International Journal of Innovative Technology and Exploring Engineering (IJITEE)
ISSN: 2278-3075 (Online), Volume-8 Issue-11, September 2019

Modeling change of Land use on Hydrological Response of River by Remedial Measures using Arc SWAT: Case of Weib Catchment, Ethiopia

Tesfahun Addisu Messele, Dereje Tolosa Moti

Abstract: ***Ethiopia has altered natural ecosystems through experiencing a huge amount of land use change has effect on the hydrological condition. Therefore, this study was initiated to compare the past and potential future change of land use with its effect the hydrological response of the Weib catchment which is found in the upper Genale Dawa River basin which covers a total area of 7407.42km2. The Soil and Water Assessment Tool model was used to compare the impact of land use change on stream flow of the study area. The study was used model by using readily available spatial and temporal data and calibrated against measured discharge. The analysis of land use change has shown that the Settlement area has increased from 12.8% to 30.8%, cultivated land from 10.8% to 39.1% between 1986 and 2010, while area of Forest has reduced from 32.5% to 9.4 % and Grassland from 20.9% to 12.3%. The performance of the model was evaluated based on performance rating criteria, coefficient of determination, Nash and Sutcliff efficiency values for monthly runoff were 0.85 and 0.81during calibration, 0.88 and 0.87 during validation, respectively. The evaluation of the model response to changes indicated that the mean wet monthly flow for 2010 land cover enlarged by 40.7 % from 1986 land cover. Similarly, the 1986 land cover mean month flow was higher by 10% than the 1995 land cover flow for wet months. The dry average monthly flow was less by 45.2 %, for 2010 and 26 % for 1995 land covers when compared to that of 1986 land cover. The rapid conversion of Forest and Grassland cover to Urban and cultivated land resulted in higher peak flow and less base flow on Weib river hydrology.***

Keyword: Arc SWAT, DEM, Calibration, Land Use, Weib River Catchment, Validation.

I. INTRODUCTION

Land uses are an important factor influencing the physical conditions of the catchment as well as an indicator of the types of sources of water which are active for the change within the catchment. The terrestrial use and hydrology relationship is complex, with linkages existing spatial and temporal scales; however, land use unquestionably has a large impact on regional water yield. Land use directly impact on the hydrology of surface and subsurface flow that occurs during and after rainfall occurrence Mustard, J., R. et al [1]. Changes in land use alter water balance in hydrologic cycle such as evaporation, groundwater recharge and stream discharge Chase, et al [2]. The study on Microclimate models have even indicated that land use land cover change affects global metrological patterns, which initiate the global hydrological cycle in the most basic ways Piao, S. et al [3]. For instance, stream flow worldwide has increased noticeably since 1900, and the study suggests that terrestrial use modification may be directly responsible for the rise by 50% Lambin, et al [4]. Study of land use changes emerged as the research agenda on global ecological variation several years ago, along with the concept that land surface deviations and processes influence climate Lambin, et al [5]. The potential impact of land cover changes and global changes of climate on surface water have been of great concern in the past few decades resulting in unbalanced water occurs. It results in a conflict in water use and demands global water balance. However, methodological analysis of the on hydrological responses are still very critical for interpretation of result of land use changes Lambin, et al [5]. Different models are used to analyze the surface water and groundwater quantity and quality with development and protection, surface water and groundwater conjunctive use, water distribution systems, water use, and extent for water resources conservation t activities Singh, V.P. and D.A Woolhiser. [6]. Land use change in Africa is currently increasing that resulted for unbalanced water resource Read, J. M., and Lam, N. S [7]. This is important because the changing patterns of land use reflect changing economic and social conditions.

Land use comprises of complex topography and wide altitudinal variations contribute to the presence of various types of land use land cover class. However, the land use land cover system is a very dynamic process and various practices control the rate of this change Assen, M [8].

Land use changes are a threat to life existence in the river basins at different parts of the country. Hydrologic retort to changes in Land.This change in LUCC causes a significant impact on the hydrology by disturbing the normal hydrological processes. Future change in runoff magnitude, variability, duration of the river flow event are used hydrological issues. Reduction of land cover results in significant changes in basin hydrologic responses, such as decreased interception, evapotranspiration, increased runoff volumes, higher river flow peaks and lower base flows. GIS and remote sensing serve to prepare inputs to the SWAT model which helped to predict and quantify the impacts of land use change on the hydrology of any watershed.

Manuscript published on 30 September 2019.
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Consequently, such effect of land use/cover change have been widely contributing change of hydrological parameters in Weib River Watershed.

General Objective

The aim of this study is to compare the spatial and temporal pattern and magnitude of land use change on hydrology of Weib river flow by using GIS ArcSWAT interface simulation Model

Specific objective

- Assess the extent of past space-time land use changes
- Evaluate the hydrological performance of the
- To compare the hydrological impacts on the river flow
- Recommend necessary water conservation measures

To address the aforementioned objectives, the research questions for this study are:

- Is there LULC change in Weib Watershed over the past three decades?
- What is the trend of LULC and its effect on Weib River?
- Does the LULC change affect the watershed hydrology?
- How will the land cover changes affect the hydrologic response of the watershed?

II. Materials and Methods

Description of Study Area

The total area of the watershed is 7407.42 Km^2. In terms of geographic coordinates the catchment is bounded between $7^0 22'$ and $7^0 43'$ N Latitude and $39^0 58'$ and $41^0 04'$ E Longitude. The rainfall of Weib River watershed is generally highest on the highlands at elevations over 3072m a.m.s reaches mean annual as high as 1380mm and lowest in the lowlands with a mean annual value 547mm. The mean air temperature in the area ranges between 6.6-16.4°C.

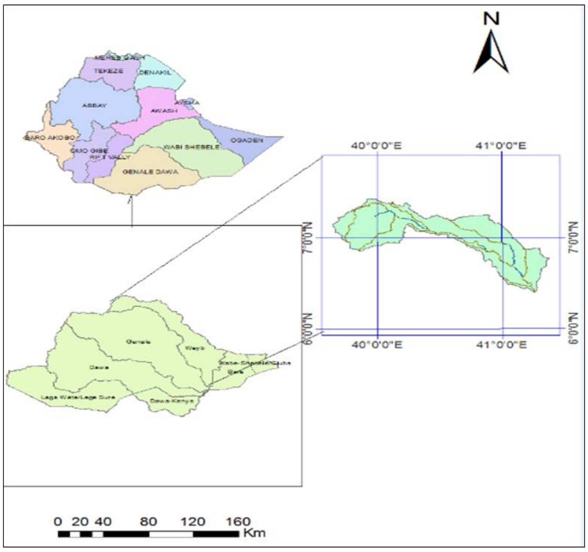

Figure II.1: Topography of study area

Description of Swat Model

The hydrological processes simulated by SWAT2009 include precipitation, evapotranspiration, surface run-off, groundwater flow, and river flow. The model is adept of simulating channel routes and receiving hydrologic cycle in time-steps. Moreover SWAT2009, a daily water balance is recognized used for every HRU based on these parameters that increase physical description of the model. The following figure shows the ways for water balance within SWAT2009.

Generally, the land phase of the hydrologic cycle of SWAT2009 model simulation is established on the water balance equation below.

$$SW_t = SW_o + \sum_{i=1}^{t}(R_d - Q_s - E_a - W_s - Q_d) \quad (1)$$

Surface Runoff Generation

SWAT2009 model used two surface runoff calculation methods; a modification of the Soil Conservation Service Curve Number method or the Green & Ampt infiltration method Green, W.H. and Ampt, G.A [9]. The CN method was originally established for small agronomic catchments and varies non-linearly with the moisture content of the soil. In this method, the ratio of actual retention to maximum retention is assumed to be equal to the ratio of direct runoff to rainfall minus initial abstraction by using the equation

$$Q_s = \frac{(R_d - I_a)^2}{(R_d - I_a + S)} \quad \textbf{(2)}$$

The variable S varies with antecedent soil moisture and other variables, it can be estimated as;

$$S = \frac{25400}{CN} - 254 \quad \textbf{(3)}$$

By considering surface retention the surface runoff equation becomes:

$$Q_s = \frac{(R_d - 0.2S)^2}{(R_d + 0.8S)} \quad \textbf{(4)}$$

Equation 3 is used to modify the curve number if a wet condition exists:

$$CN = \frac{20CN_S}{10 + 0.1CN_S} \quad \textbf{(5)}$$

Peak Runoff Rate

The peak discharge or the peak surface runoff rate is the maximum volume flow rate passing a particular location during a storm event. SWAT calculates the peak runoff rate with a modified rational method.

$$q_{peak} = \frac{\alpha tc * Q_{Surf} * Area}{3.6 * tc} \quad (6)$$

SWAT estimates the value of α using the following equation

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$$\alpha_{tc} = 1 - \exp\left[2 * t_{conc} * Ln(1 - \alpha_{0.5})\right] \qquad (7)$$

Computation of Evapotranspiration

The Penman approach is used for approximating evapotranspiration combines the mass transfer and energy balance approach because of which it gained strong physical base Dingman, S.L. [10].The Penman Monteith requires radiation, air temperature, air humidity, and wind speed data.

$$ET_o = \frac{0.408\Delta(R_n - G) + \gamma \frac{900}{T+273} u_2 (e_s - e_a)}{\Delta + \gamma(1 + 0.34 u_2)} \qquad (8)$$

SWAT Model Input Parameters

Digital Elevation Data

To create Arc Swat Dataset, the model need to access ArcGIS compatible raster (Grids) and vector datasets (shape files and feature classes) and database files which provide certain types of information about the watershed.

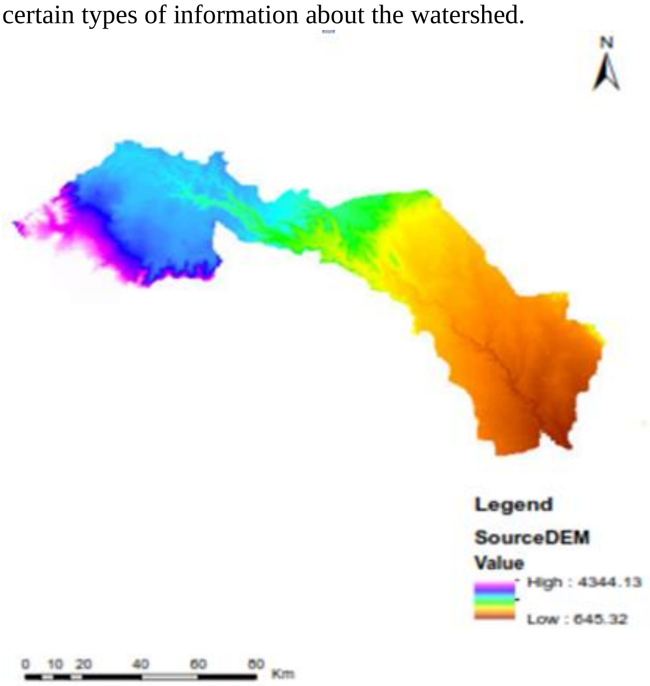

Fig II.1: DEM of Weib Watershed

The model calculates surface runoff and sediment transport for each HRU. All model inputs map were preprocessed and re projected to WGS 1984 UTM Zone 37N (Transverse Mercator of Northern hemisphere zone 37) projection.

Land Use Land Cover data

Land use and cover affect surface erosion, water runoff, and Evapotranspiration in a watershed. The available land use /cover map for the study area was taken Earth Explorer. As shown in fig below the land use and land cover of the area are Urban, Agricultural, Open grassland, open forest moderately cultivated, Grasses and Water

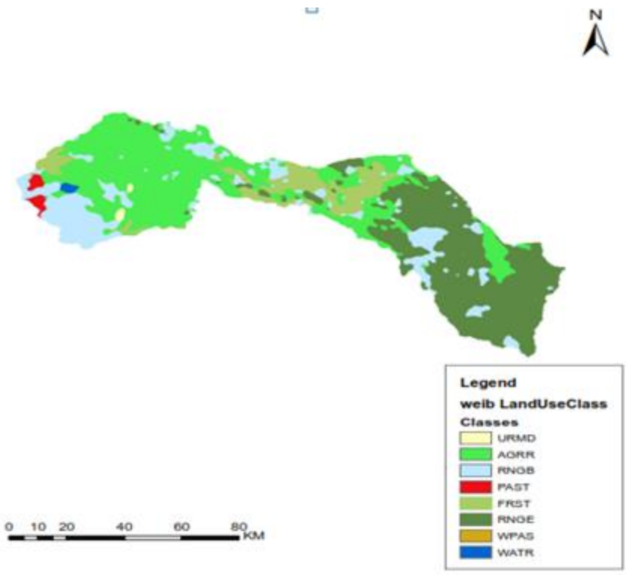

Fig II.2: Land use classes of Weib watershed

Soil Data

The soils data required in the SWAT are those describing the average water holding capacity of the soils in mm/m, average hydrologic active soil depth in cm, textural description of the soil, average saturation soil hydraulic conductivity in m/hr, average Soil Conservation Service (SCS) curve number for the soils, maximum percentage of the watershed which can be impervious, and minimum percentage which can be impervious for each sub basin that makes up the watershed was modeled.

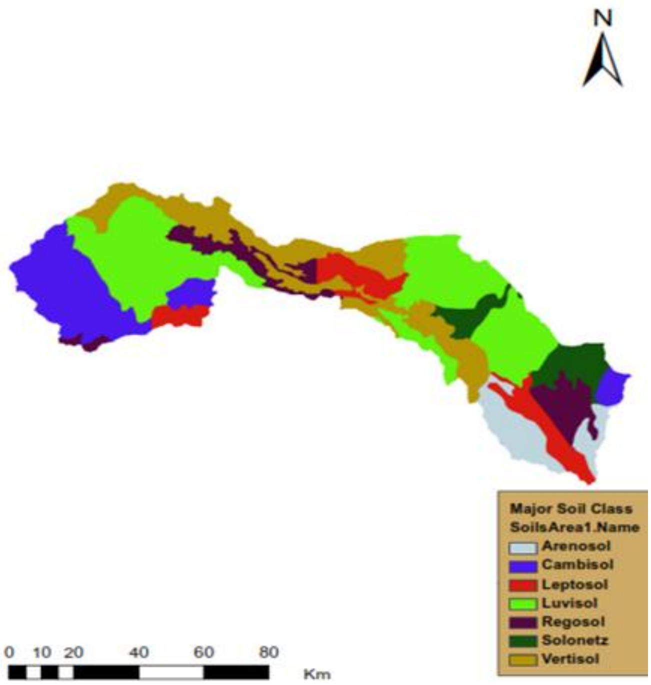

Fig II.3: Major Soil classes of Weib watershed

Based on data obtained from Ministry of water, irrigation and Electricity seven soil types namely, Arenosols, Cambisols, Labtosols, Regosols, Solonetz and Vertisols are common in the watershed and fig above shows the major soil of Weib watershed.

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Slope Data

Slope is the most important criteria in view of its effects on geomorphological mapping and the landform refers to the shape of the land surface in the area in which the soil observation is made as shown in figure below.

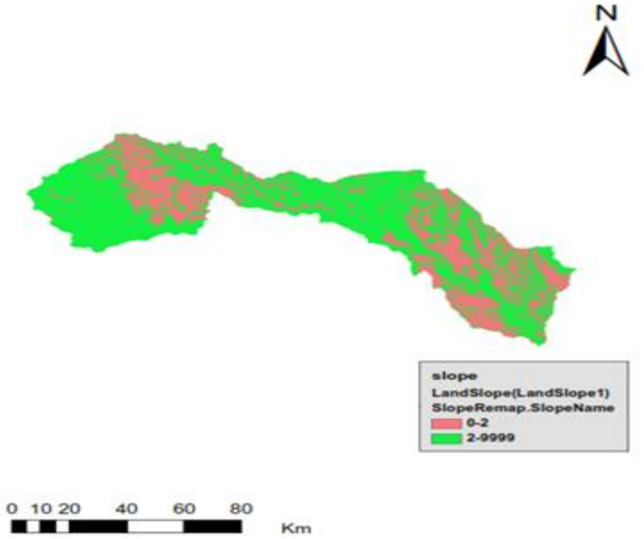

Fig II.4: Slope classification of Weib watershed

Once the lands use, slope and soil data layers are imported overlaid, the distribution of hydrologic response units (HRUs) within the watershed must be determined.

Methods Data preparation for Swat input

The metrological input of the model were prepared first by analyzing, modifying, and entering in the right format which is Text (Tab delimited) of the daily data and secondly obtaining and analyzing the required monthly statistical weather parameters for the weather generator i.e. Robe station. These monthly statistical weather parameters for the weather generator were estimated by using empirical formula in the ArcSWAT user manual, pcpSTAT and dewpoint software which was designed.

Rainfall

PcpSTAT calculates statistical parameters of average daily precipitation data. Appendix A

Temperature

Dewpoint calculate the average daily dewpoint temperature per month using daily air temperature and humidity data. Appendix B

Solar Radiation

ArcSWAT need daily solar radiation but the data acquired from National Meteorological Agency (NMA) is sunshine hour, and hence a conversion of this variable was made using Angstrom (1924) empirical equation

Landsat Images data

Landsat satellite imageries were used to identify changes in LU/LC distribution in the Weib catchment over a 28 years period from 1986-2010. Landsat TM and ETM+ were selected to represent the land cover conditions in the years 1986, 1995 and 2010 respectively. The images are particularly acquired for the dry season to capitalize on

- The pronounced difference in reflectance between forested and non-forested areas,
- Decreasing confusion at forest edges between dense forest vegetation and small scale agriculture plots.

Since the image had different file format, all images were imported in the zipped file formats (TIF). Flow chart showing the methodology of the Land use Land cover map is prepared for proper classification is shown.

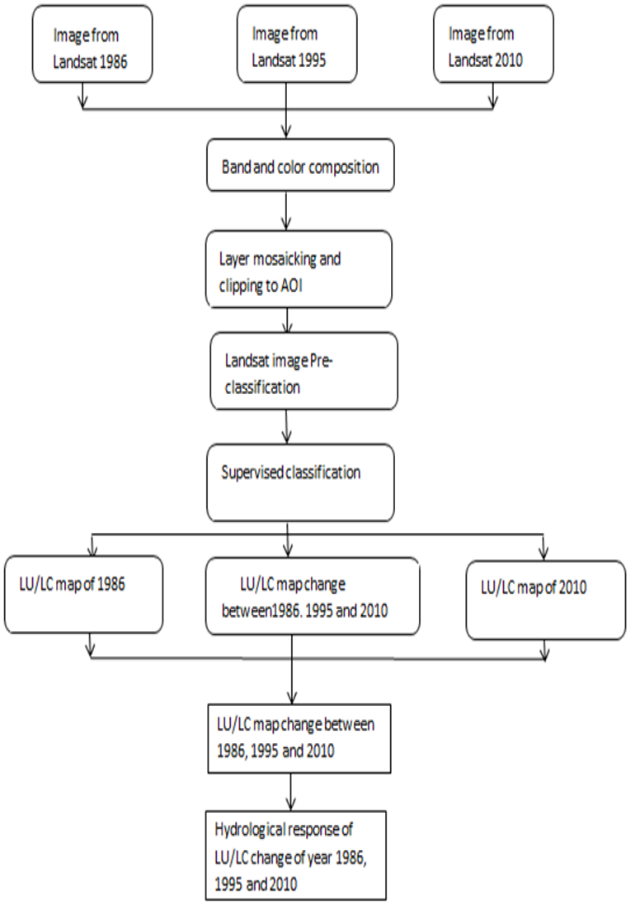

Fig II.5: Flow chart showing the methodology of the Land use classification

The Land use and land cover classification was based on classifying and defining training sites using geocoded ground observation points and visual inferring Google Earth images as shown fig II.6.

Fig II.6: land use of Weib Catchment near Weib Mezera Village and around Sof Umar Cave

Accuracy Assessment of Land use Image

Accuracy assessment was done using topographic map of the Study area prepared in 1986 for 1995 and 2010 image classification, About 60 random points were created for 1986 image and 65 random points were created for 1995 image classification of Weib Catchment. Kappa provides us with insight into our classification scheme and whether or not we achieved results better than that would have achieved strictly by chance.

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International Journal of Innovative Technology and Exploring Engineering (IJITEE)
ISSN: 2278-3075 (Online), Volume-8 Issue-11, September 2019

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                CLASSIFICATION ACCURACY ASSESSMENT REPORT
                -----------------------------------------
Image File : c:/users/fish/desktop/1986 all/supervised.img
User Name  : fish
Date       : Tue Aug 15 14:31:44 2017


KAPPA (K^) STATISTICS
---------------------

Overall Kappa Statistics = 0.9633

Conditional Kappa for each Category.
------------------------------------

    Class Name            Kappa
    ----------            -----
        forest           1.0000
         water           1.0000
         Urban           1.0000
   agricultural          0.9572
       pasture           0.8734
         grass           0.9515

              ----- End of Kappa Statistics -----
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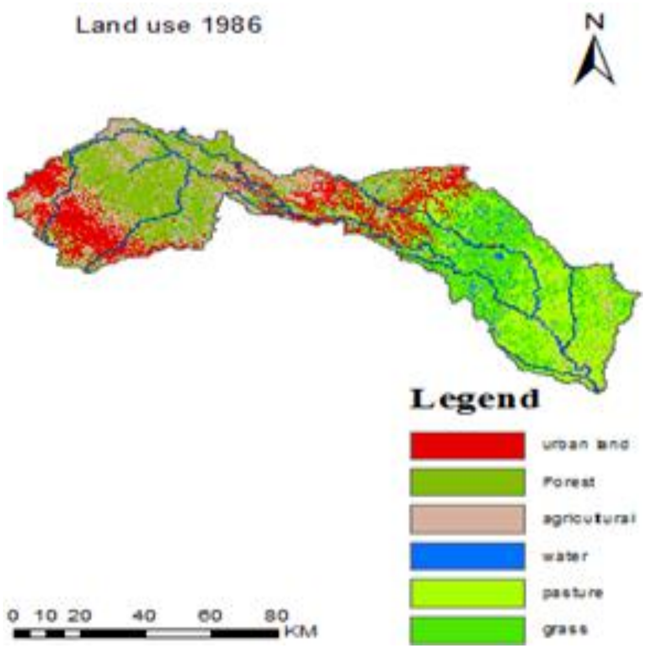
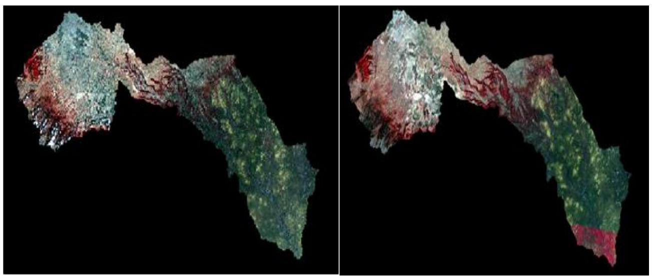


III. RESULT AND DISCUSSION

Land cover impact analysis

Weib watershed had high population and socio-economic development due to expansion of agricultural which resulted huge impact in runoff generation. The most substantial period of enlargement of agriculture and settlements was in the period 1990–2010, due to high resident's resettlement. Land use and land cover image were downloaded for 1986, 1995 and 2010 following the step-by-step procedure from earth explorer.



a) Land sat image 7$^+$TM b) land sat image 4-5 TM

Fig III.1:Band combinations for Landsat 7$^+$TM and Landsat TM

Land use of 1986

The land cover map of 1986 in fig III.2 and the histogram of the land class coverage shows that about 22.4 % of the Weib catchment was covered by Mixed Grass Land, 32.5% by Forest land, 10.8 % by cultivated land (agriculture) , 12.8 % by Settlement (Urban),20.9% covered by Bare land and 0.6% by water.Grass cover was found in most parts of the catchment; especially south western part of the catchment is more dominantly covered by forest.

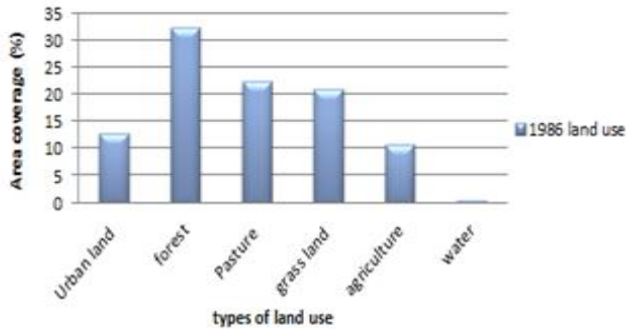
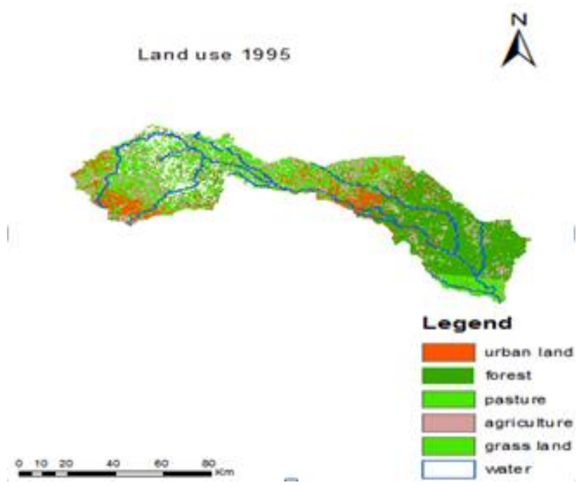


Fig III.2: Comparison of Land cover classes of year 1986

Land use of 1995

The result of land use 1995 show that the catchment was covered by 14.1 % Grass, 20.3 % Forest, 22.6 % Agriculture (Cultivated land), 24.4% Urban land (Settlement), and 0.5% of water body. For the duration of this period, mostly the woodland land in the north, and Grass land in South-Eastern and the central part of the catchment was reduced. On contrast the cultivated land was extended in utmost portions of the catchment.



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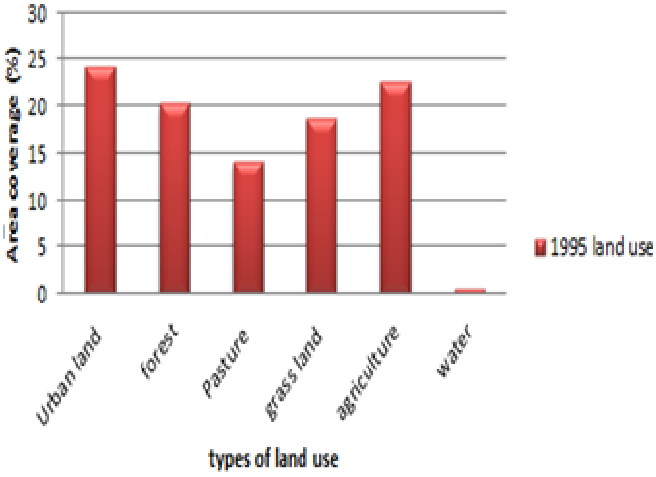
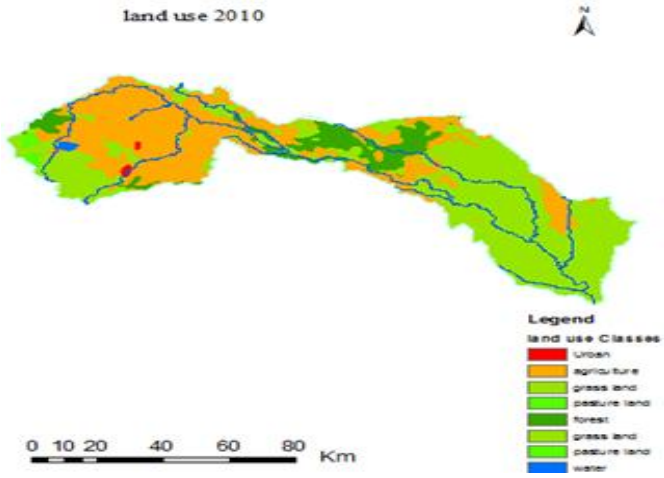


Fig III.3: Comparison of Land cover classes of year 1995

Land use of 2010

The result of each class is shown in fig III.4 and indicates that urban had 30.8 % while forest, pasture land, grass land, agriculture, water were 9.4%, 8.2%, 12.3%, 39.1% 0.3% respectively.



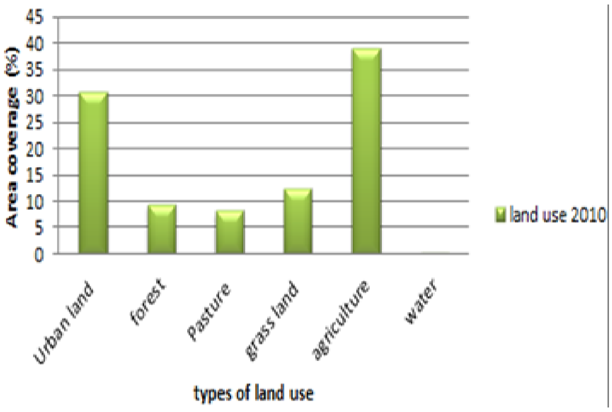


Fig III.4: comparison of land cover classes of year 2010

For the duration of this period there was large area of agricultural expansion by average 14.15% which resulted the land use rapidly changed barren land the results high surface runoff with the catchment particularly in the central and some south eastern part and less amount of forest existed in the North western part of the catchment. There was also huge decrease of grass land by average of 4.3% which result the reduction of infiltration of rainfall to ground recharge.

The general land use/cover modifications at within the catchment are shown in fig III.5

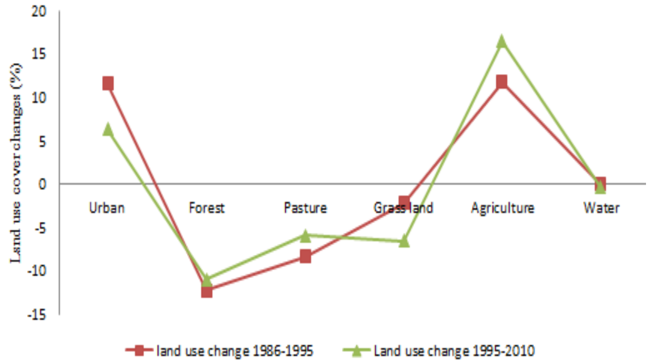


Fig III.5: Overall land use changes with types

Model Responses to Land Cover Change

The SWAT model simulated for the three time periods corresponding to the land cover of 1986, 1995 also 2010. The 2005 – 2008 meteorological data served as an input to the SWAT model. Two different simulation runs were done on a once-a-month by the year of 1986 and 2010 keeping other input parameters unchanged. Contrasts were made for the contribution of surface runoff, lateral flow and ground water flow to stream flow. The result showed that the average annual surface run off 2010 was increased by 52.7 % than 1986 land cover. Whereas the year 1995 land cover mean annual surface flow was higher by 44.6 % than 1986 land cover as shown in fig III.6

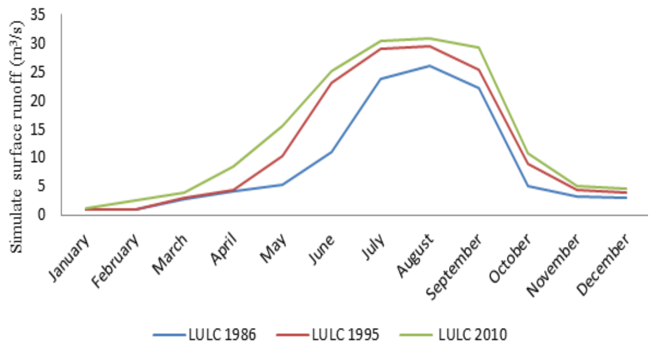


Fig III.6: Simulated mean surface run off (SURQ) for LU/LC of 1986, 1995 and 2010

Urban and cultivated land have enlarged between 1986, 1995 and 2010 with most of the increase occurring in previously Grass and Forest land that resulted reduction of infiltrations. To understand the flow processes during different seasons under different land cover conditions, the average monthly stream flows were plotted for the wet and dry season and compared.

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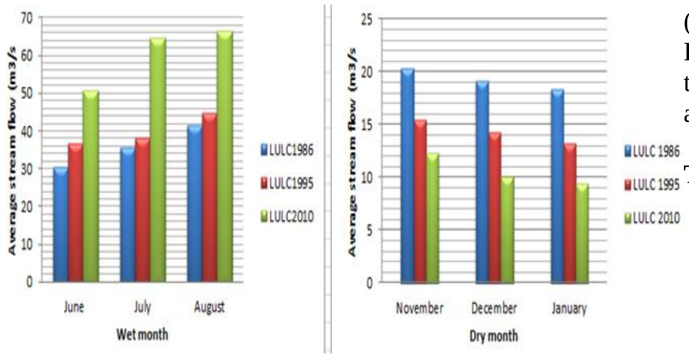

a) Wet season b) dry season

Fig III.7: Simulated monthly catchment stream flow for LU/LC of 1986, 1995 and 2010

In the Weib River catchment, there are two seasons - wet weather occurs from June to August and dry weather events occur between November and January. The average dry season stream flow shows differences between simulations. For the 1986 and 1995 land cover average monthly stream flow was 19.4m3/s,14.3m3 /s, while that of 2010 land cover data was around 10.6m3 /s.

The result indicates that the mean wet monthly flow for 2010 land cover was increased by 40.7 % than 1986 land cover. Similarly the 1986 land cover mean month flow higher by 10% than the 1995 land cover flow of wet months. On the other hand dry average monthly flow was decreased by 45.2 %, 26 % for land cover of 2010 and 1995 than that of 1986 land cover.

Hydrological Response of the Watershed

The dominant land cover changes were observed in Central part and Eastern partially of the study area which is assigned in table as sub basin 1, 2,3,4,5 and 8. Differences in surface run-off, with percentage changes are tabulated in tables 3.1 below:

Table III.1: Runoff simulated for Central and Eastern part of the study area for LULC of 1986, 1995 and 2010

	Simulated Annual Average Runoff (mm)				Change b/n	Change b/n LULC 1986 and LULC 2010	change (%) b/n LULC 1986 and LULC 1995	Change (%) b/n LULC 1986 and LULC 2010
Sub- basin No	Area(Km2)	LULC 1986	LULC 1995	LULC 2010	LULC 1986 and LULC 1995			
1	1626	19.21	29.03	38.59	9.82	19.38	33.83	50.22
2	994.27	9.37	13.64	15.82	4.27	6.45	31.30	40.77
3	476.29	9.87	20.56	26.27	10.69	16.4	51.99	62.43
4	1059	10.41	22.37	29.19	11.96	18.78	53.46	64.34
5	901.62	6.8	15.97	20.38	9.17	13.58	57.42	66.63
8	135	4.07	9.75	12.99	5.68	8.92	58.26	68.67
					Average		47.71	58.8

The result showed based on annual simulated surface run off is estimated as 47.71% between 1986 and 1995 period. In comparison, the simulated flow is estimated as 58.84 % between 1986 and 2010 period.

Performance of Model

The performance of the model is checked for the Weib watershed at the outlet near Sof Omar Cave .The model performance of flow prediction for a specific application is evaluated through sensitivity analysis, calibration, and validation and uncertainty analysis.

Sensitivity Analysis

The analysis was carried out based on the objective function of the sum of the square of residual (SSQ) for all the 27 model parameters and 10 intervals of Latin hypercube (LH) sampling.

The study result divided sensitivity into four classes: small to negligible (0<MRS<0.05), medium (0.05<MRS<0.2), high (0.20<MRS<1.0), and very high (MRS>1.0). Based on the LH sample model parameters which are more sensitive for the change of HRUs within the watershed are listed according to their effect in table III.2.

Table III.2: Sensitivity analysis result with, mean and category of the parameters.

Parameters	Sensitivity Rank	MRS	Sensitivity Category
Soil evaporation compensation factor ;ESCO	1	2.221	Very High
SCS runoff curve number for moisture condition II ; CN2	2	2.118	Very High
Threshold depth of water for return flow (Gwqmn)	3	1.924	Very High
Available water capacity [mm WATER/mm soil]; SOL_AWC	4	0.537	High
Soil depth [mm]; sol_z	5	0.4	High
Surface water'Revap'coefficient; Revapmn	6	0.394	High
Maximum canopy storage [mm]; Canmx	7	0.272	High
Maximum potential leaf area index ;blai	8	0.159	Medium
Groundwater 'revap' coefficient;GW_revap	9	0.113	Medium
Slope(mm/m);Slope	10	0.079	Small
Soil conductivity (mm/h) ; Sol_k	11	0.074	Small

Flow Calibration

Flow calibration was performed for a period of five years from January 1st, 2000 to December 31st, 2004 using the sensitive parameters identified. However, flow was simulated for six years from January 1st, 1999 to December 31st, 2004 within which the first year was considered as a warm up period.

Generally, according to study by Santhi . C et.al [11] for an acceptable calibration of hydrology model the three numerical model performance measures value fulfill D = ± 15%, $r^2 > 0.6$ and $E_{NS} > 0.5$.

The calibration results in figure 3.8 show that there is a better fit between the simulated and gauged monthly flows. This is demonstrated by the goodness-of-fit measures correlation coefficient (R^2 = 0.845), the Nash-Suttcliffe Simulation efficiency (E_{NS}=0.812) and the percent difference (D= 0.716 %) value that fulfilled the requirement suggested.

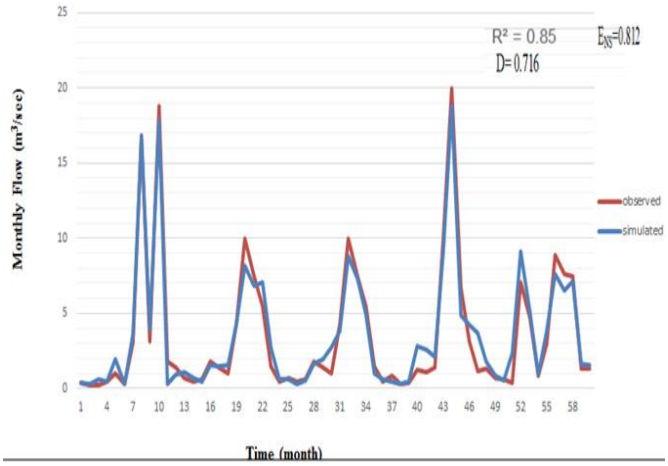

Fig III.8: Comparison of observed monthly flow with simulated (calibrated) monthly flow of Weib river watershed.

Flow Validation

validation involves re-running the model using input data independent of data used in calibration (e.g. differing time period), but keeping the calibrated parameters unchanged. In this case, flow data from a period from January 1, 2005 to December 31, 2008 at Sof Umar gauging station were used to validate the model for a monthly time-period.

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A good agreement between monthly observed and simulated flows at the outlet of the watershed station during validation processes are shown by Table 4.10 and the goodness-of-fit measures the coefficient of correlation (r^2 =0.883) , the Nash-Suttcliffe simulation efficiency (E_{NS} =0.872) and the percent difference (D= -0.275%) value.

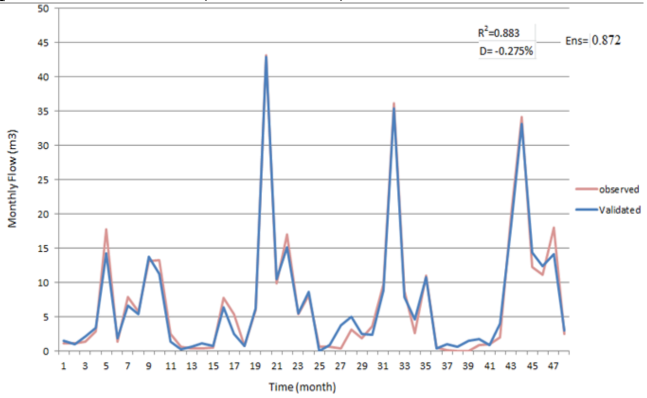

Fig III.9: Comparison of observed monthly flow with validated monthly flow of Weib watershed.

Remedial Measures on Hydrological Changes for Weib Catchment

In order to understand the effect of different farming activities in the upper catchment of the watershed , which are increasing in the area due to the population pressure, on water quantity and sedimentation in relation to land use changes and management practices, it is necessary to develop remedial measure. In general, the depth of soil varies from place to place. However; the top 30cm soil depth is very useful for human being and wild life.

The implementation of soil-water conservation programs is important to limit flood. These include farming practices, control of overgrazing and control of gully erosion. Therefore, for critical sub basin like sub basin 5, 6 and 8 when soil-water conservation program should applied with vegetation screens upstream of watershed. It is possible to increase ground water flow. as most prominent remedial measures to preserve the continuous base flow Weib River.For attaining better result continuous follow up is needed.

From the analysis selected sub basin which is under critical condition resulted higher percentage change of highest simulated surface run off due land use land cover change between 1986 and 1995; between 1986 and 2010 which is 57.42% and 66.63% respectively

To adequately feed the present world population of nearly 7 billion a diverse diet, we need about 0.5 ha of arable land per capita, but only 0.27 ha per capita is available. Moreover, in the coming 40 years, only 0.14 ha per capita arable land will be available due to urbanization by deforestation in the world. This shows that the hydrologic cycle of every catchment will have unbalanced cycle that results higher runoff and lower base flow for the rivers.

For this reason the following remedial mechanism for the catchment are outlined

Agricultural/Agronomic methods

From simulation sediment yield of 5.22ton/ha per is expected from Weib Catchment and this will be increased by 54.47% by using land use land cover of year 1986 and 2010 which shows it needs great emphasis to apply remedial measures.

Fig III.10: Image of Existing Farming system along Weib River

To employ the conservation measures the preference is always given to this method due to less expensive that reduce the rain drop impact, increase infiltration rate, reduce runoff volume and decrease the velocity of runoff and wind. It is easier to fit them into existing farming system as shown in figure above.

Mechanical Measures

Mechanical or engineering measures for protection of soil and water loss are all the methods which involve earth moving, such as digging drains, building banks, leveling sloping lands and soon. They are constructed by manipulating the surface topography.

The reasons that the mechanical measures are not much preferred than agronomic measure are:

They are ineffective on their own because they cannot prevent the detachment of soil particles and its main role is in controlling the flow of any excess water and wind that arise.

IV. CONCLUSION

The effects of land use change Weib river flow were analyzed statistically using the physically based, semi-distributed models called SWAT. Based on the results found the next conclusions are drawn:

The simulation of land cover alteration on the Catchment of Weib showed that it had experienced a significant change for the previous Thirteen years. The analysis shows that rapid conversion of Forest and Grass land cover to Urban and Cultivated land. Watershed parameters were derived from DEM and categorized into 8 sub basins. Sub basins were further divided into HRU based on land use and soil data. The result indicated that the sub basin had 59 HRUs with a threshold value of 25% for land use, 25 % for soil and 5 % for slope.

According to the hydrological analysis carried out, ground water parameters curve number (CN2), soil evapotranspiration factor (ESCO), shallow aquifer for flow (GWQMN), (Alpha base flow (Alpha_Bf), soil available water capacity (SOL_AWC), Soil depth (SOL_Z) are the most sensitive parameters

The developed model performance evaluation of the station Sof umar showed that (r^2=0.845 and E_{NS}=0.812) for calibration and (r^2=0.883 and E_{NS}=0.872) for validation. It indicated that the model can represent the actual condition of the watershed.

Retrieval Number: J95310881019/19©BEIESP
DOI: 10.35940/ijitee.J9531.0981119
Journal Website: www.ijitee.org

Published By:
Blue Eyes Intelligence Engineering and Sciences Publication (BEIESP)
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From results analysis the center and eastern part catchment parts are foremost runoff compared to upper and lower part of the catchment 53.46% and 64.34 % of 1986 and 2010 land cover respectively.

Future Scenario on effect hydrology developed established on past land use trend showed that there will be an increase in annual average stream flow.

APPENDIX

Appendix A: Daily Precipitation

Statistical Analysis of Daily Precipitation Data (1985 - 2014)
Input Filename = Rbppt.txt

Number of Years = 30
Number of Leap Years = 7
Number of Records = 10959
Number of NoData values = 228

Month	PCP_MM	PCPSTD	PCPSKW	PR_W1	PR_W2	PCPD
Jan.	17.94	2.5813	7.2720	0.0677	0.5043	3.90
Feb.	22.83	3.5862	8.0816	0.0783	0.4958	3.97
Mar.	63.69	5.0725	3.9937	0.2036	0.6012	10.70
Apr.	121.35	6.9930	2.8012	0.4244	0.6654	17.43
May.	78.34	4.7195	3.3329	0.3902	0.6434	16.73
Jun.	54.16	3.7738	3.4979	0.3458	0.5217	13.03
Jul.	98.33	6.9455	4.4345	0.4183	0.5921	16.10
Aug.	135.79	8.6938	5.3568	0.5078	0.7044	20.30
Sep.	110.05	5.2293	2.6066	0.5147	0.7484	20.93
Oct.	81.19	4.8848	3.4192	0.2596	0.7207	16.23
Nov.	39.50	4.0935	5.4635	0.1124	0.6309	7.77
Dec.	18.21	2.5249	7.9814	0.0655	0.5809	4.53

PCP_MM = average monthly precipitation [mm]
PCPSTD = standard deviation
PCPSKW = skew coefficient
PR_W1 = probability of a wet day following a dry day
PR_W2 = probability of a wet day following a wet day
PCPD = average number of days of precipitation in month

(written by Stefan Liersch, Berlin, August 2003)

Appendix B: Dew point temperature.

This file has been generated by the progr
Input Filename = dew123.txt
Number of Years = 30
Number of Records = 10957

Number of NoData values
tmp_max = 494
tmp_min = 170
hmd = 1541

Average Daily Dew Point Temperature for P

Month	tmp_max	tmp_min	h
Jan	22.78	6.07	56.
Feb	23.66	7.03	54.
Mar	23.35	8.28	60.
Apr	21.83	9.65	69.
May	22.14	9.49	69.
Jun	22.69	9.16	67.
Jul	21.93	9.19	71.
Aug	21.35	9.09	74.
Sep	20.97	9.02	74.
Oct	19.87	8.60	74.
Nov	20.65	6.74	67.
Dec	21.67	6.00	60.

tmp_max = average daily maximum temperatu
tmp_min = average daily minimum temperatu
hmd = average daily humidity in month
dewpt = average daily dew point tempera

(written by Stefan Liersch, August, 2003)

ACKNOWLEDGMENT

First all commendation and entreaty to Almighty God for his unbound graciousness and unlimited kindness in all endeavors that made me possible to begin and finish this work successfully.

I am greatly indebted to my major advisor, Dr. Agizew Nigussie for his close friendship, professional assistance, genuine and valuable criticism all the way from the outset to the completion of the study.

I would like to thank all staffs in the Ministry of Water resource, Irrigation and Electricity especially to those staffs in the Departments of Hydrology, GIS and Data Base, National Metrological Agency and Oromia Water resource, Irrigation and Electricity Bureau, for providing me with related materials.

I would like to express my sincerely thanks to Dr. Lakshimi Jintu , whose impact full share of ideas through email on how to use the software with which I was working, constructive comments and encouragements cannot be evaluated.

I must extend special thanks to all my families and relatives, for there consistence support, concern and encouragement throughout my studies.

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