AJ ACADEMIC JOURNALS
expand your knowledge

African Journal of Environmental Science and Technology

Full Length Research Paper

Land capability analysis and delineation of erosion prone areas in the case of Kulfo Watershed, Abaya Chamo Basin

Teshome Yirgu[1*], Yibeltal Yihunie[2], Alemu Assele[1] and Teklu Wogayehu[3]

[1]Department of Geography and Environmental Studies, College of Social Sciences and Humanities, Arba Minch University, Ethiopia.
[2]Department of Natural Resources Management, College of Agricultural Sciences, Arba Minch University, Ethiopia.
[3]Department of Biology, College of Natural Sciences, Arba Minch University, Ethiopia, P. O. Box 21, Arba Minch, Ethiopia.

Land is a basic natural resource which is essential for the survival and development of human being, since it supports all kind of livelihood and infrastructure. But due to varying drivers it is under the threat of degradation. Thus, the aim of this research was to analyze the land capability and delineation of erosion prone areas for sustainable watershed management in the case of Kulfo watershed located in the Abaya Chamo basin. Satellite imageries, socio-economic, soil and meteorological data were utilized in the research. Geo-spatial and descriptive statistical techniques were used to map and analyze the research data. The analysis noted that land suitable for cultivation, forest/tree crops and grazing accounted 63.9, 14.6 and 8.8% respectively. Based on spatial distribution of erosion hazards about 74.2% of the watershed falls under severe to high erosion risk category and assigned in the first and second priority list for proper conservation interventions. Additionally, seven capability classes were identified in the area, namely C1, C2, C3, C4, P, F/FT and built up area. Thus, based on the results of erosion severity and land capability classification, 61% area of the watershed was proposed for cropland. In contrast 27.7% is not feasible for cultivation, and such land use/covers can be used either for controlled grazing, wildlife sanctuary, wetland/ riverine forest development and settlement. Finally it is suggested that transforming bare lands and steep terrains into forest and fruit farm could be a viable option to rehabilitate the degraded landscape and thereby support the livelihood of the community in the watershed.

Key words: Geographic Information Systems (GIS), land capability, soil erosion risk, land use plan.

INTRODUCTION

Anthropogenic pressures lead to land degradation and reduced the natural resources at an alarming rate during the recent past (Baumler, 2015; Padalia et al., 2018; Bargali et al., 2018, 2019). Due to this the pressure on

easily available and more productive resources such as land and vegetation increased continuously leads soil erosion and have been pushed towards the threat (Bargali et al., 1993a; Joshi et al., 1997) and affected the decomposition processes on the earth (Bargali et al., 1993b, 2015; Bargali, 1996) which needs the sustainable management and utilization of these resources. Land capability is determined by different land characteristics such as the types of soil, which is critical for productivity, fundamental geology, topography, and hydrology. These characteristics limit the extent of land accessible for various purposes (Bizuwerk et al., 2005). The final aim of land capability analysis is to predict the agricultural capability of the land development units in utility of the land resources (Sys et al., 1991).

The evaluation of land suitability depends on land capability as well as other factors such as land quality, proximity to different accesses, landownership, customer demand, and economic values (Counsel, 1999). Ethiopia's economic development is greatly dependent on agricultural production since agriculture constitutes 46.6% of the national gross domestic product (CSA, 2008). Geographic Information Systems (GIS) techniques have been used to identify spatially and evaluate the physical land capability and suitability. They have been proved to be helpful and successful tools in studying, mapping, processing, and presenting certain problems (Abdel, 1997). Land use change and excessive human pressure on the marginal lands resulted to loss of soil productivity, reduction in crop yield and livestock number, and human carrying capacity. Soil erosion and rainfall variability are the major environmental constraints that put at risk the livelihood and food security of households in Kulfo watershed. Furthermore, due to increasing human population per capita farm size is too small and fragmented, which pushed them to ecologically sensitive and fragile hilly terrain for additional farm lands. Thus these conditions further complicated the situation of environmental depletion in the area.

Hence, proper land use planning creates preconditions required to achieve a type of land use that is environmentally sustainable, socially just and desirable and economically sound outcome in the study watershed. Land use planning is a procedure for planning the sustainable use of the land considering its potentialities, limitations and the user needs. Therefore, in order to meet the need of the present generation and sustainably allocate it to future generation, the need for sound land use planning is paramount. It was this research gaps that have initiated the researchers to conduct this piece of work in the watershed.

The topography of the land resources in the study in watershed is characterized as rugged, and the resource is scarce. Women and youth have little access to land and they are struggling to produce for their consumption. Degradation of watersheds in recent years has brought the long-term reduction of the quantity and quality of land and water resources, as shown in Kulfo watershed.

Changes in watersheds have resulted from a range of natural and anthropogenic factors, including natural soil erosion, changes in farming systems, over abstraction of water, overgrazing and deforestation.

Major land related constraints of Kulfo watershed are: cropland scarcity, soil erosion, declining pastures, deforestation, demographic pressure etc. As a result land resources both in the upstream and downstream are under pressure of degradation. In addition, low quality of sheep and cattle, Poor infrastructure and uneven distribution of health and educational facilities, unemployment are among others important problems in the watershed. Furthermore, low crop yield, shortage of clean drinking water and are also the other constraints of the watershed that requires due attention.. Therefore, this study is intended to analyze the land capability and delineation of erosion prone areas in the case of Kulfo watershed located in the Abaya Chamo basin in order to rehabilitate the watershed and thereby improve the livelihood of community in the study area.

MATERIALS AND METHODS

Description of the study area

Kulfo watershed is located in Gamo highland, Southwest Ethiopia. Astronomically, it is located between 5°58' 5''N to 6°15'31''N latitude and 37°18'12''E to 37°36'19''E, longitude (Figure 1). Kulfo watershed is situated in four woredas in GamoGofa Zone, namely Bonke, ArbaminchZuria, Dita and Chencha. The total area of the watershed is estimated to be 43,465.7 ha. Geographically, it is extended from the shores of Lake Abaya and Chamo (1180m a.s.l) in southern part to Gughe Mountain or Bale peaks (3384 m a.m.s.l) in the North.

The landform of Kulfo watershed is characterized by extensive plateaus and hills dissected by mountain ranges in the northern parts and rift valley plains in its southern margin. The geology of the study area is of two types. Majority of the watershed including its northern part is dominated by trap series of tertiary volcanic lava of Cenozoic era, while the southern rift valley Lake areas were dominated by deposition of quaternary sediments of alluvial and lacustrine deposits.

The upstream is consists of alkaline basalts, with interbedded pyroclastic and rare rhyolites, porphyritic amygdaloidal and olivine basalt (Southern Regional Atlas, 1985). According to the FAO classification system (FAO, 2012), the study watershed has eight major soil types (Figure 2), where orthicacrisols (59.9%), dystricnitisols (13.4%), eutricfluvisols (11.3%) and dystricfluvisols (9.5%) shared 94.1% of all soil types while the remaining, such as leptosols, eutricnitisolsand chromic vertisols contributed 5.9% of the total.

Kulfo is a perennial river which is used for domestic purposes and for small scale irrigation in its lower course. Due to East ward inclination of the landscape, all tributaries of Kulfo river (Yeremo, Baba, Gulando, Zegende, and Ambule), which are originated from LakaKuyle, KachaWusha and Dita ridges are making their way into Lake Chamo. The dominant vegetation covers in the watershed are Bamboo, Eucalyptus globulus trees, bushes, riverine trees and short mountain grasses. In the area rainfall distribution is bimodal with an average annual rainfall of 1390 mm in the upstream and 959 mm in the lower catchment. The annual average temperature in the upstream is 16.7°C, while it is 24°C in the downstream area
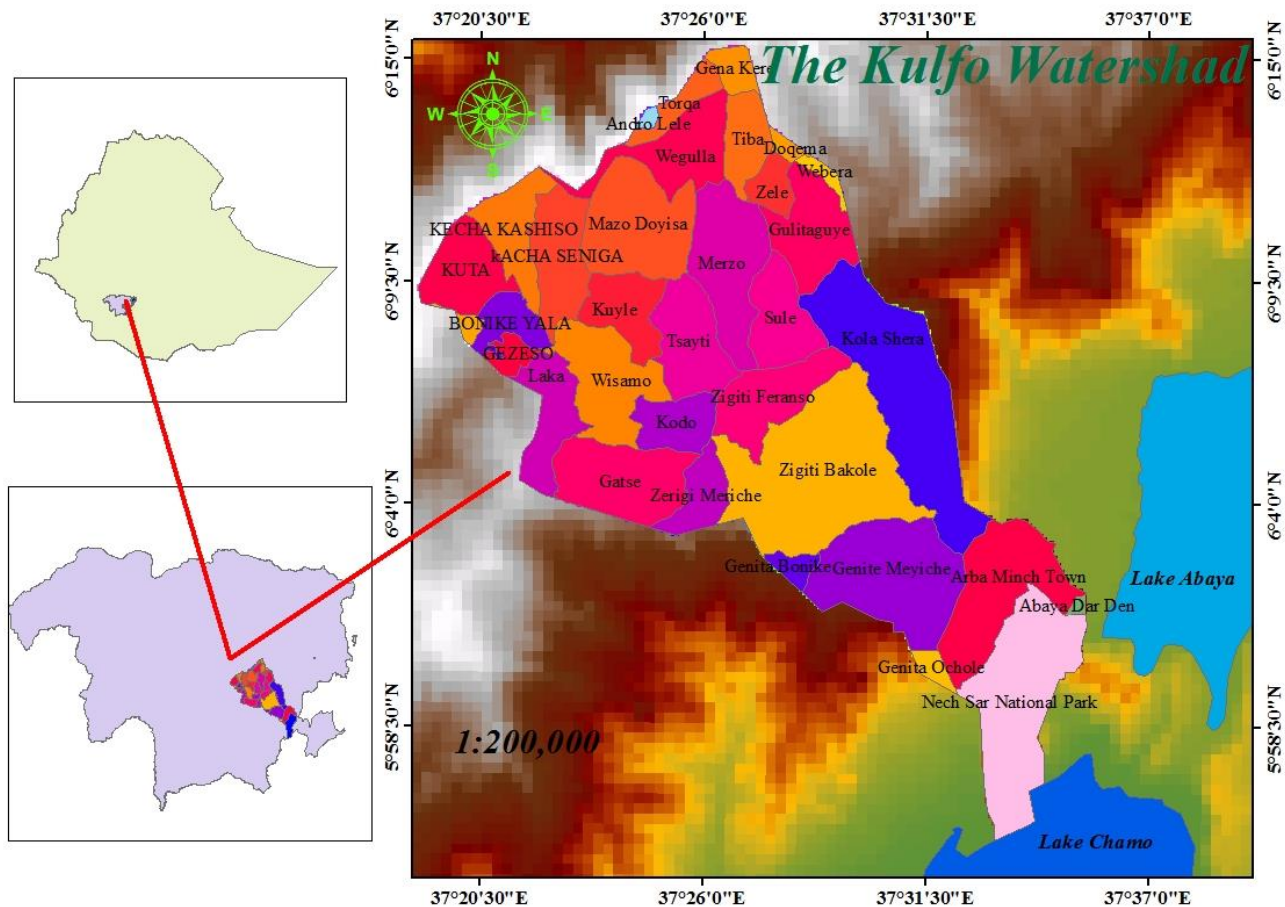
Figure 1. Location map of the study area.

(Figure 3).

Degradation of watershed in recent years has brought the long-term reduction of the quantity and quality of land and water resources. Changes in watersheds have resulted from a range of natural and anthropogenic factors, including natural soil erosion, changes in farming systems, over abstraction of water, overgrazing and deforestation. Major land related constraints of the watershed are: cropland scarcity, soil erosion, declining pastures, deforestation and low crop yield. Small scale farming, such as barley (*Hordeum vulgare* L.), potatoes (*Solanum tuberosum* L.) and cabbage, enset (*Ensete ventricosum* (Welw.) along with livestock are the mainstay of smallholding farmers.

METHODOLOGY

In order to get the general picture of the issue under investigation more deeply quantitative research approach was used. Remote sensing and geographic information system, GIS has been efficient and powerful tool in providing reliable information on natural resource classification and land use/ cover quantification and mapping over space and time (Roy et al., 1991). In remote sensing data analysis processes, selection of appropriate satellite imageries is the first task in image data processing. To map and quantify cover data, delineate erosion prone areas and land capability classes of the watershed Landsat images acquired on 7 Feb 1986, 12 Jan 1999 and 8 March 2017 (path 169/row 053) were used.

Then supervised digital image classification technique was employed. Accuracy assessment was also done for all classified images.

In analyzing spatial-temporal cover dynamics and delineate erosion prone areas remote sensing and GIS techniques were also used. A combined use of remote sensing and GIS technology can be of great use in addressing resource management problems and detecting land use dynamics. GIS and remote sensing techniques have been efficient and powerful tools in providing reliable information on natural resource classification and mapping of land-use/land-cover changes over space and time (Campbell, 1997). In addition, soil, climate and demographic data from group discussion result were analyzed using descriptive statistical techniques (mean, percentage, coefficient of variation etc). Finally the study was supported by maps, tables and narrations.

RESULTS AND DISCUSSION

Land capability analysis in the watershed

Due to lack of available data our classification is mainly based on slope and soil depth, the two most important factors to determine susceptibility of the land to erosion risks and limitation in use in hilly and mountainous
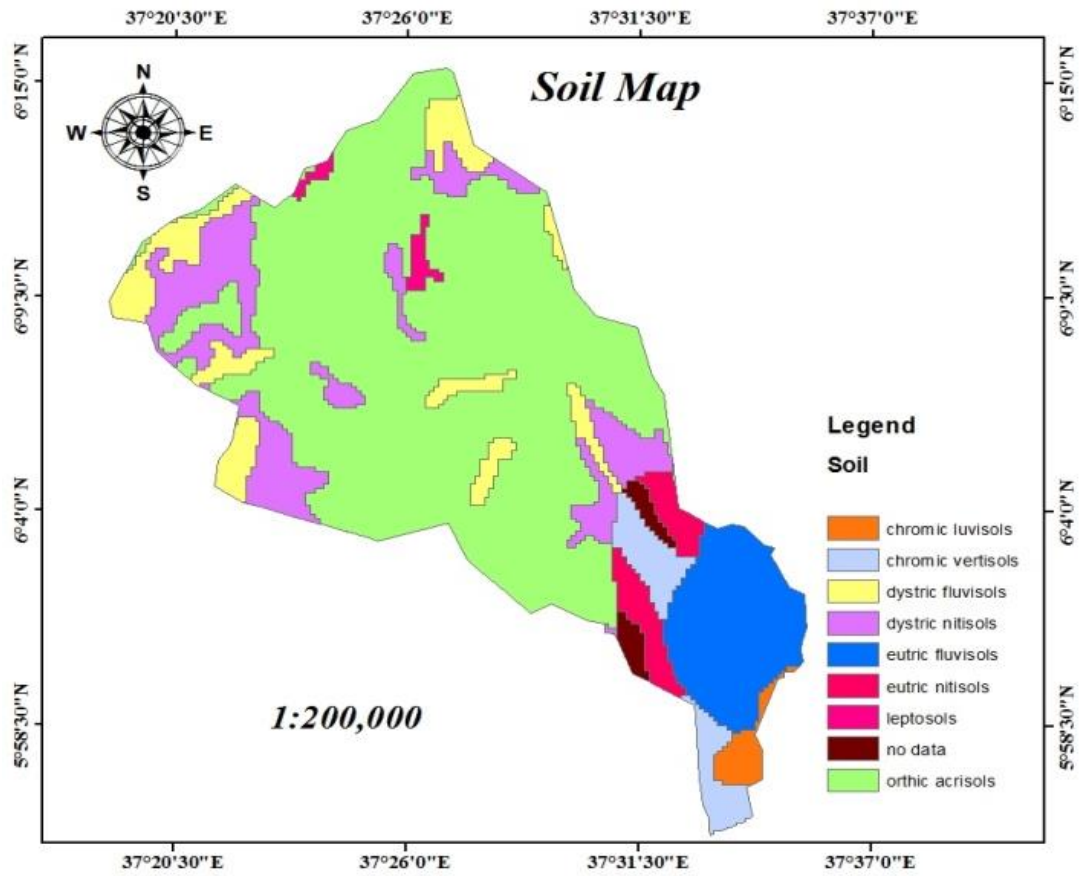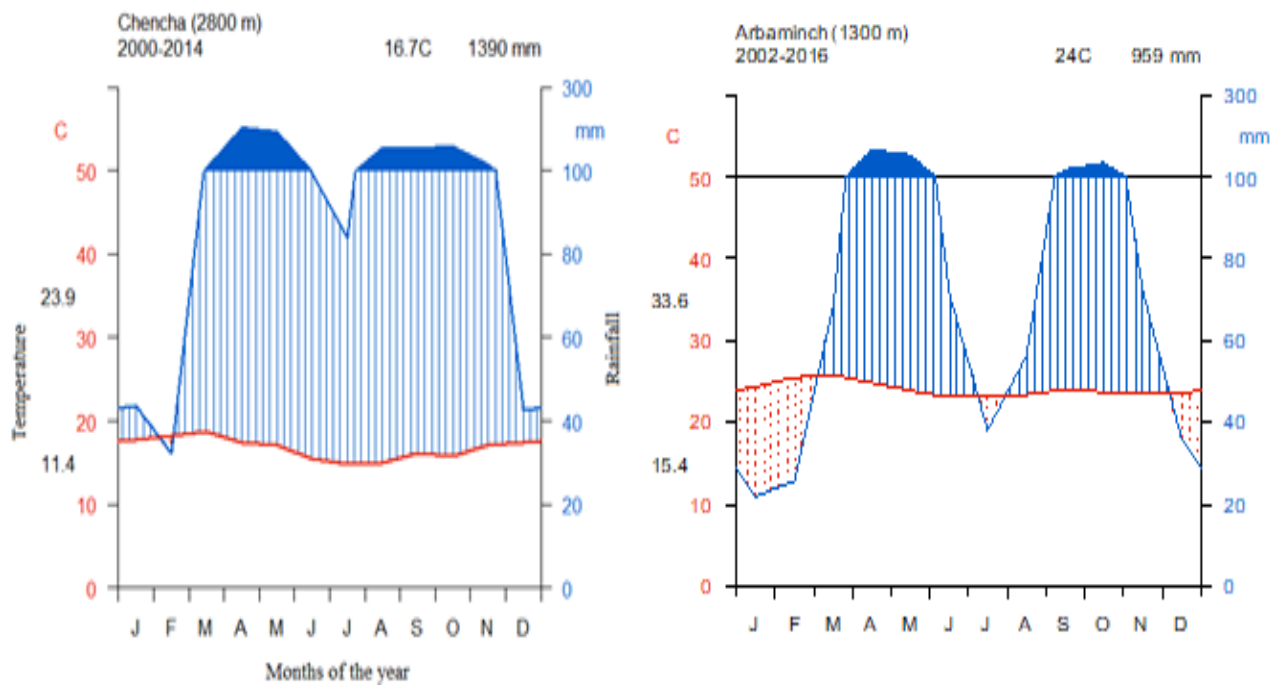
Figure 2. Soil map of the study area.

Figure 3. Walter's and LiethClima diagram of Chencha and Arba Minch stations.

Table 1. Land capability classes of the watershed.

S/N	Capability class	Area (ha)	Area (%)
1	C1	879	2
2	C2	6210.3	14.3
3	C3	15,171.2	34.9
4	C4	5539.9	12.7
5	P	3806.4	8.8
6	F/Ft	6327.2	14.6
7	Fs (shrub land)	3082.7	7.1
8	Built up area (including Arba Minch town)	2,448.9	5.6
Total		**43,465.7**	**100**

Table 2. Erosion risk category in Kulfo watershed.

S/N	Erosion severity class	Erosion risk area (ha)	Area (%)
1	High risk	1032.4	2.8
2	Risk	31109.8	71.4
3	Moderate	11,323.5	25.8
Total		**43,465.7**	**100**

Table 3. Proposed land use plan of the watershed.

S/N	Land use plan classes	Area (Ha)	Area (%)
1	Proposed forest development	1697.9	3.9
2	Proposed for urban settlement	3262.8	7.5
3	Wetland vegetation	3255.9	7.4
4	proposed crop land	25264.4	58.1
5	proposed shrub	6237.6	14.4
6	Proposed grazing	2503.5	5.8
7	Proposed homestead farm	1243.6	2.9
Total		**43,465.7**	**100**

landscape, like the upper and mid parts of the study watershed. The analysis showed that there are seven capability classes in the study watershed namely C1, C2, C3, C4, P, and F/FT and built up area (Figure 2 and Table 1). This was in lined with Gad (2015) and Atalay (2016) findings.

Accordingly, these capability classes were subdivided into three broad classes. They are capability class suited for annual crop cultivation such as class C1, C2 and C3 (Altay, 2016; Abdel et al. (2016). This classes accounted for 51.2% (22,260.5 ha) area of the watershed (Table 2). As reported by Maryati (2012) the limiting factors in these classes are slope and severe erosion. While C4 is less suitable for cultivation but it is fairly good for maintaining perennial vegetation. Thus it is used for cultivating fruit trees. The natural limitations in restricting its use for cropping are mainly slope, erosion and adverse climate.

Thus, this landscape accounts 12.7% of the study watershed. The second broad class is land that is not suited for crop cultivation but suitable for minimum grazing or pasture (P) is named as capability Class 5 (Lynn et al., 2009). As shown on Table 3 this class accounts for 8.8% (3806.4 ha) of the catchment. Such landscape is susceptible for extreme erosion and has shallow soil depth (Figure 4).

The last category is land that is not suitable for cultivation or grazing but used for forest (F) or tree crops (Ft) and categorized as capability Class IV (Panhalkar, 2011). It comprises 14.6% of the study watershed. This capability class is encompassing wetlands, riverine/ conserved areas, degraded mountain sides and those covered by rock out crops. In this part of the landscape the limiting factors are steep slope, poor quality soil, water lodging etc. Furthermore, shrub lands in the lower
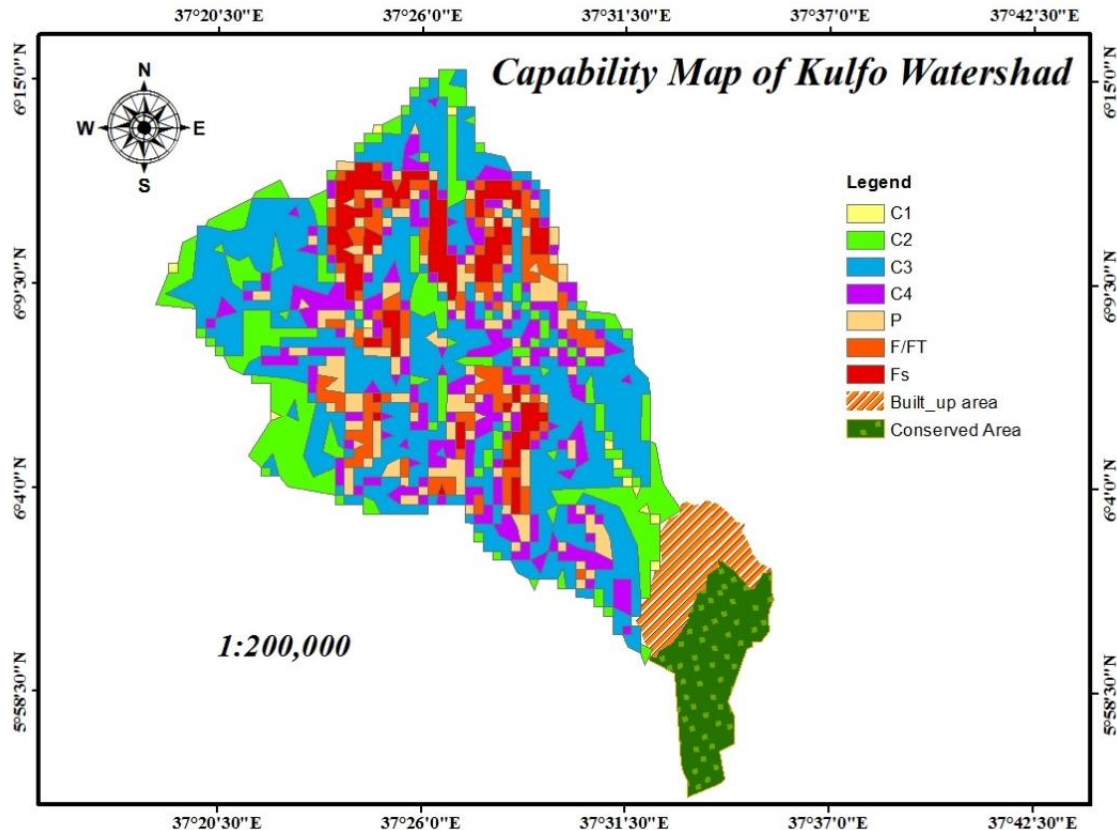
Figure 4. Spatial distribution of land capability classes of the watershed.

catchment are suited for urban establishment, which accounts for 5.6% of the total area of the watershed. It is evident that land capability classification provides better measure for determining erosion problems in the watershed. Furthermore, it helps in identifying erosion risks and allows planners to determine areas that merit priority for planning land management measures (Sheng, 1982).

Delineation of erosion prone areas

Soil erosion is the most pressing environmental problem in the upper reaches of Kulfo watershed, where the topography is rugged, population is large, and soil management practices are obsolete. In the area, more than 30% steep lands are used for cultivation and rainfall is erosive. Among the main factors for delineating erosion risk areas slope gradient/length, rainfall erosivity, land cover and drainage are the major factors (Wischmeier and Smith, 1978) as adapted in Saha et al. (2005).

Accordingly, over 60% of the study watershed has a steep slope (more than 27%), and such landscape is not recommended for farming activity. In the upper watershed behavior of rainfall is high (mean annual amount is 1390 mm) and concentrated in few months of

the year. In addition, cropland that practices traditional farming and bare lands encompassed 71 and 6.2% of area of the watershed. As a result, erosion by water is paramount and areas that are susceptible to erosion are large (71.4%), but not more than 26%, are less prone to erosion risk. Based on the spatial distribution of the erosion severity, about 2.8% (1,032.4 ha) fall under high erosion risk category, but a great extent area (71.4%) was under risk category. Hence the two soil erosion categories are assigned as the first and second priorities in order to undertake appropriate soil and water conservation measures in the area. This indicates that greaterpart of the study watershed (over 74%) is under serious threat of degradation and needs intervention measures (Figure 5).

Proposed land use plan

Based on erosion severity and capability of the land, a new land use map was developed for Kulufo watershed (Figure 6). As shown in Table 3, the watershed is proposed for seven land use types, of which a great majority (61%) is meant for homestead farming including cultivated land. These areas are situated in the northern and central parts of the catchment. In the watershed the
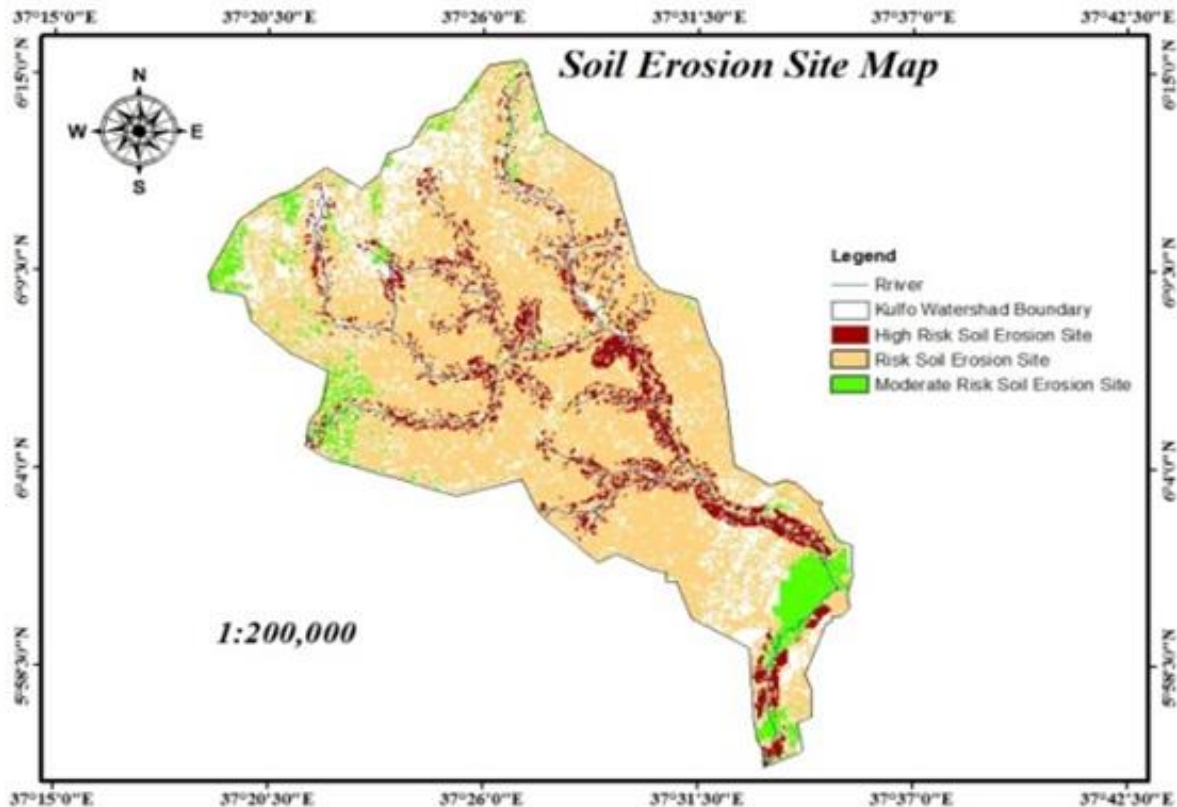
Figure 5. Spatial distribution of erosion risk areas of the watershed.

proposed grazing grounds 2,503.5 ha (5.8%) is not proportional to size of livestock as result it requires rising productive and limited livestock and sheep on well managed grazing land. Transforming bare and steep landscape into forest and fruit farm could be a viable option to rehabilitate the degraded landscape and thereby generate reasonable income for small holder households in the watershed. These areas are not recommended for cultivation, since it is susceptible to erosion and flood hazards. As a result, it can be used for highland and wetland forest development as suggested by Murphy et al. (2007).

Conclusions

From the aforementioned analysis it is possible to conclude that land use planning is an instrument for sustainable land management through protecting land of agricultural significance, erosion disaster and bare land encroachment. In the study watershed, the land capable for cultivation (27,800.5 ha) is lower than the current cropland (31,208.6 ha). While more than one third (36.1%) of the land in the catchment is not capable for cultivation, though a majority of the area (71.8%) was under crop cover. The main development constraints

in the watershed are rugged topography, high population pressure, hill side farming practices without using proper land management measures and the resultant erosion hazards. Therefore, it is recommended that land has to be studied to provide its maximum yield. Proper land use planning is also one of the appropriate ways to increase food production and to feed the highly increasing population of the country in general, and the study area in particular. Therefore, implementation of developed land use plan according to its potentials is highly a viable option. In addition, sustainable land management interventions that significantly support rural and urban developments are prerequisites for a long-term use of the land and thereby improve the livelihood of the community in the watershed.

CONFLICT OF INTERESTS

The authors have not declared any conflict of interests.
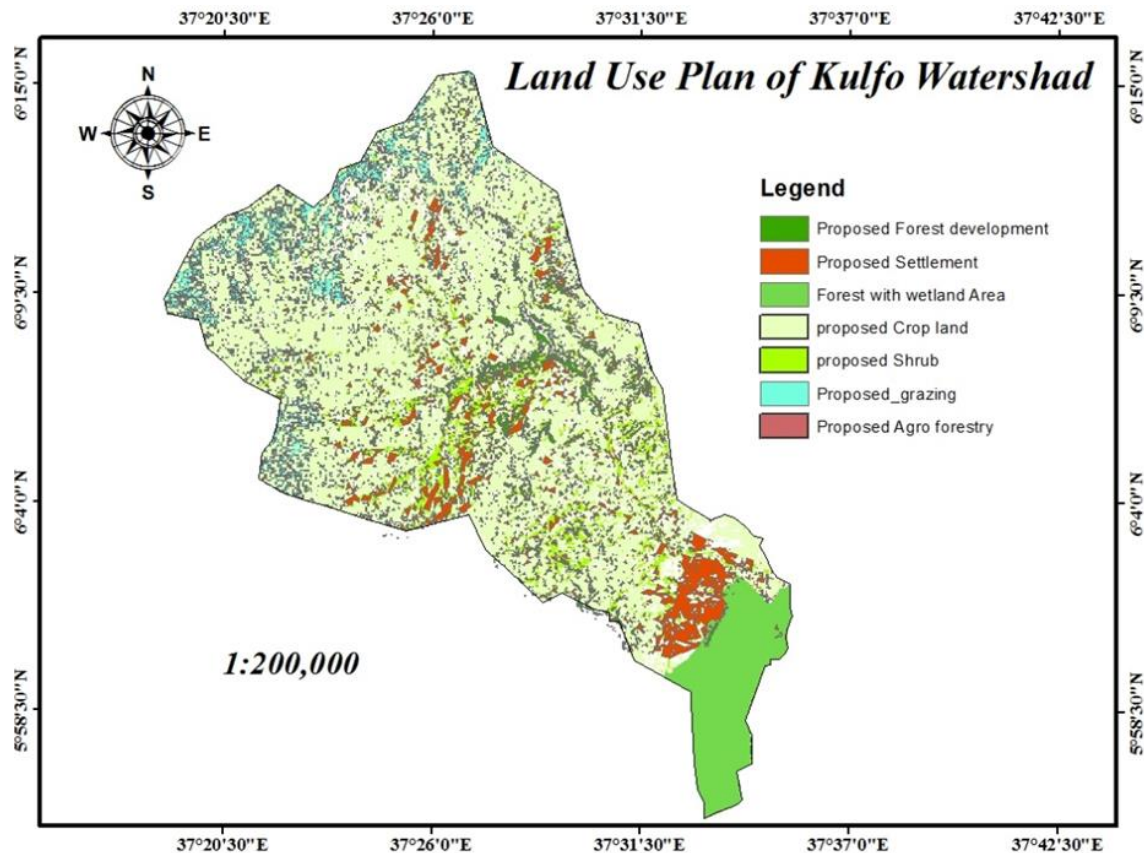
Figure 6. Proposed land use plan for the watershed.

REFERENCES

Abdel H (1997). Studies on monitoring desertification and land degradation processes at ElFayoum depression, Egypt (M.Sc. Thesis), Faculty of Agriculture, El Fayoum, Cairo University, Egypt.

Abdel M, Negim E (2016). Utilizing of Geo-informatics for mapping land use/land cover   Changes in Sohag, Egypt. American Journal of Environmental Engineering and Science 3(1): 33-42.

Atalay S, Clauss R, McGuire H, Welch R (Eds.). (2016). Transforming Archaeology: Activist practices and prospects. Routledge.

Bargali K,Vijyeta M, Kirtika P, Upadhyay V (2018). Effect of Vegetation type and seasonOn microbial biomass carbon in Central Himalayan forest soils. Catena 171 (12):125-135.

Bargali S, Kirtika P, Kiran B(2019). Effects of tree fostering on soil health and microbial Biomass under different land use systems in central Himalaya. Land Degradation and Development 30(16):1984-1998 DOI: 10.1002/ldr.3394.

Bargali S, Singh R, Mukesh J(1993a). Changes in soil characteristics in eucalypt plantations Replacing natural broad leaved forests. Journal of Vegetation Science 4:25-28.

Bargali S, Singh R, Mukesh J (1993b). Pattern of weight loss and nutrient release in Decomposing leaf litter in an age series of eucalypt plantations. Soil Biology and Biochemistry 25:1731-1738.

Bargali S (1996). Weight loss and nitrogen release in decomposing wood litter in an age series of eucalypt plantation. Soil Biology and Biochemistry 28:699-702.

Bargali S, Kiran S, Lalji S, Lekha G, Lakhera ML (2015). Leaf litter decomposition and Nutrient dynamics in tree species of Dry Deciduous Forest. Tropical Ecology 56(2): 57-66.

Baumler R (2015). Soils. In: MiehePendry CA (Eds.), Nepal: An Introduction to the Natural History, Ecology and Human Environment in the Himalayas - A Companion to the Flora of Nepal. Publisher: The Royal Botanical Garden Edinburgh, pp. 125–134.

Bizuwerk A, Peden D, Taddese G, Getahun Y (2005). GIS application for analysis of Land suitability and determination of grazing pressure in upland of the Awash River Basin, Ethiopia. Addis Ababa, Ethiopia: International Livestock Research Institute (ILRI).

Campbell J, Lusch P, Smucker A, Wangui E (1997). Multiple Methods in the study of Driving Forces of Land Use and Land Cover Changes: A Case Study of Kajiadoof District, Kenya. Human Ecology 33(6):762-794.

Counsel P (1999). Land capability assessment guidelines. Retrieved from

http://apps.actpla.act.gov.au/tplan/plan

ningregister/register_docs/landcapabilitygl5a.pdf.

CSA (2008).Summary and statistical report of the 2007 population and housing census _ Population size by age and sex. Addis Ababa: Federal Democratic Republic of Ethiopia, Population Census Commission.

FAO (2012).Agriculture Organization of the United Nations. 2012. FAO statistical yearbook.

Gad A (2015). Land capability classification of some western desert Oases, Egypt, using Remote sensing and GIS. The Egyptian Journal of Remote Sensing and Space Science18(1): S9-S18.

Joshi M, Kiran B, Bargali SS (1997). Changes in physico- chemical

properties and metabolic Activity of soil in popular plantations replacing natural broad leaved forests. Journal of Arid Environment 35: 161-169.

Lynn H, Manderson K, Page J, Harmsworth G, Eyles G, Douglas B, Newsome F (2009). Land Use Capability Survey Handbook–a New Zealand. Handbook for the Classification of land. AgResearch: Hamilton.

Maryati S (2012). Land Capability Evaluation of Reclamation Area in Indonesia Coal Mining Using LCLP Software. Procedia Earth and Planetary Science 6: 465-473.

Murphy N, Ogilvie J, Connor K, Arp A (2007). Mapping wetlands: a comparison of two Different approaches for New Brunswick, Canada. Wetlands 27(4): 846-854.

Padalia K, Bargali SS, KiranB, Kapil K(2018). Microbial biomass carbon and nitrogen in relation to cropping systems in Central Himalaya. Current Science 115 (9):1741-1750.

Roy P, Giriraj A (1991). Land use and land cover analysis in Indian Context. Journal of Applied sciences 8(8):1346-1353.

SahaK, Gupta P, Sarkar I, Arora K, Csaplovics E (2005). An approach for GIS-basedStatistical landslide susceptibility zonation with a case study in the Himalayas. Landslides 2(1): 61-69.

Sheng TC (1982). Erosion problems associated with cultivation in humid tropical hilly Regions. Soil Erosion and Conservation in the Tropics 43: 27-39.

Sys C, Van Ranst E, Debaveye J (1991). Land evaluation. Part I: Principles in land Evaluation and crop production calculations. Brussels, Belgium: Agricultural Publications nr. 7, GADC.

Panhalkar S (2011). Land capability classification for integrated watershed development by Applying remote sensing and GIS techniques. Journal of Agricultural and Biological Science 6(4): 46-55.

Wischmeier H, Smith D (1978). Predicting rainfall erosion losses: a guide to conservation Planning (No. 537). Department of Agriculture, Science and Education Administration.