecting many people in the world whereby the majority live in developing countries in Southern Asia and Sub-Saharan Africa. About 795 million people worldwide, including 780 million in the developing regions face this challenge (FAO; IFAD; WFP, 2015, p. 8). One billion of 1.4 billion poor people in the world live in rural areas where agriculture is their main economic activities to earn livelihood (IFAD and UNEP, 2013). The drivers of food insecurity in these regions include but are not limited to; climate change, political instability, population growth, changing trade patterns and economic systems through trade liberalization and globalization as well as food and energy price fluctuations (FAO; IFAD; WFP, 2015).

Various development strategies have been taken to eradicate hunger and achieve food security in vulnerable countries in the world particularly in Sub-Saharan Africa during the past decade (FAO; IFAD; WFP, 2015, p. 9). Progress to achieve food security was monitored in selected countries by FAO for 25 years from 1990-92 to 2014-16 based on Millennium Development Goal target one (MDG 1c) (ibid). The MDG1c goal was to reduce the proportion of hungry people to half their present level by 2015. However, the achievement of this indicator varies within and across countries, regions and sub-regions. Of the 129 countries monitored for progress, 72 developing countries achieved MDG 1c target (ibid, p. 11). Despite the decrease in proportion of undernourished population in the world from 18.6 percent in 1990-92 to 10.9 percent in 2014-16, the progress in achieving the indicator is overall slow in Southern Asia and Sub-Saharan Africa (ibid, p. 10). The sustainable development goal number 2 (SDG 2), took over the MDG 1c target to end hunger in the world towards achieving food security and improved nutrition.

In Sub-Saharan Africa (SSA), 23.2 percent of the population, that is about 220 million people, is estimated to be undernourished (FAO; IFAD; WFP, 2015, p. 12). The number of undernourished people has increased by 44 million between 1990-92 to 2014-16 (ibid). An increase in number of undernourished people could be due to among other factors, rising food prices, population growth, droughts and political instability in several countries (FAO; IFAD; WFP, 2015). Despite the increase of undernourished people in SSA, 18 countries have achieved MDG 1c hunger target, particularly in West Africa. These countries enjoyed the stable political conditions, overall economic growth, social protections and expanding primary sectors; mainly agriculture, fisheries and forestry (ibid). Eastern

Africa is still facing a big problem of hunger in absolute terms, and it is estimated that 124 million people are undernourished (FAO; IFAD; WFP, 2015).Tanzania is not excepted from this problem caused by poor production of crops in various regions due to the impacts of climate change among other factors (URT, 2014).

Tanzania is one of the countries in East Africa which did not achieved the MDG hunger target (FAO; IFAD; WFP, 2015). The country is still facing the challenge of food insecurity which is characterized by seasonal and regional food shortages (Schindler *et al.*, 2016b). The proportion of undernourished people and prevalent of stunting in children under five years of age is 32.1 and 34.7 percent respectively (IFPRI, 2015), p. 32). Agriculture is the vital sector appropriate for fighting hunger and poverty of the hungry and poor people in rural areas (Schindler *et al.*, 2016b). Agricultural production contributes to long-term food availability and stability of supplies under agricultural favoring weather conditions (FAO, 2014). As one of the strategies to improve food situation in the country, Tanzania work together with Germany to implement Trans-SEC project which aims at improving food situation of vulnerable smallholder farmers in Dodoma and Morogoro regions (Sieber & Graef, 2013).

1.1 Research problem

Chamwino district is charaterised with higher food insecurity (Mnennwa and Maliti, 2010). Smallholder farmers in the district practice rainfed subsistance agriculture in the semi-arid area with low and unpredictable rainfall. Among other factors, low rainfall contributes to low agricultural production which influence food shortages in households. Poor perfomance of the agricultural sector the main economic activity in the district, affects its ability to provide people with food and other livelihoods (ibid). As a strategy to improve foo security in the district, scientific and traditional knowledge are applied to implement food securing UPS to improve food situation of the vulnerable smallholder farmers (Sieber & Graef, 2013). Farmers in two villages in the district (described in detail in the methodology chapter) adopted UPS (RWH and kitchen gardens) promoted by Trans-SEC project to improve their food situation. Smallholder farmers have been working with Trans-SEC from 2014/2015 to 2017/2018 farming seasons during the lifetime of the project (ibid). There is therefore, need for research to be done to understand how the adopted UPS in crop production has helped farmers to improve their food situation. There is no study done to evaluate the impacts of UPS to improve food security which is the major expectation farmers had from the project. This study aims to accomplish the missed impacts evaluation. UPS impacts evaluation gives insight and results which may be implemented at different levels of policy, extension and research.

1.2. Aims and research questions.

1.2.1 Aims of the study

The study aims to evaluate the impact of UPS on food security through analyzing the perceptions and experiences of smallholder farmers who have adopted TR for rainwater harvesting and kitchen gardens to improve food security. This is done through a case study of smallholder farmers that have adopted UPS in crop production in the two villages of Ilolo and Idifu in Chamwino district in Dodoma region. UPS impacts evaluation depends on the data collected based on yields and income experiences from farmers' own crop production. Assessing the outcomes/impacts of the adopted UPS to food security will be the knowledge gap this study wants to address.

The main aim of this study is to evaluate the impact of the adopted TR and Kitchen gardens on crop production to improve food security of smallholder farmers in the two villages of Ilolo and Idifu in Chamwino district, Dodoma region.

1.2.2 Research questions

The research questions consist of one main research question and sub-questions responding to different part of the research problem.

How do smallholder farmers perceive and experience the roles of the adopted UPS (TR and kitchen gardens) to improve food security?

1) *How do farmers assess the achievement of the anticipated outcomes from adopted UPS in crop production?*
2) *What are the strengths and weaknesses of the adopted UPS?*
3) *How does the situation of food availability and access changes over the years after the adoption of UPS?*

1.3 Thesis outline

This thesis is divided into seven chapters. The second chapter looks at the background and literature review on agriculture and food security in Tanzania, and Trans-SEC project. The next chapter I present the theoretical concepts that I have used in the study namely food security and agricultural-nutrition framework. In chapter four I discuss the methods that I used in the field to collect data for this thesis. The next chapter I present the empirical findings of this thesis. In chapter six I present the discussion of these findings. Chapter seven contains conclusions and reccommendations.

2. Background

2.1 Agricultural sector in Tanzania

Agriculture is the main economic activity for rural households in all major farming system in Tanzania (Mnenwa *et al.*, 2010a). The agricultural sector in the country is mainly rain-fed and predominantly done by smallholder farmers in rural areas (Tzeba, 2017). Smallholder agricultural farming provides 95 percent of the national food requirements (IFAD and UNEP, 2013). The sector provides employment to 65.6 percent of the country total population of 44.9 Million people reported by National Census of people and residents 2012 (NBS, 2017). In the year 2016, the sector contributed 29 percent of the total country's GDP (Tzeba, 2017). However, agricultural production in the country is currently affected by number of factors including climate change, pests and disease, low technology and soil degradation (Tumbo *et al.*, 2015). According to Trisorio-Liuzzi & Hamdy (2008), semi-arid areas in the world are highly affected by climate change especially low rainfall on rain-fed agricultural system. Short rain and long-time of drought due to climate change are highly affecting agriculture in semi-arid regions such as Dodoma in central Tanzania. In this region, dependencies on rain-fed agriculture make smallholder farmers vulnerable to food insecurity due to poor food production. IFAD and UNEP (2013, p. 6) reported that, "Smallholders manage over 80 per cent of the world's estimated 500 million small farms and provide over 80 percent of the food consumed in a large part of the developing world, contributing significantly to poverty reduction and food security. To fight hunger in the world we therefore, need development strategies within smallholder agricultural systems.

Developmental strategies that focus on improving productivity of smallholder agriculture contributes to their economy, poverty alleviation, food security and nutrition (IFAD and UNEP, 2013; FAO; IFAD; WFP, 2015). For better outcomes, development strategies need collaboration and agreeing responses from different stakeholders (FAO; IFAD; WFP, 2015, p. 5). One of the agricultural development approaches is upgrading strategies (UPS) along food value chain components. FVC comprises all activities necessary to bring farm products to consumers (Gomez *et al.*, 2011). Food value chain components include natural resources, crop production and processing on-field, and marketing and consumption off-field (Graef *et al.*, 2014). As a strategy to improve smallholders' farming productivity, Germany, Tanzania and other stakeholders work together to improve food situation among the vulnerable smallholder farmers in Dodoma and Morogoro regions in Tanzania through food securing UPS. The adopted UPS in two regions are promoted by Trans-SEC project.

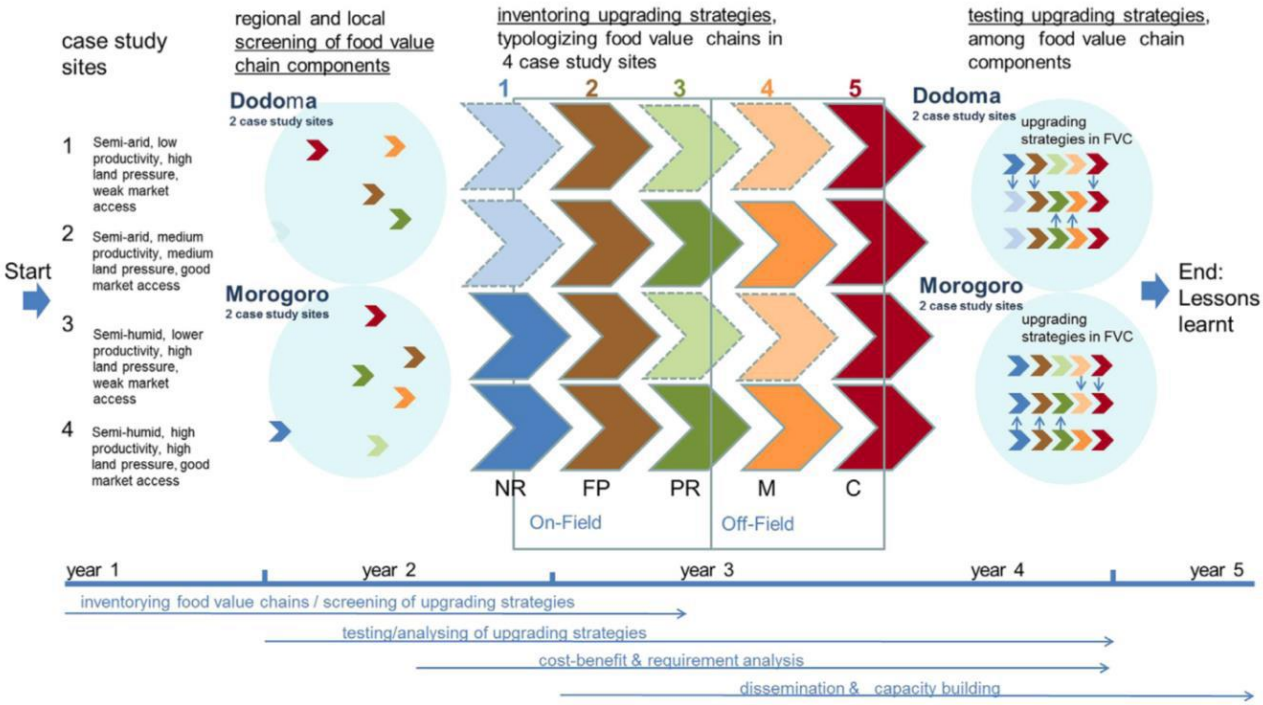
The "Innovation Strategies to Safeguard Food Security using Technology and Knowledge Transfer: A people-centered approach-Trans-SEC" has been implemented by Leibniz-Centre for Agricultural Landscape Research (ZALF) e.V. Tanzania (Sieber & Graef, 2013). The project's aim is to improve the food situation for the most vulnerable rural population in Tanzania using food securing UPS along the local and regional food value chains (FVC) (ibid). This aim was attained by designing, identifying and implementing successful food securing upgrading strategies (UPS) along local and regional rural FVC (Graef *et al.*, 2014). Trans-SEC tests and adjust UPS to site-specific, sustainable settings and tailor these concepts to be disseminated for national outreach (Graef *et al.*, 2014).

Potential UPS within the Trans-SEC project were screened by all partners to site specific and assigned among the five FVC components (Sieber & Graef, 2013). The UPS identified to have expected positive impacts on food and livelihood security in Dodoma regions along the FVC components include: RWH and micro-dosing fertilizer application, seed thresher, sunflower oil pressing, improved cooking stove, kitchen gardens and nutritional education, and tree planting. Smallholder farmers in the study area made the choice to adopt among these UPS to form different groups. This study focusses on the UPS for crop production component of FVC. UPS in crop production covered on this study are rainwater harvesting using tied ridges, and kitchen gardens and nutritional education. UPS in crop production can contribute towards yield stability and smallholder farmers' food, nutrition and livelihood security (Barron, 2004; URT, 2014). Rainwater harvesting (RWH) techniques help to increase water use by plants while raising yields (Karpouzoglou & Barron, 2014). Agricultural intervention on rainwater harvesting (RWH) could help to reduce agricultural production risk caused by unpredictable rainfall (Kato *et al.*, 2011). However, reports on the impacts of rainwater harvesting investments to improve yields report higher returns from the experimental plots of UPS than on farmers' fields (Critchley & Gowing, 2012).

Participatory development of agricultural interventions and ex-ante impact assessment are essential for assessing positive and negative impacts of project on social life, the economy and the environment before implementation (Schindler *et al.*, 2016a). The outcomes of the agricultural interventions such as UPS are assessed based on the amount of yields and incomes contributing to household's food availability, access and utilization (IEG, 2011). The UPS covered on this study are described in detail in the following sections.

2.2 Upgrading strategies (UPS).

According to (Graef *et al.*, 2015), p. 160), UPS are defined as "food securing good practices and/or technological innovations that are likely to improve productivity, efficiency or economic returns of a food system and reduce related risks to the livelihoods of its stakeholders". UPS are designed and tested for site-specific adaptation to achieve a specific objective along the local rural and regional food value chains (Graef *et al.*, 2014). There are UPS for raising sustainability of natural resources and agricultural productivity, and for enhancing post-harvest processing and reduction of post-harvest losses to mention few (ibid). UPS to improve rain-fed smallholder farming on degraded land in SSA (Winterbottom et al., 2013) need to increase adaptation to the impacts of climate change and increase soil fertility (Mongi et al., 2010). Soil fertility improvement could also be achieved through intercropping cereals and legumes (Nyantakyi-Frimpong et al., 2016). The UPS focused on in this study includes rainwater harvesting (RWH) using TR and kitchen garden along the crop production component of food value chain (figure, 1).



Figure, 1. Trans-SEC analytical framework Food value chain and temporal succession of the research tasks (NR – natural resources, FP – food production, P – processing, M – markets and institutions, CP – consumption). source: Graef et al. (2014, p. 12)

2.1.1 Rainwater harvesting using TR

RWH is the practice of collecting, concentrating, and storing water in the field. Water collected increases soil moisture and becomes available to the plant, a condition necessary for increase crop

production (Kahimba *et al.*, 2014). RWH includes technologies such as TR, infiltration pits, micro-basins, ripping, deep tillage, and mulching (ibid). The technology adopted for RWH in the study area is TR. Tied ridges (TR) reduce runoff water and soil erosion for sustainable soil fertility management and crop productivity. Kahimba et al. (2014) reported that "TR of 75-80 centimeters between and 20 centimeters high as well as cross-ties of 1.5 meters apart and 15 centimeters high are constructed to create mini-basins". Figure 2 below shows how TR, cross-ties and mini-basins look in the field. During the light rainfall, the rainwater accumulates, remains and infiltrates into the mini-basins. TR are suitable for cereal crops including maize, rice, millet, and sorghum, suitable for cash crops such as in sunflowers, sesame, legumes, and vegetables in both semi-arid and sub humid areas (Kahimba *et al.*, 2014). Many researchers in different parts of Africa, including Tanzania, have reported that RWH in semi-arid areas has helped to transform smallholder farming from food insecure to food secure (Kahimba et al., 2014). For example, Mudatenguha et al. (2014) reported maize produce improved from 1593 kg/ha under flat cultivation to 3233 kg/ha under TR techniques; Kahimba et al. (2014) reported that maize yield increases by 224 kg/ha in sub-humid and millet produce by 670 kg/ha and sunflowers produce by 794 kg/ha under TR in semi-arid Tanzania. Smallholder farmers in the study area adopted and implemented RWH technologies using TR for increasing crop production from 2013/2014 to 2017/2018 farming season.

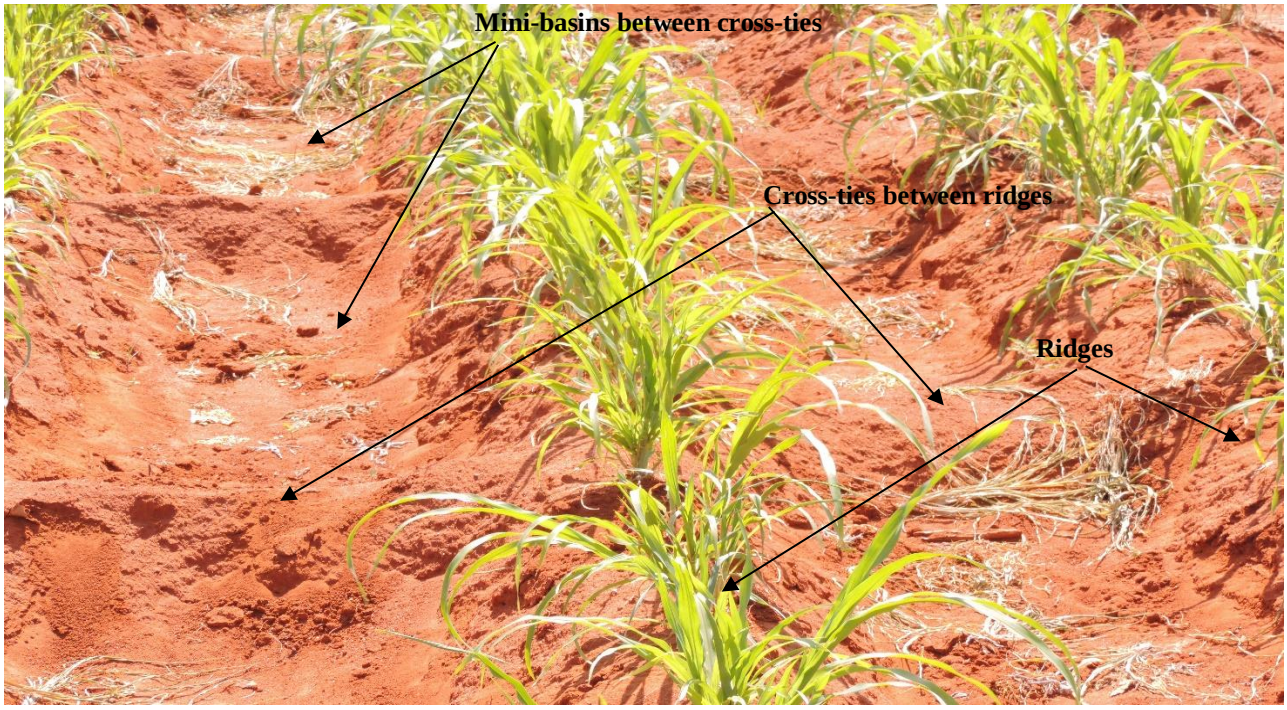


Figure 2: Ridges, cross-ties between ridges and mini-basins. Source: Author (February and March, 2018).

2.1.2 Kitchen gardens

Kitchen garden is the small garden near the house. One of the kitchen garden technology is the use of pocket/bag on the doorstep to produce leafy green vegetables at the households (Lambert et al., 2014). Manure, sand, soil, pebbles are mixed together and put into the pocket/bag to make pocket/bag gardens. Crops are then planted on top of them and irrigated as seen in figure 3 below. The advantage of kitchen gardens is that, they can be used in area where water is scarce as they need little water for irrigation than conventional ground gardens (ibid). The materials needed to make kitchen gardens are cheaply available and affordable to all farmers in the study area. Kitchen garden and household nutrition training include provision of education focusing on improving consumption patterns, nutrient intake and dietary diversity of rural households family members (Lambert *et al.*, 2014). Kitchen gardens have the potential for improving the household's access to green leafy vegetables to improve dietary diversity and family health. Leafy green vegetables are sources of Vitamin A, and important for prevention and control of Vitamin A deficiency (Codjia, 2001).

Kitchen garden improves household's consumption of leafy green vegetables while supplying them a small income after selling the surplus (Lambert et al, 2014). The little income income earned from kitchen garden could be used to meet other households needs such salt and cooking oil. Kitchen gardens are suitable for the production food crops including micronutrient rich green leafy vegetables such as chinese cabbage, spinach, collard greens, swiss chard, amaranths, sweet potato leaves, pumpkins leaves, african eggplants and hot pepper (Lambert *et al.*, 2014). Kitchen gardens in the study area are managed mostly by women who are responsible for ensuring the diet particularly of children in the households.

Figure, 3. Chinese cabbage, spinach and sweet potatoes leaves grown on kitchen gardens. Source: Lambert et al., 2014).

3. Theoretical framework

This chapter is composed of the concepts and conceptual framework guiding this study. The purpose of this chapter is to define and explain in detail the concepts that I have used throughout this work. I describe them in this order: - concept of food security and agricultural nutrition pathway framework

3.1 Food security

Food security is still a challenge in developing countries in Sub-Saharan and Southern Asian regions (FAO; IFAD; WFP, 2015). This study uses the definition of food security agreed on the World Food Summit in 1996, which states that food security; "exists when all people, at all times, have physical, social, and economic access to safe and nutritious food that meets dietary intake and food preferences for an active and healthy life" (FAO, 2008). The components of food security are food availability, food access, food utilization and stability of other three dimensions over time (FAO, 2008, 2013). FAO (2008. P. 1) defines each component as follows: 1) Availability: "the supply of food in form of domestic production, commercial importation and food aid"; 2) Access: ability of individual or household to acquire adequate food"; 3) Utilization: "the ability of the body to make most of nutrients

contained in their accessed food", and 4) Stability: "to have access to adequate food all the times. Food access depends on the households' resources (income, capital, labor, knowledge) and on the food price at the market place (Weingärtner, 2004). Achieving only food availability and access at the household level are not sufficient to meet household's food security (Weingärtner, 2004). Utilization of food is influenced by quality of food, health physical environment (safe drinking water, sanitary facilities) and an understanding of proper health care, food preparation and storage processes (Weingärtner, 2004).

Efforts and expertise need to work jointly on Global partnership for agriculture, food security and nutrition to reduce the proportion and number of people suffering from hunger and malnutrition (FAO, 2009). The increase of funding and investments focusing on sustainable smallholder agricultural production and productivity have the potential to reduce poverty, enhance food security and access to food for poor and hungry people (ibid). This study uses the agricultural- nutrition conceptual framework to generate knowledge on how interventions in agriculture can facilitate achieving food and nutrition security.

According to (FAO, 2018), food insecurity is defined as "a situation that exists when people lack secure access to sufficient amounts of safe and nutritious food for normal growth and development and an active and healthy life". Lenhart and Read (1989, cited in Bhattacharya *et al.*, 2004, p. 3) define hunger as "a condition resulting from chronic under-consumption of food and/or nutritious food products". Furthermore, Bhattacharya et al. (2004), described three catergories of food insecurity as "Food Insecure without hunger (a household buys less expensive food and so reduces diet quality); Food Insecure with moderate hunger (food intake for adults is reduced, and adults are experiencing hunger owing to self-rationing); Food Insecure with severe hunger (households with children reduce the children's food intake and children experience the physical sensation of hunger, adults show evidence of more severe hunger as a result of much reduced food Intake)" (ibid, p.7).

3.2 Agricultural-nutrition conceptual framework.

The agricultural-nutrition conceptual framework describes the pathway and principles for improving nutrition through agriculture (Herforth & Harris, 2014). It provides a better understanding on how agricultural interventions (investments or activities) could improve access to food and health care, and finally affect the nutritional status of individuals especially women and children (ibid). Agricultural- nutrition conceptual framework has three main pathways linking agriculture and

nutrition: 1) "food production, which can affect food availability for household as well as the price of diverse food; 2) Agricultural income for expenditure on food and no-food items; and 3) women's empowerment, which affects income, caring capacity and practices, and female energy expenditure" (Herforth & Harris, 2014, p. 3). These pathways are not linear but they do interact in many ways (figure 4).

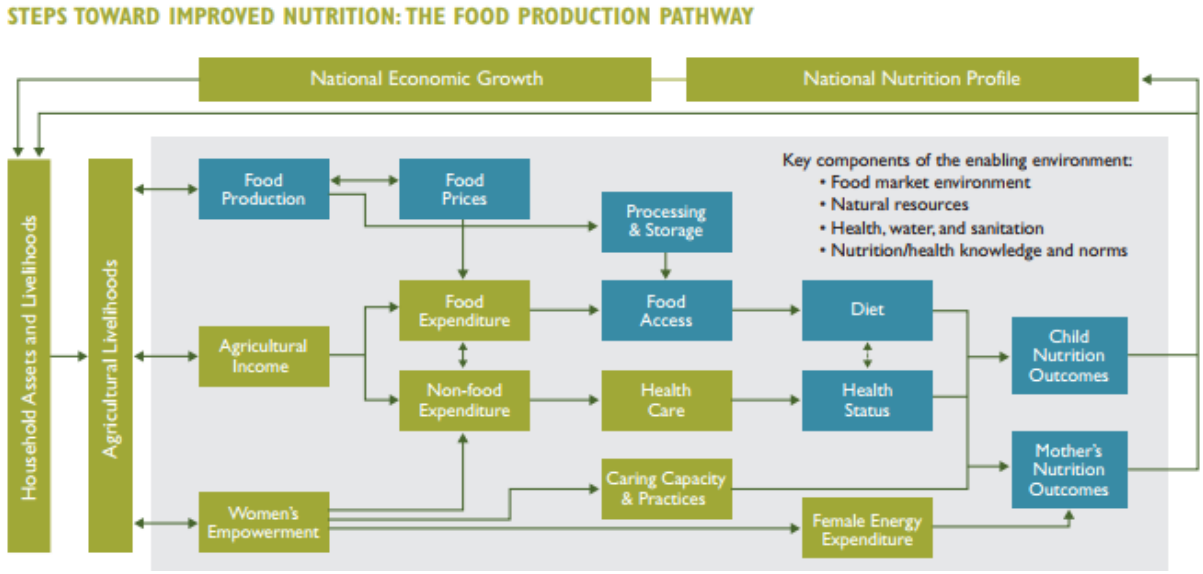


Figure 4: Conceptual pathway between Agriculture and Nutrition, production pathway is highlighted in blue. Source: (Herforth & Harris, 2014).

The framework is used as a tool adopted in studies that focus on the contribution of agriculture on nutrition of nutritionally vulnerable people (Herforth & Harris, 2014). For example, Feed the Future, the U.S. Government's global hunger and food security initiative, adopted the framework to demonstrate how agriculture affects diet and nutrition for rural families (ibid). This study uses the framework to evaluate the impact of agricultural development (Upgrading strategies) on food security, which is the precursor of nutrition security. The agriculture-nutrition framework includes direct links between agriculture and consumption of nutritious food, and indirect link between agriculture and nutrition through income and health (Turner *et al.*, 2013). Nutrition status is determined by food (access to sufficient, safe and nutritious food for health and active life), health and care which all can be affected by agricultural production (Herforth & Harris, 2014). The food security situation of smallholder adopted UPS in the study area was evaluated based on crop production and agricultural income pathways.

4. Methodology.

This study adopts qualitative research approach. In this chapter, I describe in detail the philosophical assumption guiding this study, followed with research design, description of the study area, methods of data collection, data analysis procedures, procedure to ensure trustworthiness, ethical consideration and limitation of the study.

4.1 Philosophical assumption.

The worldview and the academic training where a researcher is based on, determines the methods of the study. Positivism is linked to quantitative approaches, constructivism is linked to qualitative approaches, and pragmatism is linked to mixed method approaches (Creswell, 2014). Constructivism or social constructivism is often combined with interpretivism worldview (ibid). The basic idea of social constructivism is that individuals struggle to understand the world in which they live and work through subjective meaning of their experience towards certain object or phenomena (ibid). The experience of people on food security was studies by using qualitative research approach using qualitative methods of data collection. I draw on the constructivists views that focus on how social reality are produced, assembled and maintained through a subjective human creation of meaning (Silverman, 2015). This study could also be done by adopting mixed method research approach. In that situation qualitative and quantitative data should be collected, analyzed and interpreted which is more time consuming than using either of the two. I have adopted the qualitative approach with constructivism worldview to explore and understand the meaning that smallholder farmer's hold on the problem of food insecurity and the roles of UPS to improve food security. With the help of Constructivism views, I interpreted the perceptions and experiences that smallholder farmers hold about UPS and their roles to improve food security. Understanding farmer's perceptions and experiences on food insecurity and roles of UPS are important for answering the research question.

4.2 Strategy of inquiry/Research design.

Research design is a plan to study a research problem (Creswell, 2014). Based on the understanding about the qualitative approach and constructivism worldview, I made choice to use case study research design in this thesis. According to (Yin, 2009), p. 2), case study is used for in-depth study where the investigator has little or no control over events/behaviors, and focus on contemporary phenomenon within a real-life context. Case study design has been commonly applied in Psychology, sociology, political science, anthropology, social work, business, education, nursing and community

planning studies (ibid). I adopted case study design, to study smallholder farmers who are contemporary food insecure due poor crops harvests. Case study design allows me to retain a holistic and meaningful characteristic of real life events (Yin, 2009, p. 4). Working with smallholder farmers who are food insecure helped me to get an in-depth understanding of the nature of the food insecurity problem, economic activities, and agricultural UPS linking to secure food security. I did evaluation of the impacts of UPS to explain the presumed causal links to improve food situation of smallholder farmers. Case study can be single-case design or multiple-case design, each with either single or multiple units of analysis (Yin, 2009). This study adopted single-case study design with multiple units of analysis, and the units of analysis are the farmers' households adopting UPS in crop production.

4.3 Case study site description

The case study site is in semi-arid Tanzania and includes case study villages of Idifu and Ilolo in Chamwino district in Dodoma region. The site is located on the central plateau of Tanzania. The food system is mainly based on sorghum and millet as staple food crops with livestock integration (Mnenwa *et al.*, 2010b). Crop production and livestock keeping form the main economic activities in the district providing them with food supplies, income and employment. Rain-fed agriculture provides employment to 90% of the district's active working population of more than 280,000 persons (DALDO, 2012, cited in (Sieber & Graef, 2013; NBS, 2017). The 2012 National census reported the population of the district to be 330,543 (NBS, 2017). The district is characterized with high food insecurity due to low and erratic rainfall (350 – 500 mm per year), low yields, a lack of knowledge of improved agricultural practices and low economic development (Schindler *et al.*, 2016a). Farmers grow sunflowers, groundnuts, and legumes as cash crops. In terms of livestock, farmers keep cow, goat, sheep, oxen, donkey, chicken, rabbit and guinea fowls. The two study villages are in the same ecological zone but differ only on market access where Ilolo is better off compared to Idifu. Ilolo is near to the market in Mvumi village the headquarter of the division and Dodoma town. The decision to delimit the study to this area is due to the following reasons. Firstly, it is characterized with high food insecurity and smallholder farmers depend on rainfed agriculture. This is a semi-arid area with low and erratic rainfall. Secondly, in this area there is Trans-SEC project that promotes UPS to improve food security of smallholder farmers through crop production. My study focusses in Dodoma region and not in Morogoro region (sub humid region) where Trans-SEC project was implemented as well, because I wanted to evaluate the roles of RWH using TR and kitchen gardens to improve food security in semi-arid region (Figure 5).

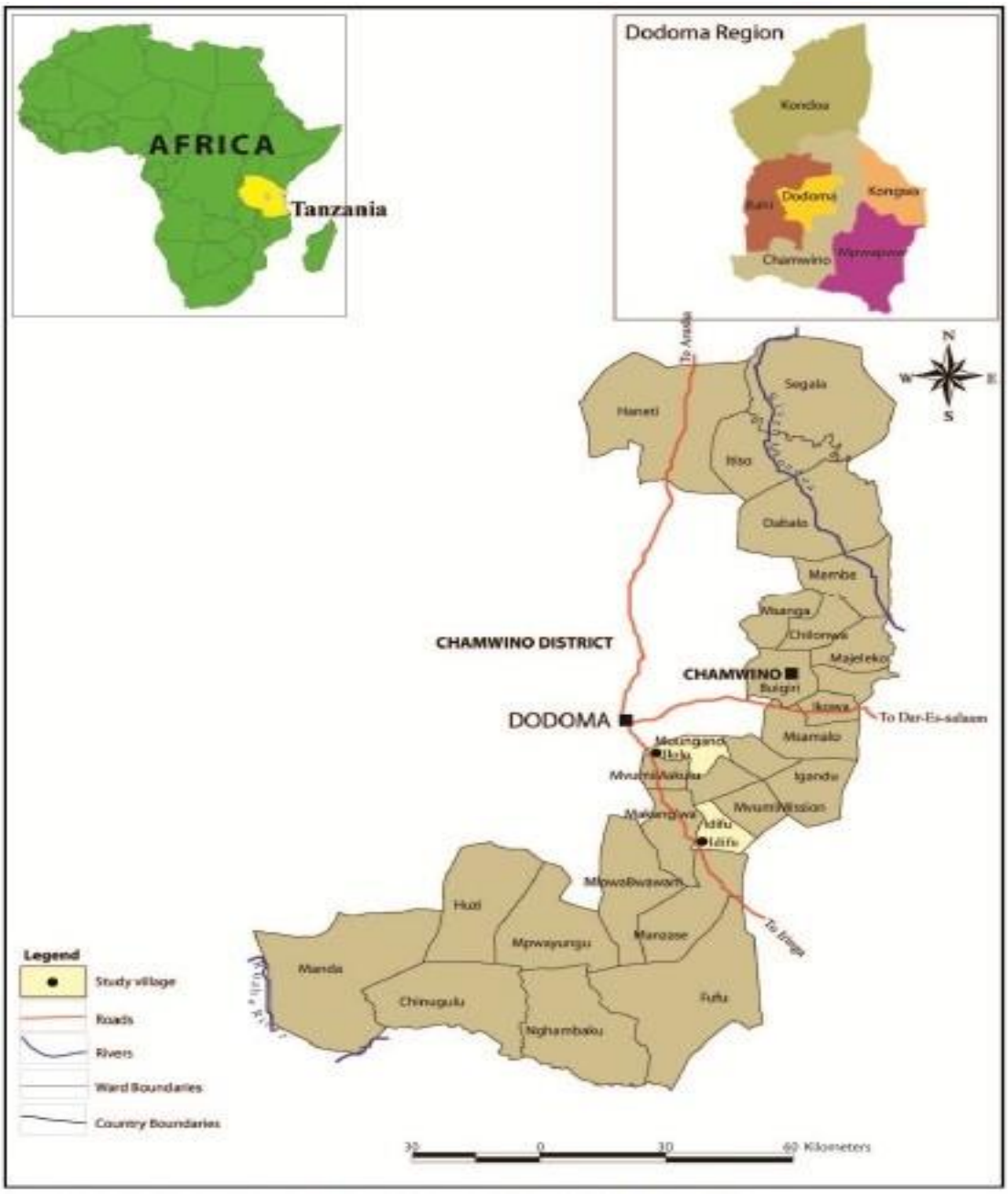


Figure 5: Maps showing Cases study sites in Chamwino Districts. Sources: (Sieber and Graef, 2013, p. 114).

4.4. Methods of data collection

This section describes the qualitative methods employed for data collection. The first part discusses site and participants sampling procedures, followed with interviews, focus group discussion, and field visit observation.

4.4.1 Sampling procedures.

In qualitative research approaches site and/or participants are sampled purposively to help a researcher understand the problem and answer the research question (Shenton, 2004; Creswell, 2014). I purposely selected two villages of Ilolo and Idifu in Chamwino district based on the research question. In the two villages, smallholder farmers are involved in testing the UPS promoted by Trans-SEC project to improve the food situation along the local rural and regional food value chains (Sieber & Graef, 2013). The area is an appropriate case study site for this study to facilitate the process of data collection regarding the agricultural interventions in place to improve food security. Furthermore, I deliberately selected participants for interviews and focus group discussions in the two villages to include only those adopted UPS for natural resources management and crop production only. Direct observation, in-depth interviews, focus group discussion and document review are commonly methods used in qualitative studies to generate data (Yin, 2009; Creswell, 2014). In this study, I used structured interviews, focus group discussion and field observation methods to generate data.

4.4.2. Interviews, Focus group discussion and field observations.

I used structured interviews to collect data on individual's perspectives and experiences on food insecurity and the role of UPS. Structured interviews allow the researcher's to be consistency in the data being collected during the interviewing process. The advantage of structured interview using interview guide helps a researcher to ask all questions necessary to answer the research question. On the other side using interview guide could be disadvantageous as it limits to explore the relevant topic not included on it. Using interview guide, it was easy for me to ask main question and follow-up questions. Face to face interview allowed me to collect direct information from respondents and control over the line of questioning (Creswell, 2014). However, the limitation of the face to face interview is that the presence of the researcher may influence the respondents to overstate or understate a phenomenon than its real being (ibid). Overstating and understating of the real situation were minimized by providing clear elaboration to the participants on the intention and usefulness of the data collected. Swahili language was the only language used during the process of data collection. It is a national language and is spoken in the whole country and everyone speaks it. Before the interviews process, respondents were asked their consent to record their voice, take photo, and let them feel free to share their experience on the subject matter. On average each interview lasted between 30 to 50 minutes per respondent. The interview guide composed of open-end questions focusing on food insecurity, coping strategies, adoption of UPS, expectations, achievement of the

expectations, household nutrition education and kitchen garden, and household food insecurity experience scale (FIES). According to (Ballard *et al.*, 2013) household food insecurity experience scale is as an experience-based metric of severity of food insecurity that relies on people's direct responses to a series of questions regarding their access to adequate food". It is used to estimate the food insecurity of the population (Ibid). Heads of households who were mostly men (76%, N=33) responded to most of the questions, and women in the same households responded to the last part of questions guide that related to nutrition education and Food Insecurity Experience scale. Women only answered these questions as they participated in the households' nutrition and kitchen garden trainings, and they are also responsible for food preparation in their households.

After individual household's interviews, I conducted two segregated focus group discussions for men and women in each village. In total, I did four focus group discussions in the two villages. Each focus group discussion had 7 to 9 individual lasting between 60 and 90 minutes. For each focus group, ten individuals were invited to participate but not all of them showed up. The advantage of focus group discussion is that it helped me to collect data from many people at the same time. However, the disadvantage of it is that few questions are likely to be covered. But during the focus group discussions all questions on my interview guide were covered, this was achieved by leading the discussion to issues relating to the topic only. According to the experience of trans-SEC facilitators in these villages, women are free to talk and discuss when separated from men. The purpose of doing focus group discussions was to supplement and get more information on some of the questions and emerged issues during individual interviews. The focus group discussion helped me to generate more information about food security and UPS as participants were feeding each other information. The participants in the focus groups were not equally articulative, but they all participated in supporting or arguing about the topic and answers. The information from the focus group discussion helped me to triangulate information collected by structured interviews.

I visited five farmers' fields to get information on agricultural practices. My intention was to collect information on the types of crops grown on both tied-ridge (TR) and flat land (FL) practices. Moreover, I wanted to look at the size of the land devoted for TR and flat cultivation, and whether they do intercropping as they reported during the individual interviews and focus group discussions. The field observation report yielded information which helped me to compare with information gathered through structured interview and focus group discussions. I observed kitchen gardens when I was visiting the farmers at their households during the individual interviews.

Data collection for this study was conducted on February and March 2018. Although it was a rainy season, there was no rain the whole month of February, it only resumed on March after its last fall on January. From some coupled households both men and women responded to different questions in the interview guide. Men responded to questions focusing on food insecurity, coping strategies, adoption of UPS, expectations and achievement of the expectations from UPS. Women responded to question focusing on household's nutrition education and kitchen garden, and food insecurity experience scale (Appendix I). Men responded to these questions because they are the heads of households in this area, and they make large part of decision making in the households including farming activities. Women were trained on how to establish and manage kitchen gardens, and I wanted them to share their experiences on this type of UPS. In the households where I met men and women, I did separate interviews with one person per time. The gendered division of the questions was due to the information that women got nutrition education and kitchen garden through Trans-SEC project. Out of 33 participated households, only women were interviewed from 12 households. Of the 12 households 4 were female headed households (Table 1). Women from 4 households in each village responded to all questions as men/husbands were absent. The average household size in the study area is five individuals. The farmers participated in this study have age ranges from 26 to 77 years old.

Table 1. Sociometry of the sampled population, from 33 households.

S/N	Items	Idifu village				Ilolo village			
		Total	Female	Male	other	Total	Women	Men	other
1	Population	5519**	2893	2626		3890**	1983	1907	
2	Number of households				1205**				851**
3	Groceries				7				10
4	Milling machine								3
5	Health facilities				1				0
6	Primary school				2				1
7	Secondary school				1				0
8	Churches				4				3
9	Market				0				1
10	Water taps				9				*
11	Interviews	26	17	9		28	16	12	
12	Focus groups discussion	17	8	9		17	7	9	
13	Field visits					3			2
14	Number of households participated in the study					17			16

Source: Author (February and March 2018), * Water taps are there but I don't know the number; ** information collected from the Village Executive Officer (VEO) in each village.

4.5. Data analysis procedures

According to Creswell (2014), data should be organized and prepared before start analyzing them. Preparation of data involves raw data transcribing, typing field notes and photos setting. I translated all interviews and focus group discussions from Swahili into English during transcription. Field visit observation data were typed. I read all the data throughout and coded all emerged appropriate issues for answering the research questions from the data. I grouped all important issues that emerged into themes or patterns. The method applied for data analysis depends on the nature and type of data collected. For example, some form of data is analyzed based on theoretical proposition strategy using pattern matching techniques (Yin, 2009), or statistical analysis for numerical data in experimental design (Creswell, 2014). This study adopted a thematic or pattern-matching method used for analysis of qualitative data collected through interviews method. Pattern-matching data analysis method led

to the development of themes that helped me to answer research question regarding food security and roles of UPS to achieve it in the study area.

4.6 Strategies to ensure trustworthiness

Strategies employed to ensure trustworthiness in qualitative research project includes credibility, transferability, dependability and confirmability (Shenton, 2004). To ensure that, I collect reliable information that could help me to answer the research questions, only participants who adopted UPS from Trans-SEC project were interviewed. These participants are the ones experienced food insecurity, adopted UPS, test them and experience the crops yields before and after adoption of UPS. They are the right candidates for this study than any farmer who did not adopt UPS. Using three methods for data collection helped me to triangulate all collected information. Some information was checked during interviewing process in form of follow up questions, and on focus group discussion for issues happened during the individual interview. Checkup of collected information using member check is important for checking the accuracy of data gathered during the interviewing process (Shenton, 2004; Creswell, 2014). Field visit observation also helped me to triangulate information regarding farming practices generated during individual interviews and focus group discussions.

4.7 Ethical consideration.

The participants in the study area provided informed consent before taking part in research. Furthermore, I guaranteed respondents with confidentiality and assurance to withdraw at any time if they wish to do so. Pseudonyms are used in research results chapter to protect the identities of the participants. The woman on the cover photo agreed to be part of the photo. I introduced myself to the participants, the purpose of the study and the importance of participants taking part in research before data collection begin. The introduction together with lunch allowance made them feel free to participate and respond to the interviews and focus group discussions. Lunch allowance does not mean to buy information from the respondents, but it has been done by other researchers to respondents working with them for many hours a day.

4.8 Limitation of the study

This study was born out of my interest to understand how smallholder famers who depend on rain-fed agriculture in semi-arid region of Dodoma. My interest was to understand on how the adopted agricultural interventions could help farmers to reduce the risk associated with climate change such as low and erratic rainfall. The study is limited by the facts that it was done only in semi-arid area,

the knowledge gained cannot be used in other agroecological zones within the Country. Secondly, the study was done for eight weeks, this makes impossible to be able to explore information from all actors involved in the implementation of the Trans-SEC project. Therefore, the information was generated from farmers adopted UPS covered by this study. The division of the questions on the interview guide to ask different questions for male and female in the same household could lead to miss of important information for the questions not asked to another couple. The UPS was adopted at the household level where men and women in this area do farming work together, therefore, perceptions and experiences on food security and roles of the TR and kitchen reflects that of the household and not an individual in the household.

5. RESULTS

In this chapter, I present the perceptions and experiences of smallholder famers who adopted UPS in crop production to improve their food security. The results derived from the data collected from four groups discussions (I name them group 1, FGD with men in Idifu; group 2, FGD with women in Idifu; group 3, FGD with men in Ilolo; and group 4, FGD with women in Ilolo), 54 individual interviews (21 men and 33 women) from 33 households with farmers adopted UPS and field visit observation. This chapter is divided into three sections that address different parts of the research problem. The first section addresses the first research sub-question which is about, the achievement of the anticipated outcomes from adopted UPS in crop production. The second section addresses the second research sub-question, which is about strength and weaknesses of the adopted UPS in crop production. The third section addresses the third research sub-question, which is about the households' food availability and access changes over the years after the adoption of UPS. All three sections are jointly answering the main research question.

5.1 Achievement of the anticipated outcomes from adopted UPS in crop production

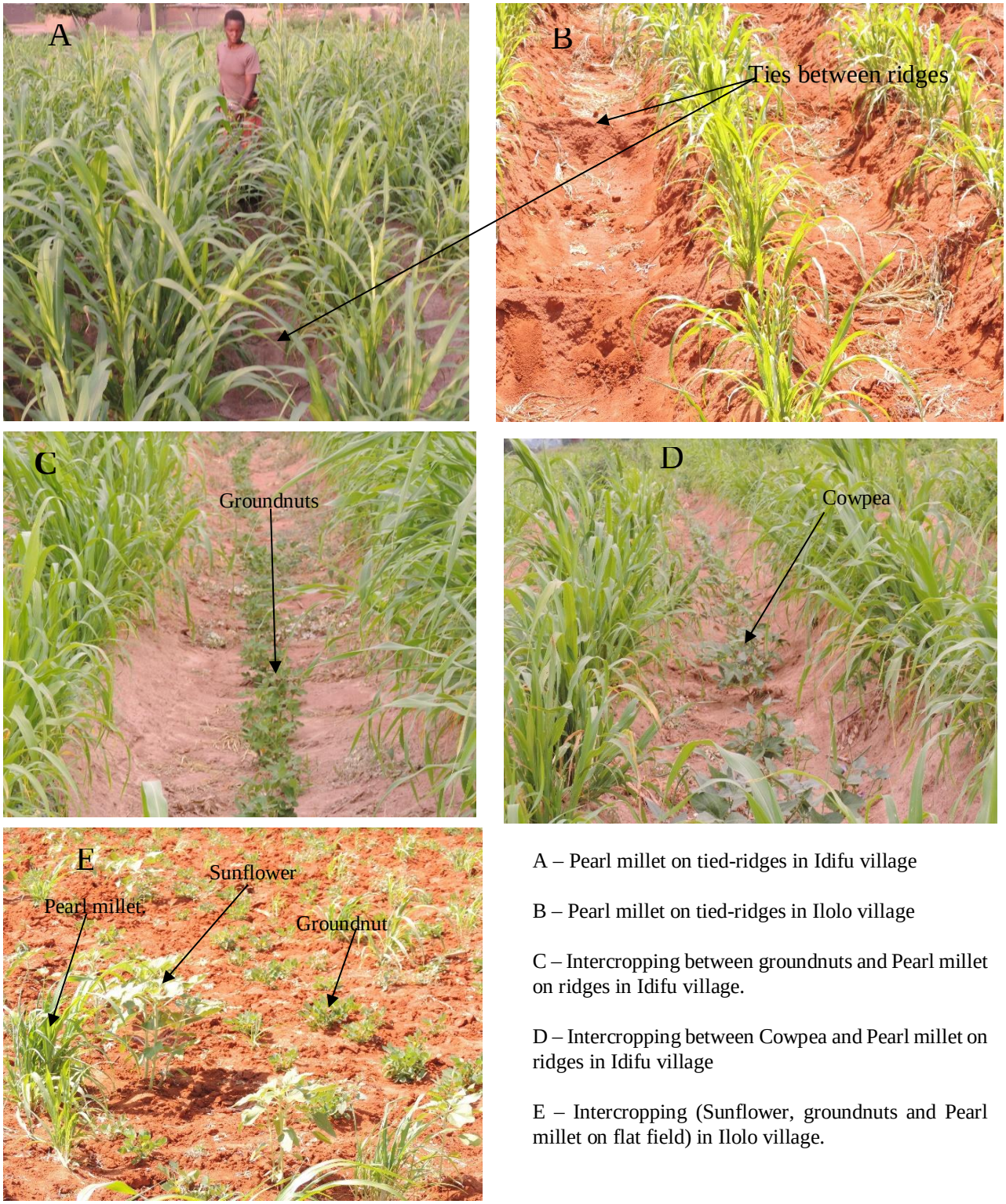
During data analysis, two themes emerged which address the research sub-question about the achievement of the anticipated outcomes from adopted UPS in crop production. These themes are interventions to improve smallholder rain-fed agricultural productivity and farmer' experience on outcomes of the adopted UPS. The interventions are first described in the first section of this chapter followed by the details of their outcomes in the second section.

5.1.1 Intervention to improve smallholder rain-fed agricultural productivity.

Men and women in FGDs 1, 2, 3 and 4, and 33 individual interviews out of 54 respondents reported that they had expectations that RWH and kitchen gardens promoted by Trans-SEC project would provide them a long-term solution to food insecurity. Farmers expected higher crop yields from a small area to get food and sell the surplus to earn income. The package of the agricultural intervention included trainings and provision of agricultural inputs (drought resistant seeds, fertilizers) for demonstration on sample plots. How to make and use TR and kitchen gardens were part of the trainings on good agricultural practices.

The knowledge acquired by farmers through training shows that improved seeds of pearl millet and sorghum withstand drought and mature in a short time. TR performs two major roles that are important for increasing crops yields from the farm if adopted by farmers. First, TR conserve water for a plant even if there is no rainfall up to three weeks. Second, TR help to improve soil fertility by reducing soil erosion through prevention of surface run-off of rainwater. As a strategy to improve soil fertility, training covered the methods of chemical fertilizers application during the planting stage and vegetative stage of the plant to increase nutrients necessary for plant growth. Not all farmers in the study area can afford the costs of chemical fertilizer. Farmers who cannot afford chemical fertilizer do practice intercropping between legume and cereal to improve soil fertility and harvest varieties of crops from the same plots of land. To elaborate more on the importance of improving soil fertility and improve yields, Tito, a 59 years old man said: "*Intercropping of pearl millet and groundnuts is very productive as it enables me to harvest pearl millet and groundnuts, or sorghum and groundnuts from the same field*" (individual interview 25).

Also, the knowledge of planting crops in lines combine with the intercropping practices help farmer to harvest more and different types of crops per unit piece of land. Based on the data I collected on farmer's land ownership, I realized that smallholder farmers in the study area own small plots, and the average size of land owned is 6 and 5 acres per household in Ilolo and Idifu village respectively. Therefore, adopting intercropping over mono-cropping is beneficial to them as they harvest different types of crops per unit area of land. The common intercropped practice I observed during the field visit observation is between cereal and legume a practice effective in improving soil fertility. During the field visit I observed that millet and sunflower intercropped with either groundnuts or cowpeas. Moreover, I observed that farmers practice TR mostly on testing sampling plots of one hundred square meters. Farmers adopted and applied intercropping techniques mostly on non-tied ridges and flatland cultivation (Figure 6).



A – Pearl millet on tied-ridges in Idifu village

B – Pearl millet on tied-ridges in Ilolo village

C – Intercropping between groundnuts and Pearl millet on ridges in Idifu village.

D – Intercropping between Cowpea and Pearl millet on ridges in Idifu village

E – Intercropping (Sunflower, groundnuts and Pearl millet on flat field) in Ilolo village.

Figure 6: Adoption and use of tied ridges, non-tied ridge and intercropping practice between cereal and legumes on both non-tied ridges and flat field. Source: Photo taken by the author (February and March 2018).

Farmers' participation in household nutrition training and kitchen gardens is feasible for addressing poor nutritional knowledge, inadequate consumption of micronutrient green leafy vegetables, low dietary intake, inadequate domestication efforts for vegetables as well as low use of vegetable during the dry season (Mini-scoping site study for the Trans-SEC project). One woman in FGD 2 said: "*Leafy green vegetables are scarce in this area especially in dry season, when all wild plants we use as vegetables became dry"*. Another woman in FGD 4 reported: "*We normally depend on wild green vegetables such as slippery vegetable, wild amaranth and wild sweet potato leaves. Adoption of kitchen gardens will provide us with another source of green vegetables we did not eat before particularly in dry season"*. When I was visiting household during individual interviews, I observed the kitchen garden but there were not in good status (healthy), may be due to the dry spells in February.

5.1.2 Farmer' experience on outcomes of the adopted UPS.

5.1.2.1 RWH using TR

Another emerging theme was that of the outcomes of the adopted RWH using tied ridges to improve crops yields. Farmers in focus groups discussions and individual interviews reported that the outcomes of the UPS were accounted based on the amount of yields they harvest from tied ridges (TR) and flat (FL) plots and comparing with yields in the past years. To illustrate more on this point, farmers mentioned that, their expectations to cultivate small area and harvest higher crops yields for food, and sale the surplus for income were not achieved as expected. Farmers reported positively and negatively regarding the roles of the adopted UPS to increase crops yields, food availability and food access at the household level. All interviewed farmers except one, reported that the UPS did not help them much to achieve their expectations of increasing crop yields, and therefore, they still find themselves in food insecure situation at different levels of severity. This is probably because they do not harvest enough food to meet their households' food consumption needs as it is the case for one reported farmer. An illustrative example came from one woman in FGD 2, who said: "*We have not realized our expectations to increase crop yields and harvest enough food through tied ridges due to rainfall problem; though we still acknowledge that based on testing sample plots we harvest more on tied ridge than on flat field of same unit area*".

The FAO food insecurity experience scale I adopted to measure the severity of food insecurity, shows that of the 33 interviewed households' members, 17 are still severe food insecure, 15 moved from severe food insecure to moderate food insecure, and 1 is food secure. One interviewee who reported

to be food secured, named John, a 64 years old man, said: *"I grew pearl millet and sunflower on tied ridges. I harvested 45 and 27 Kilograms of pearl millet on tied ridges and flat sample plots respectively. Now I am food secure as I harvest between 540 and 720 Kilograms of pearl millet. I have more land about 10 acres to grow crops than previous years. Currently I have enough food from previous harvests" (*Individual interview 24*).* Another interviewee named Grace, a 57 years old woman considered her household as moderate food insecure mentioned said: *"I adopted tied ridges and tree planting since 2014/2015 farming season. I grew pearl millet, and sunflower. In 2015/2016, a year we received good rainfall, I harvested 90 and 54 Kilograms of pearl millet on tied ridges and flat fields respectively. I have not yet harvested enough to meet the households' food consumption needs due to shortage of rainfall. I am still moderate food insecure" (*Individual interview 23*).* An interviewee named Martha, a 38 years old woman who reported to be severe food insecure said: *"I adopted tied ridges and kitchen garden since 2014/2015 farming season. I grew pearl millet on sample plots, and in 2014/2015, I harvested 5 and 2 Kilogram on tied ridge and flat land. I still do not produce enough food through tied ridges and plain fields due to low rainfall' (*Individual interview 8*).*

In both cases of those who achieved more and less yields, there was an increase in yields using the TR though yields were not enough to meet their households' food consumption needs. John, a farmer who reported to be food secured is better off compared to other farmers. In addition to the yields he harvested from TR plots, he reported to diversify sources of income by keeping livestock and growing both food crops and cash crops on tied ridge (TR) and flat land (FL) using intercropping practices as he had more land compared to other farmers. All farmers in this area reported to sell cash crops such as sunflowers and groundnuts for earning income that is used to meet other household needs such as health services and buying food. Since agriculture is their main economic activity to provide food and income, even if the harvested food crops are not enough, farmer reported to sell little for achieving other household needs. Yields from TR, FL improved households' food availability, access to diverse food and the length of time for using their own produced food.

5.1.2.2 Kitchen garden

Women in FGD 2 and individual interviews reported that the adoption and implementation of kitchen gardens in the study area has improved the availability of leafy green vegetables when comparing with the time before their adoption. Before the adoption of kitchen gardens, farmers were consuming green vegetables from the wild which become scarce after drying up in dry season. Kitchen gardens

become the main source of diverse leafy green vegetables in dry season. One woman in FGD 4 reported that the adoption of kitchen garden has contributed to the availability of diverse food particularly green vegetables in their village. Leafy green vegetables such as chinese cabbage, spinach, amaranths and sweet potato leaves which were scarce and grown at the village are now available. The composition of diet has improved in both the households growing and those not growing vegetables using kitchen garden. For example, Neema, a 44 year old woman said: "I *adopted kitchen garden since 2014/2015, the composition of my diet has changed as now I use a variety of vegetables such as chinese cabbage, sweet potato leaves and amaranth from my own garden*" (Individual interview 2). Edina, a 53 year old woman who does not have a kitchen garden said: "*I do not grow vegetables as I adopted TR only. Kitchen gardens help a lot to supply green vegetables, even us who do not grow we buy them from our neighbors growing them. Chinese cabbage, sweet potato leaves, amaranth and spinach are now accessed at the village level" (*Individual interview 18*)*.

Little income has been earned from kitchen garden through selling surplus vegetables but is only used to meet other households' needs. One woman in FGD 2 mentioned that "*I earn little income by selling the surplus vegetables to my neighbors at the village level. If I harvest more, I can take them to the market at the nearby village called Mvumi. I spend the little income I earn on buying cooking oil, salt and soap*".

5.2 Strengths and weaknesses of the adopted UPS in crop production

This section addresses the research sub-question about the strengths and weaknesses of the adopted UPS to improve food security. I use the term strength to imply the effectiveness of the adopted UPS to produce the anticipated outcome. I use the term weakness to imply any setbacks that in one way or another affect the performance and achievement of the UPS's anticipated outcomes. In the next paragraphs I start describing the strengths of the adopted UPS, and their weaknesses will be described latter in other paragraphs.

Based on the strengths and weaknesses of the adopted UPS, interviewees responded differently regarding the continued use of UPS beyond the life span of Trans-SEC project. All the households covered by this study but one, acknowledged to continue using the Tied ridge and expanding the area under tied ridge practice after the life span of the Trans-SEC project. Farmers reported that using a pair of ox-ridger and plough, and being the oxen keepers will facilitate TR construction especially

when get more pairs of the equipment. Through different experiences on yields harvested from TR and flat land sample plots, farmers expect to harvest more yields if they receive good rainfall. Interviewees who will continue on using TR beyond the time frame of the project highlighted the strength of the adopted UPS as follows: a) TR conserve water for plants especially when there is low rainfall, b) plants grown on tied ridge do not dry quickly compared to those grown on flat land for a given period of drought, c) crops grown on TR produce more yields on the small area compared to crops grown on the same area under flat cultivation, d) TR farming practices is time consuming only during TR making but it makes weeding easier, and e) kitchen gardens provide a reliable source of diverse leafy green vegetables in dry season. Thus, even though TR are time consuming, farmers experiences more benefits adopting it than not.

Shortage of rainfall in the area was mentioned as the major impediment affecting achievement of the expected outcomes from the adopted UPS. Shortage of rainfall also affects the crops and livestock farmers' have as major economic activities to provide them with food and income. Rainy season starts in November and last until April, but usually last for three months only, and not successively. Low rainfall in the study area also affected the expansion of area under TR. One woman in FGD 2, said: "*Due to shortage and unpredictable rainfall we have not increased the area under TR practices beyond the testing sample plots*". To insist on how rainfall and pests affect crops production in the area; Daudi, a 52 years old man said: *"Bad weather conditions such as low rainfall and high temperature cause crops to dry in the field. Pests also affect the pearl millet at the flowering stage and reducing the amount of yield" (*Individual interview 19*).* One man in FGD 1, said, "*rainfall is the major challenge affecting agricultural activities in our area; for example, last year I grew six acres (2.43 hectares) of pearl millet and harvested only 80 Kilograms"*. The average amount of pearl millet production in the study area varies from 800 to 1200 Kilograms per hectares.

While respondents report that TR increases yields as compared to flat land cultivation, during my field visit it was observed that farmer do TR on small plots of land compared with flat land cultivation. Even if TR technologies are so productive, using it on a small area would not help farmers to harvest more yields, and achieve food availability and access. However, farmers explained that practicing TR on small area is due to hard work involved in TR making using hand hoes. An illustration example from Sara, a 32 years old woman, said: "*TR making is a high labor and time-consuming work; it need more time to cultivate the same unit area of land than if I was doing flat cultivation*" (Individual interview 27). A cautious word from this interviewee is that, "*if any farmer is not careful, he/she can*

keep on making tied ridges on one acre up to the end of the rainy season, and by that time no crops will be grown".

Another weakness highlighted by farmers to affect implementation and achievement of the expected outcomes of the adopted TR is that of inadequate tools for TR making. One woman in FGD 2, said: *"We got one pair of Ox-ridger and Ox-plough for ridge making by the project called Climate change adaptation"*. Chamwino district council promotes the climate change adaptation in the village (Farmers in Idifu village, 2018). One pair is not enough compared to the number of people who need it. It was supported strongly by another woman who said: *"We are 44 active people(household) in our production group, to make all of us use it, the shift for the last person would happen when rainy season is over. We would acknowledge to be supplied with more sets of tools as we keep oxen, this will facilitate TR construction".*

Another weakness highlighted by farmers to affect implementation of kitchen gardens is that of scarcity and quality of water used to irrigate the gardens. Eda, a 34 years old woman said: *"the sources of water for domestic use and irrigating the garden are located far from our homes. This affects the watering of the garden daily or weekly*" (Individual interview 4). One man in FGD 1, reported that the water available in this area has salt, and is not suitable for watering gardens. The use of salt water for irrigation increases salinity in the soil that could affect the pH of the soil; different crops grow healthier at a different level of pH. Women in FGD 2 and 4 reported that pests and diseases affect the productivity of the kitchen gardens. They mentioned animals such as chicken, pigs and goats destroy the gardens and eating the vegetables. Looking at the importance of the kitchen gardens to the farmers, the findings of his study show that some of the factors such as domestic animals mentioned to affect the kitchen gardens could be prevented through fencing to prevent entrance of animals.

5.3 Households' food availability and access changes over the year after the adoption of UPS

The two themes described below addressing the third research sub-question about the households' food availability and access changes over the years after the adoption of UPS.

5.3.1 Households' food availability and access changes over the year.

Farmers in all FGDs and 33 respondents' interviews, reported changes in the time of using their own produced food after the adoption and implementation of UPS in crop production. They mention that

the agricultural education they got through the Trans-SEC project helped them improve yields compared to the time before the project. John, a 64 years old man, said: *"Before the Trans-SEC, I used to harvest 540 Kilograms of pearl millet that I consumed for five months, after Trans-SEC I harvest up to 720 Kilograms of pearl millet that I use for 8 months" (Individual interview 24).*

On average farmers who adopted RWH using TR and kitchen gardens reported that the food from their own production met the household consumption need for six months from April to September before the adoption of technologies and practices. After the adoption of good farming practices in crop production, farmers consume their own produced food for eight months from April to November. The respondents reported April to October as months of higher food availability in the households. Food availability is low from November to March over the year. Furthermore, women and men in all four FGDs and individual interviews mentioned that during the period of hunger, children under five years of age, and lactating and pregnant women are more affected because they need nutritious food for growth and development of children. To add on that, women and men in FGD 1 and 2 agreed and insisted on that lactating women need nutritious food to breast-feed their babies, as without eating they cannot produce enough milk for their babies. Furthermore, one individual in FGD 1 said that: "*A pregnant woman needs a nutrient rich diet during this period, and when she misses it, it could affect the development of the fetus in her womb".* Respondents reported that the effect of lack of enough and balanced diet is more seen in children under the age of five years old and lactating women.

During the time of food shortage or no food in the households, respondents reported to adopt various coping strategies for ensuring food is available in the households. Strategies involved the use various forms of capital (natural, social, financial), migration, casual labor, skipping meals and eating less amount of food they need to eat. Individual interviewees reported to sell livestock and livestock products (cattle, chicken, goats, ducks, pigs, and eggs), selling of land, making and selling local brew, borrowing and asking for food from neighbors and relatives. Other coping strategies reported are: - to make and sell charcoal, sell firewood, transporting people on motorbike, iron smith (making and selling spears, knives, axes), masonry, and doing small business such as selling vegetables (table 2). Each household adopted strategies that were appropriate to it and that were different from other households'. For example, one individual interviewee highlighted that to borrow money or food from neighbors or relatives depends on social trust associated with collateral bonds for either land or livestock. Households with limited assets for collateral bonding were worse off in terms of accessing loan and borrowing food from neighbors and relatives. Households which were worse off, opt for

wage labor in the village and outside the region. Farmers reported that mainly men in the households do migratory labor, and women do so only to the nearby villages where they work and return home on the same day. The most coping strategies adopted by many households in the study area are casual labor, selling livestock and livestock products and collection and selling firewood.

Table 2. Coping strategies adopted by households in the study area during the time of hunger.

S/N	Type of coping strategy	Number of households adopted
1	Casual labor	23
2	Selling livestock and livestock products	12
3	Selling firewood	5
4	Borrowing money and food from neighbors and relative	4
5	Migrant labor	4
6	Doing small businesses	4
7	Skipping meal	3
8	Making and selling charcoal	3
9	Masonry work	3
10	Eat less amount of food than required	1
11	Selling land	1
12	Iron smelting	1
13	Making and selling local brew	1

Source: Author (February and March 2018)

5.3.2 Household's food diversity and nutrition knowledge

All focus group discussions and interviews mentioned that women are responsible for food preparation, firewood collection, fetching water, looking for vegetables and taking care of children. They are working with their husband in farm activities to produce food and cash crops. One man from FGD 1 reported that the household's nutrition training and kitchen garden promoted by Trans-SEC focused on women. After training women passed on the knowledge acquired to men in their respective households. Training covered issues of kitchen hygiene, preparation of food before cooking and preparation of balanced diets (composition of food). One woman in FGD 4 mentioned that *"Through training we learn to prevent nutrients loss from food during preparation; for example, to prevent vitamins loss from vegetables through partial cooking and covering them during cooking"*. Farmers in FGD 2 and 4 highlighted that knowledge on how to prepare the kitchen gardens is helping them to grow and eat other leafy vegetables they did not eat before the project. After the adoption of kitchen gardens farmers in this area, get green leafy vegetables from their own production (gardens and field) and from wild. Through kitchen garden and field plots, they grow leafy green vegetables including amaranths, chinese cabbage, legume leaves, spinach, sweet potato leaves, pumpkin leaves, okra, eggplants and tomatoes. Wild green vegetables identified and consumed in this area include

slippery vegetables, wild amaranths and wild sweet potatoes leaves. Women reported that through training they understood that green leafy vegetables are sources of micronutrients including vitamin A. The farmers' diets in the study area are mainly composed of cereal (millet, sorghum, maize) and relish composed of one or more of the following: green leafy vegetables, beans, meat, milk, and sardine. Diverse food intake is achieved by farmers through their own production and buying at the market foodstuff not produced from their fields and gardens. Buying food at the market depends on the resources owned by the household.

6. DISCUSSION

This chapter describes the implication of the findings of this study. I do it through looking at my findings in relation to the research questions and compare with findings of other studies in the literature review. The aim of this chapter is to discuss the perceptions and experiences of smallholder farmers in the study area on the roles of UPS to improve food security. In this chapter I discuss the three sections of the results which addresses the research sub-questions about 1) achievements of the anticipated outcomes from the adopted UPS in crop production, 2) strengths and weaknesses of the adopted UPS in crop production, and 3) households' food availability and access changes over the year after adoption of UPS.

6.1 Achievements of the anticipated outcomes from the adopted UPS in crop production

6.1.1 Agricultural interventions to improve smallholder rain-fed agricultural productivity.

The UPS adopted in crop production are RWH using tied ridges and kitchen gardens. On the TR and flat plots farmers practiced intercropping. As reported by farmers that through training on good agricultural practices (TR and kitchen garden) they expected to harvest higher yields and sell the surplus to earn income. Harvesting more crops produce increases food availability at the household level. The surplus produce is normally achieved when the amount of food needed by the household for consumption is attained. Surplus yields when obtained can be sold to earn income which could be used to meet other households needs. The income generated from agriculture becomes another important resource for improving household's access to food stuffs not produced and non-food expenditure such as health care.

As farmers mentioned, they have observed that using tied ridges increase the adaptation of crops to low rainfall through conserving water and making it available to the plants during the short period of drought than flat cultivation. Conserving water for the crop plant especially during the short period of drought increases the water use by the plant which can also influence the amount of yields. This finding agrees with the finding that shows that investments on RWH help to reduce agricultural production risk (Kato *et al.*, 2011), p. 602). Being able to conserve moisture during the short period of drought, adoption and use of TR should be part of famers' farming practices in the semi-arid area where rainfall is low and unpredictable. Farmers reported that despite the recognition of the importance of TR in terms of conserving water in the soil, the hard work involved with the construction limit their adoption to large plots of land.

Moreover, tied ridges help to improve soil fertility by reducing soil erosion through prevention of surface runoff of rainwater. Prevention of surface runoff of rainwater reduces soil erosion while increasing recharge of water in the soil. Increasing water in the soil makes water available to the crop plants for a short period of drought. This finding agrees with finding of Winterbottom et. (2013) which shows that RWH reduces rainwater runoff while increasing infiltration of water into the soil to improve water supply. Despite TR improving soil fertility and infiltration, it seems farmers are not benefitting enough from using it due to the shortage rainfall in the study area.

The field visit report shows that intercropping practices is done between cereals and legumes which is important for improving soil fertility and harvesting diverse produces. The intercropping practices are appropriate for smallholder farmers who cannot afford the cost of the chemical fertilizer to replenish lost nutrients in soil. The finding agrees with the finding of the study done by Nyantakyi-Frimpong *et al.*(2016) which shows that the integration of legumes on cereal based farming improves soil fertility and food diversity. The ability of TR to conserve water, prevent soil erosion, and the improvement of soil fertility through intercropping legume form the condition necessary for improving yields of smallholder farmers. Improving households' food production of smallholder farmers improve food availability, diet and nutrition of individual in the household (Herforth & Harris, 2014).

The adoption of kitchen gardens in the study area aims at increasing the availability and access of leafy green vegetables especially in dry season when they are scarce. The introduction of kitchen gardens in the study area seem to be beneficial to the gardeners and their customers by supplying

green vegetables within and beyond the village level. As previous mentioned, one of the respondents said kitchen gardens provide vegetables to both the gardeners and those not having gardens at the village level. Farmers reported that despite that water sources are located far away from their households, it is possible to irrigate kitchen gardens as they need little water. Another study shows that kitchen gardens can be practiced in area where water is scarce as they need little water than conventional ground gardens (Lambert et al., 2014). The introduction of kitchen gardens in the area with shortage of water is likely to be implemented as they need little water and help farmers to get diverse leafy green vegetables as expected.

6.1.2 Outcomes of UPS to improve food security and challenges of implementations.

Farmers reported that the criteria they use to assess the achievements of the anticipated outcomes of the adopted TR and kitchen garden is the amount of crop yields and income earned. These criteria are in line with the report by (IEG, 2011) which shows that crop yields and income generated from agriculture form the outcome indicators of the agricultural intervention to improve agricultural productivity. Moreover, the quantity of crops from the household's production affects food availability, access and agricultural income of that household. Based on experimental plots and limited expansion of TR for four years, farmers reported to achieve higher yields of pearl millet from tied ridge plots than flat plots of the same area. As discussed in the previous section, possible reasons for higher yields on tied ridges could be their ability to conserve rainwater, which becomes available to the crop plant during dry spells as well as improved soil fertility due to erosion control. This finding is in line with the report by Karpouzoglous and Barron (2014) which shows that, RWH techniques help to increase water use by plants while raising yields. Despite that the amount of crop yields from TR are reported higher than those from flat cultivation, the yields are not enough to meet household's food consumption needs partly due to poor performance caused by little rains, and partly due to that farmers have adopted TR on a very limited scale.

There are many reports on the effectiveness of RWH to improve food situation of smallholder farmers in semi-arid areas. According to (Kahimba *et al.*, 2014), much research done in semi-arid areas of Africa including Tanzania, show that in situ rainwater harvesting is effective to transform smallholder farming prone to dryness and help farmers to improve their food security. To mention few examples; Kahimba et al (2014) observed that TR improves maize yield by 224 kg/ha (from 1661kg to 1885kg) in sub-humid area, and millet yields by 670 kg/ha (from 660kg to 1330kg) and sunflowers yields by 794 kg/ha (from 632kg to 1426) in semi-arid areas in Tanzania. Another research by Mudatenguha

et al. (2014) in Rwanda shows that maize yields increases from 1593 kg/ha under flat cultivation to 3233 kg/ha under TR techniques. Despite the good news on the importance of the agricultural intervention to improve crop yields and food security and the farmers' experience, the finding of this study shows that the real food situation of the smallholder farmers who adopted the TR does not illustrate those achievements. While the mentioned studies report increases of yields on TR compared to FL, another report by Critchley and Gowing (2012. p. 36), shows that there are high returns from the experimental plots compared to those on farmers' fields.

Notwithstanding these results from the sample plots, many farmers reported to be food insecure at different levels of severity. In this situation, they do not produce enough food to meet their households' food consumption needs over the year. This may be due to high labor demanding in the construction of TR in the area where households do not have access to significant amount of labor. High demanding labor in construction of TR limit the practices of TR on large plots of land; small plots coupled with low rainfall could also limit the amount of yields harvested by farmers. The failure of harvesting enough of both food and cash crops by farmers means they did not earn income from surplus as expected. Agricultural income is important for ensuring households' food access and nutrition through expenditure on food and non-food items (Herforth & Harris, 2014). The finding of this study shows that agricultural income from the adopted TR was not realized by farmers in the study area. Food security is a multidimensional phenomenon; therefore, single UPS cannot solve all food security problems. However, it can contribute towards mitigation to address food insecurity. Harvests from TR has contributed to the increase of time farmers use their own produced food now compared to previous time before the adoption of TR as described in the next section on households' food availability and access over the year.

Women from the interviewed households report that kitchen gardens have improved the availability and access of diverse food stuff especially green vegetables during dry season when they are scarce. Through selling the surplus vegetables they earn little income that is spent on other household needs such as salt, cooking oil and soap. According to Barbier *et al.* (2009) investments in vegetables generate income quickly. Income generation from kitchen garden depends on many factors including the availability of reliable sources of water for irrigation. The finding of this study shows that high income has not been realized in this area and this may be due to low production because of scarcity of water, especially in the dry season. Even if kitchen gardens do not generate a lot of money in the study area, little money earned is controlled by women, and as such, it is empowering them.

6.2 Strength and weaknesses of the adopted UPS in crop production.

Farmers reported the benefits of TR and kitchen gardens which in this section I treat as strengths of these UPS. I treat the factors that in one way or another negatively affected the performance of the adopted UPS to yield the expected outcomes as weaknesses. As I have described in the previous sections, the strengths of TR are that they increase crop yields through conserving water for the plant and prevention of soil erosion. In addition to TR, kitchen gardens improve the availability and access to diverse food stuff especially leafy green vegetables in dry season when they are scarce. In the next paragraphs I discuss the weaknesses of the adopted UPS.

Farmers mentioned that low and unpredictable rainfall is the main challenge that hindered them from achieving their expectation, that is to improve their food situation through increased crops yields. The performance of adopted UPS also affected by low and unreliable rainfall in the study area. This finding agrees with the study by (Tumbo *et al.*, 2015) which shows that agricultural production in Tanzania is currently affected by a number of factors including climate change, pests and diseases and soil degradation. This means that agricultural intervention whose implementations depend on rainfall also affected by impacts of climate change.

However, TR is effective in conserving moisture at a certain duration of time, beyond which it will not be effective. This finding is supported by report of the study on RWH done by (Kahimba *et al.*, 2014) which shows that rainwater harvesting using TR conserve moisture 20% longer than flat cultivation up to two weeks of drought. Another study shows that the capacity of tied ridge to conserve moisture for the plants is up to four weeks of drought (Kahimba *et al.*, 2014; Oestigaard, 2016). The implication behind this is that RWH using TR depends on rainwater to be effective in increasing crop yields. The finding implies that TR act as a buffer, but do not solve the problems of intense drought. The findings of this study show that even if farmers construct TR on a large area, they cannot harvest enough food if it does not rain enough for crops to mature.

An additional reason for the farmers not being able to realize the fully potential of TR, is the practice of TR on the small plots of land. The farmer's field visit report shows that TR practice is mostly done on sample plots of one hundred square meters. Using TR on small plots will not yield enough produce even if it rains enough for crops to mature. Farmers reported that the reason behind use of TR on small plots is hard work involved in the construction of TR. This finding agrees with the report by Kahimba et al. (2014) which shows that to construct tied ridges on one acre (4,046 m^2) takes two weeks and to cultivate the same area on flat cultivation takes three for person working 8 hours a day.

The findings of this study show that due to hard work involved with TR making using hand hoes, farmers cannot practice TR on large plots of land if they do not use ox-ridgers. Therefore, the hard work involved with TR construction using hand hoes could be overcame using ox-ridgers. Failure to use ox-ridger to construct TR on large plots of land will not help smallholder farmers to harvest more yields even if it rains enough.

In addition to low and unpredictable rainfall, participants also reported low soil fertility, pests, and diseases to affect the production of food. Apart from water availability in the soil, the amount of nutrients required by plant in the soil influences the amount of crops yields. Though farmers were trained on the use of chemical fertilizer and cereal-legume intercropping practices, but they cannot afford the cost of chemical fertilizers. This means that they rely mostly on intercropping practices as a strategy to replenish nutrients in their fields. TR result into higher yields if is compounded with soil fertility improving techniques such as intercropping techniques than when practiced on infertile land. This finding agrees with the study by Winterbottom that shows that low soil fertility due to land degradation results in low crop yields particularly in Sub-Saharan Africa (SSA) (WINTERBOTTOM *et al.*, 2013). Famers' field observations report shows that farmers practice flat cultivation, which is exposed to surface water runoff taking away the top fertile soil through erosion and reduce water infiltration. Therefore, adoption of TR to reduce soil erosion and conserve moisture coupled with intercropping may help farmers to improve soil fertility and yields.

The weakness of the adoption and implementation of kitchen gardens in the study area is shortage and quality of water, and destructive animals such as pigs, chickens and goats. The distance between water sources and households was reported to affect the daily or weekly watering of the garden. Shortage of water could affect the supply of vegetables during the dry season the time in which they are highly needed. The distance between water sources could be addressed by investing in other sources of water such as drilled boreholes in the villages.

6.3 Households' food availability and access changes over the year after adoption of UPS

6.3.1 Households' food availability and access over the year.

The findings of this study show that the household's consumption time of their own produced food after the adoption of UPS changes over different seasons of the year. This could mean the use of tied

ridge; kitchen garden and intercropping increase the amount of food consumed by the household for a longer time than before adoption. This is also reported by the studies on agricultural intervention that shows that agricultural strategies in crop production provide smallholder farmers with yield stability and food, nutrition and livelihood security (Barron, 2004; URT, 2014). The increment in crops yields realized by farmers contributed to the changes in their food availability, access and the duration of consuming their own produced food. The change has reported based on the farmers' experience of working with Trans-SEC for four years. As reported in the results chapter, despite farmers to remain in food insecurity at different levels, on average, TR and Kitchen gardens have contributed to the increase in time of consuming their own produce food from six months to eight months. The increase of two months of using the households own produced food saves resources which could be directed to secure food during the rest of the year, as well as non-food household needs. Due to the variation in food availability and access over the year, farmers reported to adopt different coping strategies to ensure that food is available in the households. Coping strategies were adopted by farmers to prevent or reduce the prevalence of malnutrition especially in children under the age of five years, pregnant and lactating women in the households.

6.3.2 Households food diversity and nutrition knowledge.

Kitchen gardens increase food diversity especially green leafy vegetables during dry season when they are scarce. Green leafy vegetables are important for provision of micronutrients and improve nutrition status of the individuals in the households. Being the source of vitamin A, green vegetables help to prevent and control vitamin A deficiency especially in children and women of child bearing age (Codjia, 2001). During the women focus group, they reported that they generate little income from selling surplus vegetables produced from the kitchen gardens. The farmers' experiences on kitchen gardens shared in this study is drawn based on four years of implementing this UPS. This finding is not agreeing with the report which shows that investment on vegetables could help to build income as it generates cash quickly (Barbier *et al.*, 2009). The income realized by farmer in the study area is too little to be spent beyond small household's expenditures such as buying salt, soap and cooking oil. Little income from kitchen gardens may be due to low production caused by shortage and salt water in the study area.

The fact that women got nutritional education, manage kitchen gardens and being the ones responsible for food preparation in the households, makes it easier for them to prepare good diets. The production of green leafy vegetables coupled with knowledge to prevent loss of nutrients through proper handling

and cooking maximize the intake of vitamin A in the households. Food availability is not enough to achieve food security, the amount and nutrient content of the food consumed, and the way food has been prepared is also essential (Lambert et al., 2014).

7. Conclusion and recommendations.

In this concluding chapter, the main research question will be answered which reads;

How do smallholder farmers perceive and experience the roles of the adopted UPS (TR and kitchen gardens) to improve food security?

Adopting a qualitative research approach using case study design, I gained an understanding on the perceptions and experiences of smallholder farmers and the roles of the adopted UPS to improve their food security. The analysis and interpretation of the data collected show that the adopted UPS potentially can be effective in improving productivity of rain-fed smallholder farming by increasing the yields and help to improve their food situation. In this case study, the adopted UPS has increased the amount of yields, but not to the extent of driving farmers from food insecurity situation. The findings of this study show higher yield from TR plots compared to flat cultivation, this could be accounted for by the fact that the conserved water helps the crops to cope with the impacts of climate change (low rainfall and high temperature). However, the increase of yield from TR plots did not provide farmers with enough food to help them move out of food insecurity. 32 of the 33 households that had adopted tied ridges and or kitchen gardens still experience food insecurity at different levels. One out of all famers from 33 households moved from food insecure to food secure. Kitchen gardens increase source of leafy green vegetables in the study area especially in dry season when all wild plant consumed as vegetables become scarce.

Inadequate yields from the adopted UPS to meet households' food consumption needs may be caused by low and unpredictable rainfall that affect rain-fed agriculture in semi-arid areas including the study area. Low rainfall affects the implementation of UPS focusing to improve crops yields and food diversity for the households. Heavy work involved in tied ridges making using hand hoes could also have limited the adoption of tied ridge on large areas. Practices of TR on small plots of land cold not yield higher yields even if the area receives enough rainfall for crops to mature. The use of ox-ridgers could address the hard work involved in TR construction using hand hoes and enable farmers to apply the technology on a lager plot of land.

Implementation and achievement of expected outcomes from kitchen garden is affected by the scarcity and quality of water used to irrigate the garden. Domestic animals such as pigs, goats and chicken destroy the pocket garden which increased burden to it. Animals could be prevented through fixing fence around the gardens.

The combination of tied ridges and kitchen gardens has increased the availability of diverse food materials potential to improve nutrition status at the household level. The increase of diverse food is important in preventing and controlling malnutrition such as vitamin A deficiency. The adopted TR and kitchen gardens have not solved the problem of food insecurity in the area but contributed to the increase of food production and the time of food availability for the households by two months from six to eight months per year. Availability of diverse food from households' production are important for improving the diet composition, health and nutrition of households' members.

I recommend that the TR and kitchen gardens should be complemented by investing in other sources of water such as boreholes for supplemental irrigation, since dependency on rainfall alone may not yield the expected results. Incorporation of an aspect of tools to facilitate tied ridge making can improve yields and adaptation to the variation in rainfall happening in the study area. Despite of the reports from many researches that RWH transform smallholder farming in areas prone to dryness while improving food security, significant research gaps remain on how this technology really affect the food situation of vulnerable smallholder farmers. In this thesis, I have contributed knowledge towards these gaps by showing how smallholder farmers who adopted the RWH and kitchen gardens are still food insecure. More researches need to be done to explore the application of the UPS on farmers plots as compared to experimental plots, since such researches would capture the real food situation of smallholder farmers in semi-arid areas.

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Appendix I: Interview guide: Smallholder farmers in Idifu and Ilolo villages.

A. Opening interviews

- Name, age, gender, occupation and marital status.
- Relationship with head of household.
- Spouse's occupation and age, size of the households and number of children.

B. Main interviews

1. Food insecurity.
   - What do you understand about food insecurity? Have you experienced food insecurity for the past five years? At what level of insecurity?
   - What are the drivers and consequences of food insecurity in the household?
   - Which group of people (children, lactating and pregnant women, old people) are vulnerable to food insecurity in the household?

- What coping strategies do you adopt to secure food for the household when you have shortage or no food?
- What variety of food and cash crops do your household grow? Who is responsible for farming activity to produce food?
- What assets do you own?

2. Trans-SEC project
    - When did you know about and join the project?
    - Did you know the aim of the Trans-SEC project in this area?
    - What UPS did you adopt? What crops do you grow using this technology?
    - Are there any expectations you had from UPS and whether you have achieved them?
    - How do you compare yields before and after UPS adoption?
    - Have you identified any challenge that may have affected you to achieve your expectations from UPS?
    - What is the situation of food in your household compared to previous time before the Trans-SEC project?
    - How does time of consuming households' own produced food differ between now and previous time before Trans-SEC?
    - Which of the year do you consider months of high and low food availability?
    - Who got nutrition and kitchen garden training in the households?
    - Do you think you needed this training?
    - What are the advantages of this training particularly kitchen garden?
    - What is the current composition of your diet?

3. Food insecurity experience scale (Asked to women in the households). Adapted from (Ballard *et al.*, 2013), p .10).
   Now I would like to ask you some questions about your food consumption in the last 12 months. During the last 12 MONTHS, was there a time when:
    - You were worried you would run out of food because of a lack of money or other resources?
    - You were unable to eat healthy and nutritious food because of a lack of money or other resources?
    - You ate only a few kinds of foods because of a lack of money or other resources?
    - You had to skip a meal because there was not enough money or other resources to get food?
    - You ate less than you thought you should because of a lack of money or other resources?
    - Your household ran out of food because of a lack of money or other resources?
    - You were hungry but did not eat because there was not enough money or other resources for food?
    - You went without eating for a whole day because of a lack of money or other resources?

C. Closing the interview

- What do you suggest could be done to improve the performance of the project to make you achieve your expectation?