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Understanding the Spontaneous Spreading of Stone Bunds in Ethiopia: Implications for Sustainable Land Management

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Abstract: This study deals with the spontaneous spreading of stone bunds in the central Ethiopian highlands, i.e., the adoption and implementation of stone bunds by farmers on their own initiative. The study tests the hypothesis that spontaneously implemented stone bunds, as compared to stone bunds implemented by mass mobilization campaigns, are more integrated with other land management practices and lead to higher yields. Data are collected in the Girar Jarso *woreda* through field observations and household surveys. Descriptive statistics are used to analyze and test the data at 1% and 5% probability levels. Results show that stone bunds are spontaneously implemented mainly on farmlands located nearby the homesteads where farmers perceive severe erosion, poor soil fertility and steep slope gradients. Compared to stone bunds implemented by mass mobilization, spontaneously implemented stone bunds are perceived as better maintained, more frequently modified to fit the farming system and better integrated with soil fertility management practices, such as applying fertilizer, compost and manure. Particularly, this better integration with other practices is very important, because it makes stone bunds more effective in reducing erosion, leading to beneficial effects on soil moisture and soil productivity, as perceived by farmers. The study, therefore, suggests that the mass mobilization campaign should use a more participatory and integrated approach, in which there is ample space for awareness raising and learning concerning the benefits of integrated farm management, and in which farmers themselves have a leading role in the decision on where to construct stone bunds. Such a strategy will lead to more sustainable impact on soil fertility and food security than the current top-down intervention approach.

Keywords: sustainable land management; stone bunds; integrated farm management; mass mobilization; spontaneous spreading and adoption; Ethiopia

1. Introduction

Subsistence agriculture is the main source of livelihood for more than 85% of Ethiopia's population [1]. However, the country faces challenging problems in its struggle to make agriculture sustainable and to achieve food security [2,3]. In Ethiopia, land degradation in the form of soil erosion and nutrient depletion seriously threatens agricultural productivity and is a major cause of food insecurity [4,5]. The problem is persistent in the highlands of Ethiopia, where the majority of the country's population lives and depends on farming. Land degradation in the highlands of Ethiopia is primarily caused by intensive cultivation on steep and fragile farmlands with unsustainable land management practices [3,6]. Furthermore, soil characteristics, topography and the cropping pattern (dominated by cereals) make the Ethiopian highlands vulnerable to soil erosion [7]. In this regard, it has been estimated that 42 ton/ha [2,8] to 179 ton/ha [9] of soil is eroded from cultivated land every year. Hence, we can infer that the fate of Ethiopian smallholder agriculture relies on the quest for Sustainable Land Management (SLM).

In Ethiopia, SLM is an important issue and receives emphasis in the country's development agenda, which aims to reverse land degradation, improve agricultural productivity and achieve food security through implementing soil and water conservation practices at a large scale [10]. In this regard, many development projects and programs have been initiated and implemented by successive Ethiopian governments in collaboration with several consortia of donors since the 1970s [8,10,11]. Between 1995 and 2009, the Ethiopian government incorporated SLM practices into agricultural extension packages/programs for individual farm-households [11]. Recently, SLM practices have been promoted and implemented through community mass mobilization at a watershed level, as part of Ethiopia's Growth and Transformation Plans (GTP I and II) [12,13]. GTPs are a national development framework for five year periods: GTP I (2010/11 to 2014/15) was directed towards achieving the Millennium Development Goals by 2015 [12], and GTP II (2015/16 to 2019/20) was directed towards achieving the country's vision of becoming a middle income country by 2025 [13]. The main SLM practices implemented through (community) mass mobilization include physical measures, such as stone/soil bunds, terraces and check-dams, as well as biological measures, such as tree planting and area enclosures [14].

Despite considerable efforts made to promote SLM through different intervention strategies, limited adoption of SLM practices by local farmers is reported in many studies conducted, for instance, in the highlands of Ethiopia [2,6,15–17]. At the same time, some farmers adopt SLM practices spontaneously, on their own initiative. Such farmers often adapt and implement these practices to make them fit to their farming system and limited available resources, and integrate them with other measures by using their own knowledge and family labor [18–20]. However, there is limited research done to better understand which practices spread spontaneously and how these are adapted to fit the farming system. Having more insight into such spontaneous spreading would help to improve current SLM scaling-up strategies and better enable the inclusion of farmers' knowledge and practices into a technology spreading strategy [21].

This study provides insights into how stone bunds have spontaneously spread in the Girar Jarso *woreda*, the central highlands of Ethiopia, as such contributing to the understanding of the process of spontaneous spreading. Stone bunds are chosen because these are widely promoted and implemented on farmlands in the study area. The study further tests the hypothesis that spontaneously implemented stone bunds, as compared to stone bunds implemented by mass mobilization campaigns, are better integrated with other land management measures, and therefore lead to higher yields.

2. Conceptual and Theoretical Frameworks

2.1. Conceptual Framework

The concept of SLM has emerged as an important global issue due to accelerating land degradation worldwide, including Ethiopia. SLM refers to the use of suitable technologies or practices that farmers implement on their farmland to satisfy individual and community needs, while simultaneously ensuring the long-term productive potential of the farmland and maintaining environmental functions [22–24]. SLM practices are structural, agronomic, vegetative and management measures used to control soil erosion, reduce nutrient depletion, improve soil conservation and enhance productivity [17,25]. Some examples of SLM practices include: terraces, stone/soil bunds, minimum tillage, intercropping, composting, manuring and agroforestry. This study focuses on stone bunds, which, in Ethiopia, can play a crucial role in addressing soil erosion on farmlands [26,27]. Stone bunds are an embankment of stones constructed along the contour line to reduce or stop the velocity of water flowing down-slope, consequently reducing soil erosion [26,27] (Figure 1).

(**a**) (**b**)

Figure 1. Stone bunds on farmlands in the Girar Jarso *woreda*, Central Ethiopian Highlands. Spontaneously implemented stone bunds (**a**); and mass mobilization campaign stone bunds (**b**) (Abi, 2015).

SLM approaches encompass the ways and means to support and enable farmers to implement, adopt and adapt SLM on the farmland [22–24]. In Ethiopia, the regular government extension program, the food-for-work program and mass mobilization are important approaches to spreading SLM practices [14,28]. Next to project- or program-based SLM approaches, World Overview of Conservation Approaches and Technologies, WOCAT [22] identifies the "spontaneous" approach, in which farmer-to-farmer learning takes place, often supported by an adequate enabling environment for spreading of SLM practices. Spontaneous spreading can be measured in terms of the distance that a practice has spread, for instance, from the original farmers involved in a project to non-project farmers through existing social networks [21]. In this research, the term 'spontaneous spreading' refers to the adoption and implementation of SLM practices based on a farmer's intrinsic motivation using his/her own resources, and using knowledge obtained elsewhere: from project interventions, from neighboring farmers or through participation in mass mobilization campaigns.

2.2. Theoretical Framework

The diffusion of innovation theory [29] was used here to better understand how spontaneous spreading takes place, because it describes how knowledge of an innovation, technical information and actual practices spread through-out a population within existing social networks [30,31]. Rogers defines diffusion as the process, by which an innovation is communicated through certain channels over time among the members of a social system [29]. Innovation, in the context of soil conservation, can be defined as a new technology for erosion control or the reduction of soil loss, and/or the integration of a new technology into the farming system [32]. It should be noted that we used the term 'innovation and technology (or practices)' synonymously, which is the same as Rogers does.

Rogers [29] and Carter Jr., et al. [33] argue that the diffusion process is determined by the characteristics of the technology, the communication channel used to share the information about the technology, and characteristics of these who adopt the technology and the environmental contexts (geographical setting). Concerning the technological characteristics, the farmer's perception of the technology determines its spreading [34,35]. This includes: (1) its relative advantage—the degree to which a technology is viewed as better than the previously used practices; (2) its compatibility—the degree to which a technology is consistent with the farming system, farmer's experiences and needs, (3) its complexity—the degree to which a technology design is perceived as difficult to understand and use, (4) its testability—the degree to which a technology can be experimented with on a limited area, (5) its observability—the degree to which the results of a technology are easily visible to others, and (6) its adaptability—the degree to which a technology is changed or modified by a user to fit the farmer's needs in a process of its implementation [30]. Therefore, as suggested by Rogers, technologies that are perceived by farmers as having greater relative advantages, compatible to the farming system, observable to others, adaptable to fit the farmland condition, and less complex to use, would spread better than other technologies [36]. Among others, observability and compatibility are crucial in terms of triggering spontaneous spreading. Farmers spontaneously implement certain technologies, when they observe the benefits of the technologies in the fields of other farmers, and find it convenient in their farming system [37].

Similarly, access to information about an innovation is a decisive factor for its diffusion [34,38]. Access to information enables a farmer to have knowledge about a new technology, how to apply it on the field and what its effect would be in terms of conservation, agricultural productivity, income, etc. [5]. In this case, the role of agricultural extension workers and development agents is crucial [39,40], named the 'change agents' [30]. In addition, Beshah [18] and Meijer, Catacutan, Ajayi, Sileshi and Nieuwenhuis [5] suggest that information and training play a significant role in the transfer of knowledge of introduced technologies. Access to information triggers farmers to learn and implement a new technology, which is crucial in the process of spontaneous diffusion [29].

Moreover, Rogers [36] explains diffusion in terms of a social learning process, through which people talking to people spread an innovation. For instance, individuals may learn about the characteristics of the technology from their neighbors' experiences [31,41,42], particularly when a technology implemented on a neighbor's farmland is visible [43]. In addition, Carter Jr, Jambulingam, Gupta and Melone [33] and Peshin, et al. [44] suggest that interpersonal communication (a face-to-face exchange) is highly effective in forming and changing attitudes towards a technology, as it increases diffusion of information on available technologies and their benefits. Similarly, Kiptot et al. [45] point out that farmer-to-farmer diffusion provides a potential alternative mechanism for technology spreading through extension campaigns. Next to this, knowledge about a technology can also be developed through self-testing and self-experimenting the technology [31,41,46].

Hence, knowledge can be obtained through different ways: through farmer-to-farmer learning, own experimentation, and through sharing experiences about a new technology [47]. Nonetheless, geographical settings, including the topography, soil condition, slope, land size and location, also affect technology use [5]; technologies can only be used when they are suitable to local conditions and the farming system [48]. Literature shows that modifying and adapting technologies to make them fit to local conditions are important for the effectivity of these technologies to tackle environmental problems [25,32,47]. Therefore, a thorough understanding of the geographical setting, in which innovations take place, as well as of the technological characteristics and sources of information that farmers use, are important aspects that help to understand spontaneous spreading; these are all addressed in this paper.

3. Research Methodology

3.1. Description of the Study Area

This study was undertaken in the Girar Jarso *woreda* (similar to district, an official administrative unit), Central Ethiopian Highlands. The total area of the *woreda* is about 494 km^2 with an elevation ranging between 1300 and 3419 m.a.s.l. The *woreda* encompasses 17 rural *kebeles* (similar to ward, the lowest official administrative unit) and has a total population of 80,080 people [49]. Annual rainfall ranges between 801 mm to 1200 mm (according to Fiche Station meteorological data) with annual temperature between 11 °C and 21.8 °C. Rain-fed mixed farming (crop production and livestock raising) is the main means of livelihood for more than 90% of the population in the *woreda,* with some small-scale irrigation practiced in some *kebeles.*

The main soil types found are Vertisols, Nitosols and Cambisols. Vertisols are the dominant soil types in the *woreda* [50]. Cereals are the most important food crop. Soil erosion and soil nutrient depletion severely threaten agricultural production in the *woreda* [50–53]. Similar to other Ethiopian highlands, various SLM technologies (structural and biological measures) have been implemented in the study area to curb erosion problems. The structural measures include construction of bunds, terraces, diversion ditches, check-dams, micro-basins and hillside terraces. The biological measures comprise enclosure of degraded lands from human and animal interference and tree plantings.

3.2. Sampling Techniques

Given that stone bunds are found widely spread on farmlands in the Girar Jarso *woreda*, we selected this practice to understand spontaneous spreading. It should be noted that we considered stone bunds implemented on the farmlands over a five-year period (2010–2014). In this period, stone bunds have been intensively implemented at a watershed level through mass mobilization campaign as part of the first GTP of Ethiopia. For the purpose of this study, three watersheds of the Girar Jarso *woreda* (Gur watershed, Dhaka–Bora watershed and Tulu Dimtu watershed) (Figure 2) were selected. The respective watersheds are 990 hectares, 570 hectares and 600 hectares in size.

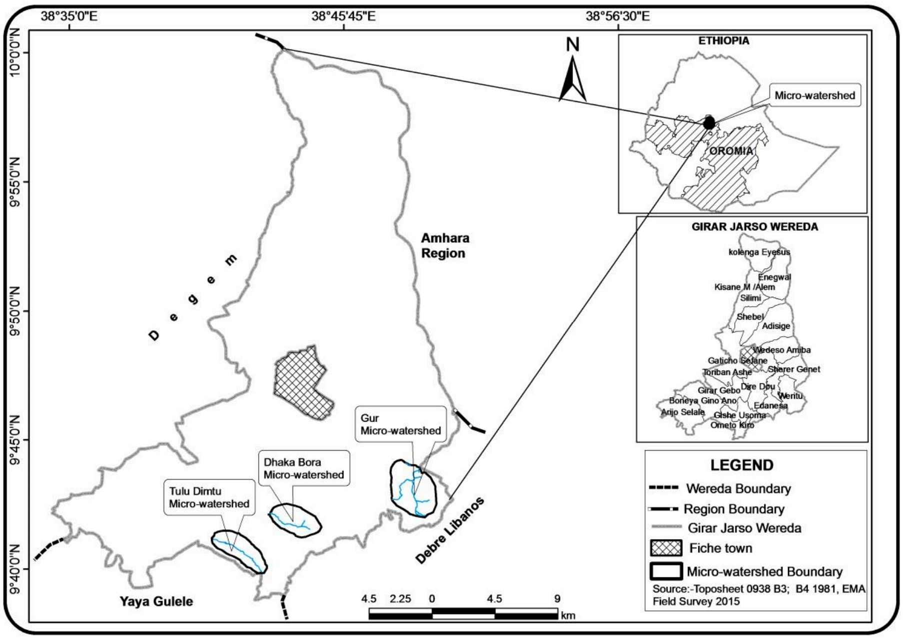

Figure 2. Map of Ethiopia, the Girar Jarso *woreda* and the three studied watersheds.

Farmers from each watershed were selected on purpose, using a two-stage sampling technique. In the first stage, farmlands with spontaneously implemented stone bunds were identified based on a snowball sampling approach. Snowball sampling is a non-probabilistic form of sampling, in which persons initially chosen for the sample are used as informants to locate other persons having similar characteristics [54–56]. This type of sampling method is used in cases, where it is hard to identify samples in the population, in this case, in farmers with spontaneously implemented stone bunds. In addition, snowball sampling is appropriate to understand technology spreading in the absence of external intervention or support [21]. Accordingly, we selected 40 farmers (20 from the Gur watershed, 10 from the Dhaka–Bora watershed and 10 from the Tulu Dimtu watershed) with spontaneously implemented stone bunds. The difference in the number of farmers chosen from the Gur watershed was based on the difference in its size (larger than the Dhaka–Bora and Tulu Dimtu watersheds) and the large number of farmers living in the watershed. In the next stage, we compared the plots of these 40 selected farmers (called spontaneous adopting farmers or SFs) with other nearby plots, where stone bunds were implemented by farmers participating in the mass mobilization campaign (called non-spontaneous adopting farmers or NSFs). Subsequently, we selected 20 NSFs from the Gur watershed, 10 from the Dhaka-Bora watershed and 10 from the Tulu Dimtu watershed based on purposive sampling technique. Hence, in total, 80 farmers were selected for household surveys: 40 SFs and 40 NSFs.

3.3. Data Collection and Analysis

Data were collected through different data collection techniques, including field observations, household surveys and key informant interviews. Field observations were held in consultation with development agents working in the studied watersheds to obtain general information on the implemented stone bunds. Household surveys with the 80 farmers were carried out from May to June 2015 using structured and semi-structured questionnaires. Data related to farmers' perceived farmland characteristics, such as the farm size, erosion, soil fertility status, slope and location, were collected to help understand *where* the stone bunds were implemented. Data related to stone bund characteristics included maintenance of stone bunds, modifications made to make them fit to the farming system, and integration with soil fertility management measures. Application of chemical fertilizer, compost and manure are among the soil fertility management measures considered to measure integration made with the stone bunds. Data related to the characteristics of stone bunds were used to understand *how* stone bunds differ, and whether there is a difference between stone bunds implemented by SFs and NSFs.

Furthermore, data were collected on the perceived effect of stone bunds on soil erosion, soil moisture and yield to compare both types of stone bunds. Definitions of the variables considered for this study are presented in Table 1. With regard to data analysis, descriptive statistics, including cross-tabulation of the percentage distribution, as well as the mean and standard deviations, were used for analysis in Statistical Packages for Social Science (SPSS). Significance levels were tested at the 1% and 5% levels using a paired-sample *t*-test.

Table 1. Descriptions of variables used in this study.

Variables	Description	Values
Perceived farmland characteristics		
Farm plot size	Size of farm plots where the stone bunds are implemented	Hectare
Soil erosion	Level of erosion before stone bunds implementation	1 = Severe, 2 = Moderate, 3 = Low
Soil fertility	Fertility status where stone bunds are implemented	1 = Poor, 2 = Medium, 3 = Fertile/Good
Slope gradient	Slope gradient where stone bunds are implemented	1 = Steep, 2 = Gentle, 3 = Flat
Distance	Estimated walking distance of the plot to homestead of the farmers	Minutes
Stone bund characteristics		
Maintenance	Whether the implemented stone bunds were maintained	1 = No, 2 = Yes
Modification	Whether the implemented stone bunds were modified to make them fit to the local conditions	1 = No, 2 = Yes
Fertilizer	Whether chemical fertilizer was applied together with the stone bunds	1 = No, 2 = Yes
Compost	Whether compost was applied together with the stone bunds	1 = No, 2 = Yes
Manure	Whether manure was applied together with the stone bunds	1 = No, 2 = Yes
Perceived Effects		
Erosion	Effects on erosion after stone bunds were implemented	1 = Increased, 2 = No-change, 3 = Reduced
Soil moisture	Effects on soil moisture after the stone bunds were implemented	1 = Reduced, 2 = No-Change, 3 = Increased
Soil productivity	Effects on soil productivity after the stone bunds were implemented	1 = Reduced, 2 = No-Change, 3 = Increased
Crop yield	Effects on yield after the stone bunds were implemented	1 = Reduced, 2 = No-Change, 3 = Increased
Yield improvement	Believed that yield improvement was only due to stone bunds	1 = No, 2 = Yes

4. Results

This section presents the findings of the study. In the first sub-section, farmers' perceived characteristics of the farmlands are presented. In the second sub-section, we compare the differences between stone bunds implemented by SF and those by NSF. In the third sub-section, farmers' perceived effects of implemented stone bunds on erosion, soil moisture, soil productivity and crop yield are presented.

4.1. Perceived Farmland Characteristics

Figure 3 presents some clear perceived differences between SFs and NSFs. Firstly, the findings revealed that 90% of SFs implement stone bunds on farmlands at perceived moderate to severe erosion levels, compared to 67% of NSFs. In addition, 40% of SFs and only 10% of NSFs implement stone bunds on farmland with perceived poor soil fertility. Hence, a large majority (90%) of NSFs and 60% of SFs implement stone bunds on their most fertile farmlands, respectively. Furthermore, more SFs (23%) implement stone bunds on steeper farmlands, as compared to NSFs (15%). A large majority of farmers (77% of SFs and 85% of NSFs) implement stone bunds on slope gradients that are perceived as flat to moderate. Moreover, the mean farm plots sizes, where the stone bunds are implemented, are 0.58 hectare for SFs and 0.65 hectare for NSFs, respectively. Concerning locations of farmlands where stone bunds are implemented, the mean walking distances from home are about 13 min for SFs and about 32 min for NSFs, respectively.

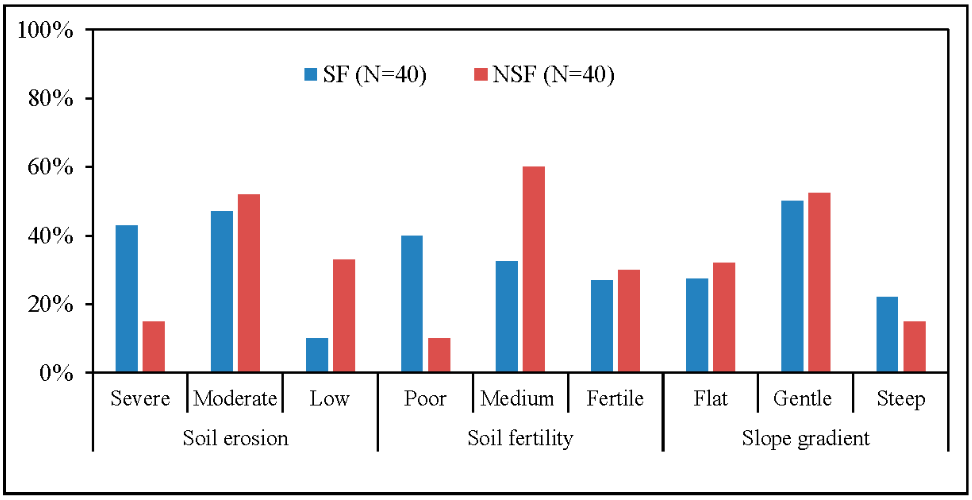

Figure 3. Perceived farmland characteristics in the Girar Jarso *woreda*, Central Ethiopian Highlands. Key: SF—spontaneous adopting farmer, NSF—non-spontaneous adopting farmer.

4.2. Stone Bunds Characteristics

Figure 4 compares SFs and NSFs concerning the characteristics of their stone bunds. The results showed that about 91% of SFs maintain their stone bunds, compared to only 18% of the NSFs. Moreover, a great majority of SFs (83%) confirmed that they modified their stone bunds during implementation to make them better fit to the local conditions, whereas only a small proportion of NSFs (13%) made such modifications. Furthermore, a majority of SFs used higher numbers and more diverse soil fertility management measures integrated with their stone bunds, with 92% using compost (vs. 32% of NSFs), 83% using chemical fertilizer (vs. 55% of NSFs) and 67% using manure (vs. 13% of NSFs).

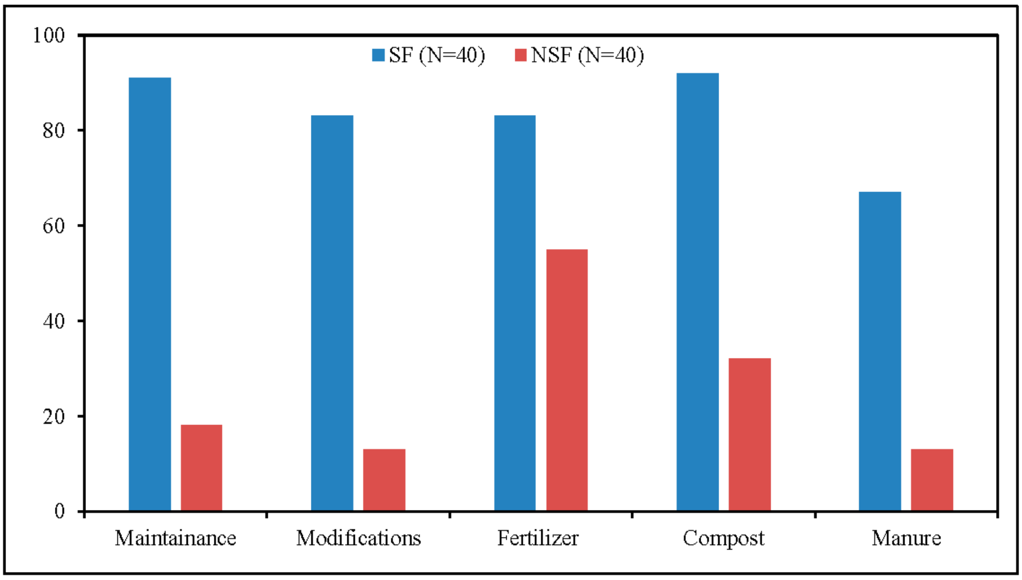

Figure 4. Perceived stone bunds characteristics in the Girar Jarso *woreda*, Central Ethiopian Highlands. Key: SF—spontaneous adopting farmer, NSF—non-spontaneous adopting farmer.

4.3. Perceived Effects of Stone Bunds

With regard to the effect of stone bunds, Figure 5 shows how farmers perceive changes in erosion problems, productivity of the farmland and yield. About 88% of SFs perceive that soil erosion has decreased after constructing the stone bunds, while only 27% of NSFs perceive the same phenomenon. Moreover, 90% of SFs and 38% of NSFs observe that the soil productivity of their farmland has increased with stone bunds, while 93% of SFs and 61% of NSFs perceive increase in soil moisture of the farmlands. Furthermore, much more SFs than NSFs (70% vs. 23%) perceive that the crop yield has increased after stone bund implementation, although 79% of SFs and 44% of NSFs believe that this is not merely due to stone bunds, but also due to the integration with soil fertility management measures.

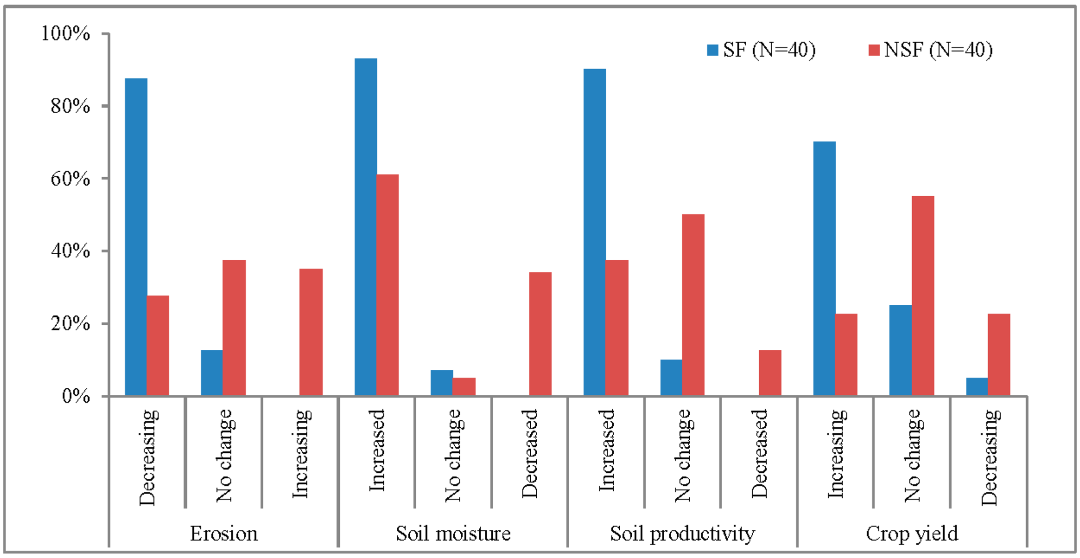

Figure 5. Perceived effects of stone bunds on the farmland in Girar Jarso *woreda*, Central Ethiopian Highlands. Key: SF—spontaneous adopting farmer, NSF—non-spontaneous adopting farmer.

Overall, stone bunds are mainly spontaneously implemented on farmlands with a poor to medium soil fertility status, where erosion is perceived as moderate to severe, and these farmlands are located nearby the homestead of the farmer. This indicates that stone bunds are spontaneously implemented where they are most needed, and that stone bunds implemented by the mass mobilization campaign are often constructed on other farmlands. Besides, spontaneously implemented stone bunds are better maintained, more often modified to fit into the farming system, and more often integrated with diverse soil fertility management measures. As a result, compared to stone bunds implemented by the mass mobilization campaign, more beneficial effects are perceived from the spontaneously implemented stone bunds; not only in decreasing erosion problems on the farmlands, but also in enhancing soil productivity and crop yields.

5. Discussion

The aim of this study was to understand spontaneous spreading of stone bunds. Summarizing the results of this study, Table 2 shows that there are numerous significant differences between stone bunds implemented by SFs and NSFs. When looking at the farmland characteristics, the statistical analysis reveals that significant mean differences ($p < 0.01$) exist concerning perceived soil fertility of the farmland, erosion levels and the locations of farmlands where stone bunds have been implemented. These three characteristics together are decisive in explaining where stone bunds are implemented by SFs. An explanation for this result is that farmers, who use farmlands in areas that are more vulnerable to soil erosion, perceive erosion problems and loss of soil more easily [11,16]. Particularly when visible signs (rills and gullies) appear on the farmlands, farmers perceive soil erosion as severe [19] and hence decide to use erosion control measures [39,57]. Moreover, farmlands closer to the homesteads can be better monitored and taken care of, enabling more frequent supervision of the implemented conservation measures [2]. Consistently, Pender and Gebremedhin [58], Abebe and Sewnet [59] and Cholo, et al. [60] reported that farmers give more attention to farm plots closer to homestead areas than distant farm plots. This also enables farmers (farm owners) and/or other neighboring farmers to observe the effects of implemented stone bunds, suggesting that visible effects are crucial in terms of triggering spontaneous adoption and implementation of technologies.

Table 2. Summary of main differences between stone bunds implemented by SFs and NSFs in the Girar Jarso *woreda*, Central Ethiopian Highlands. Values for characteristics and effects are shown in Table 1.

Variables		SF (*N* = 40)		NSF (*N* = 4 0)		*t*-test
		Mean	Std. Dev	Mean	Std. Dev	
Perceived farmland characteristics	Farm plot size	0.58	0.243	0.65	0.258	0.224
	Soil erosion	1.68	0.656	2.18	0.656	0.001 **
	Soil fertility	1.88	0.822	2.20	0.608	0.048 *
	Slope gradient	2.05	0.714	2.18	0.675	0.424
	Distance	13.13	8.25	31.45	7.278	0.000 **
Perceived stone bund characteristics	Maintenance	1.95	0.221	1.18	0.385	0.000 **
	Modification	1.83	0.385	1.13	0.335	0.000 **
	Fertilizer	1.83	0.378	1.55	0.506	0.013 *
	Compost	1.92	0.280	1.32	0.475	0.000 **
	Manure	1.67	0.478	1.13	0.341	0.000 **
Perceived effects	Erosion	2.88	0.335	1.93	0.797	0.000 **
	Soil moisture	2.93	0.267	2.21	0.963	0.000 **
	Soil productivity	2.80	0.608	1.88	0.939	0.000 **
	Crop yield	2.65	0.580	2.00	0.679	0.000 **
	Yield improvement	1.21	0.418	1.56	0.527	0.053

** *p*-value significant at 0.01; * *p*-value significant at 0.05.

Concerning the characteristics of the stone bunds, Table 2 shows that stone bunds implemented by SFs were significantly better maintained than those implemented by NSFs. Observations during fieldwork confirmed this: stone bunds implemented by NSFs were poorly maintained and some were even destroyed and broken during ploughing. These poorly maintained and damaged stone bunds can even be the cause of additional erosion problems [19]. However, the work of mass mobilization campaigns focuses more on constructing new structures rather than paying attention to maintaining the old or previously constructed structures [15]. Modifying stone bunds to make them fit to local conditions is another important variable included to understand the process of spontaneous spreading. Our analysis showed that spontaneously implemented stone bunds were significantly more often modified during construction to fit to the local conditions of the farming system than those implemented by the mass mobilization campaigns. Several characteristics of these stone bunds were modified, including the recommended spacing between bunds as well as the height and length of the stone bunds to fit the needs of the farming system. This was also observed in a study conducted in Hunde-Lafto area [2] and the Beressa watershed [19], where farmers modified the original design of introduced technologies to fit the local conditions. Our findings support the diffusion of innovation literature [29,30,36], which argues that technologies modified or changed by farmers during implementation spread better than other technologies, hence facilitating the spontaneous spreading of stone bunds.

Another important finding concerns the integration of stone bunds with other measures on the same field, as perceived by farmers. Integration means that soil management measures that are intended to conserve the soil, as well as to improve crop yields (such as fertilizer, compost and manure), are applied on the farmlands together with stone bunds. It was hypothesized that stone bunds implemented by SFs were better integrated with these soil fertility management measures and lead to higher yields, as compared to stone bunds implemented by NSFs. The analysis confirmed the stated hypothesis. With spontaneously implemented stone bunds, significantly more fertilizer, compost and manure are used in integration with the stone bunds. An explanation for this is the proximity of the stone bund plots implemented by SFs to their homesteads, because farmers are more likely to apply fertilizer, compost and manure on farmlands close to the homesteads [58]. Another explanation is that SFs are more dedicated and aware about the importance of integrating stone bunds with these soil fertility practices.

Moreover, the better integration of the stone bunds with fertilizer, compost and manure has its beneficial effects on erosion control, soil moisture, soil productivity and crop yield. The statistical analysis shows that significant differences between the perceived effect of stone bunds implemented by SFs and NSFs exist for all these factors ($p < 0.01$). Results showed that a large proportion of SFs perceive that erosion on the farmland has decreased, and that both soil productivity and crop yield have increased after stone bund implementation, and hence confirmed the hypothesis that stone bunds implemented by SFs lead to higher yields. These results may be explained by the fact that spontaneously implemented stone bunds are better maintained and integrated with more compost and manure. In line with this, Kessler [57] suggests that manure use together with erosion control measures, such as stone bunds, is a promising alternative for more productive farmlands and agricultural production.

A study conducted by Hurni [8] describes that erosion adversely affects crop productivity by reducing availability of water to crop growth and soil nutrients. As a result, when soil erosion control measures, such as stone bunds, are combined with the use of compost and manure, they enhance soil moisture and improve availability of soil nutrients [58,61]. This is consistent with observations in this study, where a high number of SFs perceived that water availability on the farmland has increased after stone bunds were implemented. In addition, this will also result in higher crop yields, which, in this study, was significantly higher for SFs than for NSFs. This implies that the importance of 'relative advantage' [36] holds true in our research, suggesting that farmers' perceived relative advantage of stone bunds determines the process of spontaneous spreading.

Most interestingly, the study found that many farmers (particularly SFs, but not significantly more than NSFs) believe that yield improvement was not due to the stone bunds only, but rather to the integration of these with soil fertility management measures. The analysis indicates that NSFs are also aware of the importance of integrating practices, but they perceive that they use less fertilizer, compost and manure. Because of this, NSFs do not experience higher crop yields. This finding is in line with a study conducted by Posthumus, et al. [62] in Burkina Faso, reporting that conservation measures are more profitable when integrated with soil fertility measures. Therefore, technologies that enhance profitability are crucial in stimulating farmer's adoption decision [4], and hence are important to understand spontaneous spreading. In general, because the effect on yield is related to application of more fertilizer, compost and manure and they are constructed on erosion prone farmlands where the effect of stone bunds is more visible, spontaneously implemented stone bunds result in more short-term benefits than stone bunds implemented by the mass mobilization campaign. Therefore, in order to convince NSFs of becoming SFs, the mass mobilization campaign must focus on constructing stone bunds, where these are most needed, resulting in quick wins.

However, the study also found that the mass mobilization campaign is an important source of knowledge for farmers, and often motivates farmers to spontaneously implement stone bunds on their own farmlands [14]. About 60% of the farmers acknowledge to have learned from the mass mobilization campaign and other projects (53%). Nevertheless, most knowledge about stone bunds comes from neighboring farmers (93%) and practical training (80%). This implies that spontaneous spreading of stone bunds is particularly enhanced by farmer-to-farmer exchanges in the community, by education and by training. This was also observed in a study conducted in Keita valley [42], where farmers are inspired to adopt soil and water conservation practices by observing their neighboring practices and sharing their knowledge about the benefits of adoption. Our result is in line with the theory of diffusion of innovation discussed above, where Rogers [29] argues that sources of information are important in learning and implementing an introduced technology. Therefore, this is an important requirement for the process of spontaneous spreading to take place.

6. Conclusions and Recommendation

The central aim of this study was to provide insights into how stone bunds have spontaneously spread in the central highlands of Ethiopia, thereby contributing to the understanding of the process of spontaneous spreading. A first conclusion drawn from this study is that stone bunds are spontaneously implemented where they are most needed: mainly on farmlands where farmers perceive severe erosion, poor soil fertility, steep slope gradient and located nearby the homestead area. This finding has important implications for the current mass mobilization campaigns, where farmers walk long distances to construct stone bunds on the selected farmlands. Essentially, long walking distances may discourage farmers to integrate stone bunds with soil fertility management measures, which is important to contribute to yield productivity and achieve household food security. Therefore, during the mass mobilization campaigns, stone bunds should be constructed based on farmers' opinion of where they are most needed and where the short-term (visible) effects can be achieved.

The result of this study further indicated that spontaneously implemented stone bunds affect soil erosion, soil moisture and soil productivity, and that they lead to higher yields compared to stone bunds implemented through mass mobilization. These findings provide important insights to policy makers and extension workers on *how* to control erosion problems and improve soil fertility, simultaneously. Putting more stone bunds on farmland is hardly useful unless they are integrated with soil fertility management measures, such as compost, manure and improved tillage practices to contribute to improve yields. As a final conclusion, we recommend that the mass mobilization campaign should use a more participatory and integrated approach, in which there is ample space for awareness raising and learning concerning the benefits of integrated farm management, and in which farmers themselves have a more leading role in the decision on where to construct stone bunds. Such a strategy will lead to more sustainable impact on soil fertility and food security than the current top-down intervention approach.

In general, this article addressed the process of spontaneous spreading of SLM in the central highlands of Ethiopia. The study found that spontaneously implemented stone bunds had different characteristics than the conventional way of spreading technologies, through mass mobilization campaigns. However, there is still an important issue to be addressed with respect to spontaneous spreading, namely to what extent SFs and NSFs are different. The next research challenge is to compare the characteristics and motivations of farmers who spontaneously implement stone bunds with those of farmers who do not perform spontaneous conduct on stone bunds.

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