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Assessment of Medo Watershed on the Biophysical Aspect for Planning and Impact Monitoring, Central Rift Valley Area of Ethiopia

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Abstract

The essence to characterize biophysical features at a watershed level has a significant input for further Improvements to promote sustainable and productive livelihood through the integration of different watershed components in a participatory approach. The objective of this study was to assess the current biophysical characteristics of the Medo watershed in the West Arsi Zone of Oromia, Ethiopia. To do so, relevant data and tools were used; ArcGIS, Microsoft Excel sheet, and fundamental formulae were applied to the analysis. The results of the study indicated that the major land use types in the watershed are agricultural land covering 50%, vegetation (shrubs, forests, and, plantations) covering 24%, and settlement covering 16% of the total land use. The slope gradient of the Medo watershed ranges from zero to more than 20 and the slope gradient of 2-5 and 5-10 cover the greatest area coverage, representing 201 ha and 170 ha, respectively. We can also observe that about 8% of the total area is subjected to severe erosion. Sandy clay loam was the dominant soil textural classes in the surface soils, and Phaeozems, Retisols, and the dominant soil types, which covered 57%, 36%, 36, % and 7% of the sub-watershed area for lower, middle, and upper slope positions, respectively. The mean annual rainfall of the area ranges from 960.09 mm in the lower part of the watershed to 1304.93 mm in the upper part of the watershed. Accordingly, the Medo sub-watershed is laid in the majority of the sub-humid agro-ecological zone. An assessment of the trees within the watershed landscape showed some remnant natural forests and a wide variety of shrubby vegetation is encountered in all landscapes. About 40 % of the watershed is under high to extremely severe soil loss values (>45 tons per hectare per year). The baseline study also identified that natural resource degradation such as land and/or soil fertility, reduction, and recent changes in the area's weather conditions in line with climate change prevailing in current years are few of the many factors that contribute to land and crop productivity reductions in the area. Therefore, prioritizing the identified problem and preparing intervention of different technologies and development plans by participating communities and different potential stakeholders to solve the problems by considering the existing opportunities of the watershed.

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ArcGIS, Biophysical characteristics, Mapping, Medo Watershed.

Introduction

Natural resource degradation is a serious problem in Ethiopia, threatening agricultural development and rural livelihoods. The major natural resource degradation problems of the country include severe soil erosion, soil fertility decline, soil acidity and salinity, and deforestation, all of which result in recurrent drought, and hence, a decline in agricultural productivity (Admassu *et al.,* 2008). Arable land is decreasing due to increased natural resource degradation that leads to loss of agricultural production and productivity, and increased risks of flooding and sedimentation (Birhanu, 2014). Land degradation reduces the production potential of land and the overall utility of land resources, thus making it unsustainable to produce enough food, feed, and fiber crops for the growing population in the country. In a nutshell, natural resource degradation in Ethiopia directly impacts water resources, livestock and crop production and productivity, unemployment and rural-urban migration, the incidence of drought, and ultimately on food security (Desta *et al.,* 2005). To address the problem of natural resource degradation in the country, government, and non-governmental organizations have introduced different conservation measures since the 1970s famine. However, due to the poor consultation and participation of local people in the planning and implementation of the practices, shortage of skilled human power, and lack of state-of-the-art scientific approach, the natural resource management efforts were not as effective as desired to bring fundamental change. (Becket, 2003; Lemenih, 2004; Gebremedhin *et al.,* 2003).

Learning Watershed as a framework approach consists of different harmonizing approaches and a series of procedures at different stages of implementation (Carol, 1996). Baseline characterization helps understand the initial livelihood conditions of the people in the watershed before intervention. It builds the necessary foundation for the plan and obtains proper information for effective planning, implementation, and monitoring (Bonsa *et al.,* 2020). The general biophysical characteristics of a watershed are groups of features that distinguish one watershed from the others. These groups of features or biophysical characteristics are crucial inputs or elements whenever one needs to study the availability, utilization and management of watershed resources (Amanuel *et al.,* 2011).

Some impact studies have shown that investments in watershed management in the developing world pay off in economic terms. However, such impact studies do not typically include detailed biophysical and socio-economical components (Sisay *et al.,* 2019). Similarly, watershed management in West Arsi, including attention for more physical interventions to restore degraded lands and improve livelihood benefits, but biophysical characteristics of the watershed was not assessed. Because of this, detailed biophysical and socioeconomic characteristics of the watershed must be known for accurate planning to solve problems.

Therefore, the analysis from biophysical and socioeconomic information in the watershed helps prioritize the problems with appropriate management options and technologies, which in turn leads to the implementation phase to make all the community in the watershed benefit from watershed management. Therefore, the study aimed to assess biophysical characteristics to identify constraints and opportunities and document baseline information for appropriate watershed management, which is also used as a benchmark for impact monitoring.

Materials and Methods

The description of the Edo watershed

Edo learning watershed is located in Wendo district of the West Arsi Zone of Oromia Regional State, Ethiopia, where soil degradation, gully formation, and loss of agricultural land caused by inappropriate land use and land management practices, mainly triggered by the growing population pressure on natural resources, are serious problems in the watershed (Wolka *et al.,* 2015). It covers an area of 504 hectares and the Edo subwatershed is one of the main streams draining into the Rift Valley basins. The area is located around 12 kilometers northeast of Shashemane town and 250 km south of Addis Ababa. Geographically, it is located between 38°35'E - 38°38'E longitude and 7°05'N - 7°06'N latitude. Edo watershed, which belongs to the sub-watershed, is a main tributary to Lake Hawassa catchment at the low-lying areas (38º36´13´´E, 7º5´52´´N) outlet that is partially found in the central rift valley of Ethiopia.

Data Collection and Analysis

Watershed Delineation and Topographic Mapping

A reconnaissance survey was conducted with different stakeholders to identify the watershed. Based on the preliminary outlet identified during the site selection process, the watershed boundary was delineated using an ArcGIS environment. The delineated watershed was georeferenced and digitized for its contour, roads, rivers, and other features. The preliminary delineated boundaries were verified in the field using GPS and established reference benchmarks for future operations. Finally, a map of the watershed was produced with other information such as elevation ranges, area, slopes, and aspects extracted using a digital elevation model of 30 m resolution. Before analyzing these spatial input data, these data were projected into the same projections called UTM Zone 37 N in ArcGIS. The ArcGIS program was used to analyze the watershed characteristics.

Biophysical Resource Survey

Biophysical baselines were characterized to identify detailed information on topography and landforms, present land use, soil erosion status, vegetation, climate, and water resources. It was supported by remote sensing technology, especially with the availability of high spatial and temporal resolution satellite data, and aided by Geographic Information System (GIS) tools and hydrological modeling. Using this biophysical information and feedback obtained from farmers and other stakeholders, constraints, and opportunities were identified and prioritized for intervention planning.

Land use/land cover

The current land use/land cover of the watershed was assessed and mapped depending on the availability of historical data (existing maps, aerial photographs, knowledge of the local community, and satellite images) and ground truth collected by GPS. Landsat Thematic Mapper images were acquired and classified using supervised classification methods. The land use land cover map generated with the ArcGIS environment was crosschecked, and verified by field observation and Google Earth.

Topography

The digital elevation model (DEM) was used to analyze the topographic characteristics (elevation, slope class) of the watershed using ArcGIS.

Soil sample collection

The soil of the watershed was characterized in two stages. First, a reconnaissance survey was conducted with the participation of the local community in which local soil classes were identified. This was followed by replicated auger soil sampling for each locally identified soil class. The sampling depths were from 0 to 20 and 20-40 cm. The soil samples were analyzed for important physical and chemical properties. Soil samples were taken from every systematically selected georeferenced sampling point across the slope. Profiles were opened for each locally identified soil class and pre-identified sampling points.

The newly opened representative soil profiles and horizons were described and designated according to the guidelines of the soil description (FAO, 2006). On standard soil site and soil profile description sheets, all key morphological and physical parameters and other pertinent information were documented in the field.

Soil samples were collected from each genetic horizon to characterize and classify their physicochemical features. The undisturbed soil samples were collected for the determination of bulk density (BD) using a core sampler.

Climatic data collection

A 30-year seasonal climate (mean annual rainfall, minimum and maximum temperatures) was obtained from the National Meteorological Agency (NMA). For the nearest weather stations located around the watershed.

Vegetation and farming system data collection

Frequent field observations; transect walks and survey works have been carried out in order of land use types such as vegetation, grazing, and shrubs across the watershed. Necessary data including vegetation and farming systems have been extracted from secondary data sources including the CSA of Ethiopia, Woreda Administration, and Agricultural Development offices. The questions in the field data-recording sheet are designed to guide one through the classification process.

Methods of Data Analysis

Analysis of Soil Physical Properties

The soil particle size distribution was analyzed using the Bouyoucos hydrometric method to determine soil textural classes (Chapman, 1965; WRB, 2014). Bulk densities of the soils were determined using the core sampler method from undisturbed soil samples.

Analysis of Soil Chemical Properties

Soil pH was determined electrochemically by a pH meter as described by Jenkins (1958) in suspensions of a 1:2.5 soil-to-water ratio. Electrical conductivity was measured using a conductivity meter on saturated soil paste extracts obtained by applying suction (Okalebo *et al.*, 2002). The wet digestion method developed by (Walkley and Black, 1934) was used to determine the organic carbon of the soils. The Kjeldahl digestion, distillation, and titration method were used to determine total nitrogen, while the standard Olsen extraction method was used to determine available phosphorus (Olsen, 1954). Cation exchange capacity was determined by the one N neutral ammonium acetate method which was subsequently estimated by distillation of ammonium that was displaced by sodium (Chapman, 1965). The leachate of one molar ammonium acetate (NH4OAc) solution at pH 7 was used to determine the exchangeable base (Ca, Mg, K, and Na) in the soil. A flame photometer was used to read K and Na, while an atomic absorption spectrophotometer was used to read exchangeable Ca and Mg (Rowell, 1994). Then, percent base saturation (PBS) was calculated from the sum of exchangeable bases as a percentage of the sum of CEC. Available micronutrients Fe, Mn, Zn, and Cu were extracted from the soil samples with diethylene triaminepentaacetic acid (DTPA) as described by Lindsay and Norvell (1978). All the micronutrients extracted were measured by an atomic absorption spectrophotometer.

Soil Classification

The soils of the study area were finally classified into different units based on morphological, physical, and chemical properties according to the (FAO, 2006) classification system**.**

Results and Discussion

Biophysical Characteristics of Medo Watershed

Soil Physical Properties of the Watershed

Soil texture was investigated for upper, middle, and lower slope profiles. Accordingly, the particle size distributions of the watershed revealed that the sand, silt, and clay particle percentages in the three Pedon surface soils ranged from sand (63 to 74), silt (1 to 6), and clay (23 to 39) percent, upper, middle, and lower slope positions, respectively. The subsurface layers ranged from sand (61 to 78), silt (8 to 12), and clay (19 to 41%), respectively (Table 2). Soil sand, silt, and clay concentrations ranged from high to low and low to moderate, respectively (Table 2). In all slope positions, the results indicated that the textural classes of surface soils were sandy clay loam and sandy loam textural classes (Table 2). This indicates that slope positions were extensive and continuous cultivation, which could have resulted from clay translocation from surface soil caused by intensive and continuous cultivation. Similarly to Teshome *et al.*, (2013), the reason for low clay in the surface soil of cultivated fields may be due to erosion selectively removing clay from the surface (Achalu *et al.*, 2012). Despite this, the clay buildup in the lower Pedon subsurface horizons could have been caused by the predominant in situ synthesis of clay from the weathering of primary minerals in B layers Rust (1983); Chadwick and Grahm (2000).

The current study findings revealed variable bulk density values across soil depth in the three pedons (Table 2). The three pedons' surface horizons ranged from 0.8 to 1.0 gm cm^{-3}, whereas the subsurface horizons ranged from 0.8 to 1.3 gm cm$^{-3.}$ The bulk density values in all profiles increased with depth. This is due to the presence of high organic matter content and abundant root systems resulting in well-structured and porous surface soil, whereas subsurface horizons had high bulk density values as per the lower distribution of organic matter content, a rare abundance of roots, and poor aggregation of soil. The results agreed with (Adhanom and Teshome, 2016), as the bulk density of soils increased with the depth of the profiles, which could be due to changes in organic matter content, porosity, compaction, and the weight of the overlying soil, which is conducted in Bambasi Wereda of West Ethiopia. Achalu *et al.*, (2012) and Wakene (2001) also reported that surface soils have lower bulk density than deeper layers from their studies of selected physicochemical properties of soils under different land use systems conducted in Western Oromia and Alemaya University, Ethiopia.

Soil Chemical Properties of the Watershed

The soil pH (H2O) at the surface layers (A- horizon) of the pedons was found to be mildly acidic, with values ranging from 5.43 to 5.81 (Table 2). The upper slope landscape had the lowest pH value in surface soil when compared to the middle and lower slope landscapes; this was probably owing to the removal of base cations from the top slope gradient to the middle and lower slope gradients (Table 3). This conclusion is consistent with (Mulugeta and Sheleme’s, 2010) findings conducted in the KindoKoye watershed in southern Ethiopia, which showed that soil pH rose as the slope gradient decreased. In all of the soil profiles from the various landscape sites, soil pH increased in general as profile depth increased, which may be attributed to the removal of basic cations from the overlying horizon via leaching and crop absorption. The EC values of the studied soils ranged from 0.73 – 2.78 dSm^{-1}. Thus, the EC values of the soil in all profiles were rated as salt-free according to (Ethiosis, 2016). The EC values throughout the profiles at all slope positions increased with depth, which could be due to continuous leaching and soil erosion aggravated by over-cultivation and the removal of crop residues.

Organic carbon (OC) contents in pedons ranged from extremely low to medium (Ethiosis, 2016). The OC concentration in the surface soils of the three pedons was determined to be in the middle range according to Ethiosis (2016) ratings (Table 3). The OC concentration of the three pedons' surface soils ranged from the top slope profile recorded (1.97%), (2.11%), and (2.23%) upper, mid, and lower slopes in surface soil positions, respectively. In general, the OC increases with decreasing slope gradient, with the maximum OC found in the lower slope pedon, which may be ascribed to the movement of organic materials from higher slope positions to lower slope positions and thus higher organic material accumulation. Similarly, Dinku *et al.,* (2014) discovered a negative and substantial relationship between organic matter and slope locations or slopes.

Furthermore, the soil TN distribution inside the particular Pedon horizon showed a declining tendency compared to soil depth, and this accompanied a pattern similar to that of OC, indicating that OM was the primary source of TN. This is consistent with the findings of Mulugeta and Sheleme (2010), who found that TN concentration dropped as profile depth increased. The available P content in the investigated pedons ranged from 1.19 mg kg^{-1} in the bottom horizon of the upper pedon to 15.92 mg kg^{-1} in the A horizon of the lower slope (Table 3). The decrease in available P down the profile in these pedons might be attributable to lower layers that fix phosphorus having less OM and more clay. Because of the presence of clay, illuviation in the high-to-low slope gradient in the upper, middle, and lower slopes, respectively, is in accordance with this conclusion (Alemayehu *et al.,* 2016).

According to Hazelton and Murphy's (2007) rating of (6, 6- 12, 12-25, 25-40), and more than 40 cmolckg^{-1} soil, CEC of the soils classified as very low, low, medium, high, and very high. As a result, the soils cation exchange capacity (CEC) ranged from (8.56 to 17.62) cmolckg^{-1} across the surface and subsurface layers, indicating a low to medium CEC. From the upper to lower slope topo sequence, the distribution of CEC increases.

This was due to the relationship between slope location and soil properties. (Kravchenko and Bullock, 2000) discovered that when the slope position changed from upper to lower, CEC increased. The CEC values of the pedons were incongruent with the profile depth (Table 4). However, the CEC of the soils increased with profile depth in general, owing to an increase in clay content and basic cations caused by leaching.

The exchangeable Ca2+ content of surface soil ranged from 6.0 cmolckg-1 in the upper pedon to 10 cmolckg^{-1} in the lower pedon, while the exchangeable Mg2+ content ranged from 1.2 cmolckg-1 in higher pedon to 1.86 cmolckg-1 in middle pedon. According to the FAO (2006) assessment, both exchangeable Ca2+ and Mg2+ were discovered in medium ranges. In all pedons, the subsurface horizons had more exchangeable Ca2+ and Mg2+ than the surface horizon, which could be attributed to leaching from the overlaying horizons. With increasing soil depth, the exchangeable cation content of all pedons increased marginally (Table 4). The minor increase in basic cations along the profile depths could be due to soil material leaching from the surface to the subsurface horizons (Ashenafi *et al.,* 2010). The exchangeable K content of the surface soil ranged from 0.72 cmolckg-1 in the middle pedon to 1.19 cmolckg-1 in the bottom pedon (Table 4).

The surface soils of the three pedons were found to have higher exchangeable K levels, implying that the nutrient is less limiting for plants. Except for the top pedon, the exchangeable K content of the soils increased with soil depth (Table 3), which could be attributed to the increased clay content in the subsurface layer that holds the cation.

Surface soil exchangeable Na content ranged from 0.36 cmolckg^{-1} in the upper and lower pedons to 0.39 cmolckg^{-1} in the middle pedon. In general, the concentrations of exchangeable sodium (Na) and potassium (K) in the soil exchangeable complexes were lower than those of Ca and Mg (Table 3), which may be attributed to the higher intensity of reactivity of divalent cations on the exchange complexes.

Classification of Soils According to WRB

The soils of the study area were finally classified into different units based on morphological, physical, and chemical properties according to the studied soils were classified; according to the World Reference Base Legend IUSS Working Group (WRB, 2014) classification system. According to the WRB soil classification system, three soil types are identified in the Edo watershed. Therefore, the studied soils were classified as Vitric Andosols (Arenic), Leptic Retisols (Arenic), and Cambic Phaeozems (Aric) for upper, middle, and lower slope positions, respectively. Phaeozems, Retisols, and Andosols are the dominant soil types, which cover 57%, 36%, and 77% of the sub-watershed area, respectively.

Topographic Characteristics of Medo Watershed

The altitude of the Medo watershed ranges from 1700 to 2100 meters above sea level and therefore its physical features are featured by undulating highlands (valleys) and plateaus (flat highlands) respectively.

Topography affects the landscape by facilitating physical land cover changing problems such as flooding and degradation based on steep slopes and slope lengths. The slope gradient of the Medo watershed ranges from 0 to more than 20 and the slope gradient of 2-5 and 5-10 cover the greatest area coverage, representing 201 ha and 170 ha, respectively (table 6).We can also observe that about 8% of the total area is subjected to severe erosion, which is not suitable for agriculture (FAO, 2006). This indicates that more of the watershed landscape might be exposed to extreme flooding at times of high rainfall occurrences, which implies the need for soil and water conservation structures for sound natural resource conservation in the area. This agrees with the findings of stating (Betteridge *et al.,* 1999) that the slope configuration provides few depositional sites within the hill slope. However, where excessive slope lengths occur, off-slope transport of sediment (erosion) can be anticipated.

Climate and Agroecology Characteristics Medo Watershed

The mean annual rainfall of the area ranges from 960.09 mm in the lower part of the watershed to 1304.93 mm in the upper part of the watershed, with an average annual rainfall of 1126.67 mm. The rainfall pattern of the area is bimodal type. The short rainy season occurs from February to May and the long rains extend from June to September. The mean maximum temperature varies from 26.30°C to 30.82°C, while the mean minimum temperature varies from 10.4°C to 14.5°C, with an average temperature of 21.2°C (Table 6). Subhumid is the region with an optimum temperature from 1500 to 2500 m above sea-level altitude. Accordingly, the Medo sub-watershed is laid in the majority of sub-humid agro-ecological zones.

Land Use/Land Cover of Medo Watershed

From the analysis of LULC in ArcGIS, there are five major types of land uses identified and reclassified in the watershed. As shown in Figures 5 and 6, the major land use types in the watershed are agricultural land covering 50%, vegetation (shrubs, plantation, and natural forest) covering 24%, and settlement covering 16% of the total land use. The remaining land use types are grazing land and bare land covering 9% and 1% of the area, respectively. Maize, wheat, haricot bean, potato, and teff and perennial crops i.e. sugarcane, coffee, and khat are the dominant crops grown in the study area.

Croplands are expanding at the expense of grazing and vegetation lands and the marginal lands between the farmlands are becoming very narrow. After the crop products are collected, the ground will be left bare and then exposed to erosion, since there is no habit of integrating perennial cash crops with these cereal crops. Away from the outlet, the vegetation cover varies from a closed dry thicket to open shrubland and further to grassy plains. Small-scale eucalyptus stands near settlements and agricultural field edges. Additionally, a few scattered trees were found in the landscape during the survey. Cropping schedules are twice annually in that it is between February – April and July – September. Moreover, different types of irrigated agriculture have been practiced in the lower part of the watershed. Potato and perennial crops are the dominant crops grown in the study area, which predominantly use supplementary irrigation water. Enset (*Ensete ventricosum*) is a staple perennial crop that is dominantly grown on homesteads.

Soil erosion and conservation measures status

Soil erosion in almost all of the survey areas showed visible signs of sheet erosion and active rill erosion. Many rills that have a prominent role in the development of gullies were observed in the watershed. Accordingly, two big gullies and other small gullies were formed because of water erosion in the watershed.

Table.1 Particle size distribution and bulk density of soils in the Medo sub-watershed.

Horizon	Depth (cm)	Sand (%)	Silt (%)	Clay (%)	Textural class	BD (g cm-^{3})
Upper slope position (UP)						
A	0–21	63	6	31	Sandy clay loam	0.8
A2	21-32	57	4	39	Sandy clay	0.8
B1	32–50	61	12	27	Sandy clay loam	0.8
B2	50-70	71	10	19	Sandy loam	1.0
BC	70–142	74	7	19	Sandy loam	1.2
R	142+	-	-	-	-	-
Middle slope position (MP)						
Ap	0-12	70	1	29	Sandy clay loam	1
A2	12–30	74	3	23	Sandy clay loam	0.9
B1	30-65	53	6	41	Sandy clay	1.1
B2	65–107	63	2	35	Sandy clay	1.1
BC	107–128	61	2	37	Sandy clay	1.3
R	128+	-	-	-	-	-
Lower slope position (LP)						
Ap	0-10	74	1	25	Sandy clay loam	0.95
A2	10–43	63	6	31	Sandy clay loam	1.0
BA	43-71	64	3	33	Sandy clay loam	1.1
Bt1	71–107	61	6	33	Sandy clay loam	1.1
Bt2	107–136	61	8	31	Sandy clay loam	1.1
C	136–200	78	9	13	Sandy loam	1.2

Table.2 Soil chemical properties in the soil of the Medo Watershed

Horizon	Depth(cm)	pH (H_2O)	TN (%)	EC dSm^{-1}	OC (%)	Avi P (mg kg^{-1})
Upper slope (US)						
A	0–21	5.43	0.17	2.34	1.97	10.56
A2	21-32	5.52	0.14	2.16	1.46	6.25
B1	32–50	5.82	0.12	2.62	1.22	4.21
B2	50-70	5.75	0.09	2.31	0.92	3.35
BC	70–142	5.68	0.1	1.71	0.91	1.19
R	142+	-	-	-	-	-
Middle Slope (MS)						
Ap	0-12	5.76	0.16	2.02	2.11	6.08
A2	12–30	5.69	0.13	1.84	1.58	7.42
B1	30-65	5.25	0.13	1.53	1.41	5.54
B2	65–107	5.31	0.12	1.61	1.08	4.36
BC	107–128	5.39	0.1	1.92	0.86	3.76
R	128+	-	-	-	-	-
Lower slope (LS)						
Ap	0-10	5.81	0.22	2.78	2.23	15.92
A2	10–43	5.90	0.13	2.06	1.63	11.46
BA	43-71	5.92	0.09	1.25	1.6	6.40
Bt1	71–107	5.81	0.08	1.33	1.58	3.89
Bt2	107–136	5.54	0.06	1.22	1.04	3.85
C	136–200	5.48	0.05	0.73	0.87	2.46

Table.3 Exchangeable bases and cation exchange capacity of the soils in the Medo Watershed.

Horizon	Depth (cm)	Exchangeable bases and CEC ($cmol_c kg^{-1}$)					PBS
		Ca	Mg	K	Na	CEC	
Upper slope (US)							
A	0–21	6.00	1.20	1.14	0.36	10.68	83.3
A2	21-32	4.59	1.27	1.15	0.44	12.72	58.6
B1	32–50	4.74	1.20	0.54	0.26	7.14	94.4
B2	50-70	5.73	0.60	0.31	0.21	7.06	97.0
BC	70–142	7.01	1.01	0.49	0.10	8.76	98.2
R	142+	-	-	-	-	-	-
Middle Slope (MS)							
Ap	0-12	8.00	1.86	0.72	0.39	12.88	85.2
A2	12–30	4.24	2.21	1.00	0.44	8.56	92.2
B1	30-65	8.13	2.26	1.08	0.41	12.78	92.9
B2	65–107	8.76	2.46	0.87	0.22	12.92	95.3
BC	107–128	7.29	2.44	1.05	0.13	11.69	93.3
R	128+	-	-	-	-	-	-
Lower slope (LS)							
Ap	0-10	10.0	1.81	1.19	0.36	13.5	98.9
A2	10–43	10.25	2.32	2.02	0.40	17.62	85.1
BA	43-71	10.40	2.31	1.78	0.67	16.86	89.9
Bt1	71–107	9.15	1.46	1.42	0.85	13.36	96.4
Bt2	107–136	10.99	1.55	1.45	0.92	15.96	93.4
C	136–200	11.04	1.42	1.78	0.59	17	87.2

Table.4 Medo watershed soil type based on the (FAO/WRB, 2014) classification system

Profile	Soil unit	Soil types	Local names	(%) of watersheds
Upper	Vitric Andosol	Andosols	Dima	7
Middle	LepticRetisols	Retisols	Guaracha	36
Lower	CambicPhaeozems	Phaeozems	Guaracha	57
Total				**100**

Table.5 Medo watershed slope class is based on the FAO classification system (FAO, 2006).

No	Slope class	Description	Area (ha)	Area (%)
1	0-5	flat	201	39.49
2	5-10	gentle	170	33.40
3	10-15	moderate	96	18.86
4	15-20	steep	37	7.27
5	>20	Extremely steep	5	0.98
Total			509	100

Table.6 Average monthly climatic data of the watershed (1985- 2015).

Month	T_{max}(^{O}C)	T_{min}(^{O}C)	RH (%)	Sunshine hour (hr)	Rainfall (mm)
January	29.48	11.18	51.82	9.03	22.06
February	30.82	12.08	50.38	8.70	51.80
March	30.34	13.03	55.47	7.90	92.52
April	28.56	14.10	65.20	6.86	123.21
May	28.15	14.10	69.29	7.32	135.94
June	27.39	14.26	69.69	6.65	111.88
July	26.80	14.47	72.90	4.84	130.46
August	26.30	14.34	72.49	5.34	185.72
September	27.37	13.70	73.30	5.77	124.27
October	27.11	12.57	65.16	7.15	92.67
November	29.56	10.42	54.06	8.97	40.02
December	29.72	10.46	52.50	9.34	16.13
Average	28.48	12.89	62.69	7.32	1126.67

Table.7 Soil erosion severity and conservation priority class

Soil loss (t ha^{-1} yr^{-1})	Severity classes	Priority classes	Proportion by Area (%)
0-5	Low	VII	31.63
5-11	Moderate	VI	29.73
11-20	High	V	19.40
20-30	Very high	IV	11.19
30-45	Sever	III	5.36
45-60	Very Sever	II	1.64
>60	Extremely Sever	I	1.05
Total			**100**

Table.8 List of woody tree/shrub species in the watershed.

No.	Scientific name	The local name of spp.	Growth status
1	*Eucalyptus globules*	Bahirzaf	Tree
2	*Croton macrostachus*	*Makkannisa*	Tree and Bush
3	*Cordia africana*	Wedesa/Wanza	Tree
4	*Podocarpus falcatus*	Zigba	Tree
5	*Ficus sychromus*	Cholla	Tree
6	*Maytenus arbutifolia*	Kombolcha	Bush
7	*Calpurnia aurea*	Sesa/Digta	Tree
8	*Aningeria adolfi-friederich*	Birbira	Tree
9	*Grevillea robusta*	Gravina	Tree
10	*Bersama abyssinica*	Azamer	Bush and tree
11	*Maytenus senegalensises*	Atat	Bush
12	*Erythrina abyssinica*	Korch	Bush

Fig.1 Location map of the Medo watershed

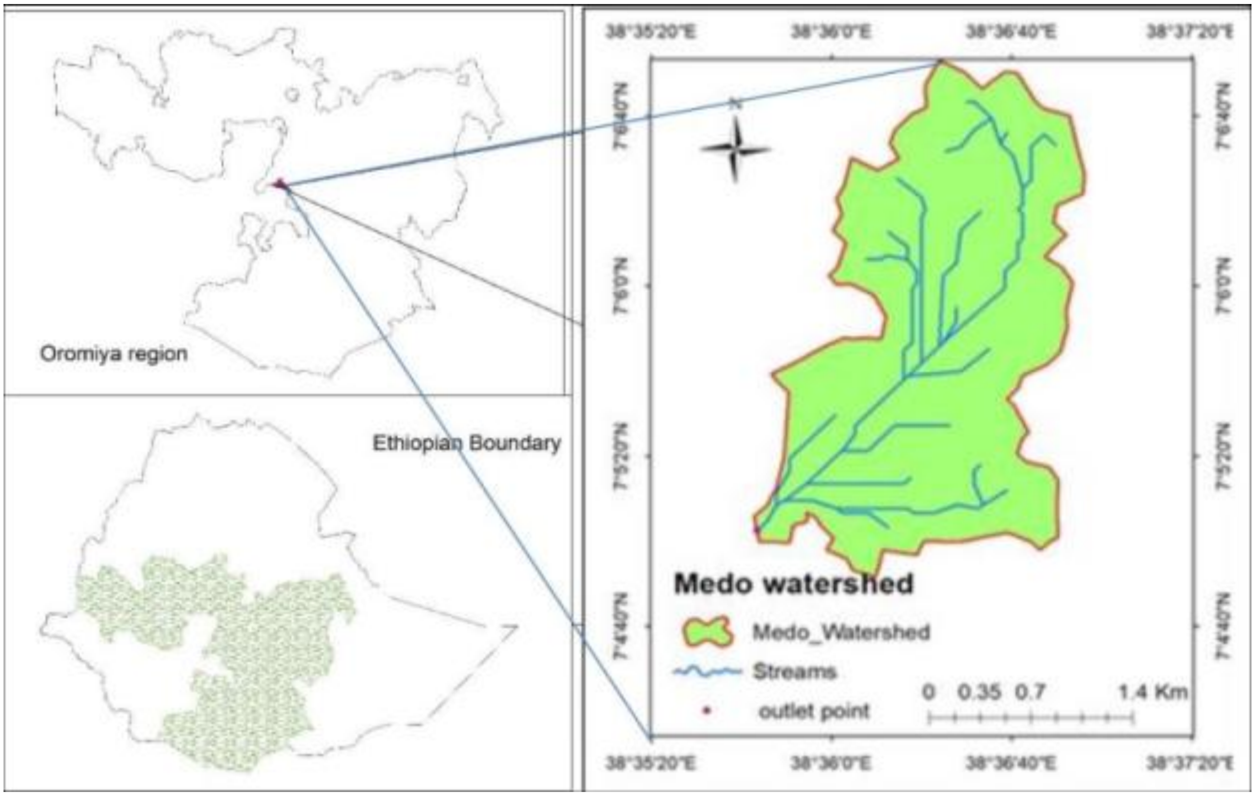


Fig.2 Soil map of the memo watershed

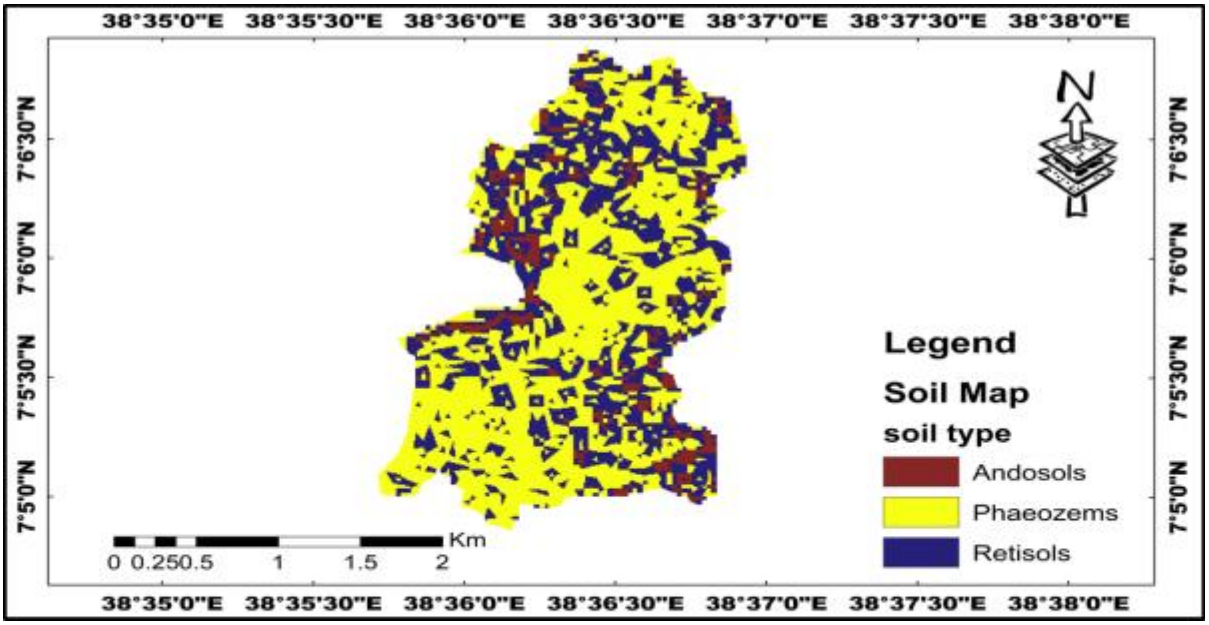


Fig.3 Slope map of the memo watershed.

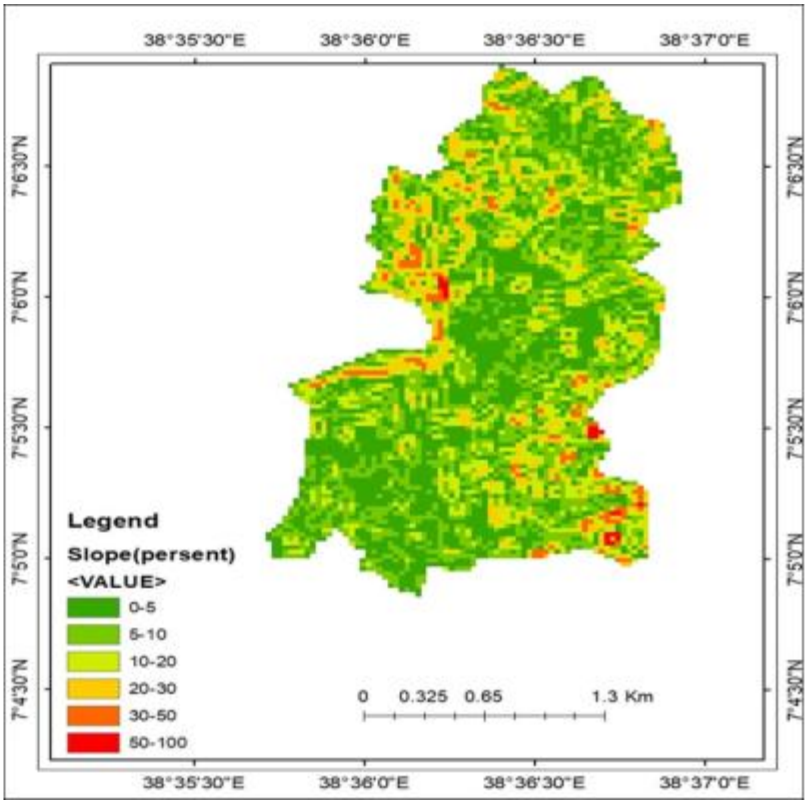


Fig.4 Observed monthly mean rainfall, maximum and minimum temperatures of the medo watershed

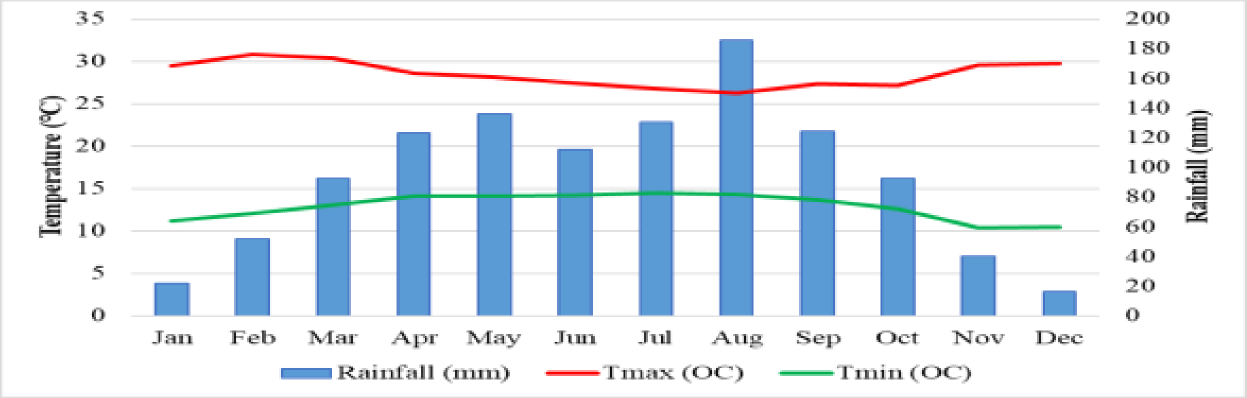


Fig.5 Land use types and percent coverage of Medo Watershed

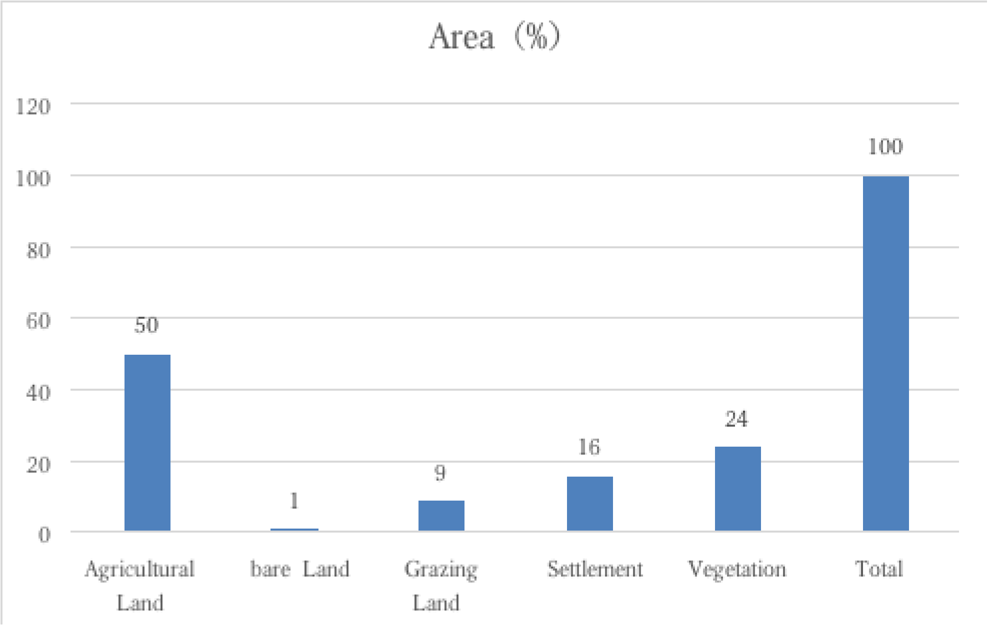


Fig.6 Land use/cover map of Medo Watershed.

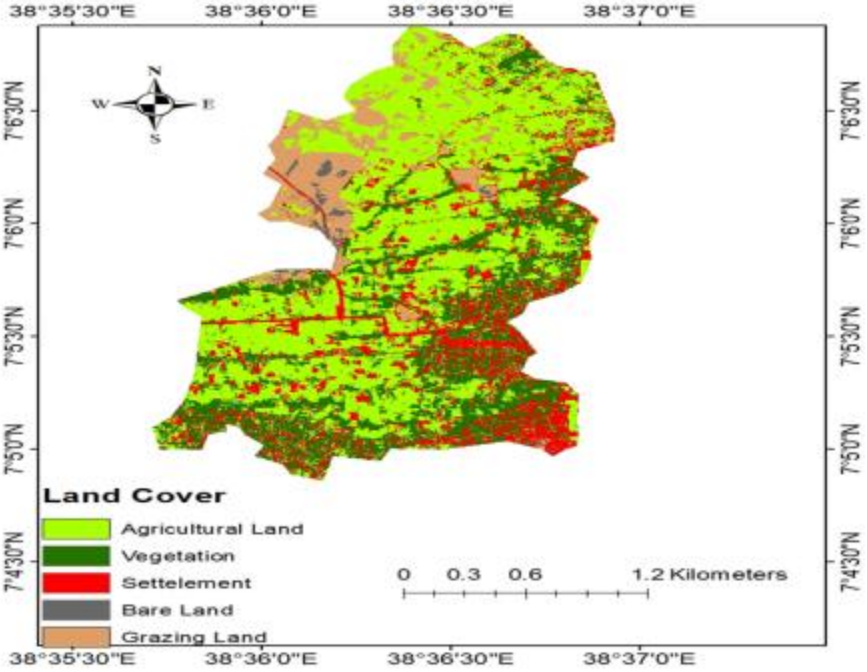
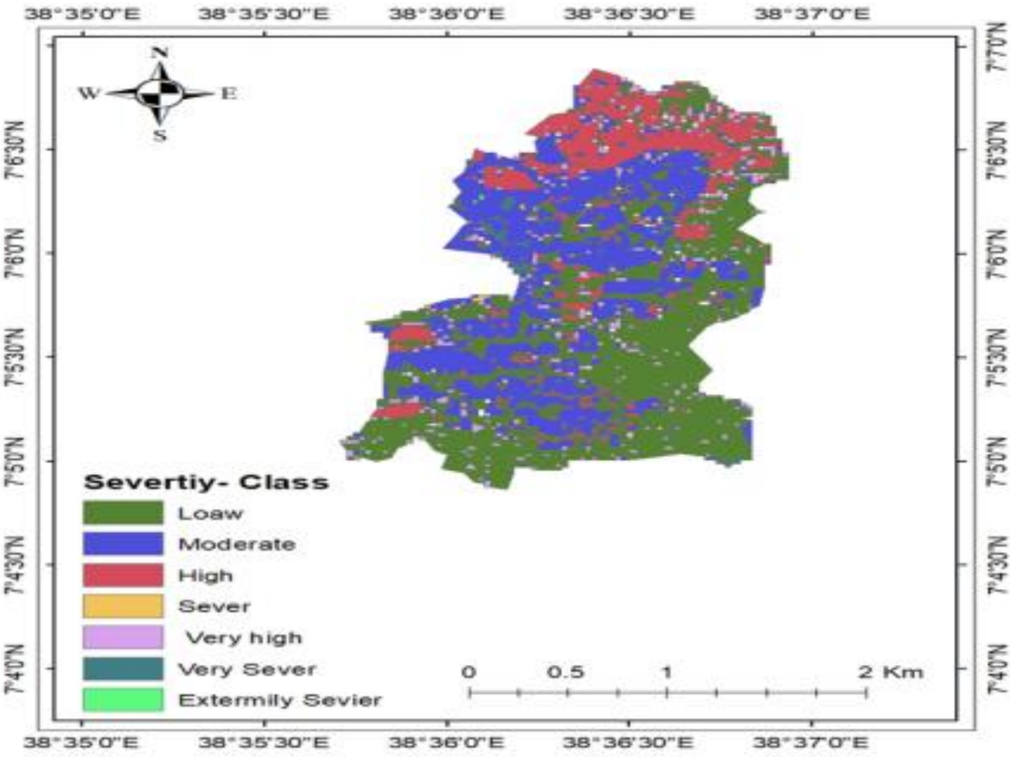


Fig.7 The soil erosion assessment of med watershed and conservation priority class



According to the rangeland health and pasture condition (2003) scoring models, the reduction of vegetative cover causes increased surface runoff and often leads to accelerated erosion. Rills and gullies develop followed by larger flow concentrations. Runoff is closely linked to chemical and nutrient cycling, erosion, and contaminant transport. It can also be a sensitive indicator of ecosystem change. Plant community types and the character of vegetative cover are factors that determine the rate and areal distribution of runoff from a watershed. For every watershed and site within the watershed, there exists a critical point of deterioration resulting from surface erosion. However, only very few farms have established structural soil and water conservation measures. The high presence of soil erosion and the low number of soil and water conservation measures should be one of the key entry points in this watershed. Therefore, soil and water conservation in association with tree planting should be one of the first activities undertaken in this watershed.

The soil loss amount, severity, and extent varied for the different parts of the sub-watershed. About 50 % of the study area has a soil loss value of less than 10 t ha-1 yr-1 (Figure 7 and Table 7), mainly along the flat to gentle slopes of the downstream area. About 40 % of the watershed is under high to extremely severe soil loss values (>45 tons per hectare per year). This includes the mountain chain and the valleys of the upstream part of the watershed (Figures 2 and 3). Most of the parts of this watershed have experienced intensive soil erosion behavior, which is beyond the tolerable soil loss level. This threatens the annual crop production and the productivity of the land, influencing the local farmers' food security (Brevik, 2013; Pimentel and Burgess, 2013).

Knowing the distribution and slopes on which trees exist in the watershed helps in preparing an intervention plan for massive tree planting. An assessment of the trees within the watershed landscape showed some remnant natural forests, which comprise tree species including *Maytenus arbutifolia*, *Prunus africana*, *Calpurnia aurea*, *Aningeria Adolf-Friederich*, *Cordia africana*, and *Croton macrostachus*. *Podocarpus falcatus*, *Bersama abyssinica*, and *Ficus synchronous* (Table 8) were mainly left uncut for timber and construction, whereas the other species were left uncut for shade, boundary demarcation, windbreak, and fuel wood, and some were planted. A wide variety of bush and shrubby vegetation is encountered in all landscapes and is generally a mixture of annual and perennial types. Few exotic trees and herbs were found in the watershed area. Eucalyptus spp. and *Grevillea robusta* were widespread in some blocks, indicating low soil fertility. The most familiar plantation in the study area is Eucalyptus (*Eucalyptus globules*). Small-scale eucalyptus stands near settlements and agricultural field edges. Eucalypts are highly preferred and appreciated by local people over other indigenous species because they produce high biomass and grow rapidly to sell them for cash income and construction. Fruit trees in the watershed are mainly avocado (*Persia Americana*), papaya (*Carica papaya*), and banana (Musa sp.) At homestead and farm boundaries, agro-forestry activities are commonly practiced. Most of the plain areas are predominantly agricultural lands, where some ficussp, acacia sp., and eucalyptus are scattered along the farm plots. Deforestation is a serious problem in this area. The major causes of deforestation are population growth, agriculture, resettlement, grazing, fuel wood, and timber exploitation (key informant discussion).

Recommendations

This baseline report presents the results of the data collected from a combination of field and farm surveys of the Edo watershed. The assessment of the biophysical characteristics of the Medo watershed gives awareness on how to significantly describe the basic features and to use them as input for different activities to be conducted inside the watershed. Therefore, the analysis of biophysical information in the watershed helps prioritize the problems with appropriate management options and technologies, which in turn leads to the implementation phase so that all the communities in the watershed will benefit. Results show that this watershed has moderate climatic conditions, which are suitable for massive agricultural production. The rainfall pattern is bimodal in that with little support of irrigation, crop production can be possible with a rain-fed system. The significant variations in the physicochemical properties of the studied soils indicate slope positions and soil management needs of each soil type to maintain soil organic matter and essential plant nutrients. Despite the presence of soil erosion on farms and steep slopes on several farms, only a few of the farms in the watershed had established contour lines, terraces, or other conservation measures to divert runoff and control soil erosion. The cause and impact of land degradation in the Medo watershed were explored using different methods explained in the study. Natural resource degradation such as land and/or soil fertility, reduction, and recent changes in the area's weather conditions in line with climate change (rainfall in amount and duration, unusual length of dry season) prevailing in current years are few of the many factors that contribute to crop productivity reductions in the area. Factors that affect the depletion of these natural resources by hampering the production and productivity of the local community in the areas were the scarcity of land for farming families, soil infertility, and fluctuation of weather conditions.

These situations are happening at the expense of species diversity and bringing a reduction in food provision for poor rural households in addition to other resource depletion in the area. It can be concluded that planned watershed management as an intervention for Edo watershed improvements is impressive for the success of any development works carried out for the surrounding communities.

Based on the findings obtained from the study, the following recommendations are suggested:

- Since baseline characterization helps understand the initial livelihood condition of the people in the watershed, detailed biophysical characteristics of the watershed must be known for accurate problem-solving before intervention.
- Participatory implementation of degraded land rehabilitation in the watershed, particularly the construction of integrated physical and biological soil and water conservation measures, should be encouraged.
- Significant variations in soil physicochemical properties were studied. However, further research is required into these areas, particularly in terms of soil-landscape and land management connections, as well as selecting appropriate agricultural technology depending on soil type to provide a solid conclusion for sustainable agricultural output.
- Generally, prioritizing the identified problem and preparing intervention of different technologies and development plans by participating communities and different potential stakeholders to solve the problems by considering taking the existing opportunities of the watershed.

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Author Contributions

K.J.A.: idea conceptualization, methodology setup, data curation and analysis, investigation, original draft, writing and revision of the manuscript, editing, visualizing. M.G.: idea conceptualization, methodology, editing, review, visualization, and supervision. G.B.: review, editing, visualization, writing, and revision of the manuscript. All authors have read and agreed to the published version of the manuscript.

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Data Availability Statement

The data that supports the funding of this study are available from the corresponding author upon reasonable request.

Conflicts of Interest

The authors declare no conflicts of interest.

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