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## FOOD SCIENCE & TECHNOLOGY | RESEARCH ARTICLE

# Evaluation of adoption behavior of soil and water conservation practices in the Simein Mountain National Park, Highlands of Ethiopia

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**Abstract:** This study examines the farmers' adoption behavior of soil and water conservation (SWC) technologies in Semein Mountain National Park. A simple random sampling method was employed to select the sample households. A total of 150 household farmers were selected from 12 kebeles based on the farmers' proximity to the park. This study identified existing SWC practices, constraints and opportunities with the view of improving and upscaling appropriate soil and water conservation technologies. The results also show that even though the involvement of farmers was very limited in participation by consultation to implement the SWC technologies, majority of the farmers acknowledged that the introduced conservation technologies were effective measures to control soil erosion and for improvement of productivity. The sustainable adoption of SWC measures seems unlikely due to labor intensiveness and unfitness with the farmers' farming systems and land tenure insecurity. These problems are associated with the inactive involvement of farmers in the conservation activities. Therefore, this study suggests that adoption

### ABOUT THE AUTHORS

We submitted a manuscript entitled: "Evaluation of adoption behavior of soil and water conservation practices in the Simein Mountain National Park, Highlands of Ethiopia," which will be published in *Cogent Food and Agriculture* journal. All authors certify that they have participated sufficiently in the work to take public responsibility for the content, including participation in the concept, design, analysis, writing or revision of the manuscript. For example, Dr. Mohammed Gedefaw made substantial contributions to the design, idea generating, analysis, interpretation and drafting of the manuscript. Dr. Basaznew Alemu and Professor Mersha Chanie are the resources persons in this article who contribute great. Mr. Genanew Agitew is a co-author who contributed greatly his part in data collection and analysis. Professor Yan Denghua and Professor Wang Hao also assisted and commented the draft manuscript and supervised the whole work. This article is under water and natural resources management research thematic team. The final manuscript before submission was checked and approved by all the authors.

### PUBLIC INTEREST STATEMENT

Land degradation, which affected the production of crops in Semein Mountain National Park (SMNP), is a major problem for smallholder farmers. This study investigated farmers' adoption behavior of newly introduced soil and water conservation technologies implemented in SMNP based on data gathered through formal and informal survey methods to illustrate the impacts. It was found that majority of the farmers (76%) had adopted different soil and water conservation measures in study area. The local farmers acknowledged the introduced soil and water conservation technologies. However, the sustainability seemed unlikely due to personal, socio-economic and institutional factors with regard to the implementation of the technology as part of the agricultural production systems. Understanding the adoption of soil and water conservation technologies can improve the future risk of erosion on farms. Therefore, active involvement of all smallholder farmers in all aspects of technological development is important to strength their capacity and increase motivation to use the newly introduced soil and water conservation technologies.

of SWC interventions should be designed based on the active involvement of the local farmers for future soil and water conservation activities. Finally, we conclude that policy program which is intended at shifting of the people from the park to other areas for the sustainability of the park as well as the farmers' livelihood improvement is a sustainable solution.

**Subjects:** Agriculture & Environmental Sciences; Environment & Health; Biodiversity & Conservation

**Keywords:** erosion; soil and water conservation; Semein Mountain National Parks; adoption; policy intervention

### 1. Introduction

The economic development of developing countries depends on the performance of the agricultural sector, and the contribution of this sector depends on how the natural resources are managed (Bewket, 2007; Gebremedhin & Swinton, 2003). Ethiopia is one of the developing country in which its economy is based mainly on rainfed agriculture providing employment for over 80% of the labor force which accounts for a little over 50% of the GDP (Bewket, 2007). In fact, agriculture in Ethiopia is not only an economic activity but also a way of life for which agricultural land is an indispensable resource upon which the welfare of the society is built. Directly or indirectly, the vast majority depends on this sector. This leads to increased vulnerability of the economy and to problems related to land degradation (Holmatov, Lautze, Manthrilake, & Makin, 2017). Most farmers in the country are poor and operate at subsistence level, and investment for intensification of agriculture is not well developed (de Graaff et al., 2008). This has created a vicious circle of low productivity—land degradation reduces the production potential of the land and this, in return, makes it difficult for farmers to produce enough and invest in protecting the land (de Graaff et al., 2008; Gebremedhin & Swinton, 2003).

Recognizing land degradation as a major environmental and socioeconomic problem, the government of Ethiopia has made several interventions. As a result, large areas have been converted to terraces, covered by soil bunds, closed by area closures and planted with millions of tree seedlings. Nevertheless, the achievements have fallen far below expectations. The country still loses a tremendous amount of fertile topsoil, and the threat of land degradation is broadening alarmingly (Teklu, Adriaanse, Ter Horst, Deneer, & Van den Brink, 2015).

The adoption of improved soil and water conservation technologies in developing countries has attracted much attention from scientists' and policymakers' point of view mainly because land degradation is a key problem for agricultural production (de Graaff et al., 2008). According to de Graaff et al. (2008), there are three phases in the adoption process: the acceptance phase, the actual adoption phase and the final adoption phase. The acceptance phase generally includes the awareness, evaluation and the trial stages and eventually leads to starting investment in certain measures. The actual adoption phase is the stage whereby efforts or investments are made to implement soil and water conservation measures on more than a trial basis. The third phase, final adoption, is the stage in which the existing soil and water conservation measures are maintained over many years and new ones are introduced on other fields used by the same farmers.

Ethiopia is exceptionally high in biodiversity but exceptionally low in capacity for protected area management (Deininger & Jin, 2006). Most of the population are almost completely dependent on natural resources for their livelihoods. Consequently, 97% of the original highland vegetation has already been lost in recent decades due to encroaching agriculture, grazing and settlement by agropastoral communities (Wondie, Schneider, Melesse, & Teketay, 2011).

Nearly 4% of the SMNP is under agricultural land and an estimated 436 households are living within the park boundary. Local communities depend on the park's grazing land, and a recent 2012

dry season census suggests that livestock densities are about three times that recommended for such high altitudes, at 1.6 TLU (tropical livestock units) per hectare. Although this settlement issue dates back to the time of the park's creation and the 2008 boundary realignment removed most settlements, the use of natural resources is currently unsustainable (Gebremedhin & Swinton, 2003; Holmatov et al., 2017; Wondie et al., 2011). Resource degradation is evident with extensive soil erosion, poor yields and depauperate grassland diversity. Intrinsic population growth in these communities is accentuating the issue year on year, (e.g. the Gich population has increased fourfold in 40 years) and food insecurity is increasing in these already impoverished communities (Wondie et al., 2011). Whilst tourism in the park has grown with around 17,000 visitors in 2012, and it is providing substantial benefits to local communities and the central treasury, the scale of its expansion is now threatening to degrade the resources on which a positive visitor experience depends.

Previous studies show that various personal, economic, socioinstitutional and biophysical attributes have influential roles in farmers' decisions about the adoption of soil and water conservation measures in different parts of Ethiopia. This relationship between attributes has not yet been studied in the study area. Appropriate understanding of these factors in the study area would assist in the formulation and implementation of the policy interventions designed to induce voluntary continued use of soil and water conservation measures.

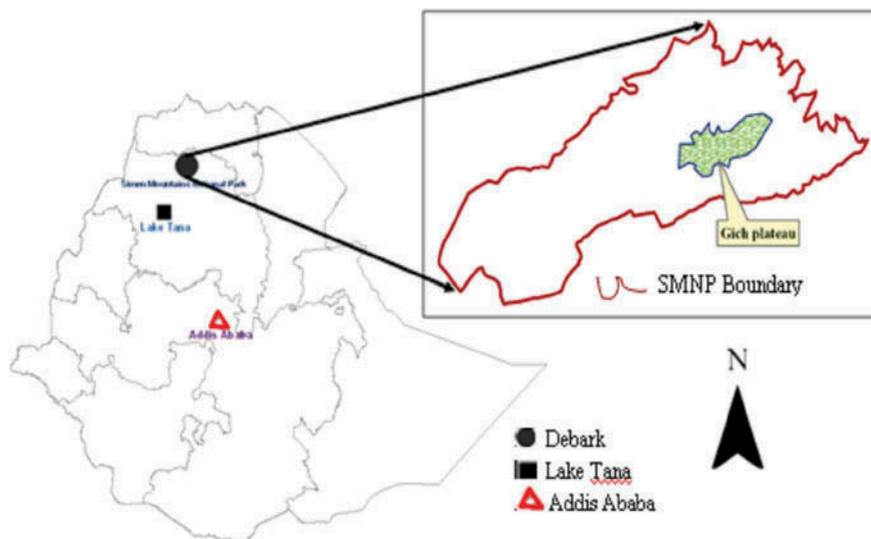
The main objective of this study was to investigate farmers' adoption behavior of newly introduced SWC technologies in SMNP. Specifically, the study tried to (i) describe processes of the conservation intervention and farmers' participation; (ii) examine extent of farmers' adoption of SWC and (iii) identify factors influencing farm-level adoption of the conservation technologies.

## 2. Materials and methods

### 2.1. Study area

SMNP is located in the North Gonder Zone of the Amhara National Regional State, 920 km north of Addis Ababa. It lies between 13°09' and 13°12'N and 38°00' and 38°12'E (de Graaff et al., 2008) (Figure 1). The altitude of SMNP ranges from 1,900 to 4,543 m. It has an Afro-alpine undulating grassland plateau, with steep escarpments lying toward both the north and east direction, giving spectacular views of peaks and canyons of areas found outside the boundary of the park. There are V- and U-shaped canyons due to geological processes. The rainfall pattern is characterized by a single rainy season, whereby the highest amount of precipitation is between June and September

Figure 1. Map of study area.



(Bewket, 2007; de Graaff et al., 2008; Wondie et al., 2011). The average annual rainfall is between 1,350 and 1,550 mm and varies with altitude. Temperature ranges from  $-2$  to  $18^{\circ}\text{C}$ .

Due to differences in land use practice, geological events, topography and climate, different soil types are found in the SMNP. Andosol type of soil is found on uncultivated land above 3,000 m, whereas below 3,000 m and on cultivation land above 3,000 m, the dominant types of soil are Phaeozem, Vertisol, Luvisol, Regosol and Leptosol (Wondie et al., 2011). The grassland is dominantly covered with Andosol. The very small area, with no agricultural potential, is attributed to Fluvisol.

When first established in 1966, the SMNP encompassed an area of just  $136\text{ km}^2$ . A further extension was agreed in 2007, and the park was extended to include the peaks of Silki, KidusYared and also RasDejen, the highest mountain in Ethiopia. Currently, the total park area is  $412\text{ km}^2$ . Because of its rich biodiversity, high number of endemic species and special biophysical features, SMNP is one of the World Heritage Site in the country listed by UNESCO.

## **2.2. Methodology**

### **2.2.1. Data sources**

The data used for this study were obtained from both primary and secondary sources. The primary sources mainly related to adoption behavior are collected using both formal and informal survey methods. All the necessary quantitative data required for the study were gathered through a farm household survey. At the beginning stage of the survey, informal meetings were undertaken with experts of the park in order to understand the general agricultural and socioeconomic situation of the population of the study area. Also, informal meetings with key informants (farmers, elder people, researchers, experts and development agents) were held to obtain in-depth knowledge about the area and to pre-test the farm survey questionnaire.

Secondary data from literature (scientific and non-scientific reports and published material, proceedings and statistical abstracts) and the park office were obtained.

### **2.2.2. Sampling techniques and sample size**

A simple random sampling technique was used to select the sample sizes. SMNP is surrounded by five weredas with 38 kebeles, of which 12 kebeles had a direct contact with the park. These 12 kebeles were taken as a sample size to see their impacts on the park, and from these kebeles 150 representative households were selected and the questionnaire was distributed.

To develop the farmer's trust in the interviewer, each farmer was well informed about the purpose of the survey and why he/she is chosen for the interview. One enumerator was selected based on their understanding of farming and SWC practices and their educational level for each kebele. One day of intensive training on how to conduct interviews and record information in the questionnaire properly was given. Subsequently, an interview was conducted by the selected enumerators and the corresponding main researcher. At the end of the formal survey in each village, discussions were held by the researcher and the enumerators with key informants including community leaders and development agents. This informal technique is used to acquire useful and detailed information about biophysical factors and farmers' perceptions.

## **2.3. Methods of data analysis**

The data were analyzed using descriptive statistical techniques provided by the Statistical Package for Social Sciences (SPSS). MS-Excel was also used to generate tables and graphs. For the informal key informant interviews and field observation notes, a qualitative analysis was used.

### 3. Results

#### 3.1. Socioeconomic characteristics of the farm households

The gender proportions from the total 150 respondents indicated that 90.5% male and the 9.5% were female. The Chi-square test showed that the expected proportion of the male respondents were significantly higher than the female respondents. The descriptive results further show that among the farmers having land, the ploughing land included and excluded in hectare was 86.5% and 13.5%, respectively. 98% of the land owner have land certificate, whereas the remaining 2% have no land certificate. The results also show that 18.2% of the responders are seftnet program users, while the remaining 71.6% are not.

#### 3.2. Farming systems in the settlement scheme

Crop and livestock production were the main farming practices in the settlement scheme. Crop production was mainly occupying 85% of the land, while livestock production (grazing/pasture) takes 15%.

The results confirmed that more than 40.7% of the livestock (cows, goats and sheep) feed on open grazing land, while 33.9% are semi-grazed, 15% feed under communal grazing land and 19% are under zero grazing lands. During the dry period, 30% of the animals fed the stored dry barley Stover, while 25% fed with other crop residues collected either from own and/or neighbors' farms. The different types of livestock have different benefits to the households including food, income, manure, labor, transport and breeding and others (Table 1).

#### 3.3. Trends of fertilizer consumption in the study area

From the result, we observed that farmers' need of fertilizer use dramatically increased to maximize their production (72.3%). This is due to the increasing of crop productivity as compared to traditional systems when fertilizer is used (Figure 2).

#### 3.4. Determinant factors that decreased crop production in SMNP

The result of this study shows that the reduction of crop productivity since the last two decades was related to drought, flooding, conflict, wind force, ice, insect infestation, inflation, shortage of ploughing land, shortage of grazing land and population growth. The level of significance was tested at 95% ( $\alpha = 0.05$ ). The extent of significance impacts of each factors mentioned above is indicated in Table 2.

#### 3.5. Alternative means of increasing production

From this study, we observed that 95% of the farmers agreed that climate has changed over the 15 years. The change in climate was associated with temperature and rainfall. In line with this, 35% of

**Table 1. Type of livestock within the farming systems in study area**

Type of livestock	Number of livestock	Minimum	Mean	Maximum
Horse	100	1	1.5	2
Cow	250	1	1	1
Oxen	300	1	2	3
Donkey	50	1	1	1
Goats	30	1	3	5
Sheep	1,500	2	16	30
Poultry	400	2	11	20
Others	2	1	2	3
Total	2,632		37.5	

Figure 2. Trend of fertilizer use.

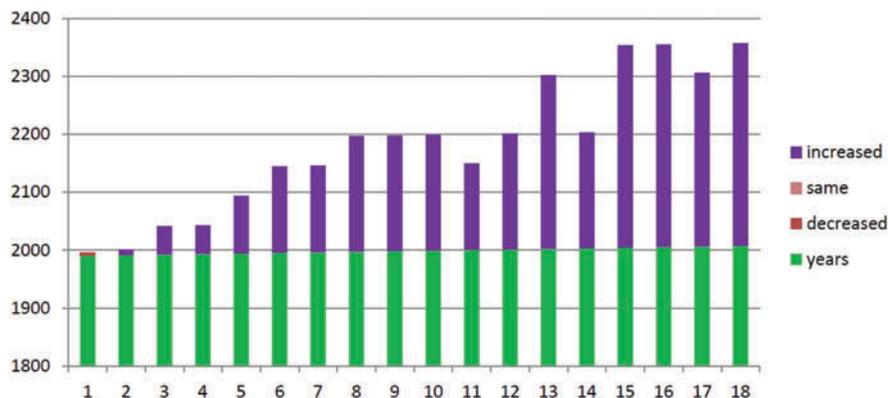


Table 2. Determinant factors that decreases the production of crops in the study area

Determinants	Significant impacts
Flooding	0.507 (0.603)
Ice	6.706 (0.002)***
Drought	1.276 (0.283)
Insects infestation	0.340 (0.713)
Wind force	1.761 (0.176)
Inflation	0.191 (0.826)
Population booming	0.704 (0.496)
Conflict	10.411 (0.000)***
Shortage of land	10.442 (0.000)***
Shortage of grazing land	9.335 (0.000)***

Note: \*\*\* indicates it is statistically significant at 0.01, 0.05 and 0.1 level.

the farmers responded that the rainfall was decreasing and 50% of the respondents replied an increasing of temperature from time to time. These led to the reduction of crop productivity. To overcome these problems, the local famers used alternative means for the improvements of their livelihoods (Table 3).

### 3.6. Adoption of soil and water conservation (SWC)

Acceptance of SWC refers to evaluation of the newly introduced technologies regardless of its effectiveness control erosion and the capacity to increase productivity. Whereas, adoption describes the farmers' commitment to utilize the technologies sustainably with confidence.

Majority of the farmers (76%) in the settlement scheme had adopted different types of SWC technologies in their farms. However, 65% of these farmers experienced soil and water erosion with serious cases. Lack of appropriate SWC (35%), lack of water harvesting measures (38%) and overgrazing (5.5%) were the reported causes of SWC problems in the study area by the respondent farmers. These lead to land degradation, resulting in poor crop performance (Bekele & Drake, 2003; Mekuriaw, Heinimann, Zeleke, & Hurni, 2018; Nigussie et al., 2018; Shively, 1997). Terracing and check dams are the most adopted SWC practices in the study area. The farmers were asked to mention any changes in the land condition they may have observed since the SWC technologies were implemented. They responded that they witnessed improvement in vegetative cover of the watershed, reduced rate of soil erosion and improved growth of crops along the conservation structures.

**Table 3. Alternative means of increasing production and improving livelihoods**

Determinants	Significant impacts
Timber	2.954 (0.056)
Medicinal value	4.135 (0.019)**
Water	6.101 (0.003)***
Ploughing land	22.726 (0.000)***
Cultivation of more land to increase production	5.236 (0.007)***
Choosing migration as a means to improve life style	2.405 (0.094)
Integration of animal and crops production	8.636 (0.000)***
Crop rotation	8.417 (0.000)***
Land renting	4.443 (0.014)**

**Note:** \*\* indicates it is statistically significant at 0.05 level.

\*\*\* indicates it is statistically significant at 0.01, 0.05 and 0.1 level.

### 3.7. Factors affecting adoption of SWC

The local farmers acknowledged the introduced new SWC technologies as effective measures against soil erosion and for improving land productivity. However, the sustainability seemed unlikely. These were related to the personal, socioeconomic and institutional factors with regard to the implementation of the technology as part of the agricultural production systems.

#### 3.7.1. Perception of farmers on soil erosion versus crop production

The perception of the local farmers on the impacts of soil erosion on crop production is the profound determinant factor for adoption of SWC measures on their farmland. Those farmers who perceive soil erosion as a risk having negative impacts on productivity and expect positive returns from conservation are likely to decide in favor of adopting available conservation technologies (Nahayo et al., 2017; Nigussie et al., 2018; Sietz & Van Dijk, 2015; Wauters, Biolders, Poesen, Govers, & Mathijs, 2010; Wondie et al., 2011; Zeweld, Van Huylbroeck, Tesfay, & Speelman, 2017). However, if the farmers do not appreciate the SWC measure to control erosion, they will decide against adopting any conservation technologies. Majority of the farmers (76%) in the settlement scheme had adopted different types of SWC technologies in their farms. However, 65% of these farmers experienced soil and water erosion with serious cases.

According to Bewket (2007) and Napier (1991) the majority of the farmers have experienced soil erosion as an agricultural problem, but yet most of the farmers have no willing to construct SWC structures. These imply that the perception of farmers on soil erosion risk may be a necessary but not a sufficient condition for farm-level adoption technologies.

#### 3.7.2. Human capital

The adoption of SWC technologies by the farmers are related to labor supply within the households. Members of households are the suppliers of human capital/labor force for the implementation of SWC technologies on the farmland. This implies that labor availability became an important influencing factor.

#### 3.7.3. Appropriateness of the technologies to farmer requirements and farming system conditions

The best SWC technologies are the one which influences the farmers' decision for implementation, effectiveness in soil erosion control, improvement in land productivity and simplicity in adoption. Therefore, the newly introduced SWC technologies should be in line with these criteria. In SMNP, farmers used both physical and biological SWC measures. During fieldwork of this study, the treated lands were under strict protection from livestock.

The findings of this study with regard to the deterministic influencing factors for adoption of SWC are consistent with the results of previous studies within the country. For example, Bekele & Drake (2003) reported that adoption of level soil bunds and graded fanyajuu bunds had significant positively correlated impacts on production in central highlands of Ethiopia.

#### 3.7.4. Land tenure system

Land tenure was another influencing factor that discourages most farmers to adopt SWC measures in SMNP. Informal discussions with the sampled household farmers indicated that security of tenure was an important factor given the labor input required to implement SWC technologies. Previous studies also confirmed that land tenure insecurity was a major obstacle to adopt SWC (Zeweld et al., 2017). Similarly, Gebremedhin & Swinton (2003) found that the influence of land tenure security on adoption of stone terraces, which are costly but durable, was statistically significant, while its influence on adoption of soil bunds, which are less durable but cheaper, was not statistically significant. This implies that securing land tenure will be an incentive for the farmers to adopt the introduced SWC technologies in SMNP.

### 4. Discussions

A number of SWC technologies have been introduced in SMNP. The local farmers acknowledged that the technologies were effective measures against soil erosion and have the potential to improve land productivity and lead to increased crop yields. However, the sustainable adoption and widespread replication of the SWC technologies seemed unlikely. One of the factors that discouraged the farmers for adoption of SWC was that the introduced new SWC technologies were not suitable to farmers' farming system.

The vast majority of the local farmers believed that the technologies had complex design to construct without expert and the spacing between the structures was very narrow. Thus, it consumes more land, labor and ploughing activity is also become difficult (Asfaw & Neka, 2017).

Inappropriateness of the intervention strategy was another determinant factor to local farmers to adopt the newly introduced SWC technologies since it was not fit with the land tenure system of the study area and the local farmers did not involve in any assessment of soil erosion as an agricultural and economic problem, selection of the conservation measures and planning and priority setting for implementation of the newly introduced technologies. Most of the time, the newly introduced technologies go to farmers' field forcefully without the full involvement of the farmers and lead to failure to achieve the final result (Adusumilli & Wang, 2018; Asfaw & Neka, 2017; Bunclark et al., 2018; D'Souza & Mishra, 2018; Permadi et al., 2018; Wolka, Sterk, Biazin, & Negash, 2018). Therefore, active participation of the local farmers is important for effective implementation of SWC technologies.

The findings of this study confirmed that, local farmers in developing countries reject the newly introduced SWC technologies due to inappropriateness to their farming systems as well as unawareness of the technologies.

### 5. Conclusion

This study tried to explore the farmers' adoption behavior of soil and water conservation practices in the SMNP, highlands of Ethiopia. Soil and water erosion continues to be a major problem in SMNP, despite the efforts that farmers have made in adopting some of the SWC technologies that are best to the environment. However, the findings of this study show that the respondent farmers lack adequate knowledge and technical skills on how to apply and use appropriate SWC practices. The number of Development agents (DAs) in each kebele is not enough to facilitate the implementation of SWC technologies.

The findings have two broad important policy implications for future SWC intervention in the study area. These are the need to develop alternative technologies and the need to adequately

involve local farmers in conservation efforts. The newly introduced SWC technologies were labor-intensive, complex designs to construct, conflicting with the free-roaming livestock grazing system and unsuitable to the existing land tenure system. Therefore, introducing less labor demanding technologies and easy to construct is appropriate one. Active participation of all the local farmers in all aspects of technological development is important to strength their capacity and increase motivation to use the newly introduced SWC technologies. Thus, participation of all the stakeholders especially farmers achieve better success for implementing SWC technologies. Although most farmers perceive their soils as being fertile, this was not reflected in the crop yields. There is need, therefore, for further investigation on soil fertility in order to help the farmers achieve expected crop and livestock yields as per their locality.

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#### Competing Interest

The authors declare no competing interests.

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