ISSN (e): 2250 – 3005 || Volume, 08 || Issue, 5|| May – 2018 ||
International Journal of Computational Engineering Research (IJCER)

Assessment of Climate Change Impacts on Lege Dadi Water Resources Catchment, Ethiopia

Wakuma Midaksa Kajela[1], Dr. Shital Shah[2]
[1]P. G. Student in WRM, Civil Engineering Department, Parul Institute of Technology, Parul University
[2]Guide Dr. Civil Engineering Departments, Faculty of Engineering and Technology, Parul University
Corresponding Author: Wakuma Midaksa Kajela

ABSTRACT
This study is an attempt to assess the impact of climate change on water resources of Lege Dadi River basin which is situated in Oromia Regional State and located about 24km east of Addis Ababa. Lege Dadi catchment is one of the largest of the three main water supply sources of Addis Ababa city having area of 206km2 and located between latitude of 9°04'59'N-10o01'48''N and longitude 38°54'58''E-50o8'0'' E and elevations range from 2398 to 3248 m.a.s.l. The main objective of the study is to select appropriate model for assessing the impact of climate changes on Lege Dadi water resources catchments. In this study data such as climatic, hydrologic data, land use/cover and soil data available are used to assess climate change impacts on water resources catchments. For analyzing rainfall-runoff for the study area, the actual rainfall runoff data were divided into six periods; 1st actual data collected from 1996-2007 (60% of the period of data availability), 2nd actual data collected from 2008-2015 (40% of the available data), 3rd 60% of 8 years actual data from 2008-2013, 4th actual data from 2013-2015, 5th 1996-2010 i.e. 75% of the 20 years data and lastly the rest of the 20 years data (25% of total) were analyzed to compare and select the appropriate model for Lege Dadi water resources catchment. Then using the above mention data for 20 years monthly average rainfall-runoff data, the model is formulated using DATAFIT 9.1. Formulating 60%, 40%, 60% of 40% data, 3 years data, 75% and 25% of the 20 of the 20 years using DATAFIT 9.1, the model name, model equation and the following model performance values are calculated.
KEY WORDS: Hydrologic modeling, Rainfall, Runoff, Climate Change

----
Date of Submission: 28-04-2018 Date of acceptance: 14-05-2018

I INTRODUCTION

The rising in temperature is due to an increase in greenhouse gases in the atmosphere and it affects the natural and managed ecosystems. The increase in temperature can enhance the climate change which is referred as a change in the state of the climate that can be identified by changes in the mean or the variability of its properties and that persists for an extended period, typically decade or more. Climate variability can affect the precipitation pattern and other climatic parameters. Some important impacts of climate change will be changes in regional and local water availability. An availability of water is one of the essential components and responsible for ecosystem, human livelihood, and crop production and hydroelectric power production (McGuire et al. 2001; Mialhe et al. 20150. The impacts of climate change on catchment hydrology and water resources are usually evaluated by defining scenarios for changes in climatic parameters to a hydrological model and these scenarios based on the future emissions of greenhouse gases. The main objective of this study is to assess climate change and select appropriate model for assessing the impacts climate change on Lege Dadi water resources catchment.

Description of the Study Area-This study is conducted on Lege Dadi watershed which is found in Oromia Regional State and located about 24 km east of Addis Ababa. It is one of the largest of the three main water supply sources of Addis Ababa city. The geographic location is between latitude of 9°04'59'N-10o01'48''N and longitude 38°54'58''E-50o8'0'' E and elevations range from 2398 to 3248 m.a.s.l. In general, the Watershed has a total area of 206 km2 and approximately lies in geographic coordinates of 481.3kms east to 508 km east of UTM and 996kms north to 1019kms north UTM.

II METHODOLOGY

Data Collection-The basic data sets that are required to develop an input data for the model are climatic data such as maximum and minimum temperature, precipitation (rainfall), stream flow, soil data, topographic and land use data. These data are collected for the study to develop the model for the assessment of climate change impact on the water resources of the study area. The data selection criterions for this study were based on the availability of data, quality of data and possibly whether the station is within the Watershed or not. The data was used as an input to the hydrological model
development. The locations of the climate stations nearest to Lege Dadi are presented with respective data availa bility

Filling Missing Rainfall Data

Rainfall measuring stations sometimes fail in providing a continuous record of precipitation. This failing of precipitation data may be due to malfunctioning of instruments and backup systems may not always provide accurate data. There are two commonly used procedures for estimating daily rainfall records. The two procedures for estimating daily totals rely on the data from any nearby stations. If the locations of the adjacent stations are such that they are close to site with missing data and when a mean annual rainfall at each of the adjacent stations differs from the mean at the missing data station by less than 10%, the *arithmetic formula* can be used to estimate the missing daily data and it is given by the following equation.

$$\mathrm{Px} = \frac{\mathrm{P1} + \mathrm{P2} + \mathrm{P3} + \cdots \mathrm{Pn}}{\mathrm{n}}$$

Where P_X = Estimated daily rainfall at station X.

P_1, P_2, $P_3 \ldots P_n$ = are daily rainfall depths at adjacent stations 1, 2, 3, and up to an adjacent station.

When the difference between the mean annual precipitation at any of the nearby stations and the missing data station is greater than 10%, a *normal ratio method* is used and given by:

$$\mathrm{Px} = \frac{\mathrm{Nx}}{\mathrm{n}} \left(\frac{\mathrm{P1}}{\mathrm{N1}} + \frac{\mathrm{P2}}{\mathrm{N2}} + \frac{\mathrm{P3}}{\mathrm{N3}} + \cdots \frac{\mathrm{Pn}}{\mathrm{Nn}}\right)$$

Where P_1, P_2...Pn = are the rainfall data of index stations. N_1, N_2...Nn = the normal annual rainfall of index stations. $P_X$and $N_x$are the corresponding values for the missing stations x and n is the number of stations surrounding the station x.

III CLIMATIC DATA

Data such as Daily precipitation, maximum and minimum temperatures were obtained from National Meteorological Service Agency (NMSA) for the study area and nearby weather stations. Solar radiation data, relative humidity, and wind speed data were generated by the model. The model requires daily weather data, but there are only few meteorological stations in the catchment having full record of data. Therefore, to fill the missing rainfall data, we use the two methods mentioned above and the model uses a random weather generator that uses information found in weather station files and the weather generator algorithm in ArcSWAT were used to generate unavailable climate data.

Hydrological data

The distribution of the study area watershed is depends on the availability of concurrent long year daily data as that of climate data and to maintain the distribution as far as possible throughout the basin of Lege Dadi. The stream flow data of the watershed was required for calibrating and validating the model. Therefore daily stream flow data from (1996-2015) and remote sensing data work were collected from the Hydrology Department of Ministry of Water resources.

Land use/ land cover

The land use/ land cover of this catchment mainly consists of cropland/grassland mosaic (6.70%), grassland (31.45%), Eucalyptus trees and natural vegetation (3.43%), mixed grassland/shrub land (4.93%) and agricultural land (53.49%). The cultivated fields are located in the mid and lower slopes of the mountains and the hills, slopes, undulating plains, flat to almost flat plain valley sides, and at part of the edge of the perimeter of the reservoir. The cultivated fields situated on the steep and undulating slopes are not protected from water erosion by any soil and water conservation measures. ArcGIS requires different soil textural and physic-chemical properties such as soil texture, available water content, hydraulic conductivity, Ph. and organic carbon content for different layers of each soil type. The data was acquired from Hydrology Department of Ministry of Water resources and Oromia Water works Design and Supervision Enterprise.

Soil Data

The physical characteristics of soil govern water and air movements through soil structure and have a major impact on the cycling of water within the HRUs. Inputs for chemical properties can set initial levels of the different chemicals in the soil. Physical properties are required and information on chemical properties is optional. The soil input file defines the physical properties for all layers in the soil. The soils of the basin reflect the combined effects of the soil formation (primary fine grained, weathering to produce clays); climate (moderate to high rainfall); topography and time, reflecting the long period of stability to produces soils which generally receive much higher rainfall. The highland soils in the area were developed primarily under conditions of forest with a regular cycling of nutrients between the trees and the topsoil, and with the subsoil deeply leached under conditions of high rainfall. Based on Food and Agricultural Organisation (FAO, 1986) soil classification, major soil types of Lege Dadi catchment are four types. These soils are Vertisols, Leptosol, Luvisol and Cambisol. Vertisol is the dominant soil type which, is found in almost all parts of the watershed. SWAT is a conceptual model capable of simulating the catchment hydrologic processes at a continuous time scale (Wang S, Kang S, Zhang L, Li F. 2008) [24]. It is used to simulate basin level hydrologic characteristics for varying land use and climate conditions which makes it a widely adopted tool for climate change studies related to hydrology [26]. It is physically based, computationally efficient and capable of continuous simulation over a long time periods. Geographical Information System (GIS) interface of ArcSWAT allows the users to provide spatially referenced data. Using the topographical information, ArcSWAT divides the catchment into sub-basins. Each sub basin is further divided into homogeneous Hydrological Response Units (HRUs) using the spatially distributed soil, land use and slope information.

IV MODEL SETUP

The climate change impact assessment on catchment hydrology can be best handled through simulation of the hydrological parameters that shall prevail under the projected weather conditions in the study area. Such assessment is essential because of the fact that the hydrological response is a highly complex process governed by a large number of variables such as terrain, land use, land cover and soil characteristics. For this study, ArcSWAT model is selected generate some climatic data and DATAFIT 9.1 selected in rainfall-runoff analysis and to evaluate model performance parameters.

Model Performance

After preparing data files and completing all simulation inputs, the data analyses and simulation were done. The results are analysed using ArcGIS, Calibration was performed by comparing the simulated and observed flow data. After achieving a reasonable value of calibration, hydrological parameters are used for validation and the validation should be done to evaluate the performance of the simulation with calibrated parameters. The calibration and the validation are carried out using the Coefficient of Determination (R2), refined index of agreement (d1') and Theil's inequality index (U):

Index of agreement: The Index of Agreement (d) developed by Wilmot (1981) as a standardized measure of the degree of model prediction error and varies between 0 and 1. A value of 1 indicates a perfect match, and 0 indicates no agreement at all.

$$d = 1 - \frac{\sum_{i=1}^{n}(P_i - O_i)^2}{\sum_{i=1}^{n}(|P_i - \overline{O}| + |O_i - \overline{O}|)^2}$$

Refined Index of Agreement: Our primary goal is to present a refined index of agreement that, like d and d_1, is bounded on both the upper and lower ends. Many other existing indices are bounded on the upper end (usually by 1.0) but lack a finite lower bound (cf. Legates and McCabe, 1999; Krause et al., 2005)[30], which makes assessments and comparisons of poorly performing models difficult. With this in mind, we have developed our new index with an easily interpretable lower limit of − 1.0. With an upper limit of 1.0, the range of our new index is double the range of d or d1. Our refined index also is logically related to increases and decreases in MAE. The revised d_1 (d_1') then can be written as;

$$d_1' = 1 - \frac{\sum_{i=1}^{n}|(P_i - \overline{O}) - (O_i - \overline{O})|}{\sum_{i=1}^{n}(|O_i - \overline{O}| + |O_i - \overline{O}|)} = 1 - \frac{\sum_{i=1}^{n}|P_i - O_i|}{2\sum_{i=1}^{n}|O_i - \overline{O}|}$$

Theil's U index of inequality: Theil's inequality index is a measure of the degree to which one time series (xi) differs from another (yi). The index is computed as;

$$U = \frac{\sqrt{\frac{1}{n}\sum(X_i - Y_i)^2}}{\sqrt{\frac{1}{n}\sum X_i^2} + \sqrt{\frac{1}{n}\sum Y_i^2}}$$

The score returned by the THEIL this test is 1-U for consistency; varies from 0 to 1 with 1 meaning maximum disagreement.

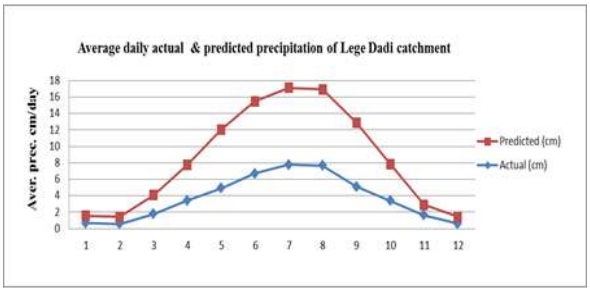
Coefficient of Determination (R^2)

The Coefficient of Determination is used to analyse how difference in one variable can be explained by a difference in a second variable. In statistics, the coefficient of determination is denoted as R^2 or r^2 and pronounced as R square. The Coefficient of Determination is one of the most important tools to statistics that is widely used in data analysis. The Coefficient of Determination is used to forecast or predict the possible outcomes. The value of Coefficient of Determination comes between 0 and 1. The higher the value of R^2 indicates the better the prediction. The formula of correlation coefficient is given below;

$$R^2 \equiv 1 - \frac{SS_{\rm res}}{SS_{\rm tot}}.$$

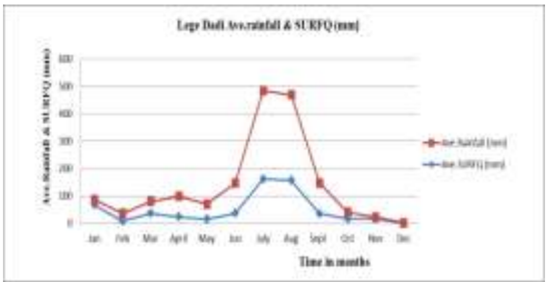
V RESULTS AND DISCUSSIONS

Climate Data Analysis: The average daily precipitation of the climate model result and the observed precipitation for the base period show that the SWAT2012 output tries to generate daily behaviours.



Rainfall and SURFQdistribution

In climate change impact assessment, the sequential and spatial precipitation characteristics are very important factors that affect hydrological cycle and runoff generation. Rainfall distribution over the Lege Dadi catchment is highly concentrated in the months of June to September whereas less concentration in the other months. The SWAT2012 model was assessed using the simulation results and the measured flow data. It was observed that the threshold area of 245.83 hectares having 23 HRUs along the main drainage lines within the watershed. Comparing observed and simulated values, the results were a better representation of the hydrological processes. An important part of the modelling process is to establish that the results simulated by the model are consistent with that of the physical system it represents. The calibration of hydrological models is necessary to get a good fit between observed and simulated variables. A model can only be applied with confidence once the model output has been tested for accuracy and correctness, i.e. verified, against observed data and where no observed data are available, to ensure that sensible values are generated.

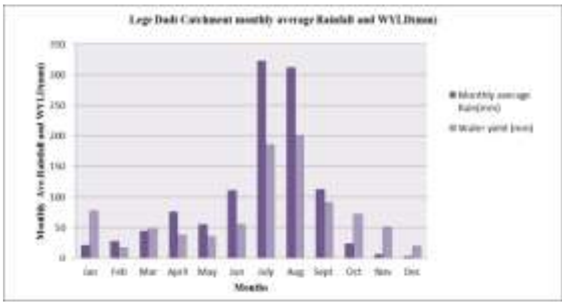


As shown from the above, monthly average precipitation based on nearest weather station indicates that the amount of rainfall between JUN to SEP are the maximum value because of wet season for the catchment and the other seasons are minimum values because of dry season for the catchment.

In addition to the other factors such as soil infiltration, land use/land cover change and slope-length, surface runoff is directly related to rainfall patterns. The maximum value of surface runoff occurred at rainy season and the minimum value at dry season as shown above the graph in fig 5.4. Increased variability in rainfall may decrease groundwater recharge in the catchment area because more frequent heavy rainfall will affects the infiltration capacity of the soil, thereby increasing surface runoff. However, increased rainfall variability may increase groundwater recharge, because only high-intensity rainfalls are able to infiltrate fast enough before evaporating, and aquifers are recharged mainly by inundations during floods.

Rain Fall Distribution and Water Yield

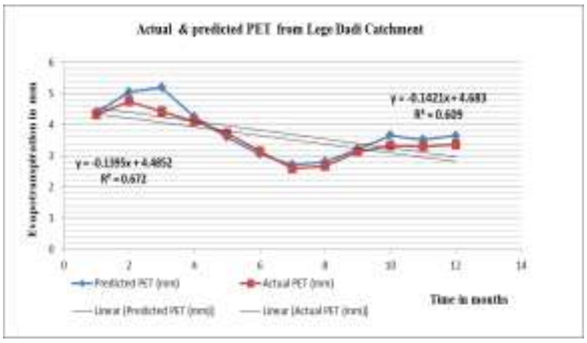
Monthly average water yield indicate that the average water yield produced by HRU in the catchment is varied and less in amount due to less rainfall in dry season, whereas water yield produced by HRU in the catchment is high due to high rainfall due to rainy-season. There are some reasons for the variability in the amount of water yield, such as land use/land cover change, soil type, surface runoff and ground water recharge. In addition to these factors rainfall distribution aspect, is greatest factor to decrease or increase the water yield in the watershed. See in fig.below.



VI HYDROLOGICAL ANALYSIS

PET of the Study Area

Evapotranspiration (ET) from the 23HRUs is important for sustainable water resources management in basin-sc ale. Evapotranspiration for the whole Watershed is calculated by using SWAT2012 automatically. The result of long term daily (monthly) average potential Evapotranspiration of the observed data and the outputs of SWAT2012 within the base period shows good agreement. It shows how good the climate model tries to simulate the phase of the observed data. Normally correlation coefficient doesn't show the magnitude of the difference but it shows the phases of the difference. As we can observe from the sample Figure (5.3) the potential Evapotranspiration at base period have with observed data, but for the months January to April and August to December is over estimated and May to July it is under estimated. Figure below represents actual Evapotranspiration which fluctuates from month to month. The maximum actual Evapotranspiration occurs in February while the minimum value of Evapotranspiration was found to be occurred in the month of July. From this figure, Lege Dadi water resource catchment evapotranspiration trend-line equation (***y=-0.1395x + 4.4852***) indicates that actual evapotranspiration is decreased by 0.1395 mm of water/month in the catchment. Similarly, for the predicted Evapotranspiration the trend line, y = -0.1421x + 4.683, indicates that predicted evapotranspiration is decreased by 0.1421mm of water/month in the catchment. Fluctuate of Evapotranspiration in Lege Dadi catchment is contributed by natural and anthropogenic activities and results in fluctuation of water balance in the catchment.

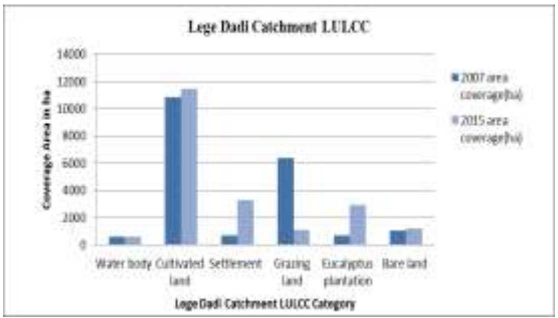


Land Use/Land Cover analysis (2007)

The land use/cover data obtained from Oromia Water Works Design and Supervision Enterprise was actual data over longer times which help in visualizing the change and its consequence impact. Accordingly, there are six major LULCC classes for the periods of 2007 which includes; Water body (man-made reservoir) (2.87%,), cultivated land (53.49%), settlement (3.55%), grazing land (31.45%), forest (Eucalyptus globules Plantation) (3.43%) and bare land (5.21%), in Watershed of Lege Dadi Reservoir.

Land Use/Land Cover analysis (2015)

Based on data collected from Oromia Water Works Design and Supervision Enterprise, the major LULCC classes for the period of 2015 are; Water body (2.94%), cultivated land (55.49%), Settlement (16.03%), grazing land (5.43%), Eucalyptus Plantation (14.15%) and bare land (5.96%), constituted large proportion of the study area.



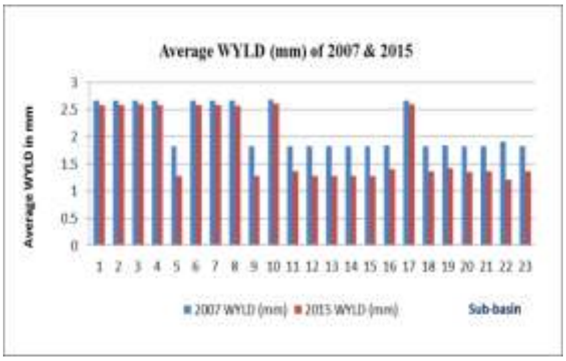
From this result a continuous and active LULC change was observed. The Change is the alteration of the physical character and various nutrient contents of the land. It could be both under the influence of human activities and nature, resulting in various kinds of impacts on the catchment. The daily activities of human being to secure social and economic needs interfere with nature and the land features that makes the land use/cover dynamic. In this study, the settlement and Eucalyptus plantation area were dramatically increased by 12.48 and 10.72% respectively. Grazing land was dramatically decreased by 26.02% within 8 years. These area coverage increment and decrement indicates that various human activities affect the land covers and increase surface erosion in the catchment.

Surface Runoff Responses to LULCC

Fig.5.12 represents that daily average runoff is greater in 2015 as comparison with 2007 in the watershed. The main reason of this variation may be the amount of precipitation varied in 2007 and 2015. However, cultivated land which is changed to crop land was continuously increased by the rate of 2.1% and Grazing land was decreased by 26.02%. The average daily runoff from 2007 to 2015 is changed from 48% to 52%. Monthly average surface runoff in the whole catchment is calculated by using SWAT2012 automatically.

Water Yield Responses to LULC Changes

Daily average water yield varies from years to year due to the different factors. Among these factors land use land cover change is the main factor either increase or decrease water yield in the watershed. The result indicates that the water yield is changed from 53% to 47 % in 2007 and 2015 respectively. In comparison LULC change in 2001 with LULC in 2015, cultivated land increased by the rate of 2.1%, grazing land changed into crop land by the rate of -26.02% and settlement changed by the rate of 12.48 % through 8 years (2007-2015). See fig. below;



Hydrological analysis and model performance

To analyze rainfall-runoff for the study area, the actual rainfall runoff data were divided into six periods; 1st actual data collected from 1996-2007 (60% of the period of data availability), 2nd actual data collected from 2008-2015 (40% of the available data), 3rd 60% of 8 years actual data from 2008-2013, 4th actual data from 2013-2015, 5th 1996-2010 i.e. 75% of the 20 years data and lastly the rest of the 20 years data (25% of total) were analyzed to compare and select the appropriate model for Lege Dadi water resources catchment. Then using the above mention data for 20 years monthly average rainfall-runoff data, the model is formulated using DATAFIT 9.1. Formulating 60%, 40%, 60% of 40% data, 3 years data, 75% and 25% of the 20 of the 20 years using DATAFIT 9.1, the model name, model equation and the following model performance values are calculated. Table below summarize the results gained from DATAFIT 9.1.

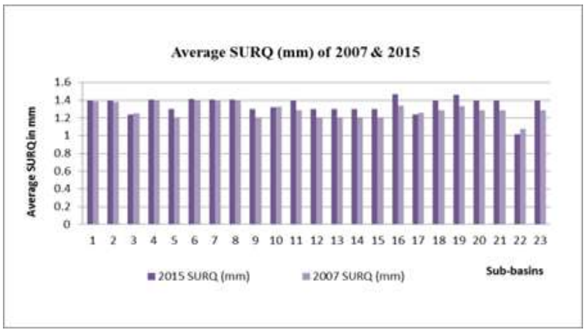


Table 1: Equations and variables for DATAFIT 9.1 model analysis

Year	Name of the Model	Model Equation
1996-2007	Tenth Order Polynomial	Y=a*x^10+b*x^9+c*x^8+d*x^7+e*x^6+f*x^5+g*x^4+h*x^3+i*x^2+j*x+k
2008-2015	Tenth Order Polynomial	Y= a*x^10+b*x^9+c*x^8+d*x^7+e*x^6+f*x^5+g*x^4+h*x^3+i*x^2+j*x+k
2008-2013	Ninth Order Polynomial	Y=a*x^9+b*x^8+c*x^7+d*x^6+e*x^5+f*x^4+g*x^3+h*x^2+i*x+j
2013-2015	Ninth Order Polynomial	Y=a*x^9+b*x^8+c*x^7+d*x^6+e*x^5+f*x^4+g*x^3+h*x^2+i*x+j
1996-2010	Tenth Order Polynomial	Y= a*x^10+b*x^9+c*x^8+d*x^7+e*x^6+f*x^5+g*x^4+h*x^3+i*x^2+j*x+k
2011-2015	Tenth Order Polynomial	Y=a*x^10+b*x^9+c*x^8+d*x^7+e*x^6+f*x^5+g*x^4+h*x^3+i*x^2+j*x+k

Table 2: R^2, d_1, d_1' and U values

Year	Model performance values			
	R²	d1	d1'	U
1996-2007	0.991	1	0.9501	0.0438
2008-2015	0.897	0.951	0.9997	0.0561
2008-2013	0.987	0.9992	0.9998	0.0511
2013-2015	0.993	0.9995	0.987	0.0171
1996-2010	0.995	0.9997	0.9974	0.0152
2011-2015	0.999	1	0.999	0.0103

VII CONCLUSIONS

Studies like this, which focus on likely future climate change impacts on water resources catchment at local level, are essential because of the fact that most water resources developments are carried out at local scale. Thus, assessing the level of impact is a prerequisite to propose adaptation measures that can reduce the damage and consider the problems for future developments implemented in the area. Hence, the impact of climate change on Lege Dadi water resources catchment using ArcSWAT2012 and DATAFIT 9.1 for rainfall-runoff analysis in the consistency analysis of model performance, were carried out to address the problems and help to analyze the trend for different parameters. The average daily precipitation of the climate model result and the observed precipitation for the base period of the Lege Dadi catchment show that the SWAT2012 output tries to generate daily average precipitation. The long term daily average potential Evapotranspiration of the observed data and SWAT generated data shows good agreement within the base period. Formulating 75% of original data and validating with 25% of the original data, the values R^2, d1, and d1'and U are highly improved towards the perfect value. Hence, the Tenth Order Polynomial model obtained with 75% data is selected to determine accurate monthly water yield for Lege Dadi river basin rainfall-runoff. In comparison of land use/land cover change in 2007 with LULC in 2015, cultivated land increased by the rate of 2.1%, grazing land changed into crop land by the rate of -26.02% and settlement changed by the rate of 12.48 % through 8 years (2008-2015).

REFERENCES

[1]. Uhlenbrook, S., Y. Mohamed, and A. S. Gragne. "Analyzing catchment behavior through catchment modeling in the Gilgel Abay, upper Blue Nile River basin, Ethiopia" Hydrology and Earth System Sciences 14, no. 10 (2010): 2153-2165.

[2]. Pandey, B.K., Gosain, A.K., Paul, G. and Khare, D., 2017. Climate change impact assessment on hydrology of a small watershed using semi-distributed model. Applied Water Science, 7(4), pp.2029-2041.

[3]. Tarekegn, D. and Tadege, A., 2006. Assessing the impact of climate change on the water resources of the Lake Tana sub-basin using the WATBAL model. Discuss.

[4]. Pandey, B.K., Gosain, A.K., Paul, G. and Khare, D., 2017. Climate change impact assessment on hydrology of a small watershed using semi-distributed model. Applied Water Science, 7(4), pp.2029-2041.

[5]. Yehun, D., 2009. Hydrological Modeling to Assess Climate Change Impact at Gilgel Abbay River, Lake Tana Basin (Doctoral dissertation, MSC Thesis degree at Lund University, Sweden).

[6]. Tadele, K. and Förch, G., 2007. Impact of land use/cover change on stream flow: the case of Hare River Watershed, Ethiopia. In Catchment and lake research, proceedings 2nd Lake Abaya research symposium (LARS), Arba Minch, Ethiopia.

[7]. Solomon, S. ed., 2007. Climate change 2007-the physical science basis: Working group I contribution to the fourth assessment report of the IPCC (Vol. 4). Cambridge university press.

[8]. Change, I.C., 2001. Impact. Adaptation and Vulnerability, p.563.

[9]. Conway, D. and Schipper, E.L.F., 2011. Adaptation to climate change in Africa: Challenges and opportunities identified from Ethiopia. Global Environmental Change, 21(1), pp.227-237.

[10]. Gleick, etal. 2002. Regional Hydrologic Consequences of Increases in Atmospheric CO2 and Other Trace Gases. Climate Change 10: 137-161

[11]. Mearns, etal, 2003: Guidelines for use of climate scenarios developed from Regional Climate Model experiments. Data Distribution Centre of the International Panel of Climate Change.

[12]. Katz, R.W. and B.G. Brown. 1992. Extreme Events in a Changing Climate: Variability is More Important than Averages. Climate Change 21:289-302.

[13]. Wilby, R.L. 1995, Simulation of precipitation by weather pattern and frontal analysis. Journal of Hydrology 173: 91–109.

[14]. Xu, C.Y., 1999. Operational testing of a water balance model for predicting climate change impacts. Agricultural and Forest Meteorology, 98, pp.295-304.

[15]. Arnold, J.G. and Fohrer, N., 2005. SWAT2000: current capabilities and research opportunities in applied watershed modeling. Hydrological processes, 19(3)

[16]. Beven, K. and Freer, J., 2001. Equifinality, data assimilation, and uncertainty estimation in mechanistic modelling of complex environmental systems using the GLUE methodology. *Journal of hydrology*, *249*(1-4), pp.11-29

[17]. Conway D. 2000, The Climate and Hydrology of the Upper Blue Nile River, School of Development Studies, University of East Anglia, Norwich NR4 7U,The Geographical Journal, Vol. 166, 2000

[18]. Aleix S.C, Juan B. V, Javier G.P, Kate B, Luis J.M, Thomas. M (2007), Modelling Climate Change Impacts and Uncertainty on the Hydrology of a Riparian System: Journal of Hydrology

[19]. Virtanen, P., Palmujoki, E. and Gemechu, D.T., 2011. Global climate policies, local institutions and food security in a pastoral society in Ethiopia. Consilience, (5), pp.96-118.

[20]. Fujihara, Y., Tanaka, K., Watanabe, T., Nagano, T. and Kojiri, T., 2008. Assessing the impacts of climate change on the water resources of the Seyhan River Basin in Turkey: Use of dynamically downscaled data for hydrologic simulations. Journal of Hydrology, 353(1-2), pp.33-48.

[21]. Tambe, S., Kharel, G., Arrawatia, M.L., Kulkarni, H., Mahamuni, K. and Ganeriwala, A.K., 2012. Reviving dying springs: climate change adaptation experiments from the Sikkim Himalaya. Mountain Research and Development, 32(1), pp.62-72.

[22]. Nuñez, T.A., Lawler, J.J., McRae, B.H., PIERCE, D., Krosby, M.B., Kavanagh, D.M., Singleton, P.H. and Tewksbury, J.J., 2013. Connectivity planning to address climate change. Conservation Biology, 27(2), pp.407-416.

[23]. Liu, L., Liu, Z., Ren, X., Fischer, T. and Xu, Y., 2011. Hydrological impacts of climate change in the Yellow River Basin for the 21st century using hydrological model and statistical downscaling model. Quaternary International, 244(2), pp.211-220.

[24]. Penner, J.E., 1999. Aviation and the global atmosphere: a special report of the Intergovernmental Panel on Climate Change. Cambridge University Press.

[25]. Winchell, M., R. Srinivasan, M. Di Luzio, and J. G. Arnold. "ArcSWAT interface for SWAT2005–User's Guide. Blackland Research Center, Texas Agricultural Experiment Station and Grassland." Soil and Water Research Laboratory, USDA Agricultural Research Service, Temple, Texas (2007).

[26]. Wang, Sufen, Shaozhong Kang, Lu Zhang, and Fusheng Li. "Modeling hydrological response to different land‐ use and climate change scenarios in the Zamu River basin of northwest China." Hydrological Processes 22, no. 14 (2008)

[27]. Schuol, J., and K. C. Abbaspour. "A daily weather generator for predicting rainfall and maximum–minimum temperature using monthly statistics based on a half-degree climate grid." Ecol. Model 201 (2007): 301-311.

Wakuma Midaksa Kajela. "Assessment of Climate Change Impacts on Lege Dadi Water Resources Catchment, Ethiopia." International Journal of Computational Engineering Research (IJCER), vol. 08, no. 05, 2018, pp. 33-41.