Peer-reviewed version available at Sustainability 2018, 10, 3268; doi:10.3390/su10093268

*Type of the Paper (**Article**)*

Empowerment and Tech Adoption: Introducing the Treadle Pump Triggers Farmers' Innovation in Eastern Ethiopia

Shimelis Beyene1, Teshome Regassa1*^, Belaineh Legesse2, Martha Mamo1^, Tsegaye Tadesse3^

[1] Department of Agronomy and Horticulture, University of Nebraska-Lincoln, Lincoln, Nebraska, United States of America; sbeyene2@unl.edu, mmamo3@unl.edu

[2] School of Agricultural Economics and Agribusiness Management, College of Agriculture and Environmental Sciences, Haramaya University, Haramaya, Ethiopia; belaineh.legesse@gmail.com

[3] National Drought Mitigation Center, School of Natural Resources, University of Nebraska-Lincoln, Lincoln, Nebraska, United States of America; ttadesse2@unl.edu

* Correspondence: tregassa2@unl.edu; Tel.: +x1-402-472-1489

^ Daugherty Water for Food Global Institute Faculty Fellow

Received: date; Accepted: date; Published: date

Abstract: In 2013, thirty-eight treadle pumps (TPs) were installed as low-cost technology introduction for small-scale irrigation in eastern Ethiopia. This pilot project also trained six farmers on tube well excavation, installation and maintenance of pumps. In June 2015, researchers visited nine of the 38 TP villages, and found only two functional TPs. The rest were replaced with a new technology developed by the trained farmers. Adopters of the new technology stated that the limited water output and high labor demand of the conventional TP did not optimally fulfil their irrigation water requirements. The new technology had spread quickly to more than one hundred households due to three key factors. First, farmers' innovative modifications of the initial excavation technique addressed the discharge limitations of the conventional TP by excavating boreholes with wider diameter. Second, local ownership of the new technology, including skills used in well drilling and manufacturing excavation implement, made the new irrigation technology affordable and accessible to the majority of households. Third, this innovation spread organically without any external support, confirming its sustainability. Farmers, empowered by training, gained more control in developing technology options tailored to local needs and conditions of their communities.

Keywords: irrigation; technology adoption; farmers' innovation; diffusion

---

1. Introduction

In Ethiopia, smallholder farmers contribute to more than 90% of all the agricultural production and cultivate over 96% of the total arable land [1]. Thus, agricultural growth has the potential to contribute not only to food security, but also to poverty reduction and livelihood improvement for the rural population. This is particularly true in light of the high yield gap between potential and the actual agricultural production in Ethiopia [2]. Almost all smallholder farming in Ethiopia is rain-fed [3]. Erratic rainfall and recurrent drought exposes the majority of the rain-fed farming population to food insecurity and perpetual poverty [4], and negatively affect the economy of Ethiopia [5]. Given the rapid population growth and low level of current food production, the country cannot meet its food deficit through rain-fed production alone [6]. Even during relatively good rainfall years, the survival of about 10% of the population depends on external food assistance [7]. Furthermore, climate change is expected to exacerbate extremes in weather patterns and rainfall

Peer-reviewed version available at *Sustainability* **2018**, *10*, 3268; doi:10.3390/su10093268

variability [8]. Paradoxically, the highlands of Ethiopia receive very high amounts of rainfall, with annual runoff volume of up to 122 billion m³ of water from 12 major river basins [3]. The region also possesses an estimated ground water potential of 27 to 40 billion m³ [3,9-11]. However, lack of water storage structures [5], weak water management institutions, and poor implementation of water use and management policies in Ethiopia have limited realization of the economic potential possible from the abundant water resources [12].

The government, recognizing the economic and livelihood importance of agriculture, expresses commitment to solve this paradox through an agriculture focused development program that also includes irrigation development as one of the major strategies [13]. Key government documents such as the Water Resources Management Policy [14], Water Sector Strategy [15], and the country's Growth and Transformation Plans have all emphasized irrigation development as crucial to ensure food security, reduce poverty, and improve the broader national economy [16]. Small-scale irrigation development is widely viewed as having great potential for improving livelihoods of rural households and facilitating adaptation to climate change [17]. As rural households constitute more than 80% of the population [17], significant effort is being made by the Ethiopian government and its development partners to expand irrigated agriculture, including small-scale irrigation [18].

Similar to other parts of sub-Saharan Africa [19], data on small-scale irrigation in Ethiopia is very limited [9]. It is estimated that current irrigated area covers only about 5-6% of the total estimated 5 million hectares considered suitable for irrigation [20,11]. The Ethiopian government has introduced new irrigation technologies for small-scale irrigation that includes rainwater harvesting, ponds, hand-dug-wells and stream diversions. Depending on the spatial position of the farm plots and the water sources, farmers are introduced to the use of gravity irrigation, manual water lifting devices, treadle and powered pumps to irrigate their crops [18,21]. Because of the enhanced productivity, relative to rain-fed farming, governmental and non-governmental development actors have invested considerable efforts and resources to support adoption of irrigation by smallholder farmers [18] with some positive results in, both rural poverty reduction and improved technology adoption [22]. However, many researchers observed that the uptake rate of improved agricultural technology is lower than expected due to primarily the top-down approach and coercive nature of agricultural development in general and implementation of extension services in particular [23] contributing to chronic food insecurity in Ethiopia. In order to improve the relationships between farmers and researchers, we designed an empowering approach through participatory action research, which developed pilot projects, based on community stated needs, and assessed the performance of these pilot projects for lessons learnt for improvement, scaling and sustainability.

In 2010, we developed a long-term collaborative research program, "Farming, Food and Fitness" (3F), which aimed to develop strategies to enhance agricultural productivity, improve dietary practices and measure the efficacy of these strategies through participatory action research and pilot projects in two of the most drought prone regions in Ethiopia: East Hararghe Zone and South Wollo Zone [24]. Baseline information collected in 2010 and 2011 revealed high demand for access to irrigation among study households. In order to address this high demand through a pilot project, the 3F research program sponsored International Development Enterprise (iDE) Ethiopia to install 38 treadle pumps (TPs) in 2013. This report presents the result of a preliminary assessment of this pilot project. The objectives of the preliminary assessment were to assess outcomes of the pilot project in general and the status of TPs installed by iDE in particular from the farmers' perspectives. The preliminary assessment had the following research questions. What was the status of the TPs installed by the pilot project? What were the benefits and limitations of the TPs? Why did farmers switched to the new technology? What were the contributing factors for the diffusion of the new technology? What were the outcomes of the pilot project?

2. Approach and Methods

2.1. Approach

This preliminary assessment and the pilot project were part of the long-term multi-disciplinary, collaborative research program, 3F, involving three universities: University of Nebraska-Lincoln in the USA, and Haramaya and Wollo Universities, both in Ethiopia. The partners are engaged in a participatory approach to address agricultural productivity, food security and nutrition in two drought prone areas: South Wollo and East Hararghe in Ethiopia (see Figure 2). Qualitative fieldwork and extensive quantitative surveys were conducted in 2010 and 2011, respectively, to provide baseline information for the program [24]. Subsequent fieldwork focusing on small-scale irrigation in Haramaya was carried out in 2012 and 2013 to assess areas suitable for installing TPs for low cost Household Irrigation Technologies (HITs).

Between February and June 2013, fifty-five wells were drilled in five *Kebeles* (sub districts) Haramaya Woreda (district) in East Hararghe as a pilot project to provide HITs (Figure 2). Out of the 55 wells drilled during the pilot project, 38 wells were successful, with sufficient water at appropriate depth for manual pumps. The remaining 17 wells were unsuitable due to stone impediment, insufficient and/or absence of a permeable layer, and static water level being too deep for manual pumping. This 70% success rate is considered good by international standards [25].

Figure 1. Traditional Irrigation Water Extraction (3F Photo Archive)

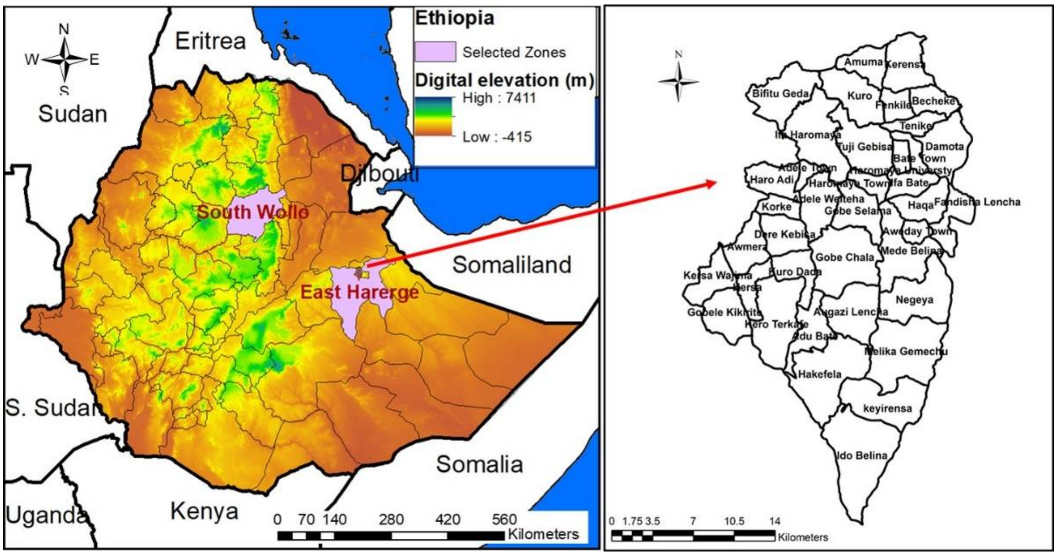
During the pilot project, the area irrigation branch of the ministry of agriculture, in collaboration with Haramaya University and an iDE Ethiopia, trained six individuals in drilling boreholes and installing casings, hoses and pumps. Although the training mainly focused in manual well drilling, it also included skills on well casing installation, maintenance of wells, installation and maintenance of pumps. The trainees, hired as daily laborers during the pilot project, participated in excavating and installing TPs and quickly attained the skills required to maintain the wells and service the equipment for proper function. The TP technology, although very low in capacity, was an improvement over the preexisting farmers' irrigation practices in the study sites. The pilot project assumption was that TPs, in addition to being low-cost HITs, would also minimize the dependency of local farmers on harvesting water in big and open hand-dug wells, with diameters of up to 20 meters (Figure 1). These wells created large soil disturbances and required costly cleaning, using both human labor and excavators when the water level drops during the dry season, to remove accumulated sediment. Moreover, these open wells pose perpetual danger to human and livestock.

After the completion of the pilot project, these trainees, in collaboration with local artisans, were able to locally manufactured replacement parts and excavation tools modified from the original implements. These local entrepreneurs proceeded to install modified technologies based on farmers' needs and willingness or ability to invest in additional technological solutions. Using the most influential theories in agricultural technology adoption, the theory of 'diffusion of innovations' by Everett Rogers [26] [27], this report investigates the adoption and subsequent fate of the TPs introduced during the pilot project and the diffusion of the new technology in East Hararghe Ethiopia. This theory explains not only how innovations are adopted and spread through a population, but also how they are modified or altered during implementation, providing an appropriate framework for interpretation of the preliminary assessment findings in this report.

2.2. Study Areas

Haramaya Woreda (district) is located in East Hararghe Zone of Oromia Regional State (Figure 2). The capital town, Haramaya, is located about 500 km from Addis Ababa. Haramaya Woreda has 33 rural and two urban *Kebeles* (subdistricts) with a total population of 220,986 [28]. Most of the *Kebeles*, including those selected for this study, are considered highland and mid-land. The average annual rainfall, based on 25 years of data from the Haramaya meteorological station, shows a mean total annual rain fall of 775 mm [29]. Although the amount and pattern vary locally, rainfall is bimodal in distribution; a short season from March to May is known as *belg*, and a longer rainy reason from July to September is known as *meher*. The maximum and minimum mean annual temperatures for the area are 23.8 °C and 9.6 °C respectively [30]. The endowed with high underground water, the woreda is characterized by frequent drought, crop failure, severe land degradation, and increased vulnerability to chronic food insecurity.

Figure 2. Map of Ethiopia showing the study areas.



In East Hararghe Zone, Lake Haramaya and shallow, ground water (6 to 30 m deep) in the dry lakebed and catchments provided the opportunity to access irrigation for the households that can afford the irrigation infrastructure [31]. Deep wells, open pits, and ponds were used to access the underground water for irrigating fields (Figures 1). The management of these small-scale irrigation schemes also varied; most are privately owned but large ponds were shared by multiple households. Farmers used furrow and flood irrigation by pumping the water directly to the fields using large hoses, often using motorized pumps. Alternatively, farmers pumped water to a reservoir (3000 to 10000 m^3) first and then distributed the water from the reservoir to fields (Figure 3). Sometimes, they also have a series of reservoirs and pumps that can take the water more than half a kilometer away from the original source. Irrigation is primarily used for vegetable and high value cash crops in East Hararghe. The major vegetable crops include onion, potato, tomato, carrot, beets, various leafy greens and Khat, a perennial shrub produced for its stimulant leaf and soft buds [32]. Farmers dedicate irrigation plots primarily to market-oriented high value crops, although it is common to observe a portion of irrigated plot used for the production of subsistence crops during one of the cropping cycles [32].

2.2. Data Collection

Qualitative data was collected using focus group discussions, key informant interviews and field observations. Before the actual interviews were made, enumerators obtained informed consent from participants. The University of Nebraska Institutional Review Board reviewed and approved the study protocol and all supporting documents (IRB Approval #: 20100710992EP).

Focus-Group Discussion: Focus-group discussions (FGD) were conducted with farmers from eight different villages in Haramaya where the TPs were installed. The size of a group differs from village to village ranging from three to nine farmers of mixed gender, as determined by the number of people available in the proximity of their farm plots. Points of discussions covered a wide variety of issues but focused on farmers' perceptions of TP irrigation experience and impacts (both negative and positive) of TP irrigation. Included in the discussion were topics, such as cropping patterns, use of inputs (seeds, fertilizers, pesticides), concerns and challenges related to irrigation practices and institutions related to water use and management. Also included were questions related to why farmers switched to the new technology, whether or not there are households who abandoned the TP without switching to the new technology, and why as detailed in the Appendix.

Key Informant Interview: Key Informant Interviews (KIIs) were held with government officials (4), development agents (2), local well drillers (2), technical experts (1), researchers (2), university officials (4) and local elders (4). The KIIs included semi-structured interviews covering a wide variety of information, depending on the interviewee's institutional affiliation. It included topics on aggregate data on irrigation, policies and practices related to irrigation development, institutional support to farmers, market-related and natural resource management issues.

Field Observation: During farm visits, observations were made on the status of the irrigation schemes, major crop types grown on irrigated fields, cropping patterns (strip or intercropping), cropping cycles, irrigation methods used (flood, furrow or other), climatic impacts (frost), plant pests and disease pressures and use of TP systems and the new technology.

3. Results and Discussion

3.1. Farmers Perception of Irrigation

The majority of farmers in the focus group discussions were enthusiastic about access to irrigation. Farmers who have access to irrigation explained the benefits, but also challenges of access to irrigation. Among the benefits, farmers explained that they were able to cultivate at least two times a year, which would not have been possible without irrigation. In addition, they stated that irrigation enabled them to produce high value crops for the market. This enabled them to generate income to meet some of their financial needs, such as children education, health care services and improved homes. The income generated from TP irrigation, for example, paid for the new technology. The most important outcome in all focus group discussions was that access to irrigation minimized the impacts of drought. They also indicated that access to irrigation improved the wellbeing of not only the households who have access to irrigation but also communities at large due to the social support system of relatives and friends.

Farmers that have practiced irrigation for at least two cropping cycles mentioned improved production and increased income. The challenges farmers faced included not realizing the full potential of irrigation agriculture due to limited access to improved seeds and other inputs, price fluctuations for their crops, and plant pests and diseases. Despite these challenges, which sometimes

Preprints (www.preprints.org) | NOT PEER-REVIEWED | Posted: 15 August 2018 doi:10.20944/preprints201805.0108.v2

Peer-reviewed version available at Sustainability 2018, 10, 3268; doi:10.3390/su10093268

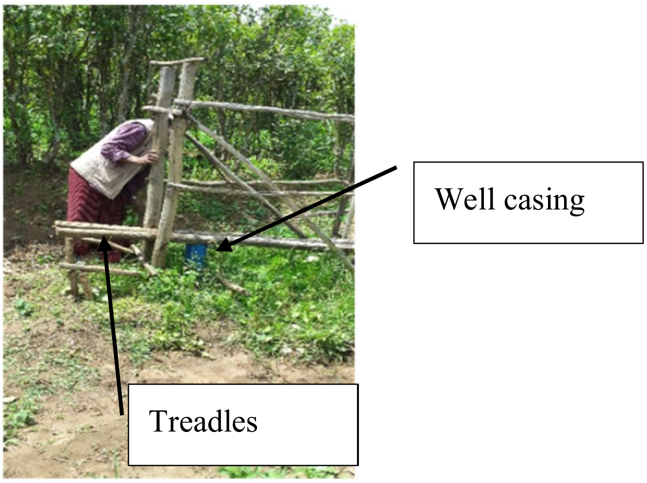
caused economic losses, farmers claimed that irrigation agriculture outperformed rainfed agriculture significantly.

3.2. Farmers' Innovation in East Hararghe

Most of the TP component systems installed in 2013 had been partially or entirely replaced by locally modified technology. Farmers stated that the TPs had two primary limitations:

1. Limited capacity of water lifting – farmers mentioned that the area that can be irrigated with TP is at most 50 by 50 m, which was too small for most farmers' needs, especially when they need to expand irrigated fields.
2. High demand for labor – farmers explained that the manual operation of the TP required high labor input for the small amount of water output. One of the farmers, who still uses the original TP as his only means of irrigation, stated that he was planning to switch to the new technology.

Figure 4. Still Functional Treadle Pump (3F Photo Archive)



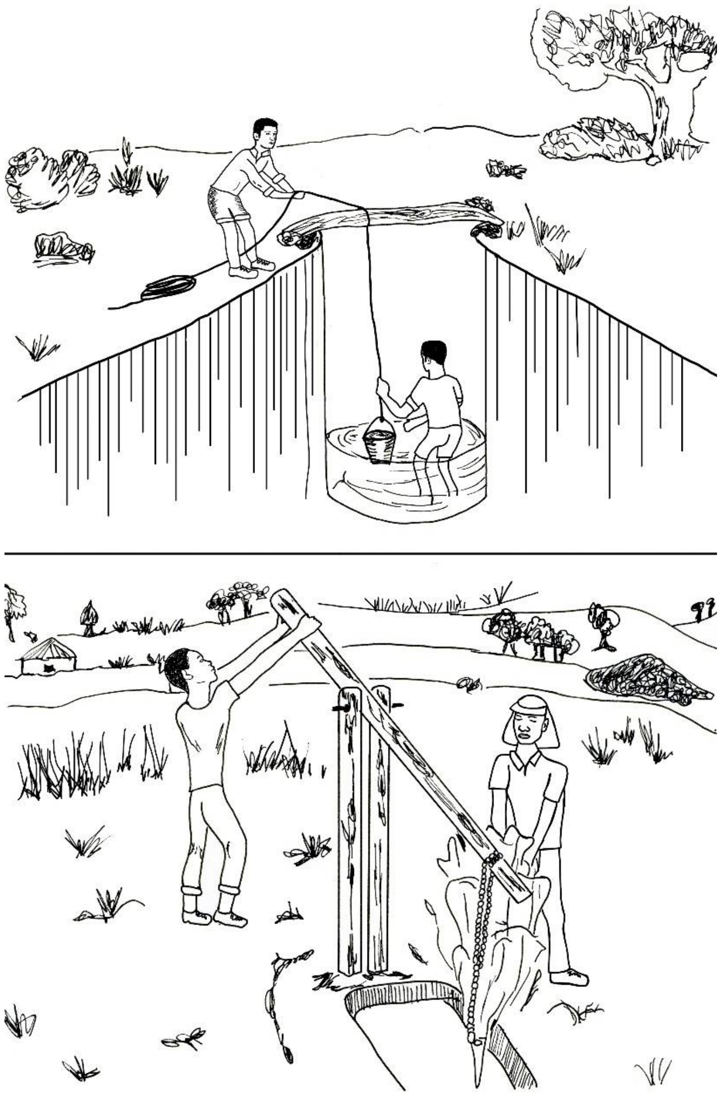
For these two reasons, among the nine TP sites observed during the preliminary assessment, only two were still functional. The other seven had been replaced by locally modified technology. Furthermore, of the two TPs that were still functional, one was being used as a supplement to a new system installed about 5 m away. The second, owned by an elderly farmer, was the only TP still in use as a sole source for household irrigation (Figure 4). During the preliminary assessment, this farmer was planning to switch to the new technology. One of the female farmers who recently moved to the new technology acknowledged the significant impact of the TP. She stated, "the TP enabled me to compete with male farmers" and that she would not be in the position she is now, if she did not have the TP.

3.3. Local "Reinvention": The New Technology

As mentioned above during the pilot project, one of the interventions included training selected community members on construction and maintenance of TP systems. The training aimed to build local capacity for maintaining installed TP systems or for installing new TPs if the demand would arise. Although the local demand for access to irrigation was high and the drilling skills acquired by trained farmers was expected to be high, the assumption was that the conventional TPs would spread widely. However, the demand was more for the higher capacity system than what the conventional TP could provide and the newly trained individuals were able to meet this demand through local innovation. This local innovation had four main components: locally manufactured efficient excavation tools, wider diameter boreholes, effective casing and installing pumps. The later three are the direct result of training by the pilot project. However, the first, although inspired by the augur used in the pilot project, was an improved version, in both its diameter and excavating efficiency due to its serrated edges.

Locally constructed tools: The need to increase the diameter of the well required a different sized drilling tool than the one used originally for TP systems. The trained individuals, in consultation with the local blacksmith, were able to design a more efficient auger with different diameters and serrated edges. These augers, developed locally, were used to excavate wider boreholes to provide a larger volume of water than the TP system could provide, meeting farmer's demands for higher water volume per unit time.

Figure 5. Well Excavation: Traditional (Top) and New Excavation (Bottom).



Wider diameter of borehole: One of the limitations of the TP technology is the narrow diameter of the well. According to farmers, the TP borehole of 4 cm in diameter was too small to conduct enough water to irrigate more than one plot (an average household plot was about 0.2 ha and households typically have multiple plots). The farmers trained during the pilot project were now able to excavate wells with a diameter of 13 cm, which, depending on the discharge rate of the well, can deliver three times more water than the original TP. This diameter seems optimal for Haramaya households, where the average landholding is about 0.5 hectares [24]. The wide use of underground water raised issues among communities. Farmers revealed their concerns for underground water depletion due to increased extracting of water for irrigation and other purposes. However, they also indicated hope on the recent watershed management efforts and signs of recovery of the dried Lake Haramaya.

Cost effective casing: One of the major constraints for traditional methods of accessing underground water for irrigation in Haramaya *Woreda* was the collapsing of well walls, due to the common nitisols soil [33] in Haramaya [33] that easily fall apart. The high diameter of the open pits wells in the *woreda* minimized wall collapse (Figure 1). The trained farmers were able to innovate using cost effective, plastic casing for the new system to function properly.

Between the end of the pilot project in June 2013 and the preliminary assessment in June 2015, community members trained during the pilot project constructed more than 100 new systems. Furthermore, the new system costs 250 to 400 USD. Farmers used to pay more than 1,000 USD for excavation of traditional water pits as in Figure 1. One particularly large water pit, shared by 21 individuals, cost nearly 2,000 USD. Traditional water pits are not only expensive to construct and maintain, as the walls cave in frequently, but also take more land that could be used for cultivation.

Since the introduction of the TP system, farmers reported doubling crop production. Using the new system, they reported increases in income from an estimated 2,000 USD to 4,500 USD annually (Focus Group Discussion in Tuji Gebissa, June 13, 2015). According to farmers, the new excavation techniques (Figure 5) go deeper, up to 30 meters making more areas available for irrigation, while the initial TP excavation could reach a maximum depth of only 20 meters. The new systems can support up to 10 households, with an average of six individuals per household. This, according to farmers interviewed, is 10 times more than the original TP system. Building the capacity of selected farmers empowers local communities and individuals to think and act in their own interests and to develop irrigation technologies that meet their needs and conditions without the support or direction of external bodies. This confirms the sustainability of the innovation.

It may be instructive to see our preliminary observation through the framework of Rogers' diffusion of innovation theory [26] particularly the five attributes that influence the rate of adoption: relative advantage, compatibility, complexity, trialability, and observability. First, with respect to relative advantage, it is clear that both in terms of water output and reduced labor demand, the new technology is considered advantageous over both the TP system it replaced as well as the traditional pit well irrigation system. Second, the technology is consistent with values, experiences and needs of farmers in Haramaya *Woreda*, where about 60% households were engaged in some form of irrigation prior to the pilot project [24]. Third, the unique aspect of the new technology in Haramaya is that it was a local innovation, which makes the 'complexity attribute' [26] negligible. The relatively rapid spread of the innovation is an indication of its ease of use for local farmers. Fourth, regarding trialability, the rapid diffusion of the innovation and the preliminary nature of our study preclude the proper assessment of this attribute. The training of selected farmers and their participation in installing the TP systems can be considered trialing without cost to them. It is also fair to assume that the close social network of farmers in Haramaya would allow the rapid dissemination of information about the nature of the TP as well as the new technology experiences across the *woreda* and beyond. Finally, in terms of 'observability', the results of the new technology will be apparent at least to neighboring farmers immediately. The same mechanism mentioned for rapid dissemination of information mentioned above, would also enhance observability of the results to distant farmers. Moreover, the proximity of the study *Kebeles* to Haramaya University and *Woreda* Extension Office, two entities that have an interest in associating with the farmers' success stories, could have helped.

Another insightful contribution by Rogers [26] is the concept of "reinvention" – "the degree to which an innovation is changed or modified by a user in the process of its adoption and implementation" (p. 180). He argues that although experts and development agents do not generally see reinvention as desirable, a higher degree of reinvention often leads to faster rate of adoption as reinvention makes the innovation fit to a broad range of adopters' conditions [26]. As reinventions enhance the fit between an innovation and adopters' needs, they are likely to lead to the continued use of the innovation, hence to the sustainability of the innovation [26,32]. Although difficult to generalize from this preliminary study, the reinvention of the TP system in East Hararghe has led to not only the rapid diffusion, but also the sustainability of this local innovation. Future studies in East Hararghe may reveal that the reinvention on the TP system also plays a key role in scaling up of the new technology.

In East Hararghe, almost all farmers with TP systems have invested in the reinvention and created a new irrigation system. Nevertheless, the new system would not have been possible without the introduction of the TP system in the first place and, in particular, without the training of local farmers on excavating tube wells and installing pump systems. However, without the independent experimentation of the trained farmers (empowerment), the new systems would not have been possible. The local origin of the new technology suggests it will continue to be adopted by farmers until further improvements, which meet the changing needs of farmers, replace it. The local control of this technology suggests it will continue to be sustainable. This has profound implications to adoption and diffusion of agricultural technologies elsewhere. This can be a classic example of capacity building and provision of technology options open enough to empower local communities to shape their own destiny.

4. Conclusions

Trained farmers, empowered to experiment independently, developed new tools and came up with sustainable solutions tailored to the local needs. The breakthrough and the missing link from the traditional irrigation schemes in Haramaya *Woreda* to the pilot project was the introduction of the controlled excavation technique. Compared to the traditional hand excavation, the new excavation technique was more efficient in reducing cost, labor and the land area needed for construction of the system, which enhanced its comparative advantage. The introduction of controlled excavation, now wide spread in the study areas, led to innovative modifications of the initial TP technology to satisfy the needs and aspiration of the farmers. The major impact of the new technology is that it made irrigation affordable and accessible to a large number of households and enabled many farmers to accumulate enough resources to diversify their livelihoods into off-farm activities. It is not, therefore, surprising to see the rapid diffusion of the new technology. Local capacity for installing and maintaining the whole irrigation structure and for fabricating tube well excavating tools ensures sustainability of the innovation. A more detailed study is necessary to gain more insights into the nuances of this successful case of technology introduction, reinvention (innovative modification) and diffusion for possible replication in other sites with similar conditions.

Acknowledgments: We gratefully acknowledge financial support from Daugherty Water for Food Global Institute at University of Nebraska-Lincoln and in-kind support of Haramaya University. We thank our partners at Haramaya University, Haramaya *Woreda* officials, and iDE Ethiopia for their time and commitment. We are also grateful for all the farm households who took their time to respond to our interviews.

Conflicts of Interest: The authors declare no conflict of interest

References

1. Taffesse, A., Dorosh, P. and Gemessa, S. Crop Production in Ethiopia: Regional Patterns and Trends. In Food and agriculture in Ethiopia: Progress and policy challenges, Dorosh, P. and Rashid, S., Eds.; University of Pennsylvania Press: Philadelphia, PA, USA 2013; pp. 53–83. https://doi.org/10.2499/9780812245295 (Accessed on 23 April 2018)
2. Licker, R.; Johnston, M.; Foley, J.; Barford, C.; Kucharik, C.; Monfreda, C.; Ramankutty, N. Mind the gap: how do climate and agricultural management explain the 'yield gap' of

croplands around the world? *Global Ecol. Biogeogr.* **2010**, 19, 769–782.

3. Awulachew, S.B.; Yilma, A.D.; Loulseged, M.; Loiskandl, W.; Ayana, M.; Alamirew, T. Water Resources and Irrigation Development in Ethiopia. Colombo, Sri Lanka: International Water Management Institute. Working Paper 123, 2007.
4. Chemeda, E.D.; Babel, M.S.; Gupta, A.D.; Seleshi, B.A.; Merrey, D. Farmers' Perception of Water Management under Drought Conditions in the Upper Awash Basin, Ethiopia. *Int. J. Water Res. D.* **2006**, 22(4), 589–602. DOI: 10.1080/07900620600779723 (Accessed on 30 July 2018).
5. World Bank. Ethiopia: Managing water resources to maximize sustainable growth. A World Bank water resources assistance strategy for Ethiopia. The World Bank Agriculture and Rural Development Department. Report No. 36000-ET. Washington, DC, USA, 2006.
6. Devereux, S. *Food insecurity in Ethiopia: A discussion paper for DFID*. IDS: Sussex: England; 2000, pp. 1-18. Available online: https://www.ids.ac.uk/files/FoodSecEthiopia4.pdf. (accessed on 25 April 2018)
7. Diouf, J., Sheeran, J. The State of Food Insecurity in the World: Addressing food insecurity in protracted crises. Rome: World Food Program (WFP) and Food and Agriculture Organization of the United Nations (FAO) Joint Report. 2010.
8. Conway, D.; Schipper, E. Adaptation to climate change in Africa: Challenges and opportunities identified from Ethiopia. *Global Environ. Chang*. **2011**, 21, 227–237.
9. Makombe, G.; Kelemework, D.; Aredo, D. A comparative analysis of rainfed and irrigated agricultural production in Ethiopia. *Irrig.Drainage Syst.* **2007**, 21, 35–44.
10. MoWIE (Ministry of Water, Irrigation and Energy).Water Resources of Ethiopia. The National and International Perspective, Awareness Creation Program prepared for Public Relation officials, Addis Ababa, Ethiopia, 2013.
11. Semu, M. Agricultural Use of Ground Water in Ethiopia: Assessment of Potential and Analysis of Economics, Policies, Constraints and Opportunities. AgWater Solutions Project Case Study IWMI, 2012.
12. Mosello, B.; Calow, R.; Tucker, J.; Parker, H.; Alamirew, T.; Kebede, S.; Alemseged, T.; Gudina, A. Building adaptive water resources management in Ethiopia. ODI Report, London: ODI, 2015. Available online: https://www.odi.org/ (accessed 10 February 2018).
13. GTP I. Growth and Transformation Plan (GTP) 2010/11-2014/15. Ministry of Finance and Economic Development (MoFED), Addis Ababa, Ethiopia, 2010.
14. MoWR (Ministry of Water Resources). Water Resources Management Policy. Federal Democratic Republic of Ethiopia, Addis Ababa, Ethiopia, 1998.
15. MoWR (Ministry of Water Resources). Irrigation Development Strategy (Component of the Water Sector Development Strategy). National Planning Commission Draft Report. Addis Ababa, Ethiopia, 2001.
16. NPC. The second growth and transformation plan (GTP II) (2015/16-2019/20). National Planning Commission, Ethiopia, 2015.
17. Burney, J.; Naylor, R.; Postel, S. The case for distributed irrigation as a development priority in sub-Saharan Africa. *Proceedings of the National Academy of Sciences of the United States of America* (PNAS). **2013**, 110(31), 12513-12517.
18. Haile, G.G.; Kassa, A.K. Investigation of Precipitation and Temperature Change Projections

in Werii Watershed, Tekeze River Basin, Ethiopia; Application of Climate Downscaling Model. *J. Earth Sci. & Clim. Change*. **2015**, Jan 1:6(8), 1-11. Doi: 10.4172/2157-7617.1000300

19. Woodhouse, P.; Veldwisch, G.; Venot, J.; Brockington, D.; Komakech, H.; Manjichi, A. African farmer-led irrigation development: re-framing agricultural policy and investment? *J. Peasant Stud.* **2017**, Jan 2;44(1), 213-233.
20. Awlachew, S.B.; Ayana, M. Performance of irrigation: An assessment at different scales in Ethiopia. *Exp. Agr.* **2011**, Jan;47(S1), 57-69.
21. Dessalegn, M.;Merrey. D. Motor pump revolution in Ethiopia: Promises at a crossroads. *Water Altern.* **2015** Jun 1;8(2), 237-57.
22. Dercon, S.; Gilligan, D.; Hoddinott, J.; Waldehanna, T. The Impact of Roads and Agricultural Extension on Consumption Growth and Poverty in Fifteen Ethiopian Villages. Amer. J. Agr. Econ. 2009, Nov;91(4), 1007–1021
23. Berhanu, K.; Poulton, C. The Political Economy of Agricultural Extension Policy in Ethiopia: *Economic Growth and Political Control. Development Policy Review.* **2014**, 32(s2), s197–s213.
24. Beyene, S.; Regassa, T.; Legesse, B.; Mamo, M.; Willis, M.S.; Tadesse, T.; Woldehawariat, Y. Rural livelihoods in drought prone areas of East Hararghe and South Wollo, Ethiopia: Surviving or thriving? PLOoS One (Under Review).
25. Holistic Approach to Sustainable Food Security through Adaptive Eco-Region Based Watershed Management in Ethiopia. International Development Enterprise (IDE) Final Report. 2013. Addis Ababa, Ethiopia.
26. Rogers, E. *Diffusion of Innovations*, 5th ed. A Division of Macmillan Publishing Co Inc. The Free Press: New York. New York, 2003.
27. Ansari, S.; Fiss, P.; Zajac, E. Made to Fit: How Practices Vary as They Diffuse. *Acad. Mgmt. Rev.* **2010**, Jan;35(1), 67-92.
28. Central Statistical Agency (CSA). Statistical Oromiya. Central Statistical Agency of Ethiopia, Addis Ababa, Ethiopia, 2007. http://catalog.ihsn.org/index.php/catalog/3583 (Accessed on 25 March 2018).
29. Alemayehu, T.; Furi, W.; Legesse. D. Impact of water overexploitation on highland lakes of eastern Ethiopia. *Environ. Geol*. **2007,** Mar 1;52(1), 147-154.
30. Tadesse, N. and Abdul Aziz, M. Water Balance of Haromaya Watershed, Oromiya Region, Eastern Ethiopia. *Int.l J. Earth Sci. Eng.* **2009**, 2(06), 484-498.
31. Senti, E.; Tufa, B.;, Gebrehiwot, K. Soil erosion, sediment yield and conservation practices assessment on Lake Haramaya Catchment. *World J. Agricul.l Sci.* **2014**, Nov;2(7), 186-193.
32. Setegn, S.; Chowdary, V.M.; Mal, B.C., Yohannes, F., Kono, Y. Water Balance Study and Irrigation Strategies for Sustainable Management of a Tropical Ethiopian Lake: A Case Study of Lake Alemaya. *Water Res. Manage.* 2011, Jul 1;25(9), 2081-2107.
33. Asad, Z.; Adem, D.; Farah, A. Evaluation of the existing conservation practices on Lake Haramaya Catchment. *Afri. J.Soil Sci.* **2016**, 4(3), 321-327.