agriculture

MDPI

Article

Sustainability of Improved Crop Varieties and Agricultural Practices: A Case Study in the Central Rift Valley of Ethiopia

Getachew Sime [1,2,*] and Jens B. Aune [1]

[1] Department of International Environment and Development Studies (Noragric), Norwegian University of Life Sciences (NMBU), 1432 Ås, Norway; jens.aune@nmbu.no
[2] Department of Biology, Hawassa University, Hawassa, Ethiopia
* Correspondence: getachew.simef@gmail.com; Tel.: +251-916-825-422

Received: 9 September 2018; Accepted: 5 November 2018; Published: 9 November 2018

Abstract: Technological change has been the major driving force for increasing agricultural productivity and promoting agriculture development in developing countries. To improve the agricultural productivity and farmers' livelihoods, several agricultural technologies (improved crop varieties and related agricultural practices) were introduced by various agencies to the farmers in the Rift Valley of Ethiopia. Thus, the objective of this study is to identify these technologies, and evaluate their characteristics and sustainability. The data were collected from farmers, agricultural extension workers, and agricultural experts, through a series of focus group discussions, key informant interviews, and farm observations, selected through purposive and random sampling techniques. Results showed that extension systems, social networks, or research projects were the agencies that introduced the technologies to the farmers. Haricot beans (*Phaseolus vulgaris* L.) and early and mid-maturing maize (*Zea mays* L.), as well as agricultural practices like row-sowing, banding fertilizer application, intercropping, and traditional rainwater-harvesting, were found to be in continuous use by the farmers. In contrast, the use of extra-early-maturing maize, sorghum (*Sorghum bicolor* L.) and finger millet (*Eleusine coracana* L.), as well as the use of related practices, including harvesting maize at physiological maturity, seed priming and fertilizer microdosing, were the technologies that were discontinued at the time of pursuing this study. Most of the continuing technologies had a high potential for reducing the vulnerability of the rain-fed agriculture to rainfall variability. Regardless of sources, the national extension system supported technologies that were integrated into the system only. Most of the discontinued technologies were found to be introduced by the research projects. These technologies were not brought into the attention of policy-makers for their integration into the extension system. The farmers also disliked a few of them for unfitting the existing socioeconomic setting. Whereas, the technologies that were introduced by the social networks were found to be widely used by the farmers, though they were not supported by the extension system. This is because most such technologies offer better yield and income. For instance, social networks have popularized haricot beans and hybrid maize because of their higher benefits to farmers. Farmers consider both socioeconomic and agroecological conditions for selecting and using technologies, whereas the extension system centers on existing agroecological conditions for recommending and supporting agricultural technologies. Consideration of both socioeconomic and agroecological settings would increase the prospect of a technology for sustainable adoption. Overall, rainfall variability, high price and poor access to improved seeds, farmers' poor economic conditions, and the inadequate linkage between extension systems, social networks and research projects, remain critical factors influencing the sustainable use of agricultural technologies. It is, thus, commendable that policymakers should consider local socioeconomic and agroecological settings in recommending and supporting agricultural technologies besides instituting a strong consortium of extension systems, research institutes, research projects, social networks and farmers for improved agricultural technology development, extension system and sustainable adoption.

Keywords: technologies; rural livelihood; agricultural policy; extension system; semi-arid Ethiopia

---

1. Introduction

The sustainable use of agricultural practices has become an important issue in the development-policy agenda for sub-Saharan Africa (SSA), especially as a way to tackle land degradation, low agricultural productivity, and poverty [1]. To achieve increased agricultural productivity and improved food security, investment in agricultural research and extension is a key factor [2]. This is because the growth generated by agriculture in SSA is several times more effective at reducing poverty and shortages in food supply [3]. In Ethiopia, the adoption of agricultural technologies has long been emphasized for Green Revolution technologies (chemical fertilizer and improved crop varieties) and physical soil and water conservation technologies [4].

Agricultural productivity depends on the use and availability of better agricultural technologies and practices. The government of Ethiopia has given high priority to agricultural development, natural resource management, and agricultural productivity [5,6]. The country has followed an agricultural production intensification approach to boost crop productivity on the smallholdings through the application of modern agricultural inputs, primarily improved crop varieties, agronomic practices, and fertilizer technologies [5,7]. As part of the intensification, the demand for improved technologies, including improved seed and fertilizer, has increased in Ethiopia [8], which could maximize the productivity of farmland with new agricultural inputs [9]. The supply of improved technologies like improved seeds is a key factor in Ethiopian agricultural production [10]. To satisfy the seed demand, improved seeds are supplied by private and public seed enterprises, agricultural research institutes, and universities [10]. As part of achieving Ethiopia's 10-year Growth and Transformation Plan (GTP) goals, the government has also made substantial investments in roads and agricultural extension services [11,12] and has endorsed ambitious socioeconomic plans [5]. In the first phase of the GTP that ran from 2010–2015, fertilizer application and the use of improved crop varieties were key elements that were emphasized [13]. Despite considerable efforts to promote various agricultural practices in Ethiopia, the sustainable adoption of many of the introduced technologies is minimal [1]. This study argues that the sustainable use of these technologies is variously influenced by biophysical, socioeconomic, or institutional factors. The introduced improved crop varieties and practices might be impeded or be operating in the agricultural system under varying scenarios.

In Ethiopia, scant attention has been paid to the factors that impede or facilitate the adoption of agricultural practices like conservation tillage, improved crop varieties, water conservation structures, fertilizer application technologies, cereal-legume intercropping and crop rotations. Past research also focused on the adoption of component technologies in isolation, whereas farmers typically adopt and adapt multiple technologies as complements or substitutes that deal with their overlapping constraints. Such a combination of technologies should enhance household food security through increasing income and reducing production costs [14]. The major factors impeding or facilitating the sustainable use of the technologies include biophysical, socioeconomic, and policy issues [5,14–17].

In SSA, increasing agricultural productivity for improved food security is challenged by poor investment in climate and agricultural research and extension services, and poor infrastructure [18]. Though chemical fertilizer remains the main yield-augmenting technology being aggressively promoted by the government and research institutions [16], Ethiopian farmers are among the lowest users of fertilizer and improved seeds in SSA [19]. The other major constraint on productivity growth and sustainable intensification in Ethiopia is the heavy dependence on rain, with high vulnerability to seasonal rainfall shocks [1,7,13,15]. Generally, low external input use [1,13], and widespread land degradation [16,17], along with the poor water-holding capacity of the soil and infiltration problems [20], are important constraints on increasing agricultural productivity in Ethiopia.

Climatic shocks can be disastrous, particularly in the semi-arid regions of Ethiopia, and discourage the sustainable adoption of improved seeds and agricultural practices [19]. Most of the risks associated with discontinuing adopted technologies originate from the recurrent droughts and dry spells [17] that strongly depress crop yield [21]. The variable rainfall, coupled with the absence of reliable agrometeorological forecasts, influences the sustainable use of improved seeds and fertilizer technologies [17]. To cope with unfavorable rainfall conditions, farmers use various risk diversion strategies such as desisting from investing in fertilizers and improved seeds [17,22], and adjusting the cropping calendar, crop, and crop variety to be grown, practicing intercropping and traditional rainwater harvesting and conservation [17,23]. This shows that seasonal fall pattern alone could strongly influence farmers' decision to continue or discontinue the sustainable use of a once adopted technology.

The inability to develop and deliver locally appropriate technologies and, thus, the discontinuity of existing and new technologies is a challenge to the technology development and extension system in Ethiopia [16,24]. High cost of inputs, insufficient credit services, and high financial costs are critical constraints on the use of the available seed–fertilizer technology packages [7]. Limited availability of and access to improved seeds is regarded as one of the main obstacles to increasing agricultural productivity in Ethiopia [25]. Farmers' insufficient knowledge and inadequate extension services [5], insufficient supply of improved seeds, limited choice of new crop varieties [17], and market failures [7] are other important factors limiting the sustainable use of agricultural technologies.

In the Rift Valley of Ethiopia, apart from the high rainfall variability and other constraints, the low fertility and water-holding capacity of soils increased farmers' reluctance to invest in the high-price inputs of improved seeds and fertilizers [17]. The national extension system promotes the banding method of fertilizer application, which involves application of fertilizer at a relatively high rate [26]. The extension system also promotes the use of early-maturing maize [27]. The improved seed-fertilizer package being promoted institutionally is, however, expensive to the farmers as both improved seeds and fertilizers are expensive [27]. Sime and Aune [26] suggested the need for developing an efficient fertilizer application method that is low-cost, low-risk, and productive. In addition, limited access to cash increased farmers' aversion to risk and made the continuous use of improved technologies difficult [15,17,27].

The objective of this paper is to identify and characterize, and to explore the factors that influence the sustainable use of the improved crop varieties and related practices, which were introduced to the farmers by the national extension systems, social networks and DCG (Dryland Co-ordinating Group of Norway) project in 2006-7 and 2010-11 in the central Rift Valley of Ethiopia. The authors primarily used qualitative information, which was collected through focus group discussions, key informant interviews, and farm observations. The data were used to evaluate whether those technologies were continued or discontinued at the time of the study and the reasons for their continuity or discontinuity, addressing the questions of why farmers keep using technologies or discontinuing them. While the factors related to adoption decision are relatively better addressed in the previous literature, the factors related to continuing or discontinuing of the technologies are relatively less documented in Ethiopia in general and non-existent in the study area. Interestingly, a significant part of this paper discusses this issue.

2. Materials and Methods

2.1. Description of the Study Sites

The study site, Adami Tulu Jido Kombolcha district (Figure 1), is located in the East Shoa Zone of Oromia Regional State in the central Rift Valley of Ethiopia. The district is located at 7°9′ N latitude, 38°43′ E longitude, at an altitude of 1643 meter above sea level (m.a.s.l), and is between 136 and 148 km south of Addis Ababa. It is bounded by a western and eastern escarpment with highest altitudes of over 4000 m.a.s.l. The study targeted three villages, namely Ellilan Ababo, Denbe Adansho, and Chitu

Getu, with 758, 680, and 764 households, respectively. According to the Central Statistical Agency (CSA) of Ethiopia, the population size of the district is 164,234 in an area covering approximately 1094 km^2, with an average population density of 150.1 persons per km^2 [28]. The average family size ranges from 5.3 to 7.5 [29,30]. Kassie et al. [17] report that the average household landholding size ranges between 0.75 and 2.5 hectares (ha) in the central Rift Valley. The rainfall conditions in the central Rift Valley exhibit high intra-seasonal variability with a coefficient of variation of 15 to 40% and a significantly increased temperature (0.12–0.54 °C per decade) over the past 30 years [31]. The soil has poor fertility [23].

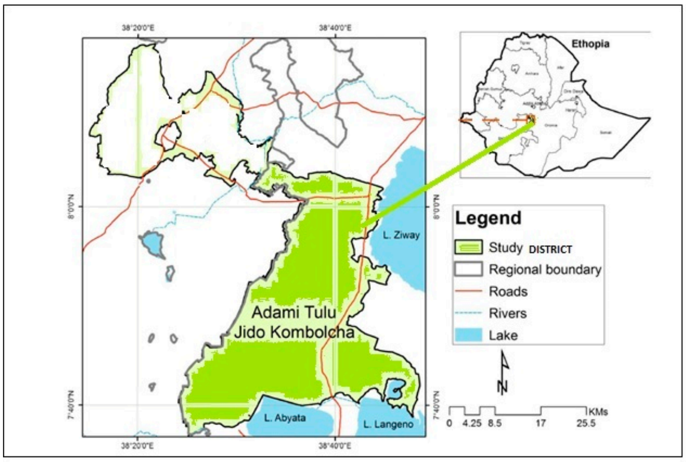

Figure 1. The physical map of the study area.

Rain-fed and cereal-based crop production is combined with modest livestock production [17]. The increasing inter-seasonal rainfall variability and intra-seasonal dry spells associated with increasing temperature cause severe challenges to the rain-fed crop production [17,32]. The main crop is maize (*Zea mays* L.), but teff (*Eragrostis tef* (Zucc.) Trotter) and haricot beans (*Phaseolus vulgaris* L.) are also widely cultivated. Livestock kept include cattle, sheep, goats, horses, and poultry. Oxen are primarily kept as a source of draft power, while horses, donkeys, and mules are used for transportation and packing. The livestock is a source of manure and domestic fuel. Crop residues are the main source of feed for livestock, particularly during the dry season. Livestock also graze freely on the crop residues after crop harvests [23,33].

2.2. Methodology

Primary data related to improved agricultural practices and improved crop varieties introduced to farmers, and the challenges to their extension, were collected through key informant interviews, focus group discussions, and field observations. The viewpoints of stakeholders pertaining to technology variables, extension services, and the market system pertaining to the extension practices of the introduced technologies were collected.

2.2.1. Sampling Technique and Data Collection Method

Three separate focus group discussions, each with nine farmers, were held in the three villages. Altogether, 27 farmers were involved in the discussion. The selection of the farmers was based on purposive sampling technique in order to obtain comprehensive information about the farming systems and livelihoods in the sample villages. The purposeful sampling technique is widely used in qualitative research for the identification and selection of information-rich cases related to the phenomenon of interest [34]. The researchers selected the farmers with the assistance of extension workers and village leaders based on previously set criteria. The selected farmers were village headmen, lead farmers, and leaders of local farmer organizations who had decent community acceptance and exercised leading roles in agricultural activities. These focus group members had different social status, farm size, income, religious affiliation, age, and sex. The age of the members ranged from 32 to 75 years. Six of them were female. Most of the households are male-led. Like elsewhere in rural areas, the ability of men and women to influence farming decision-making is different. Women mostly do not influence most such decision-making activities. The participants had awareness about the problem under investigation. That is, they had information from the national extension system and social networks, as well as from research conducted by research institutes, universities, and/or non-governmental organizations. Before launching the discussion, trust between participants and researchers was built and a consensus of valuing information was reached. The same discussion questions were used in each village for cross-checking of the information to increase the validity and reliability of the data collected. McHugh et al. [35] noted that repeated discussion and interaction with various stakeholders helps to obtain comprehensive knowledge about agricultural production and livelihoods of farmers.

The other group members were extension workers. Extension workers are the lowest level agents in the government administration structure who closely work with the farmers. They were selected using a purposive sampling technique because there were only three extension workers in each village, that is, one extension worker for crop, livestock, and environment management. Thus, in each village a separate group discussion was held with a group of three agricultural extension workers, making the total number of extension workers involved in the study nine. Among the leading questions raised during the focus group discussion were those pertaining to shortlisting technologies introduced by the national extension system, DCG, and social networks; characterizing the technologies; characterizing the introduced technologies in relation to the existing socioeconomic and agroecological settings; identifying continued and discontinued technologies; and identifying reasons for continuing and discontinuing of the technologies, among others.

In addition to the focus group discussions, key informant interviews were held with agricultural experts from the district agricultural office who were directly engaged in input supply, input market prices and subsidies, extension of improved technology, and policy-making. Three experts with competence in crop, livestock, and environmental management were interviewed in depth. They were leaders in their sectors and, therefore, were selected using the purposive sampling technique. The discussion held with agricultural experts and extension workers emphasized the adequacy of agricultural extension services; the availability of external inputs such as improved crop varieties at farmers' capacities and subsidy or credit arrangements; the stability of input and output market prices; and the suitability of the improved crop varieties and related agricultural practices to the existing biophysical settings (such as rainfall events, soil quality such as fertility, water holding capacity).

A series of field observations were also carried out before harvest (seedbed preparation, planting, weeding, and harvesting) and after harvest (threshing, storing, and marketing). These field observations were made for three consecutive years. During the field observations, interactive discussions were held with 36 other farmers who did not engage in the focus group discussion, using a random sampling technique. A random selection technique enables researchers to select a sample representative of the population, with all individuals having a legitimate chance of being selected [36]. This made the total number of farmers engaged in this study 63. The three extension workers in each village assisted with the field observations. During these observations, various issues were explored to confirm the viewpoints collected from the participants and key informants. To evaluate the possible developments in the course of this study, the same survey instrument was used, including source of technologies introduced to farmers, information sharing systems, agricultural extension service sessions, status of use of improved crop varieties and agricultural practices, virtual farmers' constraints to improved technology extension, external input supply system, and marketing procedures.

While conducting the discussion, interviews, and field observations, comprehensive field notes were hand-written by the researcher and an assistant, complemented with audio recording. Field notes allow researchers to maintain and comment upon impressions, environmental contexts, behaviors, and non-verbal cues that may not be adequately captured by an audio recording; they are typically hand-written in a small notebook at the same time the interview takes place. Field notes can provide important context for the interpretation of audio-taped data and can help remind the researcher of situational factors that may be important during data analysis. Field notes need not be formal, but they should be maintained and secured in a similar manner to audio tapes and transcripts, as they contain sensitive information and are relevant to the research [37].

2.2.2. Data Management and Interpretation

This is a qualitative study. Quantifiable data were entered into Microsoft Excel for descriptive analysis. Qualitative research can help researchers access the thoughts and feelings of research participants, which can enable development of an understanding of the meaning that people ascribe to their experiences [37]. The qualitative data collected from the focus group discussion, in-depth interviews, and field observations were transcribed (hand-written and audio-taped). The data were broken down into different themes and sub-themes for analysis. Two researchers independently reviewed the data. The data were analyzed using an inductive approach, without the presupposition of an existing theoretical framework. It is important to conduct this phase of analysis without the presupposition of a particular framework to allow flexibility in data exploration and discovery [38]. Using coding techniques of the different themes and sub-themes, the researchers open coded the transcripts as explained in [39]. Open coding entailed holistically reviewing the data, reading line by line, reviewing each individual response, comparing and cross-checking the responses of participants to the same questions, labeling concepts, and breaking data further down into the themes that best fit the research questions. Axial coding involved exploring the data (i.e., open codes) for connecting between themes and sub-themes. Two researchers met after coding the data to discuss the coding process, and discrepancies in coding were discussed until a consensus was reached. The credibility and internal validity of the data were assured via use of multiple data sources for cross-checking (focus group participants, key informants, and field observations) that allowed for triangulation of data as described in [39,40].

Since this study was based on the cross-checked stakeholders' viewpoints, specific stakeholders might not be indicated in the text unless otherwise mentioned for specific purposes.

3. Results

Agricultural experts stated that improved crop varieties and agricultural practices were introduced to the farmers via the national extension system, social networks, or research projects. The purpose of the introduction was to reduce the vulnerability of agricultural system to the prevailing variable rainfall in the Rift Valley and to improve food security, farm income and overall rural livelihoods. This was justified by the respondents and the field observations. Tables 1 and 2 present the improved crop varieties and agricultural practices that were introduced to the farmers by the DCG (Dryland Co-ordinating Group) of Norway in 2006-7, the national extension system 2010-11 cropping season, and farmer social networks.

The technologies introduced by the DCG were extra-early- and early-maturing maize, haricot beans, finger millet, and sorghum. These technologies also included agricultural practices of harvesting maize at physiological maturity, row-sowing, intercropping, seed priming, fertilizer microdosing, and conservation tillage. The DCG project was phased out at the end of the 2009-10 cropping season, after upscaling some farmers' best practices. The upscaled technologies were haricot beans, finger millet, harvesting maize at physiological maturity, intercropping, seed priming, and fertilizer microdosing. The project was phased out before most of the technologies were integrated into the national extension system. Technologies developed in such ways need to be integrated into the national extension system to get input supply and extension service for their continuity. However, integration into the national extension alone is not always a guarantee of their sustainable adoption. Consequently, the DCG technologies that were not integrated into the national extension system or social networks were discontinued, following the phasing out of the project. Despite a lack of integration into the national or social networks, technology characteristics and socioeconomic factors were found to be the reasons for the discontinuation of a few of the DCG technologies. These are the potential factors contributing to the discontinuation of these technologies, including lower yield potential or high vulnerability to dogs, birds, or other wild animals. The cultivation of extra early maturing maize, sorghum and finger millet, as well as the practice of harvesting maize at physiological maturity and conservation agriculture, had encountered these challenges. Among the DCG technologies, early-maturing maize, intercropping, row-sowing, and banding fertilizer were re-introduced and integrated into the national extension system in 2010-11 and were continuing at the time of the study.

Table 1. Continued improved crop varieties and agricultural practices, key characteristics and reasons for their continuation in the agricultural system.

Crop	Improved Variety	Practice	Characteristics and Reasons for Their Continuation in the Existing Farming System
Maize	Early maturing, open pollinating, namely Melkassa-2, 6Q, Awassa-511		Matured early and more adaptive to low seasonal rainfall and intra-seasonal rainfall variability, provided moderate yields with no or low fertilizer application
	Mid-maturing hybrids, such as BH-540 and 543		Provided higher yields than early and local maize under optimum seasonal rainfall events and high grain market prices, but seeds cannot be saved and recycled, inaccessibility of first generation seed, which is supplied only by government institutions or certified agencies, less adaptive to intra-seasonal rainfall variability and is more vulnerable to end of the season cut off of rainfall or to dry spells
Haricot bean	Early maturing, such as Awash-1 and Awash Melka		Matured early and adaptive to low and variable rainfall, provided high yields even with no or low fertilizer application, high market prices for outputs, seeds can be saved and recycled Low labor for weed control and low oxen energy for tillage (minimum tillage is usually used) After harvest, haricot bean fields used as pasture; high grass weeds from minimum tillage and less weed control Used as a partial or entire replacement in failed maize fields (from low or prolonged dry spells) and is ideal as an intercrop with maize Grown in July when farmers have less fair time and seasonal rainfall variability is minimal
		Row-sowing method, for maize and haricot beans	Provided high yields; saved seeds and fertilizer; eased agronomic practices such as weeding, thinning and traditional rainwater-harvesting, *Shilshalo* and *Dirdaro* that make ridges and furrows–compatible with other practices Replaced the predominant low yielding broadcasting method of seed sowing practice, which is less compatible with other practices
		Intercropping, for maize intercropped with haricot beans	Increased nutritional diversity and incomes, increased resilience to rainfall variability and lessens food shocks because maize and haricot beans are differently affected by dry spells Increases soil nutrient restoration
		Banding method of fertilizer application	High yields, high labor demand, substantially saves on fertilizers Replaced lower yielding and less efficient broadcasting method of fertilizer application in practice
		Traditional practices of *Dirdaro* and *Shilshalo*	Efficient practices in in situ rainwater-harvesting and enhanced agronomic performance under low seasonal rainfall events but under high rainfall events may cause waterlogging that might affect plant growth and yield *Dirdaro* is practiced mainly for making ridges and furrows for rainfall harvesting while *Shilshalo* is practiced for multiple purposes: weed controlling, thinning and removing the surface crust to facilitate infiltration Both *Dirdaro* and *Shilshalo* practices are implemented with a traditional plough that uses oxen energy and eases labor loads

Farmers' social networks promoted haricot beans, row-sowing and intercropping cereals with legumes of the DCG and hybrid maize. Hybrid maize was not integrated into the national extension system either, but was widely adopted by the farmers (Table 1). These technologies were farmers' choices for their higher yields and farm incomes. Regardless of the sources, social networks could also promote the sustainable implementation of adaptable and profitable technologies. Whenever possible, farmers use information from both institutions and social networks in order to select new agricultural technologies.

Table 2. Discontinued improved crop varieties and agricultural practices, key characteristics, and reasons for their discontinuation from the agricultural system.

Crop	Improved Variety	Practice	Characteristics and Reasons for Their Discontinuation from the Existing Farming System
Maize	Extra early-maturing maize, namely Katumani, Melkassa-1, Awassa-511		Earliness (Katumani, Melkassa-1, Awassa-511) high adaptation capacity to low and intra-seasonal rainfall variability; drought tolerant * Low grain and stalk yields * Vulnerability to attack by dogs, birds and other wildlife
Finger millet	Early maturing, such as Tadesse and Paddet		Adaptive to the variable rainfall; provided high yield even with no or low fertilizer application; seeds can be recycled Required lower labor for weed control and low oxen energy for tillage (minimum tillage) * Lack of adequate information on grain market and consumption value; lack of support from institutions or social networks (neither integrated into the extension system nor adequately promoted and assimilated into social networks)
Sorghum	Early maturing, such as *Teshale*, *Seredo*, *Melko*-1		Adaptive to the variable rainfall; provided high yields even with no or low fertilizer application Required lower labor for weed control and oxen energy (minimum tillage) * High vulnerability to bird attack and total harvest loss (Teshale and Melko-1) * Low food value, low palatability from high tannin content despite its high use value in making local drinks (Seredo, which is less vulnerable to bird attack)
		Seed priming, for example maize, finger millet, haricot bean	Provided high yields; required no or less external input and had no risk * Lack of adequate information and lack of support from institutions or social networks (neither integrated into the extension system, nor adequately promoted and assimilated into the social networks)
		Microdosing method of fertilizer application, for example phosphorus and nitrogen fertilizer in maize	Provided high yields; required higher labor demand (although labor is not a problem in most households); saves fertilizers * Lack of adequate information on optimum fertilizer rate; lack of support from institutions or social networks (neither integrated into the extension system nor adequately promoted and assimilated into social networks)
		Conservation tillage, such as zero and minimum tillage with mulching	Reduced oxen energy; ideal for farmers lacking oxen; more adaptable to rainfall variability * Low yields over short-term practice; high weed density; high labor demand for weeding when herbicides are not used * Crop residues cannot be kept in open fields due to free grazing of animals it demands an entire change to the existing intensive tillage and the free grazing system

* denotes reason(s) for the discontinuation of the particular technology.

The rest of the improved crop varieties and practices presented in Tables 1 and 2 were introduced by the national extension system. They were early-maturing Open Pollinated Varieties (OPVs) maize and improved agricultural practices, including row-sowing, intercropping, banding of fertilizer application, traditional in situ rainwater-harvesting, locally called *Dirdaro* and *Shilshalo*, and the use of compost and manure as organic fertilizer. Most of the continued technologies were those that were integrated into the national extension system. Integration into the national extension system offers institutional support such as the provision of extension services and input supply.

Tables 1 and 2 present summaries of the introduced improved crop varieties and agricultural practices, describing their key characteristics in the agricultural systems (whether they were continued or discontinued), including constraints. That is, the tables present a summary of the responses to the questions originally raised during focus group discussions, key informant interviews, and field observations.

Farmers mentioned their satisfaction with the use of haricot beans, OPVs, and mid-maturing hybrid maize. Similarly, they spoke of their satisfaction with the related agricultural practices of row-sowing, banding fertilizer application, traditional rainwater-harvesting, and intercropping (Tables 1 and 2). However, they argued that rainfall variability, shortage of input supply, high price of inputs, inadequate extension service and training, and a poor market for produce remained among the key factors influencing their decision to continue or discontinue the technologies every cropping season.

4. Discussion

4.1. Continued Technologies and Their Characteristics

4.1.1. Improved Crop Varieties

Haricot beans. The second major crop in the study villages is the haricot bean. Haricot bean production appears to match the farmers' preferences, as the crop possesses attributes important for adoption, as identified by Rogers [41]. The most important attributes of haricot bean production are the low requirement for labor and traction power, high yield, early maturity, drought tolerance, high output market value, and high soil fertility restoration capacity (as a replacement for traditional fallowing). It is also appreciated for its high straw yield with high fodder nutritive values, and the possibility of its production as either a sole or an intercrop and its suitability for replanting in failed maize fields (as a result of dry spells or droughts). Farmers use haricot beans for the diversification of livelihood shocks resulting from unfavorable rainfall events. Haricot beans are differently responsive to the impact of rainfall variability. Farmers and extension workers indicated that haricot bean growers increase their average annual farm income from 40% to 50%, besides improving nutritional diversity.

Maize. Although maize is the major crop and the mainstay of farmers in the villages, its production is highly constrained by soil moisture stress, intra-and inter-seasonal rainfall variability and dry spells [42], and poor soil nutrients [23]. In response to the unfavorable climatic conditions, the use of early-maturing maize is an interesting option for farmers. The national extension system promotes the OPVs. The OPVs mature early and are more adaptive to the frequent dry spells or droughts. The national extension system recommends early-maturing crops as a strategy to cope with the unfavorable climatic conditions in the central Rift Valley. As a result, such maize varieties are among the widely adopted crops in this particular region. The OPVs are the farmers' choice when there is a late onset of rainfall or when more variable intra-seasonal rainfall is expected; their earliness in maturing enhances the resilience to the unfavorable rainfall events. Equally, mid-maturing maize is also widely cultivated. The mid-maturing hybrid maize is spreading principally via social networks because of their higher yield over early-maturing maize. Previous studies also showed a similar trend: most smallholder farmers tackle the seed shortage through farmer-to-farmer seed exchange or using saved seed [10]. However, the extension workers in the central Rift Valley do not provide extension services on hybrid maize production as they are institutionally recommended only for high-moisture areas [27]. The Rift Valley is a moisture-stress area with high vulnerability to unpredictable mid-season and terminal droughts and, hence, is outside the area of adaptation for the mid-maturing hybrid maize. This is a major reason for excluding mid-maturing maize from the national extension system. Beshir and Wegary [27] reported that the production of these hybrids is currently expanding in the central Rift Valley with farmers along with the OPVs. In years with early onset of rainfall, which is an indicator of a good year, farmers mostly prefer mid-maturing hybrid maize with a high yield, such as BH-540 and 543. A previous study indicated that mid-maturing maize was more productive where growing conditions were relatively favorable [43].

The challenges of hybrid maize are the higher seed costs (high production cost), shortage of supply and lack of credit facilities, and the necessity of purchasing seeds every year. Because of genetic segregation, hybrid seeds are basically not recycled, and this increases farmers' seasonal dependence on institutional provision of the seeds. These characteristics of the seeds create skepticism, particularly among the poorest farmers. Consequently, planting recycled hybrid maize seeds for two seasons is a common practice in the villages of such farmers. In Ethiopia, farmers plant recycled hybrid seed despite significant losses in vigor [7]. In addition to this, the hybrid maize seed market is characterized by limited competition among few breeders, insufficient supply of seed relative to demand, a limited choice of varieties, and high seed costs [17]. Hybrid maize seeds are supplied by public institutions or certified companies [27]. Unlike the hybrid seeds, local seeds are reproducible and can be used for successive seasons without an appreciable reduction in yield. Similarly, the seeds of OPVs maize can be recycled for two to three seasons without a significant reduction in yield.

The OPVs give a better yield than the local maize under low or variable seasonal rainfall. An assessment from the stakeholders' viewpoints indicated that the average grain yields of local, OPVs and hybrid maize are 2–3, 3–4, and 4–5 tons ha^{-1}, respectively, under varying farming conditions. The average yield obtained from OPVs was 2.3 ton ha^{-1}, while that of hybrids was 3.7 ton ha^{-1}, indicating that hybrids had a more than 50% yield advantage over the OPVs. Participating farmers reported that they hardly apply fertilizers to local maize because of the lower yield and lower margin for economic return. For a similar reason, they also apply a lower rate of fertilizers to the OPVs than to the hybrid maize. Farmers confirmed that local maize is adaptive to intra-seasonal dry spells, as the OPVs are. However, the frequent dry spells and lower rainfall from September onwards are major challenges with local maize. Local maize used to be planted in April as it matures late. Recently, however, there has been a shift in the cropping calendar from planting maize in April to early June; this shortens the length of the cropping season, increasing vulnerability to the low rainfall in September or October. Kassie et al. [16] reported similar challenges to crop production in the central Rift Valley. Mostly, farmers respond to these challenges with crop and variety choice and adjustment of the cropping calendar.

Other constraints on the production of improved maize varieties, as pinpointed by participating farmers, are low seed quality, broken seeds, and weed seeds. Farmers noted that the proportion of broken seed and weed seeds sometimes accounts for about one-third of the total weight of the improved crop varieties purchased. The broken seeds reduce seed germination and sometimes force farmers to re-sow. This makes fertilizer application less efficient and less profitable. Furthermore, despite causing an additional labor requirement for weeding, the weeds limit the agronomic performance of maize. Invasive weeds, like *Parthenium* spp., have invaded several farms in the region.

4.1.2. Improved Agricultural Practices

Row-sowing of seeds. Broadcasting had been the most popular and widely practiced method of sowing seeds in the central Rift Valley and elsewhere in Ethiopia. As an alternative to broadcasting seeds, row-sowing becomes the most widely practiced method for sowing seeds (mainly maize) in the study villages. The farmers and field visits confirmed that the practice of row-sowing had 80-90% and 15-20% success for maize and haricot beans, respectively. The transition to row-sowing was fast owing to its attractive attributes. Farmers and other stakeholders indicated that row-sowing enables aeration in maize stands, improves seedling vigor, and eases manual weeding (uprooting weeds by hand) and hoeing (with local tools) for weed control.

Farmers claimed (also confirmed by the agricultural experts and extension workers) that row-sowing saves seeds (50 to 65 kg ha^{-1} for broadcasting compared to 26 to 31 kg ha^{-1} for row-sowing), reducing the seed rate by more than 50% in favorable cropping seasons. Moreover, although experts and extension workers claim more benefits, farmers argued that row-sowing increases maize yield 2- to 3-fold compared to the broadcasting method. However, because of the high risk of crop failure in relation to the unpredictable seasonal rainfall, a low plant stand in row-sowing may reduce yields. Farmers added that too low a plant density under limited rainfall conditions could lead to low utilization of available soil water due to evaporation from the exposed surface of the soil. Thus, in seasons with low rainfall or high rainfall variability, farmers prefer a high seed rate to ensure adequate crop establishment. A previous study indicated that varying planting density according to the rainfall pattern has been shown to improve water and crop productivity in dryland rain-fed systems [44]. Under adequate maize stand establishment, the surplus maize stands are thinned for livestock fodder.

Unlike the broadcasting method, row-sowing is convenient for practicing the traditional rainwater-harvesting techniques of *Dirdaro* and *Shilshalo.* These techniques are established with the help of a traditional plow pulled by a pair of oxen. Earlier studies reported that Ethiopian farmers use traditional ridges and furrows for rainwater-harvesting [23].

Traditional in situ rainwater harvesting. Observation from field visits indicated that the *Dirdaro* practice makes ridges and furrows for in situ rainwater harvesting at sowing times. The ridges and furrows are made between every two planting rows. The ridges harvest rainwater, reduce runoff, and enhance infiltration [23,45]. In addition to harvesting rainwater, *Shilshalo* enables a traditional weeding practice that is practiced four to five weeks after sowing maize. Moreover, its practice removes the surface crust of the soil and promotes infiltration. *Shilshalo* is commonly practiced on the furrows that were made by *Dirdaro*. Biazin and Stroosnijder [23] report that *Shilshalo* is used for water harvesting and breaks the surface crust formed through intensive tillage. By contrast, the broadcasting of seeds and *Shilshalo* are incompatible. *Shilshalo* causes substantial damage to the maize stands sown by broadcasting. Therefore, row-sowing has made the methods of *Dirdaro* and *Shilshalo* more feasible in maize. Consequently, over 80% of the farmers growing maize through the row-sowing method use *Dirdaro* and *Shilshalo*.

Farmers and extension workers stated that the use of traditional in situ rainwater harvesting techniques increases maize yields and reduces its vulnerability to dry spells or droughts. A previous study indicated that in situ rainwater harvesting techniques significantly improved soil moisture and runoff and increased agricultural production in semiarid areas in Ethiopia, which in turn reduces risk [22]. However, the furrows and ridges made via these techniques may cause waterlogging during heavy rainfall. Both maize and haricot beans were found to be vulnerable to prolonged waterlogging, as well as to poor plant growth and yield reduction and loss. The experts, extension workers, and farmers indicated that the *Dirdaro* and *Shilshalo* in maize cultivation might increase yield by up to 70% compared to using flat seedbeds.

Banding method of fertilizer application. Like for the seeds, fertilizer had been traditionally applied by the broadcasting method. Together with row-sowing, the introduction of the banding technique of fertilizer application becomes an alternative to the broadcasting method. There is a synergy among practicing banding, row-sowing, and traditional water-harvesting techniques, as all use rows. As a result, the level of synergy between the banding technique and row-sowing has increased, particularly among farmers who apply fertilizer to maize. The practice of using row-sowing and banding together was reported to give high agronomic and economic returns in maize in the central Rift Valley [26].

The agricultural experts and extension workers argued that the banding method increases maize yields by approximately 60% to 70% compared to the broadcasting method. Therefore, the banding fertilizer application technique has a 'relative advantage' [41] compared to the broadcasting method. Despite the high costs of fertilizer, the number of farmers applying fertilizers has substantially increased. For instance, in one of the villages (Denbe Adansho), the official documents indicated that 35% of the farmers in the village applied nitrogen and phosphorus fertilizer (DAP) and 18% applied nitrogen fertilizer (urea) in maize during the 2013/2014 cropping season. However, only 13% of the farmers had applied DAP and none had applied urea fertilizer in the preceding cropping season in maize. Besides other benefits such as enabling easier agronomic management, the yield advantage of synchronized row-sowing and banding fertilizer methods are the major reasons for the increased interest in fertilizer application.

However, the high price of fertilizer and the obsolete technologies for forecasting highly variable rainfall are underlying factors limiting the number of farmers applying fertilizers. Moreover, the high labor requirement is potentially a limitation of practicing the banding method. The other limitation to the banding method is the existence of the blanket (same fertilizer rate regardless of soil type and fertility status) national application rate of 100 kg of DAP and 100 kg of urea for a hectare of maize field. This high application rate discourages fertilizer application, particularly in the poorest segment of the communities. A previous study conducted in the central Rift Valley indicated that attractive agronomic and economic benefits could be obtained by a reduction of 73% of the national recommendation fertilizer rate, if it is applied by the microdosing technique in a row-sowing maize [26]. The microdosing technique is a low cost, low risk and profitable option, particularly for financially constrained farmers. Such a fertilizer technology can increase the affordability of fertilizers and motivate farmers to apply fertilizers. Despite all these merits, however, farmers who originally adopted the microdosing technique discontinued it later mainly due to a lack of adequate training and support from the national extension.

4.2. Discontinued Technologies and Their Characteristics

About 29% of the farmers who hosted the technologies on their farms took up most of the technologies during the DCG project's lifetime. However, after the project was phased out, except for fertilizer banding and row-sowing (they were reintroduced and were integrated into the extension system), the rest of the originally adopted technologies were finally discontinued. They include extra-early-maturing maize, finger millet, and sorghum as well as improved practices of seed priming, fertilizer microdosing, conservation tillage, and harvesting maize at physiological maturity. The discontinuation of these technologies is attributed to the fact that the project ended before the adopted technologies were adequately integrated into the national extension systems or thoroughly taken up by social networks. The lack of support from the national extension systems or social networks discouraged the farmers and ultimately led to the discontinuation of the technologies.

Furthermore, most stakeholders indicated that they lack adequate information about these technologies. Extension workers and agricultural experts observed that the technologies were not brought to the attention of policymakers and, hence, were not integrated into the national extension system. Seed priming is cheap, does not add any external expenditure for farmers [46], and improves crop establishment and yields in semi-arid agriculture [47–49]. It is still an option for farmers if proper attention is given by the national extension system.

Harvesting maize at physiological maturity was originally adopted for its higher grain yields and better quality stover yields compared to harvesting at maturity. Nevertheless, farmers later discontinued it when they realized a post-harvest problem: that such grains are susceptible to pest and fungal attacks. Farmers added that they could not store the grains to wait for a better market price or for later domestic consumption.

Farmers and extension workers noted that extra-early-maturing maize was discontinued because of its lower yield potential and high vulnerability to dogs, birds, and other wild animals. This maize matures far earlier than all others, which increases its vulnerability. Agricultural experts indicated that this maize variety was introduced due to its better adaptability to shorter cropping seasons when there is a late onset of seasonal rainfall, meaning it is better able to escape terminal drought. High vulnerability to bird attack, as with *Teshale,* or low palatability for consumption and market values, as with *Seredo*, are the reasons for the discontinuation of sorghum. Although the improved crop varieties of finger millet give high yield and good quality of grain and straw, inadequate information on food values, an absence of market for grains, and a lack of institutional support are the major reasons for their discontinuation. The advantages of finger millet were scarcely promoted among the adopter farmers, and they were barely assimilated into social networks or integrated into the national extension system. The discontinuation of conservation tillage contributes to a change in the entire tillage and grazing system, high weed infestation, and low yields. In particular, the widespread practice of free-roaming livestock in the Rift valley is one of the key reasons for discontinuing conservation agriculture. Free grazing on stubble after harvest is not compatible with conservation agriculture, which includes retaining crop residues as mulch [23,33]. However, conservation tillage is still an option in the central Rift Valley around homesteads, where it is possible to prevent free grazing with traditional fences [33]. This shows that there is no single factor that can explain the discontinuation of technologies. However, one common denominator is the lack of integration of these technologies into the national extension system or social network.

5. Limitation of the Study

This study is limited to evaluating the technologies introduced to farmers in the central Rift Valley by the national agricultural extension system, DCG, and farmer social networks, between the 2006-7 and 2013-14 cropping seasons.

6. Conclusions

The empirical findings from this study showed that improved crop varieties and related agricultural practices were introduced to the farmers in the central Rift Valley of Ethiopia through the national extension systems, research projects, or social networks. Mostly, technologies reached farmers following the top-down technology development and extension model. Extra-early-, early-maturing, and mid-maturing maize, haricot beans, finger millet, and sorghum were introduced by the DCG project in the 2006-7 cropping season. Likewise, the major improved agricultural practices introduced by the DCG were harvesting maize at physiological maturity, row-sowing, seed priming, fertilizer microdosing and banding, intercropping, and conservation tillage. In the 2010-11 cropping season, the national extension system introduced the practices of in situ rainwater-harvesting and re-introduced DCG technologies including early-maturing maize, haricot beans, row-sowing, fertilizer banding, and intercropping. These technologies were included in the technology package with the national extension system for offering institutional support. The social networks introduced hybrid maize and promoted the cultivation of haricot beans and hybrid maize.

The technologies introduced to the farmers by the social networks or research projects receive support from the national extension system only when they are integrated into the system. Such a deficiency was the reason for the discontinuation of the DCG technologies (extra-early, finger millet and sorghum, harvesting maize at physiological maturity, seed priming, fertilizer microdosing, and conservation tillage). Most of these DCG technologies were also discontinued due to a lack of support from the social networks or were found to be inappropriate by the farmers themselves in association with their socioeconomic settings (extra-early, finger millet and sorghum, harvesting maize at physiological maturity, and conservation tillage). Row sowing, and intercropping maize and haricot beans, which were originally introduced to the farmers by the DCG, were integrated into the extension system for accommodating farmers' preferences.

Early- and mid-maturing maize and haricot beans were able to capture the farmers' interests for their higher yields and economic returns and, hence, were further popularized by the social networks. Likewise, improved agricultural practices of row-sowing, banding fertilizer application, intercropping and traditional in situ rainwater-harvesting techniques were able to offer attractive benefits. The compatibility among row-sowing, intercropping, fertilizer banding, and traditional in situ rainwater-harvesting techniques attracted the interest of farmers. Most of these technologies have demonstrated enormous potential for reducing the vulnerability of farming systems to rainfall variability in the central Rift Valley. However, the poor economic capacity of farmers, harsh biophysical factors, and the inadequate link among research projects, social networks, and the national extension system remain key constraints on the sustainable use of the technologies. Integration of technologies into the national extension system depends mainly on the decisions of policy-makers in connection with their appropriateness, primarily, to existing agroecological settings. Farmer social networks, in contrast, select and recommend technologies, primarily, in association with their appropriateness to the existing socioeconomic settings. For improved agricultural productivity, food security, and rural livelihoods, therefore, policy-makers should pay particular attention to developing agroecologically and socioeconomically appropriate technologies and efficient extension systems with a view to creating strong linkages among researchers, extension systems, social networks, and farmers.

Author Contributions: G.S. identified the research problem, designed tools for data collection, collected and analyzed the data, and wrote the manuscript. J.B.A. made a significant contribution to the data management, analysis, and write-up of the final manuscript.

Acknowledgments: The Norwegian Ministry of Foreign Affairs funded this research through an institutional collaboration between Hawassa University, Ethiopia and the Norwegian University of Life Sciences (NMBU0, Norway. We are grateful to the agricultural extension workers, experts, and participating farmers for their unreserved assistance during the data collection. They provided useful insights and assistance to the researchers. We are also thankful to the district agriculture and rural offices for their generous hospitality and support.

Conflicts of Interest: The authors declare no conflict of interest.

References

1. Teklewold, H.; Kassie, M.; Shiferaw, B. Adoption of multiple sustainable agricultural practices in rural Ethiopia. *J. Agric. Econ.* **2013**, *64*, 597–623. [CrossRef]
2. Vanlauwe, B.; Kihara, J.; Chivenge, P.; Pypers, P.; Coe, R.; Six, J. Agronomic use efficiency of fertilizer in maize-based systems in sub-saharan africa within the context of integrated soil fertility management. *Plant Soil* **2011**, *339*, 35–50. [CrossRef]
3. Schaffnit-Chatterjee, C. *Agricultural Value Chains in Sub-Saharan Africa*; Deutsche Bank: Frankfurt, Germany, 2014; pp. 1–28.
4. Gebremedhin, B.; Swinton, S.M. Investment in soil conservation in northern Ethiopia: The role of land tenure security and public programs. *Agric. Econ.* **2003**, *29*, 69–84. [CrossRef]
5. Byerlee, D.; Spielman, D.J.; Alemu, D.; Gautam, M. *Policies to Promote Cereal Intensification in Ethiopia: A Review of Evidence and Experience*; Ifpri Discussion Paper No. 707; International Food Policy Research Institute: Washington, DC, USA, 2007.
6. Diao, X.; Fekadu, B.; Haggblade, S.; Taffesse, S.; Wamisho, A.; Yu, K. *Agricultural Growth Linkages in Ethiopia: Estimates Using Fixed and Flexible Price Models*; IFPRI Discussion Paper 695; International Food Policy Research Institute (IFPRI): Washington, DC, USA, 2007.
7. Alemu, D.; Mwangi, W.; Nigussie, M.; Spielman, D. The maize seed system in Ethiopia: Challenges and opportunities in drought prone areas. *Afr. J. Agric. Res.* **2008**, *3*, 305–314.
8. Spielman, D.J.; Byerlee, D.; Alemu, D.; Kelemework, D. Policies to promote cereal intensification in Ethiopia: The search for appropriate public and private roles. *Food Policy* **2010**, *35*, 185–194. [CrossRef]
9. Sisay, D.T.; Verhees, F.J.; van Trijp, H.C. Seed producer cooperatives in the Ethiopian seed sector and their role in seed supply improvement: A review. *J. Crop Improv.* **2017**, *31*, 323–355. [CrossRef]
10. Alemu, D.; Bishaw, Z. Commercial behaviours of smallholder farmers in wheat seed use and its implication for demand assessment in Ethiopia. *Dev. Pract.* **2015**, *25*, 798–814. [CrossRef]
11. Dorosh, P.; Rashid, S. Food and Agriculture in Ethiopia: Progress and Policy Challenges. *J. Dev. Studies* **2013**, *50*, 343–344. [CrossRef]
12. Dercon, S.; Hill, R.V. *Growth from Agriculture in Ethiopia: Identifying Key Constraints*; Department for International Development (DFID): London, UK, 2009.
13. IFDC. Ethiopia fertilizer assessment. In *The African Aertilizer and Agribusiness Partnership*; International Fertilizer Development Center (IFDC): Muscle shoals, AL, USA, 2012.
14. Teklewold, H.; Kassie, M.; Shiferaw, B.; Köhlin, G. Cropping system diversification, conservation tillage and modern seed adoption in Ethiopia: Impacts on household income, agrochemical use and demand for labor. *Ecol. Econ.* **2013**, *93*, 85–93. [CrossRef]
15. Tura, M.; Aredo, D.; Tsegaye, T.; La Rovere, R.; Kassie, G.; Mwangi, W.; Mwabu, G. Adoption and continued use of improved maize seeds: Case study of central Ethiopia. *Afr. J. Agric. Res.* **2010**, *5*, 2350–2358.
16. Kassie, M.; Zikhali, P.; Manjur, K.; Edwards, S. Adoption of Sustainable Agriculture Practices: Evidence from a Semi-Arid Region of Ethiopia. *Nat. Resour. Forum* **2009**, *33*, 189–198. [CrossRef]

17. Kassie, B.T.; Hengsdijk, H.; Rötter, R.P.; Kahiluto, H.; Asseng, S.; Ittersum, M.K.V. Adapting to climate variability and change: Experiences from cereal-based farming in the central rift and kobo valleys, Ethiopia. *Environ. Manag.* **2013**, *52*, 1115–1131. [CrossRef] [PubMed]
18. Binswanger-Mkhize, H.P.; Byerlee, D.; McCalla, A.; Morris, M.; Staatz, J. The Growing Opportunities for African Agricultural Development. In *Agricultural R & D: Investing in Africa's Future, Analyzying Trends, Challenges & Opportunities*; ASTI/FARA, IFPRI: Accra, Ghana, 2011; Volume 16, pp. 1–30.
19. Food and Agriculture Organization. Country Fact Sheet on Food and Agriculture Policy Trend. Available online: http://www.fao.org/3/a-i4181e.pdf (accessed on 27 July 2015).
20. Stroosnijder, L. Modifying land management in order to improve efficiency of rainwater use in the African highlands. *Soil Tillage Res.* **2009**, *103*, 247–256. [CrossRef]
21. Segele, Z.T.; Lamb, P.J. Characterization and variability of kiremt rainy season over Ethiopia. *Meteorol. Atmos. Phys.* **2005**, *89*, 153–180. [CrossRef]
22. Yosef, B.A.; Asmamaw, D.K. Rainwater harvesting: An option for dry land agriculture in arid and semi-arid Ethiopia. *Int. J. Water Resour. Environ. Eng.* **2015**, *7*, 17–28.
23. Biazin, B.; Stroosnijder, L. To tie or not to tie ridges for water conservation in rift valley drylands of Ethiopia. *Soil Tillage Res.* **2012**, *124*, 83–94. [CrossRef]
24. Ariti, A.T.; Vliet, J.; Verburg, P.H. Farmers' participation in the development of land use policies for the central rift valley of Ethiopia. *Land Use Policy* **2018**, *71*, 129–137. [CrossRef]
25. Ojiewo, C.; Kugbei, S.; Bishaw, Z.; Rubyogo, J. *Community Seed Production*; Food and Agriculture Organization/ICRISAT: Addis Ababa, Ethiopia, 2015.
26. Sime, G.; Aune, J.B. Maize response to fertilizer dosing at three sites in the central rift valley of Ethiopia. *Agronomy* **2014**, *4*, 436–451. [CrossRef]
27. Beshir, B.; Wegary, D. Determinants of smallholder farmers hybrid maize adoption in the drought prone central rift valley of Ethiopia. *Afr. J. Agric. Res.* **2014**, *9*, 1334–1343.
28. CSA. *Population Projection of Ethiopia for All Regions at District Level (2014–2017)*; Central Statistics Agency (CSA): Addis Ababa, Ethiopia, 2013.
29. Ayenew, T. Environmental implications of changes in the levels of lakes in the Ethiopian rift since 1970. *Reg. Environ. Chang.* **2004**, *4*, 192–204. [CrossRef]
30. Jansen, H.; Hengsdijk, H.; Legesse, D.; Ayenew, T.; Hellegers, P.; Spliethoff, P. *Land and Water Resources Assessment in the Ethiopian Central Rift Valley–Project: Ecosystems for Water, Food and Economic Development in the Ethiopian Central Rift Valley*; Alterra: Wageningen, The Netherlands, 2007; pp. 1566–7197.
31. Kassie, B.; Rötter, R.; Hengsdijk, H.; Asseng, S.; van Ittersum, M.; Kahiluoto, H.; van Keulen, H. Climate variability and change in the Central Rift Valley of Ethiopia: Challenges for rainfed crop production. *J. Agric. Sci.* **2014**, *152*, 58–74. [CrossRef]
32. Biazin, B.; Sterk, G. Drought vulnerability drives land-use and land cover changes in the Rift Valley dry lands of Ethiopia. *Agric. Ecosyst. Environ.* **2013**, *164*, 100–113. [CrossRef]
33. Sime, G.; Aune, J.; Mohammed, H. Agronomic and economic response of tillage and water conservation management in maize, Central Rift Valley in Ethiopia. *Soil Tillage Res.* **2015**, *148*, 20–30. [CrossRef]
34. Palinkas, L.A.; Horwitz, S.M.; Green, C.A.; Wisdom, J.P.; Duan, N.; Hoagwood, K. Purposeful sampling for qualitative data collection and analysis in mixed method implementation research. *Adm. Policy Ment. Health* **2015**, *42*, 533–544. [CrossRef] [PubMed]
35. McHugh, O.V.; Steenhuis, T.S.; Abebe, B.; Fernandes, E.C. Performance of in situ rainwater conservation tillage techniques on dry spell mitigation and erosion control in the drought-prone north wello zone of the Ethiopian highlands. *Soil Tillage Res.* **2007**, *97*, 19–36. [CrossRef]
36. Lewis, S. Qualitative inquiry and research design: Choosing among five approaches. *Health Promot. Pract.* **2015**, *16*, 473–475. [CrossRef]
37. Sutton, J.; Austin, Z. A qualitative research: Data collection, analysis, and management. *Can. J. Hosp. Pharm.* **2015**, *68*, 226–231. [CrossRef] [PubMed]
38. Patton, M. *Qualitative Research and Evaluation Methods*, 3rd ed.; Sage Publications: London, UK, 2002.
39. Corbin, J.; Strauss, A. Grounded theory research: Procedures, canons, and evaluative criteria. *Qual. Sociol.* **1990**, *13*, 3–21. [CrossRef]
40. Creswell, J.W.; Miller, D.L. Determining validity in qualitative inquiry. *Theory Pract.* **2000**, *39*, 124–130. [CrossRef]

41. Rogers, E.M. *Diffusion of Innovations*, 3rd ed.; The Free press: New York, NY, USA, 1983.
42. Belay, A.; Recha, J.W.; Woldeamanuel, T.; Morton, J.F. Smallholder farmers' adaptation to climate change and determinants of their adaptation decisions in the Central Rift Valley of Ethiopia. *Agric. Food Secur.* **2017**, *6*, 24. [CrossRef]
43. Nigusie, M.; Bogale, G.; Seboke, G. *Evaluation of Maize Genotypes in the Drought Stressed Areas of Ethiopia*; CSSE: Addis Abeba, Ethiopia, 2004.
44. Tsubo, M.; Walker, S. An assessment of productivity of maize grown under water harvesting system in a semi-arid region with special reference to ENSO. *J. Arid Environ.* **2007**, *71*, 299–311. [CrossRef]
45. Temesgen, M.; Rockstrom, J.; Savenije, H.; Hoogmoed, W.; Alemu, D. Determinants of tillage frequency among smallholder farmers in two semi-arid areas in Ethiopia. *Phys. Chem. Earth Parts A/B/C* **2008**, *33*, 183–191. [CrossRef]
46. Aune, J.B.; Bationo, A. Agricultural intensification in the Sahel—The ladder approach. *Agric. Syst.* **2008**, *98*, 119–125. [CrossRef]
47. Harris, D.; Joshi, A.; Khan, P.A.; Gothkar, P.; Sodhi, P.S. On-farm seed priming in semi-arid agriculture: Development and evaluation in maize, rice and chickpea in India using participatory methods. *Exp. Agric.* **1999**, *35*, 15–29. [CrossRef]
48. Harris, D. Development and testing of "on-farm" seed priming. *Adv. Agron.* **2006**, *90*, 129–178.
49. Chivasa, W.; Harris, D.; Chiduza, C.; Mashingaidze, A.B.; Nyamudeza, P. Determination of optimum on-farm seed priming time for maize (*Zea mays* L.) and sorghum (*Sorghum bicolor* L. Moench) for use to improve stand establishment in semiarid agriculture. *Tanzanian J. Agric. Sci.* **2000**, *3*, 103–112.

© 2018 by the authors. Licensee MDPI, Basel, Switzerland. This article is an open access article distributed under the terms and conditions of the Creative Commons Attribution (CC BY) license (http://creativecommons.org/licenses/by/4.0/).