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Land Use Land Cover Change and Its Implication on Surface Runoff: A Case Study of Baro River Basin in South Western Ethiopia

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Abstract
The Baro river basin in the south western Ethiopia is potentially rich in land and fresh water resources. But, the resource of this basin is highly under change starting since 1986. The main goal of this study was to analyse land use land cover change and its impact on surface runoff processes using Geographical information systems, remote sensing techniques and simple empirical formula runoff coefficient. The result revealed that a significant spatial temporal increment and decrement of different land use land cover types in area. The major causes of these land use land cover changes were massive resettlement/ population growth, over utilization of resources and expansion of commercial farming system. This dynamical change of land use land cover has implied effect on environment by degrading in the form of surface water variability. As a result, temporally analyzed potential surface runoff has increased from 37 to 49 percent in 1984 and 2001 respectively. Land use land cover change has not only disrupted ecological balance of the watershed but also increased surface runoff.
Keywords: LULC, Surface runoff, GIS, Baro basin

INTRODUCTION

Human land use, particularly over the past few decades, has changed ecosystems more rapidly and extensively than in any comparable period of time. This has occurred as a consequence of expansion of agriculture, re-settlement, rapid population growth, overgrazing, removal of vegetation and rapidly growing demand on natural resources. In addition to these, Powerful natural processes and phenomena such as bad climate condition and natural terrain also have been identified as causes of land use land cover changes (Meshesha *et al*., 2010). These dynamic activities have resulted in changing environments causing unprecedented land degradation and depletion of natural resources(Assen 2011).

Understanding the influence of land use land cover change on river flow regimes is important for sustainable watershed management. The increased competition for water and alterations in Land use/cover in the upstream of many rivers, are argued to have contributed to change in the hydrological regimes of many rivers and wetlands. Land use land cover change pattern in the watersheds has direct implication on hydrological yield. It is an important characteristic in the runoff process that affects infiltration, soil erosion, and evapotranspiration. Due to rapid development, land cover is subjected to changes causing many soils to become impervious surfaces. These lead to decrease in the soil infiltration rate and consequently increase the amount and rate of runoff. Deforestation, urbanization, and other land use land cover activities can significantly alter the seasonal and annual distribution of soil loss and surface runoff. Thus, to understand land cover and land use change process and its implication for environmental and ecosystem functioning, it is important to recognize the services provided by the natural ecosystems, and to come up with a sustainable land use plan.

Land use land cover change in Ethiopia has been altered natural ecosystems. In many part of the country the problem is observed due to the increasing of anthropogenic impacts as a result of increasing human natural resources requirements in parallel to increasing population growth rate. In the Baro basin of Ethiopia, land use change has introduced abnormality on the rainfall- runoff processes for the past few decades. Because, changes like forest cover reduction through deforestation and conversion for agricultural purposes can alter catchments response to rainfall events that often leads to increased volume of surface runoff and sediment. Surface runoff is the balance of rain water, which flow or run over the natural surface after losses by evaporation, infiltration and interception (Rmachandra et al, 2009). Consequently, such kind of natural resources deterioration can cause different natural processes like increasing of surface runoff which is seriously poseing a threat to sustainability of hydraulic structures and livelihood. (J.P.Sutcliffe 2009) has reported that the total net present value of the cumulative sedimentation in irrigation canals and reservoirs caused by annual deforestation within the Baro-Akobo Basin in Ethiopia is more than US$ 10.5 million. In spite of such prevailing problems no adequate assessment has been made on the prevalent forms of surface runoff and its spatial and temporal variability with land use and land cover changes (LUCC). Moreover on the magnitude of converted land, and surface runoff frequency occurred with land conversion has not been assessed well. The overall objective of this study is to analyze how land use land covers change impact on environmental resources in the Baro basin that will ultimately degrade the land and water resources.

Study Area

The Baro Basin lies in the southwest of Ethiopia between longitude of 33023’39” E -36 018’21”E and latitude of 90 25’2” N -70 27’8” N. The basin area is about 30130 km2 and is bordered by the Sudan in the northwest, Abbay Basin in the east and Akobo basin in the southwest

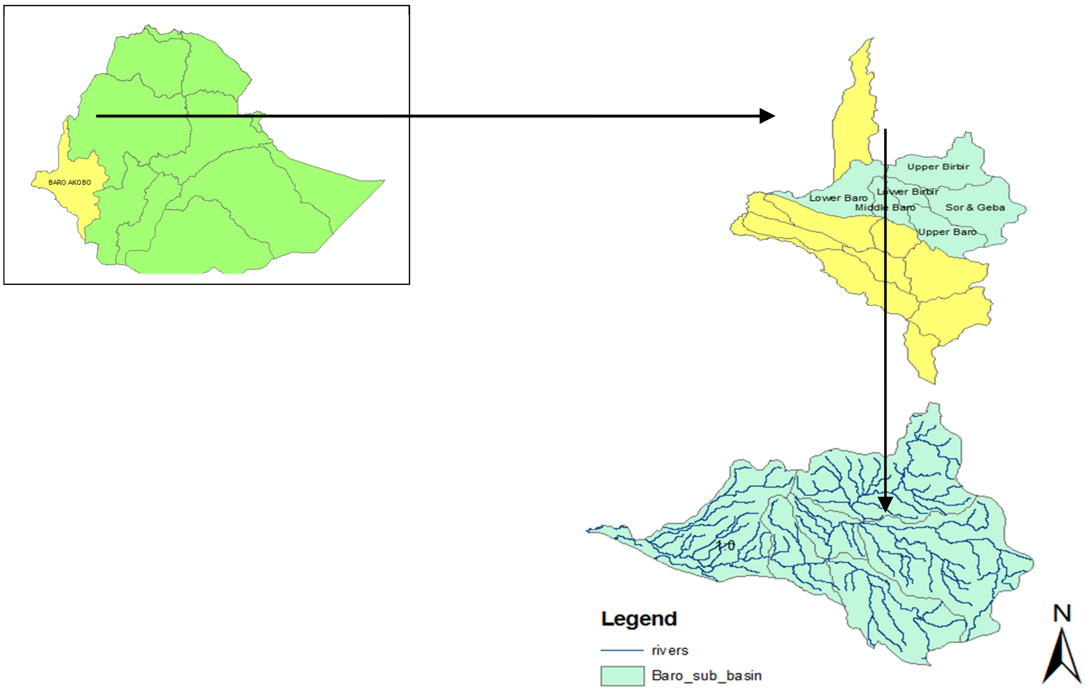


Fig. Study area

Material and Methods

In this study the result of three images with different dates which was classified using supervised classification through maximum likelihood algorithm techniques independently by Tilahun and Nigussie (2015) was taken to analysis its effect on surface runoff. The rainfall- runoff process is well described in different literatures. Numerous papers on the subject have been published and many computer simulation models have been developed. All these models, however, require detailed knowledge of a number of factors and initial boundary conditions in a catchment area which are not readily available for the study area. Therefore, the relationship between rainfall and the resultant runoff from the catchment can be described in a number of ways, the simplest of which is to use a linear runoff coefficient. The runoff coefficient (C) is a dimensionless coefficient relating the amount of runoff to the amount of precipitation received (Woube, 1999; (Alcorn 2007) and Ramachandra *et al*, 2009). Where it is given as;

$$\text{Runoff coefficient (C)} = \frac{\text{Runoff depth (mm)}}{\text{Rainfall depth(mm)}} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\text{i}$$

Sor and Geba sub-watershed of Baro basin was selected for runoff- rainfall analysis depending on the availability of data and changes recognized in this sub-watershed. Therefore, under this sub-watershed there are five catchments of gauged stream flow data obtained from Ministry of Water Resources of Ethiopia (MoWR). For each of these catchments 24 to 27 years of daily and monthly flow data has been collected. Since some of these catchments have no daily data, to see uniformly the general hydrological flow trends, their daily flow data has been converted to monthly and annual data.

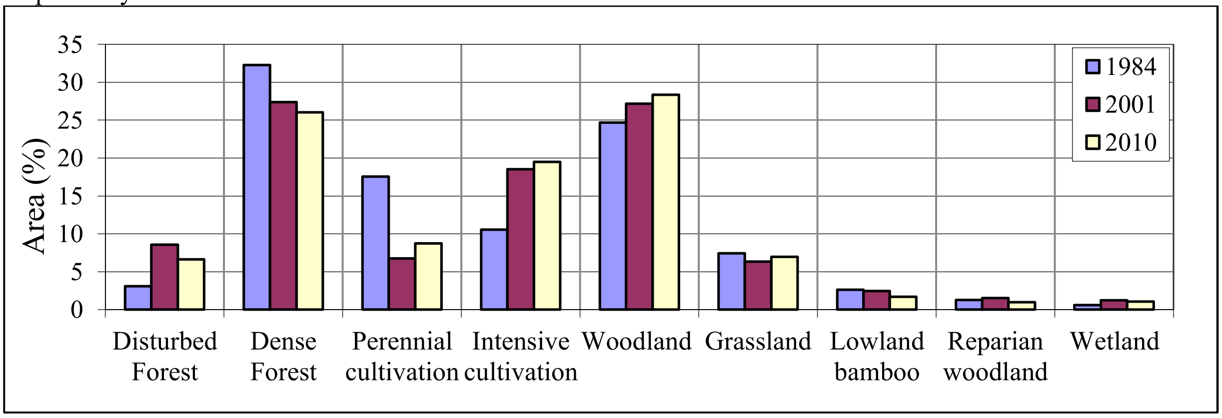
Using the rainfall data which was obtained from the National Meteorological Agency of Ethiopia (NMAE) the runoff coefficient of these catchments was developed. The runoff coefficient assists to see the relation of precipitation and/or stream flow with the catchment’s land use/cover characteristics. Before working on the stream flow and rainfall data, Correlation and regression analysis was used for filling up few missing daily data and extending shorter length records of some catchments which have fair and satisfactory correlation coefficients with neighbouring catchments rainfall and runoff patterns.

Table .1 Lists of Hydrological Gauging Stations and available data.

station name	Longitude	Latitude	Catchment area(km2)	Available data
Elika	35.649	8.533	36.9	1980-2006
Gumuro	35.482	8.152	106	1981-2005
Uka	35.349	8.165	52.5	1980-2005
Suppi	35.649	8.482	3894	1980-2006
Sore Metu	35.605	8.321	1622	1980-2006

Result and Discussion

From 1984 to 2010 some land use land cover changes types showed increment while others showed decrement. Between 1984 and 2001 areas of dense mixed high forest, perennial cultivation, grassland and lowland bamboo decreased by 17.74, 61.48, 14.45 and 5.93 percent respectively, mainly due to their conversion to agricultural land (Intensive cultivation) and to the other land use land cover, whereas disturbed high forest, intensive cultivation, woodland, riparian woodland and wetland increased by 64.23, 43.10, 9.19, 16.21 and 51.66 percent respectively.

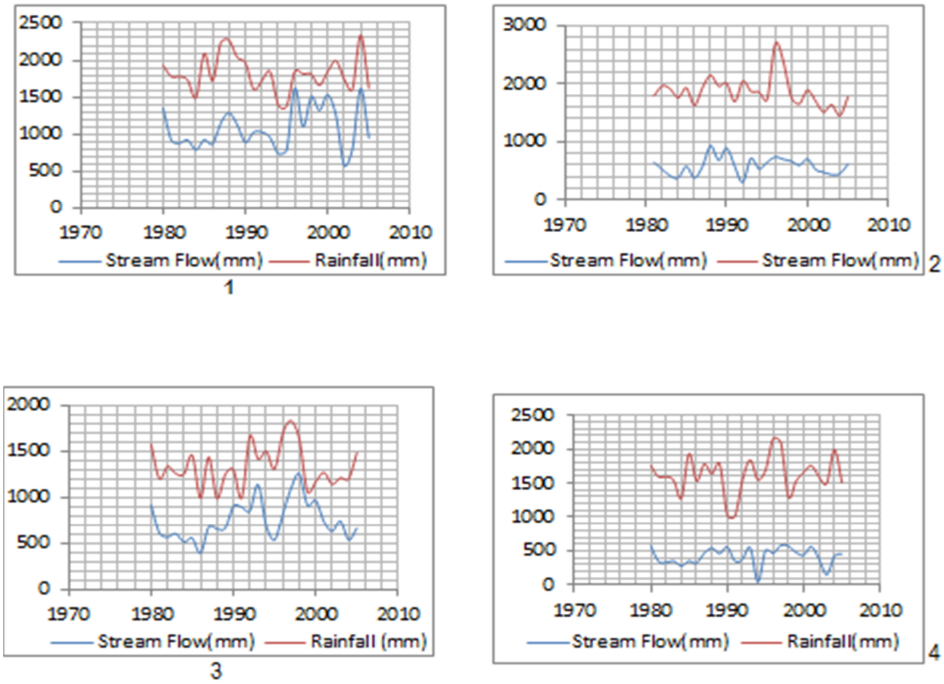


Similarly, in the period 2001 to 2010, dense mixed high forest, perennial cultivation, lowland bamboo, riparian woodland and wetland decreased by 4.93, 4.97, 30.58, 37.3 and 11.06 percent respectively while disturbed high forest, intensive cultivation, woodland and grassland increased by 4.20, 22.73, 4.96, 4.19 and 8.91 percent respectively.

Generally, between the period 1984 and 2010 various increases and decreases in area under each land use land cover type occurred due to anthropogenic pressure in the area. Areas of dense mix high forest, perennial cultivation, grassland, lowland bamboo and riparian woodland decreased by 19.25, 63.40, 6.08, 34.70 and 25.18 percent respectively while disturbed high forest, intensive cultivation, woodland and wetland increased by 65.73, 45.93, 12.99 and 45.65 percent respectively

Statistical analysis of rainfall and stream flows

The annual total rainfall and stream flow dynamics trend of each catchment for Sore and Geba watershed for 1980-2005 periods are shown in the figures (1-5) below. From the trends it is recognized that, mostly the flow and rainfall peaks where fall between year of 1988 and 2000. Due to this, the downstream area was affected by heavy floods in 1988, 1989 1994 and 1996 (Woube, 1999) in which upstream area has more contribution because of land use/ cover change.



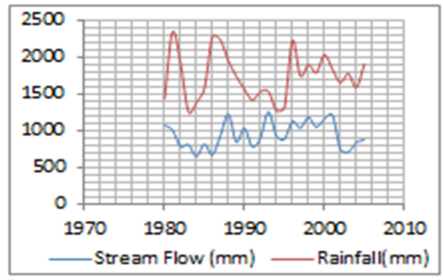


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Fig. *Time Series plot for Mean annual Stream flow and Rainfall of Elika (1), Gumaro (2), Uka (3), Suppi (4) and Sore (5) catchments of Sore and Geba respectively*

Linkage between land use and catchment yield

Land use land cover pattern in the catchment has direct implication on the hydrological yield. The yield of the catchment area is the net quantity of water available for downstream storage (Jojene Santillan 2011) and (Rmachandra et al, 2009). Therefore, to come up with the effect land use/cover has on the variability of catchment yield; simple empirical runoff coefficient equation has been used. Using runoff coefficient equation described above, the long period's relationship of Mean annual runoff and rainfall has been analyzed for different catchments. The runoff coefficient of each and average values for catchment have shown in figure blow to be related to different land use/cover characteristics.

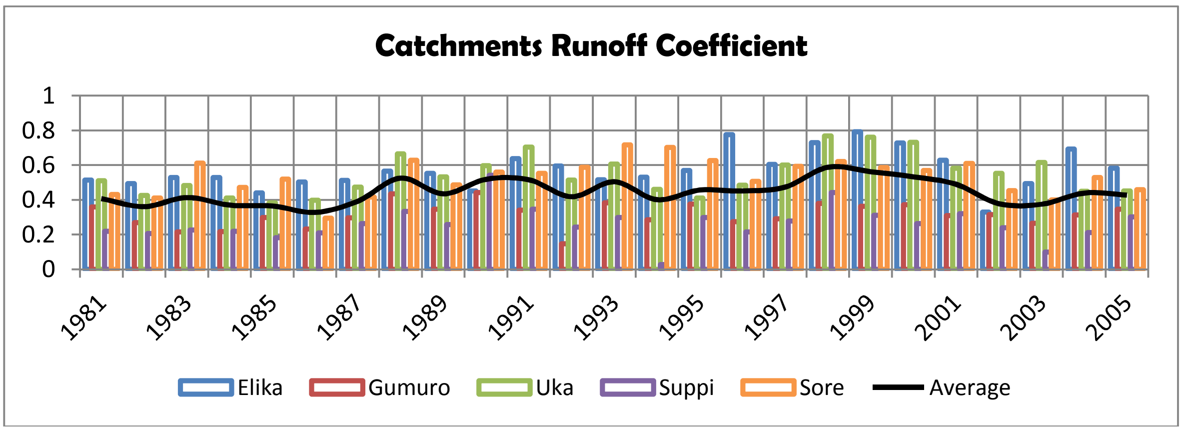

Fig.6 Runoff coefficient for different catchment from 1981-2005

From the result, it can be seen that no significant increase in rainfall before 1984 period compared to the period after the year 1984. Runoff coefficients are generally higher, with the fourteen years moving average showing a gradually rising trend since 1986. This suggests that land use land cover in the catchments area have been seriously disturbed, resulting in almost the same amount of rainfall generating an increased runoff.

Due to substantial reduction of the vegetation and increasing of cultivation land in the Sore and Geba watershed, the variation of the river flows have become particularly rapid. In this area cultivation extended from the hill tops to valley floor (Hunt 2000). Because most of land was under cultivation, the hydrological system was runoff dominated. Rainfall falling on the hills slopes runoff across the surface because slightly vegetated or bare croplands are not conducive to infiltration as heavy raindrops. The analyzed results from1981 to 2005 show that high variation of runoff coefficient values observed from the Elika, Uka and Sore catchments than from other adjoining catchments because the runoff resulting from these parts are coming from relatively disturbed land use land cover zone since post-resettlement.

In general, runoff process in the area has been influenced over long period of time by land use cover change activities. Statistically to compare land use land cover change and surface runoff variation, the average runoff coefficient to changed land use land cover types indicates that 37% of average runoff coefficient is recorded in 1984 whereas in 2001 significantly it has been increased to 49%, which point out high catchment yield degradation.

Conclusion

Knowledge of land use land cover features and their relative environmental implication is important for effective and sustainable land and water resources management. In this study multi temporal land use land cover maps were generated for the study area by processing a series land sat image data of the years 1984, 2001 and 2010 using the remote sensing and Geographical information systems. During these periods there was recognizable changes were observed in different land use land cover types. These changes were caused mainly by massive resettlement/ population growth, commercial farming expansion and over utilization of resources by people.

Furthermore, these substantial changes in land use land cover, notably the expansion of disturbed high forest and intensive cultivation, have adversely degraded proper environmental functioning in the form surface runoff variability, in which it has significance on the livelihoods of people by decreasing water yield of the environment. To identify these environmental water yield variation simple empirical formula runoff coefficient was used and it is depending on the type of land use land cover change of the area. Even though full stream flow data of the area was not obtained over the study periods, only limited data has been analyzed to be linked to the land use land cover changes. From the result, while there is no significant increase in rainfall, runoff coefficients are generally increased from 37 to 49 percent in 1984 and 2001 respectively. This suggests that land use land cover change in the catchment area has been seriously disturbed, resulting in almost the same amount of rainfall generating an increased runoff.

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