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Factors affecting sweet potato production in crop–livestock farming systems in Ethiopia

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Abstract

Sweet potato is a potential food security crop in the crop–livestock systems for subsistence small-scale farmers in sub-Saharan Africa. This study investigated social, ecological, and economic factors, as well as how livestock influence sweet potato production in the Southern Tigray and Wolayita zones in Northern and Southern Ethiopia, respectively. The research in each zone was stratified in low, middle, and high altitudes. Structured questionnaires were randomly distributed to 120 respondents; 60 in each zone, and 20 in each altitude. Nine informant interviews were conducted with researchers and local agricultural offices in the study areas. Informal interviews, transect walks, participation in planting, and discussions were also carried out during the two periods of fieldwork. Statistical Package for the Social Sciences (SPSS) was used to analyze the questionnaires. In both zones, results showed that pests and diseases, rain shortage, drought, and lack of adaptable cultivars for different conditions influences sweet potato production. In Southern Tigray, lack of knowledge about sweet potato and planting materials prevented farmers from planting the crop. In Wolayita, farmers have lost their sweet potato landraces. Livestock provided manure, draught power, and to supplement farmers' diets. This study suggests that Farmers Field School could improve farmers' knowledge, agronomical practices, and yield. A participatory breeding programs for drought-tolerant, high-yielding varieties, that are rich with nutrients, and resistant to pests and diseases is needed.

Introduction

Food insecurity and poverty are challenges many developing countries face. In particular, sub-Saharan African countries struggle with these challenges. Sub-Saharan Africa is more fragile to climate change than other regions because it depends on rainfed agriculture systems (Z. Ayele & Peacock, 2003; Kumar, 2016; Serdeczny et al., 2016). The majority of the population of sub-Saharan African countries are small-scale farmers who dominate the arable land in rural areas (Ellis, 2005). Most of these small-scale farmers integrate livestock with crops; known as crop–livestock farming systems. These systems provide food for 70 % of sub-Saharan Africa's population (Classens, Stoorvoget, & Antle, 2008). Crop–livestock systems enable farmers to use livestock for draught power, animal manure, and provide cash for purchasing various agricultural inputs such as seed and fertilizers when needed. Agricultural residues are used to feed the livestock (Herrero et al., 2010), and the crop–livestock system enables farmers to intensify the practice of intercropping and crop rotation to increase their production (Claessens, Stoorvogel, & Antle, 2008). However, in sub-Saharan Africa, crop–livestock farming systems are constrained by soil degradation, shortage of agricultural land, and lack of water resources. (Herrero et al., 2010). Ethiopia, like other countries in SSA, relies on agriculture to feed its population.

In Ethiopia, agriculture is the main source of livelihood for 80% of the population. The sector contributes to 42% of Ethiopia's gross domestic product (GDP) (Shiferaw & Holden, 1998). The country's unique location close to the equator provides bimodal rainy seasons (Mengistu, 2006), known as *Kiremt* and *Belg*. *Kiremt* is the main rainy growing season from June to September, and *Belg* is the short rainy season from February to May. The duration of these rainy seasons varies throughout the country. Therefore, rainfed agriculture dominates most of the farming land in the country. (Tilahun, Teklu, Michael, Fitsum, & Awulachew, 2011). This farming land produces a variety of crops during these seasons.

Ethiopia's crop diversity is present throughout the country. The main cultivated crops are cereals, grains, pulses, oilseeds, vegetables, perennial crops (chat, coffee, hops, and all fruit trees), enset, and root crops (CSA, 2015). Teff, wheat and barley are the main staple crops in the north (Corbeels, Shiferaw, & Haile, 2000), whereas maize and enset are main staple crops in the south (Olango, Tesfaye, Catellani, & Pè, 2014). Newly emerging root crops, like sweet potato, require few inputs, have high dual nutrition and energy values for both human and livestock (Claessens et

al., 2008), as well as the ability to perform well under different climatic conditions in different agro-ecological zones[1]. Moreover, orange-fleshed sweet potato is a good source of vitamin A (Low et al., 2007). Thus, these distinctive capabilities classify sweet potato as a food security crop (Kivuva, Musembi, Githiri, Yencho, & Sibiya, 2014).

Sweet potato *(Ipomoea batatas* **(L.) Lam.***)* is the seventh most important food crop in the world after wheat, rice, maize, potato, barley, and cassava. Furthermore, it is the second-largest root crop in the world after potato. In Africa, it is one of the most important food crops, especially in sub-Saharan African countries, where it is the third-most important root crop after cassava *(Manihot esculenta)* and yam (*Dioscorea spp*.) (Woolfe, 1992). In Ethiopia, sweet potato is the second-most important root crop in the country after enset. It provides a healthy diet for millions of people across the country (Gurmu, Hussein, & Laing, 2015). Moreover, it is commonly cultivated as an integrated crop, along with livestock, in the crop–livestock farming systems (Belehu, 2003). Nationalities and Peoples' Region (SNNPRS) and Oromia are the main regions that produce sweet potato in Ethiopia (Gurmu et al., 2015). However, Ethiopia's average sweet potato storage yield is low with 8 t/ha, although the potential yield is 30 - 73 t/ha, and the international average is 14.8 t/ha (Belehu, 2003; Kivuva et al., 2014).

Sweet potato has wide ecological adaptabilities which enable the crop to perform well under poor soil conditions. Therefore, small-scale farmers can grow sweet potato in poor soil with little or no fertilizers (Karyeija, Gibson, & Valkonen, 1998). However, temperature impacts upon sweet potato's growth. The optimal growing temperature is 24°C (Gajanayake, Raja Reddy, & Shankle, 2015). Therefore, low temperature at high altitudes causes frost, and high temperature at low altitudes reduces the crop storage root production (Belehu, 2003). Moreover, high potassium supply (Bourke, 1985) and good soil aeration conditions have been demonstrated to encourage storage root formation (Agbede & Adekiya, 2009). However, many other factors affect the crop production in the sub-Saharan Africa region. Ecological factors include abiotic elements such as climate variability, which leads to dry spells due to insufficient rains. The 15% decline in precipitation in the region since 1980 (Funk et al., 2008) has hindered economic growth and disrupted incomes (Davidson & Janssens, 2006; Dercon, Hoddinott, & Woldehanna, 2005; Kumar,

[1] In Ethiopia, agro-ecological zone is the climatic conditions based on different factors such as elevations, soil, rainfall, and locations (Mengistu, 2006).

2016). Furthermore, biotic factors such as plant pathogens, diseases, and pests destroy many crops every year.

Ecological factors that can lead to poor yield also include technical limitations such as poor land preparation, lack of high-yielding varieties that can adapt to different climate conditions, poor harvest management, and bad post-harvest management (Belehu, 2003; Woolfe, 1992). Additionally, soil compaction reduces the air and water movement in farming soils, which eventually leads to water-logging problems (Hamza & Anderson, 2005). Economic limitations to sweet potato include poverty, poor market, lack of transport infrastructure, as well as lack of government investment in agriculture, research, and policies that help local production. Current agricultural policies are not in favor of supporting small-scale farmers (Amjath-Babu, Krupnik, Aravindakshan, Arshad, & Kaechele, 2016). Social factors, such as population growth, continue to expand and put pressure on the farming land leaving the soil with no time to recover (Funk et al., 2008, Ramakrishna et al., 2002). Thus, all these factors reduce the sweet potato storage root yield production (Kivuva et al., 2014).

Just as with other crops, sweet potato production faces many challenges. The aforementioned ecological, economic, and social factors make the crops of poor small-scale farmers vulnerable to failure (Belehu, 2003; Gurmu et al., 2015). Due to lack of knowledge, and research capacity building projects in sweet potato production in the crop–livestock farming system, the Norwegian Agency for Development Cooperation (NORAD) funded a 5-year project which started in 2013. The project, "Controlling diseases in sweet potato and enset in South Sudan and Ethiopia to improve productivity and livelihoods under changing climatic conditions using modern technology", is a cooperation between the Department of Plant Sciences at the Norwegian University of life Sciences (NMBU), Juba University (South Sudan), Hawassa University, and Mekelle University in Ethiopia (NORAD, 2013). This paper is part of the research and uses a holistic agroecology (Francis et al., 2003) approach to investigate and explore the social, ecological, and economic factors that impact upon sweet potato production in three agro-ecological zones in Ethiopia. Therefore, the study in this paper contributes to the sweet potato knowledge that deals with different challenges hindering the crop growth in Ethiopia. This paper asks the following research questions: What are the main social, ecological, and economic elements

affecting sweet potato production in the study areas? What role do livestock play in sweet potato production in the crop–livestock farming system?

2.Materials and methods

2.1 The research areas

Six research areas were chosen with varying altitudes in both the southern and northern parts of the country. The south is more suitable for root and tuber crops while the North is traditionally known for productivity of cereal crops. The Tigray Agricultural Research Institute has recently introduced orange-fleshed sweet potato to the Tigray region in Northern Ethiopia, in order to tackle vitamin A deficiency among children (Kidane, Abegaz, Mulugeta, & Singh, 2013). Three altitudes - low, middle, and high - categorize the country into different agro-ecological zones, which strongly influence crop choice and farming practices. An on-going project in the same research areas investigating ultraviolet (UV) radiation's effect on different sweet potato cultivars started in 2015. These research areas are divided equally into two zones, and provided the basic information for this present study.

The Southern Tigray zone (12°15′ to 13°41′ North, 38°59′ to 39°54′ East) was selected because it produces the most sweet potato in the Tigray region. The zone was stratified to low, middle, and high altitudes. Three districts (*Woredas*) with different altitudes in each of the three agro-ecological zones were targeted. One Peasant Association (PA), the lowest administrative unit in Ethiopia, known as *kebele*, was targeted in each district because they were easily accessible: Gerjale PA in the Alamata district is in the low altitudes (*Kola*) with elevation of 1400 meters above sea level (m.a.s.l) (Yirga, 2010); Zata PA in the Ofla district represents the middle altitudes (*Woinadega*) with elevation of 1500–2300 m.a.s.l; Simret PA is in the Maychew district at the high altitudes (*Dega*)**;** 2300 m.a.s.l. These three districts are on Ethiopian Highway 2 on the main road to Addis Ababa, and they are accessible by public transport.

The Tigray region in northern Ethiopia has one of the driest climates, albeit with erratic rains, in the country (Di Falco, Chavas, & Smale, 2007). The region relies on rainfed agriculture to feed most of its population. However, in the last thirty years, rainfed agriculture in Tigray has been significantly affected by local dry spells and erratic rains more than other regions in the

country (Abrha & Simhadri, 2015). Also, over 50% of the soil is extremely depleted (Di Falco et al., 2007). Therefore, famine and drought occurs more often in the region, and farmers struggle to sustain their agricultural production (Abrha & Simhadri, 2015). Nevertheless, farmers' livelihood can vary between short distances in the region depending on, for example, the soil and climate.

The soil and climate of Tigray are suitable for a variety of crops. The region has several types of soils because of different climates and morphological soil diversity. The main soil types are *Vertisols*, *Letosols*, and *Calcisols* (Rabia et al., 2013) . Farmers cultivate teff, sorghum, pulses, different kinds of vegetables and fruits in low altitudes, whereas wheat, barley, and legumes are grown in high altitude areas (Rabia et al., 2013). Crop–livestock farming is the dominant system. The bimodal rainfall provides the region with an average of 663 mm of rainfall annually (Giday & Ameni, 2003; Yirga, 2010). Cattle, sheep, goats, donkeys, horses, chickens, and camels are the main livestock in the Southern Tigray zone. Livestock are used for draught power, transport, and manure. Additionally, livestock provide an extra source of income for many families, where 85 % of the population live in poverty (Abay, Waters-Bayer, & Bjørnstad, 2008; Gebremedhin, Pender, & Tesfay, 2004). However, the southern part of the country is quite different.

The Wolayita zone is in Southern Nations, Nationalities and Peoples' Regional State of Ethiopia (SNNPRS). Most the residents belong to the Wolayita Ethnic group, and their Wolaytta language is the dominant one. Wolayita zone was stratified based on altitudes to low, middle, and high altitudes. The Humbo and Sodo Zuria districts were selected for this study. One PA (Gerjale) in the Humbo district at low altitude was selected, and two PAs (Kokate1 and Kokate 2) at Sodo Zuria district at middle, and high altitudes, respectively. These PAs were targeted because they were easily reached by public transport. The Wolayita zone in SNNPRS is one of the highest sweet potato production zones in the country, and altitudes vary from 1200 to 2500 m.a.s.l. Wolayita is located between 6º51″ and 7º35″ North, and 37º46″ and 38º1″ East. It is one of the most densely populated zones in Ethiopia, with a population of over 1.7 million, and with 290 inhabitants per km^2 (Tekola, Mariam, & Davey, 2006). Consequently, the land holding size is relatively small and most inhabitants are subsistence farmers. The landscape varies from plains, valleys, and small hills, to high mountains areas(Kebede, Mekonnen, Wossene, & Tilahun, 2009).

Crop–livestock farming systems dominate the region. Farmers practice small-scale home gardening with mixed crops, supported with livestock. This diversified system is based on enset

(Ensete vintricosum) cultivation and combinations of maize, sweet potato, banana, legumes, coffee, and teff. It also includes tubers and root crops such as taro, yam, cassava, and different vegetables (Beyero, Tolera, & Abebe, 2010; Gurmu et al., 2015). Enset is cultivated as a staple food and used for animal feeding during the dry season. The main livestock are cattle, goats, sheep, poultry, and donkeys. Cattle is the dominant type of livestock, and oxen provide draught power for land preparations during planting time, and for threshing of cereals such as maize, teff, and wheat during harvesting time. Moreover, livestock also provide manure and generate extra income from by-products such as milk, meat, skins, and the sale of live animals (Beyero et al., 2010) .

Subsistence farmers rely on rainfed agriculture to sustain their livelihood (Devereux & Sussex, 2000). High rainfalls during the bimodal rainy seasons (*Kiremt* and *Belg)* are distributed for 8–10 months throughout the year. The main rainy season (*Kiremt*) is from May to September, and the short rainy season *(Belg*) is from February to April (Geta, Nigatu, & Animut, 2014). Therefore, temperature varies between 15 °C and 20 °C, with high annual rainfall ranging between 800 mm and 1400 mm (Hailesilassie, 2015). *Nitisols*, dark brown soils that contains 35–50 % clay, cover most of the farmland (Buni, 2015; Tolera & Said, 1992). The total land size is 48,125 ha, of which approximately 58 % (27,687 ha) is used for crop production (Kiflu & Beyene, 2013).

2.2 Methods

Mixed methods, consisting of quantitative and qualitative approaches, was used during the research period. A quantitative questionnaire was distributed to randomly selected farmers, followed by a small number of qualitative in-depth interviews of informants from research institutions, local agricultural offices, and researchers working in the study areas. In addition, informal interviews, transect walks, participation in planting, and discussions were used during two field visits in August and October, 2016.

A five-page structured questionnaire (Appendix 1) was distributed by using random sampling in each research area of low, middle, and high altitudes, respectively. The questionnaire focused on the social, ecological, and economic aspects of the crop–livestock farming systems. This included farmers' gender, family size, farmers' education level, land holding size, off-farm income, sweet potato's economic value, farm diversification, crop rotation, soil management, sweet potato cultivars, pesticides, fertilizers, and livestock's role in the farm.

In Southern Tigray, sixty questionnaires were distributed in three districts, 20 in each of the three PAs (Table 1).

***Table 1**: Total household numbers and sweet potato farmers in the three selected agro-ecological zones in the Southern Tigray region, north Ethiopia*.

Altitude	District	Peasant association (PA, *kebele*)	Total household numbers	Number of sweet potato farmers
Low	Alamata	Gerjale	2066	46
Middle	Ofla	Zata	2265	0
High	Mychew	Simret	1643	10

Source: from GRAD project, Relief Society of Tigray and the districts (*Woredas)* offices of Agriculture.

In the Wolayita zone, sixty questionnaires were also distributed in the two districts, 20 questionnaires in each of the three PAs (Table 2).

***Table 2**: Total household numbers and sweet potato farmers in three selected agro-ecological zones in the Wolayita Zone, Southern Ethiopia.*

Altitude	Districts (*woreda*)	Peasant associations (PA, *Kebele*)	Total household number	Sweet potato farmers
Low	Humbo	Ambe shoye	575	210
Middle	Sodo Zuria	Kokate 1	145	123
High	Sodo Zuria	Kokate 2	102	35

Source: districts (*Woredas)* offices of Agriculture.

Time, political instability, and language barriers constrained the research methods and sampling size. Political instability during the second phase of fieldwork in October, when roads were blocked by protesters in the southern region, made it unsafe to travel. The government declared a state of emergency (on 9th of October 2016) for six months, blocked the internet and social media, and established security checkpoints on the main highway. Therefore, data collection was delayed for more than ten days until the roads were safe to travel, and focus group discussions

were cancelled. Most farmers cannot speak Amharic, the official language, and none of them can speak English. Farmers in the research areas speak Tigringa and Wolaytta languages in the north and south, respectively. Thus, translators were hired to communicate with the farmers.

The questionnaires were pre-tested and pre-coded before conducting the interviews. Eight randomly selected farmers were interviewed for questionnaires' pre-testing, as well as discussions with agricultural extension officers (known as Development Agents in Ethiopia), researchers, and local sweet potato experts. Also, visits to the research areas, including transect walks in each agro-ecological zone, took place during the first fieldwork trip from 08.08.2016 to 24.08.2016, to ensure that all the information is relevant to the sweet potato production.

Before distributing the questionnaires to farmers, the interviewers were trained. Five local interviewers from the research area were trained during the first fieldwork in August. The questionnaires were modified after pre-testing and feedback from farmers, interviewers, and extension officers to get accurate information for the interviews and interviewees. Therefore, during the data collection time from August to October, interviewers collected and translated the questionnaires from English to the local languages, and filled out the questionnaires for the farmers because of the high illiteracy rate among farmers, (Z. Ayele & Peacock, 2003). In addition, three interviewers were observed, assisted, and supervised during data collection of sixty questionnaires in the southern region during the second fieldwork in October, 2016.

A second stage of qualitative informant interviews were used to gather a wide range of information from researchers in the research areas. Nine face-to-face informant interviews, covering each research area, were conducted with sweet potato experts working in research institutions and local agricultural offices (Appendix 3). The interview time was 25 to 30 minutes. These informant interviews were conducted in English after the questionnaires were collected during October 2016, except one interview that was conducted with help from a local interpreter. Five interviews were recorded, and notes were taken during all the nine interviews. The rest of the interviews were not possible to record because of the interviewees' tight schedule. However, these interviews were supplemented by short discussions before and after filling out the informant interview forms; a more detailed description can be found in Appendix 2.

Statistical Package for the Social Sciences (SPSS), version 24, was used to analyze the questionnaires through descriptive statistics (percentages). Informant interviews were transcribed,

organized, and coded. Then themes, suggestion, and quotes from these informant interviews were used in this study.

Results

In Southern Tigray and Wolayita zones, demographic factors varied for farmers (Table 3). Most sweet potato respondents were male, with a median age of 42 and 41 years in Southern Tigray and Wolayita, respectively. Most of the farmers were married, and the average number of children was five per family. Moreover, the farmers' education was different between the two zones. In Southern Tigray, both men and women were responsible for the farm work, from seedbed planting to harvesting. Whereas, in housework, half the respondents stated that women were responsible for cooking, cleaning, and taking care of the children, while forty percent stated that both men and women did these tasks. In some families, children also contributed to housework.

Table 3. *Demographic characteristics of respondents in the Southern Tigray and Wolayita zones (%).*

Items/Characteristics	Southern Tigray	Wolayita
Gender (%)		
Male	75	88
Female	25	12
Marital status (%)		
Married	90	93
Widowed	3	5
Single	3	2
Divorced	4	0
Education (%)		
Illiterate	55	30
Primary	28	50
Read and write	10	5
Secondary education	7	15
Farm work (%)		
Men	20	80
Women	13	5
Both	60	12

In the Wolayita zone, men were mainly responsible for the farm work (Table 3), while most of the respondents reported that women were responsible for the housework. However, in both zones, women and children contributed to sweet potato harvesting because the crop was harvested on demand.

Farmers diversified their cropping systems in Southern Tigray with an average of 2.5 crops per season, and they were distributed throughout the three altitudes. The main crops were maize, sorghum, barley, wheat, teff, vegetables, and legumes. Farmers did not intercrop sweet potato with other crops due to their lack of experience in cultivating sweet potato. Furthermore, only 18% of the respondent farmers intercropped other crops such as soybean, pepper, and tomato with sorghum and maize for ecological and economic benefits. In Wolayita, the average number was 4 crops per season. The most common crops were enset, wheat, teff, maize, barley, legumes (fava beans, haricot beans, and mung beans), coffee, banana, and taro. In the low altitude, farmers intercropped maize with mung beans to maximize land use and increase soil fertility. The majority of the farmers in this case also did not intercrop sweet potato with other crops because they had previously experienced lower yield. Thus, only 11% of the farmers intercropped sweet potato with crops such as fava beans, haricot bean, coffee, enset, and cassava to save planting materials for the next planting season.

Tigray Agricultural Research Institute introduced sweet potato to the region after an adaptation trial on eleven sweet potato varieties. The trial identified two orange-fleshed sweet potato varieties, *Tula* and *Kulfu*, which could adapt to the local climates**.** The Tigray Agricultural Research Institute produces "disease-free" sweet potato cultivars to give to The International Potato Center and donor organizations such as The Relief Society of Tigray. In addition, the Better Potato for a Better Life project is run in association with Tigray Agricultural Research Institute, The International Potato Center, Bureaus of agriculture, and other partners, to encourage and distribute orange-fleshed sweet potato varieties to farmers. Another organization, Mums for Mums, works to promote orange-fleshed sweet potato by organizing mobile kitchen demonstrations with easy recipes for farmers. They also run training for farmers on how they could produce cutting materials from vines, cooking demonstrations, nutrition education, radio programs, and school feeding programs. Moreover, The International Potato Center works with The Seed Systems Community of Practice as part of the Sweet Potato for Profit and Health

Initiative (SPHI) to reduce child malnutrition in the region. SPHI enables Tigray Agricultural Research Institute to connect with East African sweet potato experts.

In Southern Tigray, the respondent sweet potato farmers cultivated *Tula,* and *Kulfu* because of their nutritional and high-yield values. In the low altitude, all the respondents cultivated sweet potato in small parcels, with an average of 177 m^2 /farmer. While, in the middle altitude, none of the respondent farmers planted sweet potato because they did not receive planting materials from donor organizations. In the high altitude, 30 % of respondents cultivated sweet potato, with an average of 933 m^2/farmer. In the low altitude, extension officers visited all the sweet potato farmers regularly, while they only visited 50% of them in the high altitude. However, the majority of the respondent sweet potato farmers obtained planting materials from local agricultural offices as opposed to other sources (Figure 1).

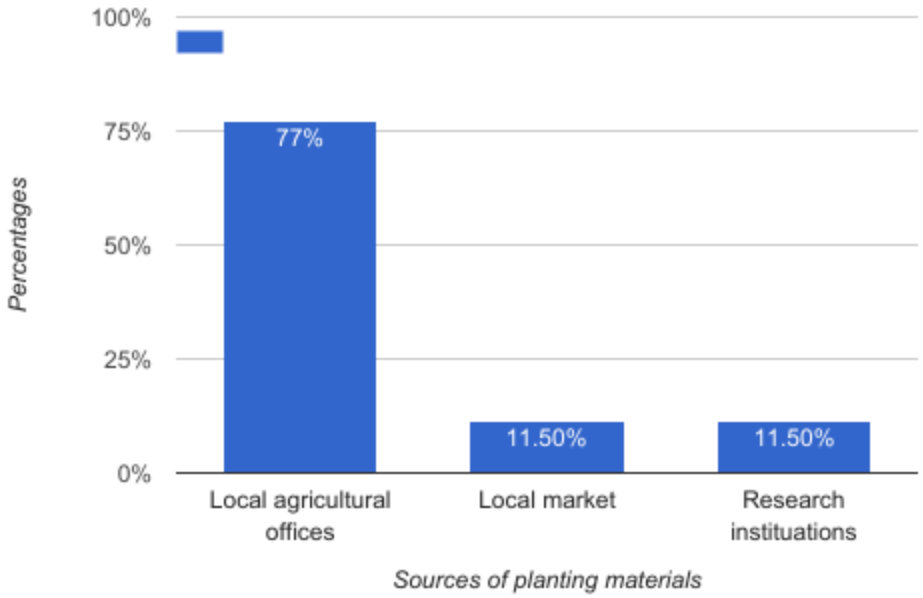

Figure 1: Sweet potato planting materials sources in the Southern Tigray.

Awassa Agricultural Research Center, The International Potato Center, and Hawassa University were the main sweet potato experts in Wolayita. Occasionally, these institutions shared sweet potato knowledge with local agricultural offices and extension officers. Extension officers visited 80 % of the farmers twice a year during planting time to distribute fertilizers, or seeds, but not specifically to help and advise the sweet potato farmers. Researchers and extension officers

shared their knowledge of different crops with farmers through training, development of brochures and manuals in Amharic and other local languages, and field demonstrations. In Areka Agricultural Research Center (located in Wolayita) there were no researchers working on sweet potato. Extension officers working at Farmers Training Centers were present in all the research areas. However, their services were limited due to tight government budgets and they lacked up-to-date knowledge to assist sweet potato farmers.

White-fleshed sweet potato varieties *Hawassa-83* and *Nechi, Kulfu, Tula, Pino,* and *Guntute* orange-fleshed sweet potato varieties were the traditional common ones in the zone. However, all the respondent farmers planted only *Hawassa-83* (*Gadisa*). This variety was cultivated in small plots of land, with an average of 0.08 ha/farmer, whereas the average total land holding size in the zone was 1.25 ha/household. Reasons for planting this cultivar were that it is high-yielding (75%), adaptable to the local climate (10%), no other cultivars were available (8.3 %), and has a high nutritional value (5%). However, farmers got their planting materials from different sources including exchanging planting materials with neighbors (Figure 2).

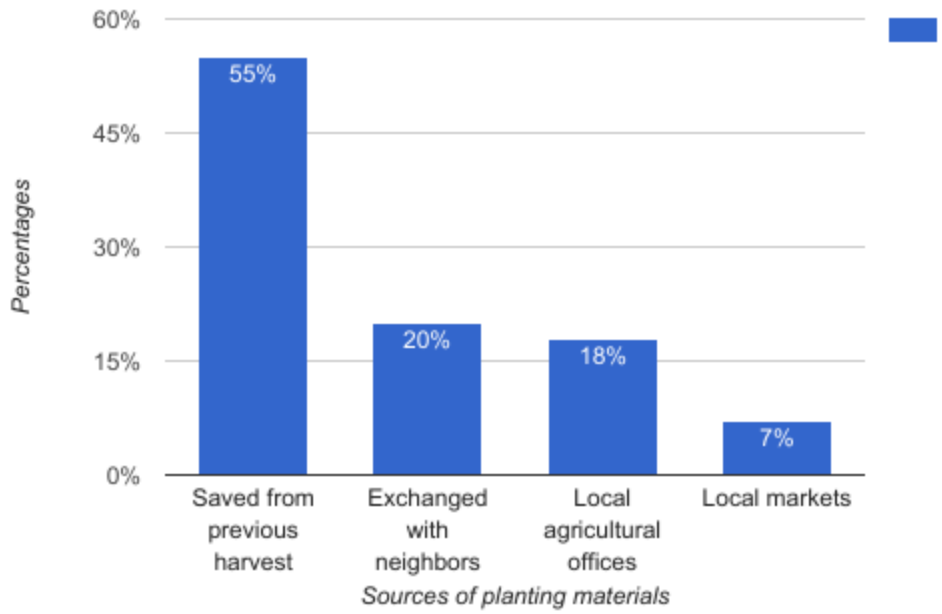

Figure 2: Sweet potato planting materials sources in the Wolayita Zone.

In the research areas, farmers use different practices and methods for sweet potato farming. These practices include the use of hand tools like shovels, mattock, and hoes in smaller land sizes,

while they use oxen in bigger plots to prepare the soil for planting. In Southern Tigray, planting time is once a year in the main rainy season during June and July. Sweet potato farmers cannot save sweet potato vines for the next planting season because of the long dry season. In Wolayita, farmers plant sweet potato twice a year, at the beginning of the main rainy season in April and May, and after harvesting of the main crops in *Meher*[2] season in October and November. This enabled many Wolayita farmers to save planting materials after harvest by planting sweet potato vines near their homes (home garden) during the dry season and, thus, to keep planting materials for the next planting season. In both study areas, weeding and harvesting is done manually. Farmers do not use chemical fertilizers or pesticides. Instead, they use combinations of crop rotation, animal manure, and crop residues to maintain soil fertility. However, fertilizers (DAP[3] and Urea) and pesticides are applied to other crops such as wheat, teff, maize, and sorghum. Some of the sweet potato farmers in Wolayita use a mixture of old cow dungs as pesticides by splashing the mixture on affected sweet potatoes' leaves. Those who did not cultivate sweet potato in middle and high altitudes gave different reasons for not doing so (Figure3).

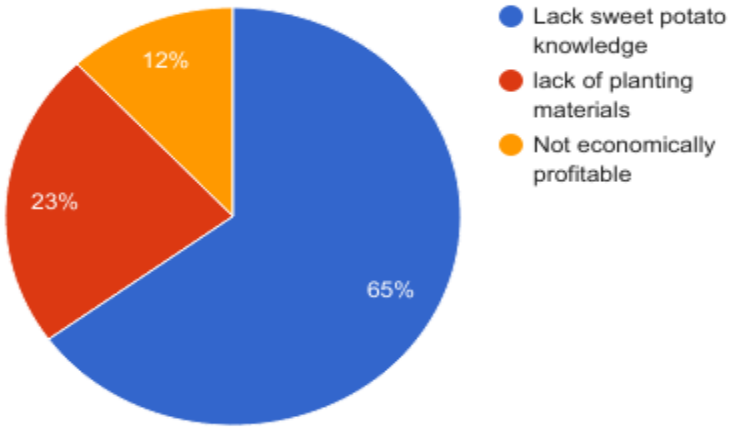

Figure 3: Farmers' reasons for not cultivating sweet potato in Southern Tigray

[2] Is the main harvesting season (Bewket, 2009) starting from September and can last until February. The duration of this season can vary throughout the country.
[3] Diammonium phosphate fertilizer.

In Southern Tigray, 93% of the respondent farmers experienced production problems (Figure 4). In the erratic rainy season, sweet potato performed better than Irish potato and wheat, whereas sorghum, barley and maize performed better than sweet potato. Farmers used diverse techniques to cope with lack of precipitation; 38.3 % used supplementary irrigation, 21.7% planted different cultivars, 15% planted tree traces to capture the runoff water when it rains, 8.3 % harvested water, 5% planted different crops, and 11% did nothing. Moreover, some farmers combined two or three techniques to tackle the lack of rainfall. However, only one-third of the farmers faced a water-logging problem during the rainy season. Thus, farmers used traditional drainage systems to dispose of surplus water, and applied manure to loosen the soils for crop cultivation.

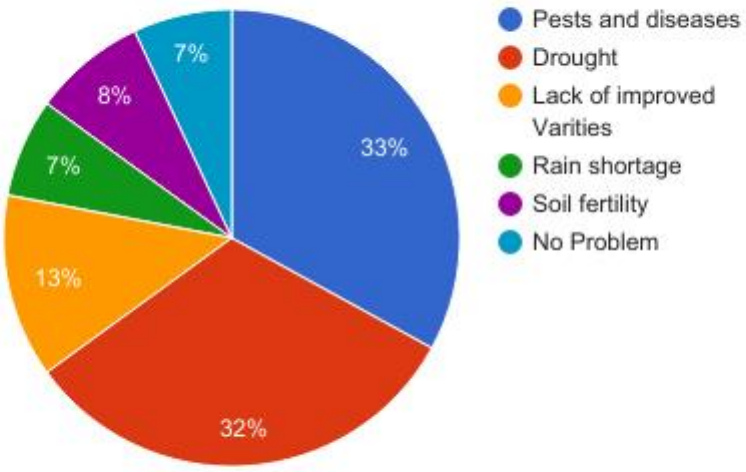

Figure 4[4]: Distribution of the production problems among the sweet potato farmers in Southern Tigray zone.

Figure 5 shows the main production problems in the Wolayita zone. In both zones, farmers found it difficult to prioritize the main production problem among the production problems they

[4] Drought in this study describes long periods without rain at all and is more serious than lack of precipitation.

had in their farms. In response to lack of rainfall, 57% did nothing but wait for the rains, while 30 % used the traditional method for coping with the rain shortage period. The traditional method implied the use of oxen for land tillage, and covering the soil surface with plant leaves (mulch) during the rainy season, to keep the soil moisture for longer times. Moreover, 73% of the respondents reported that the main rainy seasons were severely difficult for root crops production. 32% of the farmers had a water-logging problem. Therefore, farmers planted different crops and used drainage systems to remove the surplus water.

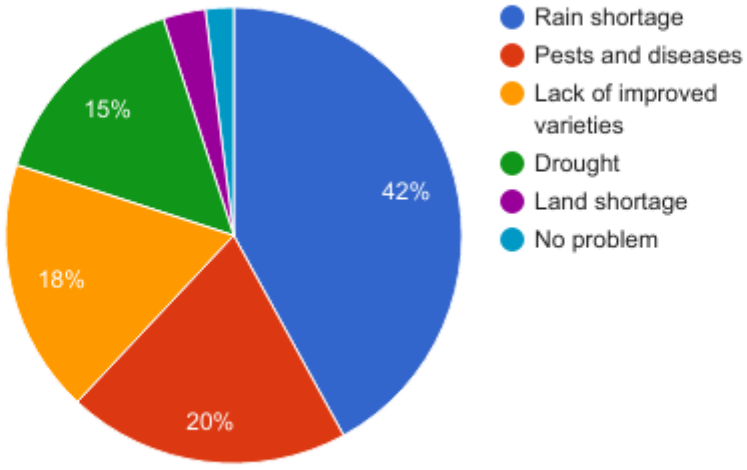

Figure 5: Distribution of the production problems among the sweet potato farmers in Wolayita zone.

In both research areas, the farmers did not rely solely on sweet potato production to sustain their livelihood. Therefore, 45% and 25 % had off-farm jobs in the Southern Tigray and Wolayita, respectively. These jobs were in daily labors, petty trade, and handicraft. Sweet potato farmers did not know how much they harvest or the amount they consume. The crop obtains a poor price on the markets and lacks consumer interest. Moreover, farmers did not sell sweet potato vines to other farmers. In Southern Tigray, farmers do not know how to cultivate, process, and eat sweet potato. Therefore, they were unwilling to use part of their land to cultivate sweet potato, which is cultivated only for household consumption. In Wolayita, farmers also consumed most of their

production, and sold any surplus to the local markets. It is common that women sell boiled sweet potato in the roadsides in nearby cities during night time.

Livestock play an important role in the farming system in the study areas. Most of the farmers owned livestock. Types of livestock found in the research areas are presented in Table 4. Livestock and poultry products like milk, meat, egg, and butter were used for household consumption, and sold at markets. Moreover, famers used animal manure from livestock as organic fertilizer to fertilize their soil. Farmers fed their livestock with a combination of free grazing, cut-and-carry, and crop residues. The most common crop residues were enset, sorghum, teff, barley, maize, and wheat. However, lack of animal feed hindered animal production by 61%, and 35%, in the Southern Tigray and Wolayita zones, respectively. In Southern Tigray, a quarter of sweet potato farmers used sweet potato roots, leaves, and vines for animal feed. In Wolayita, two-thirds of the sweet potato farmers used sweet potato leaves and vines for animal feed during the dry season.

Table 4. *Type of livestock in the Southern Tigray and Wolayita zones (%).*

Type of livestock	Southern Tigray	Wolayita
% of farmers with livestock	88	83
Cow	63	75
Oxen	48	90
Bull	18	45
Chicken	50	75
Goat	17	20
Sheep	43	50
Donkey	13	48

Discussion

The high average number of five children per family indicates high population growth in the research areas. This decreases the farming land in general, and probably farmers' ability to allocate land to sweet potato farming. In contrast, most of the sweet potato agronomic practices require hand labor. Therefore, it is possible that family members could help with these tasks during any stage of the crop growth. Population growth is evident in most of the research areas, especially in Wolayita zone (Abebe, Wiersum, Bongers, & Sterck, 2006). The average birth rate in the country is 4.8 births per women, and it is higher in the rural areas(Ayele,2015). The sweet potato farmers' average age (42 years in Southern Tigray and 41 years in Wolayita) suggests that they can work for many years, which may boost the crop production in the long term.

Illiteracy rate among Southern Tigray farmers is higher than Wolayita farmers (Table 3). This could influence Southern Tigray farmers' ability to adopt new varieties and crops such as sweet potato, and their agronomical practices. A study by Epeju (2005) in Uganda showed that farmers with formal education could deal with production problems better than uneducated ones. Moreover, Southern Tigray farmers have a higher percentage of off-farm jobs than Wolayita farmers. This may suggest that Southern Tigray farmers are more vulnerable to climate variability, drought, and soil degradation. Therefore, these farmers could leave their farming land, and move to big cities to look for jobs. Wolayita farmers rely on perennial crops to protect the farming land from erosion, and high bimodal rainfalls that enable them to grow crops throughout the year (Beshah, 2003).

In Southern Tigray, both men and women take farm responsibilities (Table 3). However, Southern Tigray women are involved in the sweet potato farming more than Wolayita women. This may be due to their awareness of the health benefits of orange-fleshed sweet potato for their children, which is promoted by extension officers and NGOs to women in the Tigray region. A study by Low et al. (2007) in Mozambique showed that orange-fleshed sweet potato have a high level of vitamin A content that could reduce malnutrition in children. In sub-Saharan Africa, women are the main sweet potato cultivators in small pieces of land, which gives them extra money to help their families (Claessens et al., 2008; Karyeija et al., 1998). In Wolayita, the women' s role in sweet potato production is limited to harvesting only, while men traditionally take responsibility for cereal crops and cash crops such as maize and coffee. Similarly, findings by Gladwin (1992)

and Stamp (1975) in Malawi and Kenya respectively found that men were responsible for cash crops. This could limit the Wolayita women's decision to allocate part of their farming land to sweet potato.

Pests and diseases hinder the sweet potato production in the two zones (Figure 4 and Figure 5). In Africa, the most common sweet potato pests are sweet potato weevil (*Cylas puncticollis*) and the sweet potato butterfly (*Acraea acerata*) (Getu & Adahanom, 1989; Shonga, Gemu, Tadesse, & Urage, 2013). Sweet potato virus diseases can reduce the crop yield from 56% up to 98% (Adam, Sindi, & Badstue, 2015). Sweet potato feathery mottle potyvirus (SPFMV) and sweet potato chlorotic stunt virus (SPCSV) are the most common sweet potato viruses in Africa (Untiveros, Fuentes, & Kreuze, 2008).

Drought and rain shortage also affects the crop's yield (Figure 4 and Figure 5). This study confirms previous studies in Ethiopia and Tanzania, indicating that pests, diseases, drought, and rain shortage were among the main factors affecting the sweet potato yields ("Editorial Board," 2015; Gurmu et al., 2015; Kapinga, Ewell, Jeremiah, & Kileo, 1995). A study in sub-Saharan Africa claimed that sweet potato is the second crop, after wheat is predicted to drop in yield by 2050 due to climate change (Ringler, Zhu, Cai, Koo, & Wang, 2010). Although, sweet potato is a drought-tolerant crop (Jansson & Raman, 1991). Pests, diseases, drought, and rain shortage reduce the sweet potato production and leave farmers with few options such as planting other crops, renting their farms to others, and selling their farm and looking for different jobs. However, farmers diversify crops in their farms to sustain their crops production.

Between the two zones, Wolayita farmers diversify their farming systems with more crops than Southern Tigray farmers do. This is probably due to a favorable climate with high rainfalls and fertile soils. According to Altieri et al (2012), farm diversification sustains agricultural land. Southern Tigray and Wolayita famers plant cereals, legumes, vegetables, and fruits that cover different soil layers because of their diverse root zones. Therefore, farming land is more resilient against natural disasters such as floods. Farmers practice intercropping for many reasons, such as to maximize yield, enrich soil nutrients, and increase natural predators and parasites that feed on pests and insects on the crops. Thus, farmers spend less money on inorganic fertilizers and pesticides (Altieri, 1999). The Wolayita farmers' low yield in sweet potato intercropping indicates the complexity of growing two or more crops at the same time in the same field.

The findings from the research areas show that sweet potato varieties *Hawassa-83*, *Tula,* and *Kulfu* might not be able to compete with other crops for nutrients, soil moisture, and sunlight. Wolayita farmers plant sweet potato in the moisture-rich soils at the end of the main rainy seasons to have planting materials available whenever they need it. However, they plant *Hawassa-83* as a single crop to have a good yield because lack of sunlight influences the sweet potato storage yield. Carlson (2008), and Lebot (2009), stated that shade-tolerant sweet potato varieties can be intercropped with early maturing maize varieties. Other crops, such as maize, have different root zones and nutrition needs, which affect the sweet potato yield. For example, a study in the semi-arid Rift Valley in Ethiopia showed that intercropping sweet potato with maize had no effect on sweet potato vines, but it reduced sweet potato storage root yield during the dry season (Carlson, 2008). In contrast, another study in Uganda indicated that maize and sweet potato intercropping produced decent amounts of biomass for both crops, without impacting upon sweet potato yield (Lebot, 2009). This finding suggests that sweet potato can be intercropped with other crops. However, further research is needed to study the effect of sweet potato varieties intercropping with other crops.

Sweet potato farmers in the research areas do not have many choices of sweet potato varieties. In Wolayita, farmers abandoned their landrace *Nechi*, *Pino,* and *Guntute*. However, these cultivars are still available in the local research centers like Awassa Agricultural Research Center. This shows that Wolayita farmers replaced the local varieties with the high-yielding *Hawassa-83*. This might also be due to pest and disease infestations. Altieri et al. (1987) mentioned that farmers discard their local varieties, for example, in favor of high-yielding ones, or plant large farming areas with one single variety. In sub-Saharan Africa, sweet potato landraces are adapted to local climates with high pests and diseases resistance (Abidin, 2004). Furthermore, the sweet potato farmers appear to have lost knowledge and practices that are related to these cultivars. This includes time for planting and harvesting, weeding, and post-harvest management. Nevertheless, farmers' knowledge is different than the knowledge farmers receive from extension services. The farmers' knowledge is based on years of experiences from local climatic and soil conditions (Koohafkan & Altieri, 2010). Extension officers' knowledge is probably from research stations, without considering small-scale farmers' various climatic zone conditions (Belay & Abebaw, 2004).

This study shows that extension officers may not have the capacity, and adequate sweet potato knowledge, to help farmers grow more sweet potato. In both zones, the number of sweet potato researcher and extension officers are few, compared with researchers working with cereal crops and cash crops. Extension officers' numbers of visits and training are limited to a few sweet potato farmers every season. This indicates that extension officers might not have the capacity to assist large numbers of farmers. Similar findings by Belay and Abebaw (2004) in south-western Ethiopia showed that extension officers were overloaded with the number of farmers they were supposed to help. This affects farmers' ability to plant sweet potato, adopt new varieties, and practices that could increase the crop production. For instance, Southern Tigray farmers may not find it economically viable to replace traditional cereal crops with sweet potato. While, Wolayita farmers might possibility consider replacing sweet potato with cereals or other crops.

The application of mulch by some of the Wolayita farmers may not be considered important for extension services. This is due to extension officers relying on information from the Ministry of Agriculture and regional agricultural offices, but do not appear to receive feedback from the sweet potato farmers. Thus, farmers' knowledge and experiences are not included in the extension polices (Gebremedhin, Hoekstra, & Tegegne, 2006). This could possibly lead to the introduction of new varieties and agronomical practices farmers do not need (Sicat, Carranza, & Nidumolu, 2005). However, NGOs and The International Potato Center work to fill the gap of the knowledge of sweet potato agronomic practices (e.g., planting, weeding, harvesting, and post-harvest management).

NGOs and The International Potato Center cooperate in sweet potato projects that have limited time and funds to promote, and increase the crop production. This is evident in middle and high altitudes in Southern Tigray (Figure3). The findings in the middle and high altitude in Southern Tigray show the lack of donor organizations' capacity to spread and distribute sweet potato planting materials to farmers. In the low altitude, the number of sweet potato farmers is higher than middle and high altitudes due to the suitable climate and fertile soils that enable them to cultivate sweet potato. Besides, Alamata Agricultural Research Center is also located in the district, which might motivate farmers to plant the crop. Furthermore, it is easy to access the district by transport for NGOs from other regions and districts. This raises questions about the long-term sustainability of The International Potato Center and the sweet potato projects of distributing

planting materials to farmers every season. For instance, one researcher explained, *"donor organizations cannot sustain their distribution of planning materials to farmers for long period"*. Therefore, farmers cannot afford the risk of planting sweet potato instead of other traditional crops.

In the research areas, Agricultural Research Centers and The International Potato Center also have limited capacities to research into the various problems sweet potato farmers encounter. They lack technical facilities (e.g., laboratories, greenhouses with controlled environment), technicians, and funds, to produce quality disease-free sweet potato planting materials. This includes to what extent disease-free sweet potato planting materials are clean from diseases, which pathogens they are clean from, and for how long these planting materials will be cleaned from pathogens. Besides, for how long The Tigray Agricultural Research Institute can multiply planting materials to farmers in the region. Research Centers in the two zones also have a big knowledge gap in sweet potato cultivation, along with a lack of shared knowledge between the Research Centers and local agricultural offices. For example, one researcher in Southern Tigray said "*farmers know how to cultivate cereal crops without support from government or NGOs, but this is not the case of sweet potato*". Ultimately, farmers can benefit more from training and support from the Research Centers, international Potato Center, and Ministry of Agriculture.

The number of sweet potato researchers are few compared with researchers working with cereal crops and cash crops in the research areas. This is evident in Areka Agricultural Research Center in Wolayita Zone. This is despite Wolayita zone being one of the major sweet potato production zones in the country (Gurmu et al., 2015). This is due to agricultural policies that consider cereal crops' intensification to achieve food security more important than other crops (Spielman, Byerlee, Alemu, & Kelemework, 2010), including sweet potato. Moreover, lack of sweet potato researchers that can deal with the crop production problems in different agro-ecological zones might possibly influence the crop yield in the short-and long-terms.

The results from the research areas show that farmers are reluctant to cultivate sweet potato instead of other crops. Farmers allocate their few resources to produce the traditional cereal crops such as teff, maize, barley, and wheat. These crops fetch good prices in the market because of their high demand. This is important because of the high poverty rate among subsistence small-scale farmers in Ethiopia (Bacha, Namara, Bogale, & Tesfaye, 2011; Jena, Chichaibelu, Stellmacher, & Grote, 2012). Culturally, local people prefer to eat cereal crops rather than sweet potato. Planting

these crops encourages farmers to invest money in improved varieties, pesticides, and chemical fertilizers. However, the sale of sweet potato by some Wolayita women in the street increases their income and could empower them to participate in their farms' decision-making. Moreover, the government assigns more money, and research, to increase cereal crop and cash crop production (Spielman et al., 2010). It appears the government is not aware of the benefits of the sweet potato to farmers' diets, and as a food security crop. Therefore, the government is unwilling to encourage farmers to plant the crop.

Sweet potato farmers integrate livestock into their farming systems (Table 4). The sweet potato farmers use oxen and bulls for draught power for better air and water infiltration in their soils. This traditional ploughing method is suitable to the topography in the research areas and to the rest of the country. Therefore, farmers can cover large areas in a short time with few laborers, and without any additional costs other than fodder. Animal draught is vital and affordable (Gebregziabher et al., 2006) for most of the sweet potato farmers in the research areas. Moreover, farmers use donkeys for carrying off loads including sweet potato on their backs, with a saddle or panniers. Donkeys are also a cheap and effective way of transporting goods or produce in such difficult high mountain areas.

Poultry feed on insects and weeds, which help the farmers' biological control in their farms without pesticides intervention. Poultry also turn household litter and post-harvest residues into valuable products (Guèye, 2000). Therefore, the farmers consume livestock and poultry products like meat and eggs to enhance their diet with essential nutrients. While farmers with a better financial situation who own several livestock sell their surplus product in the market to generate income. Livestock diversity enhances the sweet potato production in the mixed crop–livestock, which improves the complexity of the farming system (Altieri, 1999). Moreover, farmers sell livestock by-products to buy improved crop varieties, and fertilizers.

The sweet potato farmers use animal manure and compost to enrich soil nutrients. This combination reduces soil compaction for better sweet potato storage root growth (Floyd, Lefroy, & D'Souza, 1988). Farmers also do not need to spend money on chemical fertilizers; therefore, they are less vulnerable to fertilizers' price fluctuation. Moreover, the use of cow dung with water mixture, by some Wolayita farmers as organic pesticide, again reduces farmers' spending on chemical pesticides, Thus, farmers became more reliant on their natural resources (Horrigan,

Lawrence, & Walker, 2002). In the small-scale farming systems, farmers depend on recycling of nutrients back to the soil with little, or no extra inputs from outside their farms (Altieri, 1999). In return, weeds, crop residues, and sweet potato forage can be fed to livestock.

In Southern Tigray, farmers prefer to feed their livestock with cereal crop residues. Most of the sweet potato farmers do not use the newly introduced sweet potato for animal feed, although the crop is a good source of livestock fodder. This is because farmers lack knowledge of sweet potato feeding values. Increased knowledge of the values of sweet potato for animal feed could encourage them to cultivate the crop. Sweet potato leaves and roots are rich with protein and starch, respectively (An, Frankow-Lindberg, & Lindberg, 2003). In Wolayita, farmers feed their livestock with cereal crop residues and grass pasture during *Meher* season, and keep sweet potato on the field to save planting materials for the dry season. This limits the use of the crop for animal feed in the *Mehe*r season. Whereas, in the dry season farmers feed their livestock with vines and leaves, and sometimes with roots. A similar study in Central Kenya showed that farmers also use sweet potato vines to improve livestock diet during the dry season (Nyaata, Dorward, Keatinge, & O'Neill, 2000).

In the research areas, farmers' perceptions and experiences could limit their ability to recognize the main production problem related to sweet potato production. This shows the complexity of the production problems that farmers are dealing with. Farmers might mistake ecological factors such as drought for pest and virus infestation. Ebregt and his colleagues showed that farmers thought sweet potato vines' failure to grow in Uganda was because of drought, while the crop was in fact infested by millipedes (*Diplopoda*) (Ebregt, Struik, Abidin, & Odongo, 2004).

Limited infrastructure and government budgets suggest that Farmers Field School (FFS) can help farmers to identify, analyze, and find possible solutions related to sweet potato production problems. FFS is a participatory learning approach, where extension officers' jobs are to facilitate farmers' meetings. Meetings take place in their fields, and farmers learn through field experiments and problem-solving situations. Farmers can implement methods and practices that are suited to their local climatic conditions and cultural desires (Godtland, Sadoulet, Janvry, Murgai, & Ortiz, 2004). A study by Kebebe and his colleagues in Wolayita zone applied Integrated Nutrient Management (INM) on maize. The INM helped farmers reduce the use of inorganic fertilizers by 50%, without substantial differences in yield (Kebebe, Sheleme, & Wondimu, 2007). Thus, FFS

brings new ideas from the sweet potato farmers themselves that can help them manage some of the crop challenges, increase the sweet potato yield, and sustain their livelihood.

Conclusion

The results showed combinations of social, ecological, and economic factors influencing the crop production in Southern Tigray and Wolayita zones. In these zones, factors such as pests and diseases, rain shortage, and lack of suitable cultivars for different climatic conditions affected the crop yield. In Southern Tigray, lack of the sweet potato planting materials and knowledge constrained famers in cultivating the crop. In Wolayita, the sweet potato landrace varieties were lost and farmers relied on Hawassa 83 cultivar for their production. Livestock supported the sweet potato production by providing draught power, transport, biological control, boosting the sweet potato farmers' nutritional diets, and for compost and manure to fertilize the farm land.

If researchers and NGOs recognize the diversity of farmers' knowledge and sweet potato landraces, then the crop yield may increase through breeding programs at different locations. These breeding programs could include researchers working together with male and female farmers to breed varieties suitable for different conditions, with high nutritional value and yield, that are drought-tolerant, and that have high resistance to pests and diseases. This might also provide planting materials during the dry season, and sweet potato yield and knowledge could increase throughout the country, with farmers becoming an important part of this change.

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Appendix

Appendix:1. Questionnaire

Questionnaire for crop- livestock farming system in three agro- ecological zones in Southern Tigray and Wolayita zones in Ethiopia.

1. Name/ code of the respondent_____

District _____Kebele_____

Village_____

2. Sex**:** 1= Male 2= Female
3. Age (Year): _____
4. Marital status 1= Married 2= single 3 = divorced 4= widowed

5. Educational status: 1= illiterate; 2= read & write; 3 = only read; 4= primary (1-8); 5= secondary (9-12); 6= other (specify)……

6. If you have children, please fill in the table below

Family members	Male	Female
<15		
15- 64		
>64		

7. Labor division: who is taking care of the farm? 1 =Man; 2= women; 3= both; 3= children; 4 = laborer; 5= other specific……

8. Who is taking care of household activity? 1= man; 2= women; 3 = children; 4= laborer; 5= other (specify)…….. .....……

Land Ownership

Plot number (more than one plot)	Source (owned, inherited, rented in)	Distance from homestead	Land use type (cultivation, grazing, homestead, forest land)	Certification (Yes/No)	Owned or cultivated since (indicate the year)

9. Farm holding size? 1= <0.2 ha 2= >0.2 ha

10. Other occupation: do you have off farm activity? Yes = 1 No = 2

11. If yes, what off farm activity do you have? 1= daily laborer; 2= petty trade; 3= handicrafts; 4= other (specify)……

Crop production information

No	Type of crop grown (crop codes)	Plot area (ha)	Type of seed (1=local/2 =improved)	Fertilizer applied (KG/AREA)		Amount of organic manure	Season Planted (1. Main season,2. Belg)	Amount harvested (KG/Area)	Amount consumed	Amount sold
				DAP	UREA	KG/ area				

Crop code	1= Maize; 2= Teff; 3=Wheat; 4= Sweet potato; 5= Enset; 6 Coffee= 7 Taro; 8 = Yam ;9= Fava bean; 10= Haricot bean; 11= Mung bean; 12= Cassava; 13= Tomato; 14= Cabbage; 15= Beetroot ; 16=Potato; 17= Onion; 18= Garlic

12. Do you have production problem? Yes=1 No =1

13. If yes, what is the main production problem? 1= draught; 2= lack of improved varieties; 3=soil fertility; 4= pest and insect; 5= rain shortage; 6= lack of variety.

14. Which season is severing for production of root and root crops? 1= wet season; 2= dry season.

15. Which crop is the most susceptible to erratic rain?

1= sweet potato; 2= potato; 3=cassava; 4= Enset; 5= teff; 6= maize; 7= taro; 8= wheat

16. Which crop is susceptible to change in temperature? 1= sweet potato; 2= potato; 3=cassava; 4= Enset; 5= teff; 6= maize; 7= taro; 8= wheat

17. Farm diversification: How many crops do have every growing season? _____

18. Intercropping; do you practice intercropping? 1=Yes; 2= No

19 Why do you practice intercropping? 1= economical value; 2= ecological value; 3= minimizing the risk off crop failure; 4=combination of all; 5= other (specify)……

20. Soil moisture: How do you deal with lack of rainfall? 1 = planting different cultivars; 2= trees traces; 3= supplementary irrigation; 4= planting different crops; 5= water harvesting; 6= other (specify)……...

21. Do you have waterlogging problem in your farm? Yes= 1; No= 2

22. If yes, how do you deal with water logging? 1= different cultivars; 2= drainage system; 3= planting different plants; 4= others (specify)……

Sweet Potato production – information

23. Do you cultivate sweet potato? Yes=1 No = 2

24. If no, why? 1= Lack of cultivars; 2= Lack of crop's knowledge; 3= Ecological reasons; 4= Not economically profitable; 5=lack of training; 6= other reasons (specify)…

25. Do you get advice, or visit from agricultural extension officer? 1= yes; 2= No

26. If yes, how often? 1=every season; 2= every year; 3= more often 4= seldom; 5= other (specify)……

If you produce sweet potato, please fill in the following information.

Type of sweet potato cultivars (1= Kulfo 2= Gadisa)	How long has it been used? ____ years	Area planted (Ha/ Season)	How much do you produce? (KG/ season)	Amount sold	Amount consumed

27. Why do you use these cultivars? 1= high -yielding; 2= drought resistance; 3= nutritional value; 4= viruses and diseases resistance; 5= adaptable to local climate; 6= Market value; 7= other (specify)……

28. Where do you get sweet potato's cultivars?

1= saving from previous harvest; 2 =exchange with neighbors; 3= local market; 4= local agricultural office; 5= research institutions; 6= other specify…….

29. Sweet potato seedbed preparations: tillage 1 = machine; 2= manual labor; 4= zero tillage; 5= oxen tillage; 6= other (specify)……

30. Planting time: when do you plant sweet potato? 1= April; 2= May; 3= June; 3= June; 4= July; 5 August 6= after August (specify)……

31. Weed management: How do you mange weeds in sweet potato field? 1= mechanization; 2= hand weeding; 3= draught power; 4= biologically; 5= herbicides 6= other methods…….

32. How do you mange soil fertility on your farm? 1= crop rotation 2= intercropping 3= planting legumes 4= crop residues 5= general fertilizers. 6= animal manure.

33. Do you intercrop sweet potato with other crops? Yes= 1 No=2

34. If yes, which crop is intercropped with sweet potato? 1= Maize; 2= wheat; 3= barely; 4= potato; 5= cassava; 6= enset.

35. Harvest: How do you harvest? 1= hand; 2= machinery; 3= hand hoeing; 4=other (specify)……

36. Pesticides: do you use pesticides? 1 = synthetic 2= organic 3= without pesticides 4 = other (specify)…….

Type of animals

Type of Livestock used	Number owned	Livestock use for draught power
Oxen		
Bull		
Cow		
Donkey		
Goat		_____
Sheep		_____
Mule		
Horse		
Chicken		_____
Beehive		_____

Livestock products

Type of product	Amount produced (KG/Lit)	Amount consumed %	Amount sold %
Milk			
Yoghurt			
Butter			
Meat			
Egg			

37. What is the most challenging problem in animal production? 1= disease; 2= lack of animal feed; 3= shortage of drinking water; 4= laborer shortage.

38. How do you feed your animals? 1= free grazing; 2= crop residues; 3= cut and carry system; 4= other (specify)……

39. If you use crop residues for animal feeding, which is the common crop residues for animal feeding? 1= wheat straw; 2= barely straw; 3= teff straw 4= Enset; 5= potato leaves; 6= concentrate; 7= maize straw; 8=other (specify)……

40. If you use sweet potato for animal feeding, which cultivar do you prefer? 1= Kulfo; 2= Hawassa 83 (Gadisa); 3= others (specify)……

Appendix: 2. Informant interview

Informant interviews for crop- livestock farming system in three agro- ecological zones in Southern Tigray and Wolayita in Ethiopia

Introduction:

My name is _____a master degree student from the Norwegian University of Live Sciences (NMBU). The purpose of this informant interview is to get different aspects of sweet potato production, helping me on my research with a title "*Factors affecting sweet potato production in crop- livestock farming system in Ethiopia",* and is a part of the project "*Controlling diseases in sweet potato and enset in South Sudan and Ethiopia to improve productivity and livelihoods under changing climatic conditions using modern technology"*. This project is a cooperation project between the department of plant sciences at the Norwegian University of life Sciences (NMBU), Juba University (South Sudan), Hawassa University and Mekelle University in Ethiopia. The information I will get it for from you will be important in my research, and the project in general.

Anything you tell me is confidential. Nothing you say will be personally attributed to you in any reports that result from this interview. This study will be written in a manner that no individual comment can be attributed to a particular person.

Are you willing to answer my questions? Do you have any questions?

Questions

Your name: _____

1. Can you please talk briefly about your work, and how is it relate it to sweet potato farmers?

   _____

   _____

2. What are the most important crops in your area, and why?

   _____

   _____

3. Why do you sweet potato does not have the same priority in the agricultural policies as other cash crops like teff, maize, wheat, barely. Although the crop has wide ecological adaptabilities that can feed millions of hungry people?

_____

_____

4. What are the main challenges facing sweet potato production in your agro-ecological zone?_____

_____

5. What needs to happen to help the sweet potato production to address these challenges?

_____

_____

6. Farmers Field School (FFS) is a forum where farmers and trainers debate observations, experiences and present new information from outside the community (FAO, 2010). In which way, do you think FFS can help farmers to deal with sweet potato challenges? And do you have FFS in your area?

_____

_____

7. What are the economic benefits of sweet potato production for the farmers in general/ or in your area?

_____

_____

8. Form where do you get training, the latest guidance, technique, and information relate it to sweet potato production?

_____

_____

9. How do you share these knowledges to farmers, and how often?

_____

_____

10. What are the most suitable cultivars in your agro-ecological zone, and why?

_____

_____

11. What role livestock play in sweet potato production in your agro- ecological zone?

_____

_____

_____

_____

12. Do you have any comments?

_____

_____

Appendix: 3 list of informants

The number and the locations of the informant interviews.

Institutions	Number of interviews
Awassa Agricultural Research Center (SNNPR).	Three interviews.
Areka Agricultural Research Center (Wolayita zone).	One interview.
Tigray Agricultural Research Institute (Tigray Region).	One interview.
Alamata Research institute (Southern Tigray).	Two interviews.
Alamata local agricultural office (Southern Tigray).	One interview.
Mychew agricultural office (Southern Tigray zone).	One interview.

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