Determinants of Soil and Water Conservation Measures for Sustainable Land Management Practices in the Ethiopian Highlands: The Case of Hadi Micro-watershed

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Research Article

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Abstract

This study presents an assessment of smallholder farmers' perception towards adopting soil and water conservation practices in Hadi micro-watershed. The data were collected from 203 sample households using questionnaire, focus group discussions, and interview. The data were analyzed using descriptive and inferential statistics. The result of the study revealed that about 60.6% of sample households were adopters and 39.4% were non-adopters of soil and water conservation measures. The study was also focused on soil loss estimation and prioritization based on Revised Universal Soil Loss Equation model using the application of Geographic Information System software. The result of the analysis showed that the mean soil erosion rate of the watershed is 28.063 t/ha/year in the year 2018/2019. Moreover, the total soil loss in the study area is 109,642.25 tons. The results of the binary logistics regression model also revealed that sex of respondents, farm size, access to training, extension service, and access to credit service were positively correlated with the adoption of soil and water conservation measures. On the other hand, age, educational status, family size of household heads, and farm distance were found to be negatively correlated. The result of the study suggests they majority of the farmers are aware and perceived soil erosion by water and land degradation as a problem in their farm plots. Furthermore, they also able to identify the different causes of soil erosion in their land based on their farming experience.

1. Introduction

Soil and water are the most important resources for the existence of human beings and biomass on the earth surface. The whole creations on the earths' surface are depend on soil and water. The land resources such as soil, water and forest are under serious degradation due to continuous unwise use of those resources by human beings (Detamo 2011). Soil erosion by water is a worldwide phenomenon leading to loss of nutrient-rich surface soil, increased runoff from the more impermeable subsoil and decreased water availability to plants (Ganasri and Ramesh 2016).

Soil erosion is recognized as one of the world's most serious environmental problems (Pimentel 2006) globally; about 80% of the current degradation of agricultural land is caused by soil erosion. Soil erosion is the major problem in many regions of the world (Lieskovsky and Kenderessy 2014), especially in East Africa, where Ethiopia shows the highest erosion rates (Gessesse et al. 2014), Ethiopia is believed as one of the Sub-Saharan African countries most seriously affected by soil erosion. Due to in this fact, natural resource degradation in Ethiopia observed for many years (Hurni et al. 2010). In the Ethiopian highlands deforestation for crop production, cultivation of marginal lands and overgrazing dramatically increased the vulnerability of agricultural lands to rainfall driven soil erosion (Addis et al. 2016). Ethiopia losses nearly 2 billion tons of fertile soil per annum (Gebremedhin 2010).

Accelerated soil erosion by water is the primary cause of land degradation in the region (Hurni et al. 2010) and this is the consequence of a changed relationship between environmental and biophysical factors that occurred as a result of human interventions (Jemberu et al. 2017). Another study done in Ethiopia revealed that soil erosion in the Ethiopian highlands is caused by the combination of many factors such as increase of cultivation on sloppy land; high population pressure, clearance of forest, poor management of agricultural land, etc. (Mengstie 2009). Due to erosion bout 12 tons/ha/year of soils in lost every year in Ethiopia, and the economic impacts of this loss is estimated about $139 million which is 3–4% of agricultural growth domestic product (GDP) of the country (Demelash and Stahr 2010). Erosion is impacts on chemical properties (e.g., nutrient destruction), and soil physical properties (e.g., minimizing soil depth, water infiltration capacity) that determine the productivity of agriculture (Hurni et al. 2010). Soil erosion resulting several problems to sustainable agricultural land use as it minimize on farm soil productivity and cause loss of food production (Belay 2014). Additionally, soil erosion is an impact on environment, agronomic productivity, food security and the whole quality of life (Atnafe et al. 2015).

According to Okoye (2009), the northern region has the highest susceptibility rates of erosion in Ethiopia, because its soils are mainly light and susceptible to erosion. The slopes of the highlands which dominate the region accelerate run-off which subsequently encourages soil erosion. Moreover, perceiving soil erosion as a problem by farmers is an important determinant of soil conservation (Vigiak et al. 2005). The Amhara National Regional State is highly affected by soil erosion. Ninety percent of the population settled in the high land part that constitutes 66% of total land resource. Areas that are seriously affected by erosion in Amhara Regional state are found in Waghemra and North Wollo Zones followed by North and South Gondar, South Wollo and Northern part of North Shewa Zones (Lakew et al. 2005). After seriously observing that the soil and water conservation measures had little succeeded as compared to the envisaged outcomes, watershed approach was adopted by the country in the 1980s. Watershed management is a word used to express the ongoing of applying land use practices, and water management practices and enhance the capacity of the water and additional natural resources within a watershed by controlling the use of those land and water resources (Ervin and Ervin 1982). Watershed management is increasingly seen as an appropriate vehicle not, only for environmental conservation but also for improvement of rural livelihoods (Achouri 2005). However, most of these watershed management programs were not also successful except some few impressive achievements observed like in managing environmental resources to enable transitions (MERET) project as examined by Achouri (2005). The general aim of watershed development and management programs to take the watershed as the Hydrological unit, and objective to apply suitable methods for soil and water protection, provide enough water for agriculture and house use, and enhance the livelihoods of the inhabitants. Managing watersheds for sustainable rural development in developing countries is in practice (Alemu 2016). The purpose was also to implement natural resource conservation development programs. Even so, the excess scale ones remained highly unsatisfactory due to shortage of rainfall, limited sense of responsibility over asset created, and lack of manageable planning units (Lakew et al. 2010). Due to these reasons, community based integrated watershed development is practiced in Hadi micro-watershed by the help of Organization for Rehabilitation and Development in Amhara (ORDA) project. Therefore, this study was intended to assess the determinants of soil and water conservation measures for sustainable land management practices in Hadi micro-watershed.

2. Materials And Methods

Hadi micro-watershed is found in Gazgibella *Woreda*, Waghimra Zone in Amhara regional state. The watershed is located 720 km away from the country capital city (Addis Ababa). Geographically it is located between $12^0$18'46"N-$12^0$23'31"N latitudes and $38^0$58'22"-$39^0$3'14"E longitudes (**Fig. 1**). The rainfall has a temporal nature. The mean maximum temperature was 22^0C, which was also occurred during the month of May; while the mean minimum monthly temperature was 2.5^oC that occurred during the month November (**Fig. 2**). The data were collected using primary and secondary sources of data. The dependent and independent variable employed in the analysis of Binary logistic regression is typically used when the dependent variable is dummy and the independent variables are either continuous or categorical variables (Table 1).

Table 1
Type, definition, measurement, and hypothesis of variables used in the study

Variables	Definition and unit of measurement	Expected sign
Dependent variable		
Y = ADOPT SWC, Adoption of soil and water conservation	1 if a farmers adopts SWC measures, 0 otherwise	
Independent variables		
X_1 = SEX, Sex of household heads	1 if a household head is male, 0 otherwise	+
X_2 = AGYR, Household head age	Age of household head in years	+(-)
X_3 = FMLSIZE, Households family size	Number of people in the household heads	+(-)
X_4 = EDUC, Education level of HHs	1 if a household head is educated, 0 otherwise	+
X_5 = WATRSDSTAG, Stage of watershed	Stage of watershed farmers living now, 1 = Upper watershed, 2 = Middle watershed, 3 = Lower watershed	+
X_6 = FRMSIZHCR, Farm size	The total size of cultivated farm land, in hectares	+(-)
X_7 = DISCUFRM, Distance from land	Distance of cultivated land from framers home, in meters	-
X_8 = EXAGV, Extension contact	1 if a household heads has access to extension, 0 otherwise	+
X_9 = TRSWCP, Training about SWC practices	1 if a household heads has access training about SWC practices, 0 otherwise	+
X_{10} = CREDTSEVC, Credit service	1 if a household heads have credit service, 0 otherwise	+

3. Results And Discussion

The statistical result indicated that 45.4%, 37.9%, and 16.7% of the households were found to be illiterate. Of them 31.7% and 66.3% were adopters and non-adopters of SWC measures respectively. The result of the study also revealed that 27.6%, 46.3%, and 26.1% of the households have the family size of 1–3, 4–7 and > 8 respectively. Areas which are classified as severe erosion class covers an area of 1054.99 ha while areas with very low erosion risk class covers an area of 248.51 ha (**Fig. 3**). The odds ratio of logistic regression depicted that a person who live in the upper watershed 2.566 times more likely adopt SWC measures than a person who live in the lower part of watershed (Table 2).

Table 2
Results of the binary logistic regression analysis

		B	S.E.	Wald	df	Sig.	Exp(B)	95% C.I. for EXP(B)	
								Lower	Upper
Step 1[a]	Sex	1.602	.812	3.898	1	.048**	4.965	1.012	24.370
	Age in year	– .212	.463	.209	1	.647	.809	.326	2.006
	Family size	.887	.561	2.503	1	.114	2.428	.809	7.286
	Education status	.630	.429	2.156	1	.142	1.877	.230	1.235
	Stage of watershed	.942	.448	4.426	1	.035**	2.566	1.067	6.172
	Farm size in hectare	1.177	.402	8.564	1	.003**	3.246	1.475	7.141
	Distance of farm land	– .076	.296	.066	1	.797	.927	.518	1.657
	Access to credit service	2.346	.733	10.258	1	.001***	10.445	2.485	43.898
	Extension contact	2.136	.602	12.586	1	.000***	8.466	2.601	27.553
	Access of training SWC	1.802	.671	7.223	1	.007***	6.063	1.629	22.567
	Constant	-15.357	2.917	27.719	1	.000	.000		
Source: Model output, (2019); Note: *** and ** indicate significant at 1% & 5% respectively									

Table 3
Comparison of farmers' adoption level of SWC measures between upper, middle and lower section by using One-way ANOVA

Comparisons	**Sum of Squares**	**d.f**	**Mean Square**	**F**	**Sig.**
Between Groups	391351.207	2	195675.604	54.041	.000***
Within Groups	724176.428	200	3620.882		
Total	1115527.635	202			
Note: *** indicates significant at 1%					

On the other hand based on the analysis, the amount of soil loss in the Hadi watershed is about soil from 3907 hectares of land. The annual soil loss rate was determined by a cell-by-cell analysis of the soil loss surface by multiplying the respective RUSLE factor values interactively in ArcGIS 10.5. According to the study result, the potential annual soil loss of Hadi watershed ranges from 0.0189 to 180.45 t ha^{-1} yr^{-1}. The average annual soil loss for the entire watershed was estimated to be 28.063 t ha^{-1} yr^{-1} in 2018/2019.

Accordingly, the result of the study revealed that soil erosion potential of the watershed ranges from 0.0189 to 180.45t ha^{-1} yr^{-1}. While the average annual soil erosion rate for the entire watershed was estimated to 28.063 t ha^{-1} yr^{-1}. With this rate, the amount of soil lost during the study period accounts to be 109,642.25 tons of soil from 3907 hectares of land. The majority of respondents stated that they have been using different traditional soil and water conservation measures before the introduction of new SWC technologies to minimize the rate of soil erosion on their plots of land. These soil and water conservation measures include leaves crops residue, contour plowing, crop rotation, fallowing (Dibla), plantations, Grass strip (Dib), and addition of manure.

4. Conclusions

The result of the study revealed that old farmers are less interested in the adoption of soil and water conservation practices, while youning farmers are more interested. The result also showed that sex of household heads, access to extension services, credit service, farm size, stage of watershed and access to training have positive relationship to SWC measures. Whereas farmland distance, family size, level of education, and age of household heads are negatively correlated.

The majorities of the farmers are aware and perceived soil erosion by water and land degradation as a problem constraining crop production in their farm plots. Furthermore, farmers were able to identify the different causes of soil erosion in their land based on knowledge they have through farming conditions. The main causes as farmers recognized include the intensity of rainfall, over grazing, deforestation, poor agricultural practices and cultivation of steep slopes. In addition, the farmers can differentiate various indicators, effects, and consequences; due to this soil erosion a consequence lead to low yields, decrease in the fuel wood availability, famine and, migration of rural dwellers associated with severity of soil erosion and fertility depletion.

Abbreviations

GDP

Gross Domestic Product

GIS

MERET:Managing environmental resources to enable transitions

ORDA

Organization for Rehabilitation and Development in Amhara

RUSLE
Revised Universal Soil loss Equation
SWC
Soil and water Conservation.

Declarations

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Conflict of interest

The authors declared that there is no conflict of interest regarding the results and data.

Author Contributions

Both authors contributed to the study conception and design. Accordingly, material preparation, data collection and analysis were performed by Aberaw Kefyalew. Accordingly,the first draft of the manuscript was written by Aberaw Kefyalew. Alem-meta Assefa reviewed and commented the entire manuscript. He also guided and monitored the study from its conception to end. Both authors read and approved the final manuscript.

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Figures

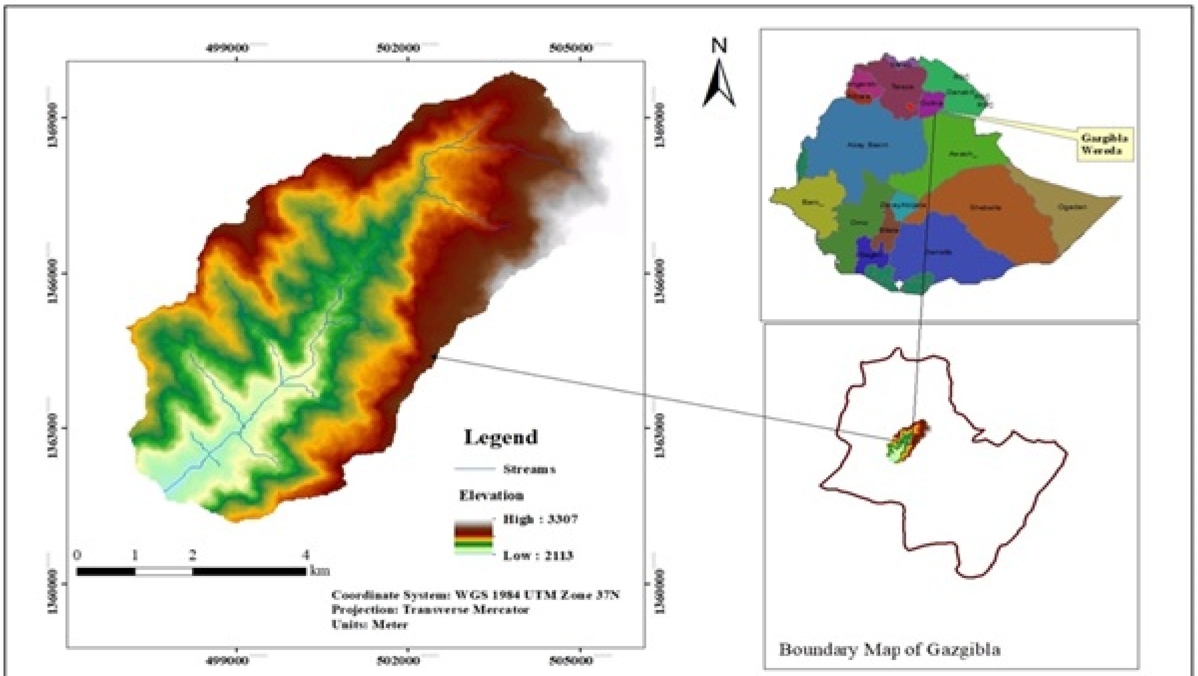

Fig. 1 Map of the study area

Figure 1

See image above for figure legend

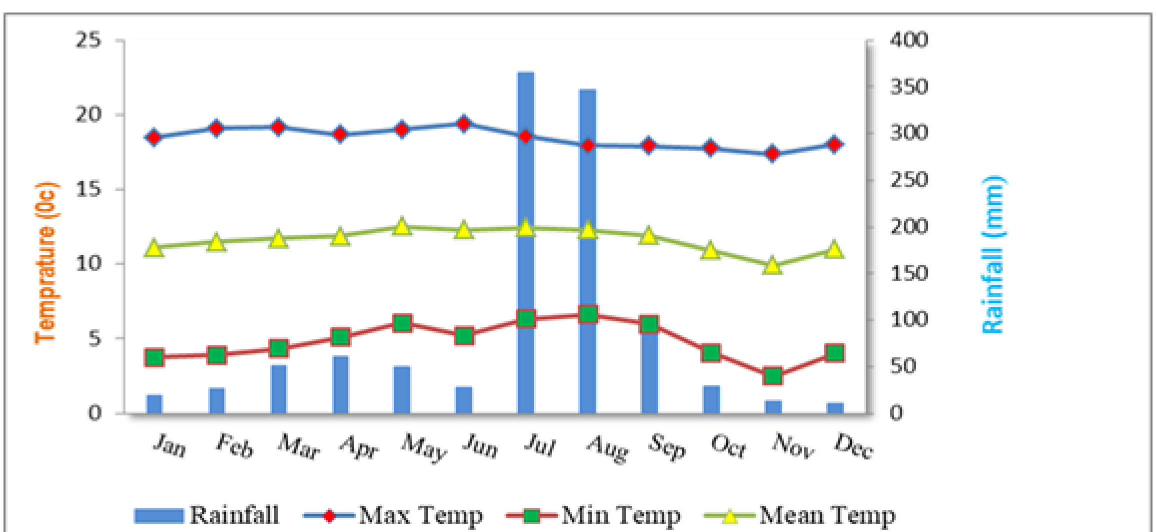

Fig. 2 Temperature and ranfall data of the study area (1988-2018)

Figure 2

See image above for figure legend

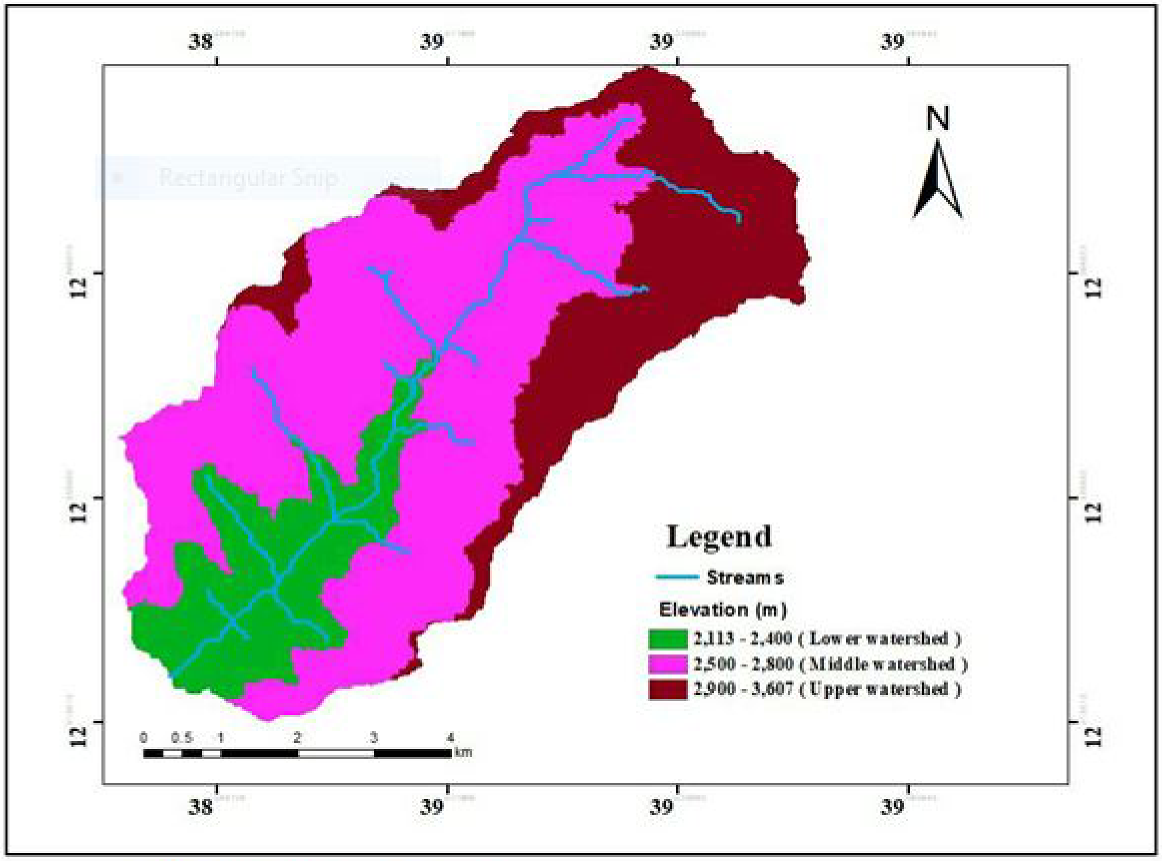

Fig. 3 Elevation map of the study area

Figure 3

See image above for figure legend

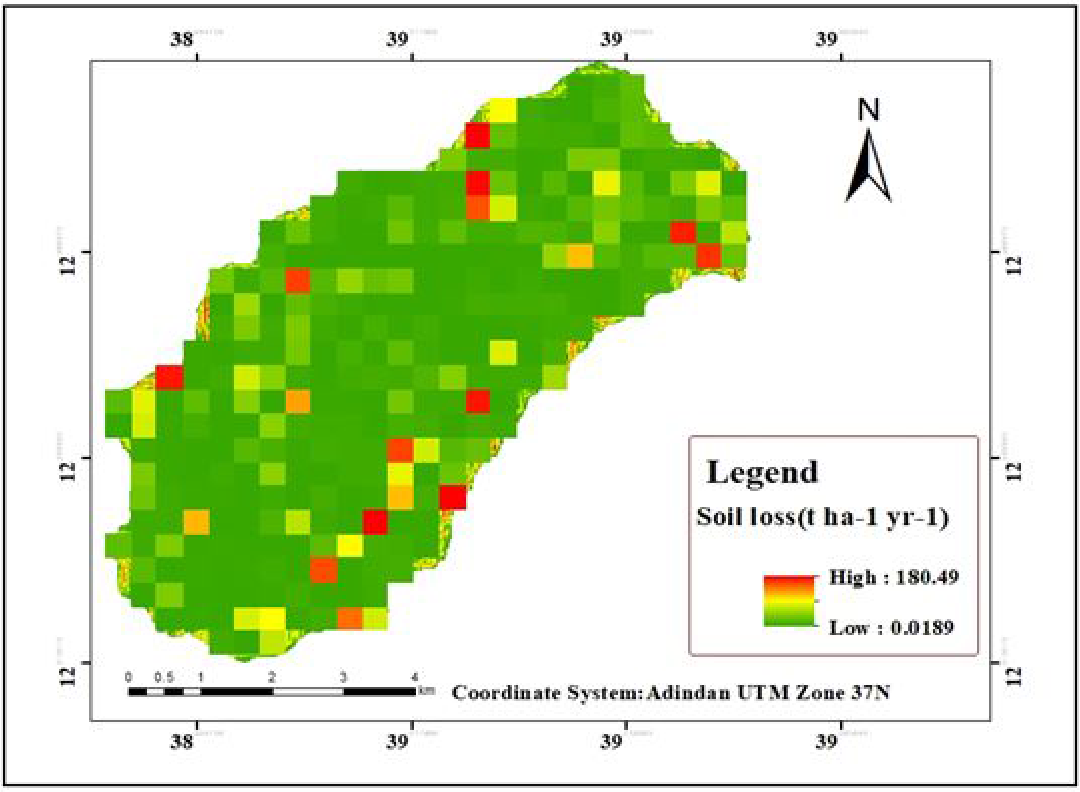

Fig. 4 Soil Erosion map of the study area

Figure 4

See image above for figure legend