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STUDY ON IMPACT ASSESSMENT OF CLIMATE CHANGE ON WATERSHED USING HYDROLOGICAL MODEL (SWAT)

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"STUDY ON IMPACT ASSESSMENT OF CLIMATE CHANGE ON WATERSHED USING HYDROLOGICAL MODEL (SWAT)"

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ABSTRACT

Water being most basic necessity for sustainability of the life on globe due to intensification in the population the distribution and sharing of water resources have become added problematical issue. With the intensification of water demand due to industrialization, agricultural practices and domestic need it is important to manage the water resources in an optimum way. With this viewpoint, hydrological modeling shows vital part which can performance as a significant tool for the assessment of water at the basin scale. In the present study, the Soil and water assessment tool (SWAT) have been adopted in assessing the climate change on Malaprabha sub-Basin. The model has been executed and calibration is carried out from the year 1988-1998 and validation is done from the year 1999- 2002 due to unsatisfactory R^2 and NSE values. SWAT-CUP (SUFI-2) is a semi-automated program has been employed in calibration and validation purpose. This study provides an ideology of extent of variation that may be caused in the forthcoming years in study Area and these data can be employed in designing the water structures, watershed management, and crop pattern adaptability.

Keywords: SWAT-CUP, Basin Scale, watershed management, crop pattern adaptability, Malaprabha sub-basin.

1. INTRODUCTION

Water plays significant part in shaping the ecosystem and is a prime requirement for the sustainability of the human on the earth. Water is a very noteworthy natural resources and its management has become the crucial challenge facing today (Nagraj et al. 2016). As Global warming produced by human actions has developed an increasing worry all around the globe and has a foremost impact on world-wide mean temperature and sea level (Chen et al. 2014; Kusangaya et al. 2014). The world is observing increased frequency of floods and scarcities. Therefore, it is very significant to examine the influence of climate variation on hydrology, mainly on a basin scale (Thompson et al. 2013, Zhang et al. 2014). The impact of climate alteration is extremely experienced in the Asia- Pacific province which is the greatest disaster-prone region on earth. It is described that sea level upsurge is an extreme concern, with 8 of the 10 countries with the highest extent of people habiting in low-lying coastal sectors (Loo et al. 2014). Several countries in Asia are now suffering more frequent floods and droughts over the few decades as an effect of climate alteration and human developments (Hansson et al. 2008). This motto of the study is to evaluate the impact or change of surface water in the upcoming years with respect to the climate change such as precipitation and temperature.

2. STUDY AREA AND DESCRIPTION

Malaprabha sub-basin (shown in figure 1) arises at the Western Ghats of Belagavi District, Karnataka at an attitude of 792.4m at kanakumbi village which of 16 kms away from the jamboti village, khanpur taluk, Belagavi district of Karnataka and the sub-basin entirely lies in Karnataka. It is a tributary of the Krishna basin and accounts 5% of Krishna basin. Study Region lies between 15° 45' N and 16°25' N and 74°00'E and 75°55' E and receives average of 766mm rainfall annually. Malaprabha sub-basin has total of 11,549km^2 catchment area and located in semi-arid region in India, rainfall of this area is seasonal (Monsoon) resulting need for reservoir to meet the agricultural and drinking demands of the area Malaprabha sub-basin is the major source for the Renuka Sagara dam which is located at the navilatirtha of Belagavi district and dam facilitates the agricultural water demand for about 2,000km^2 and drinking water demand for about 3 million people and more in four districts.

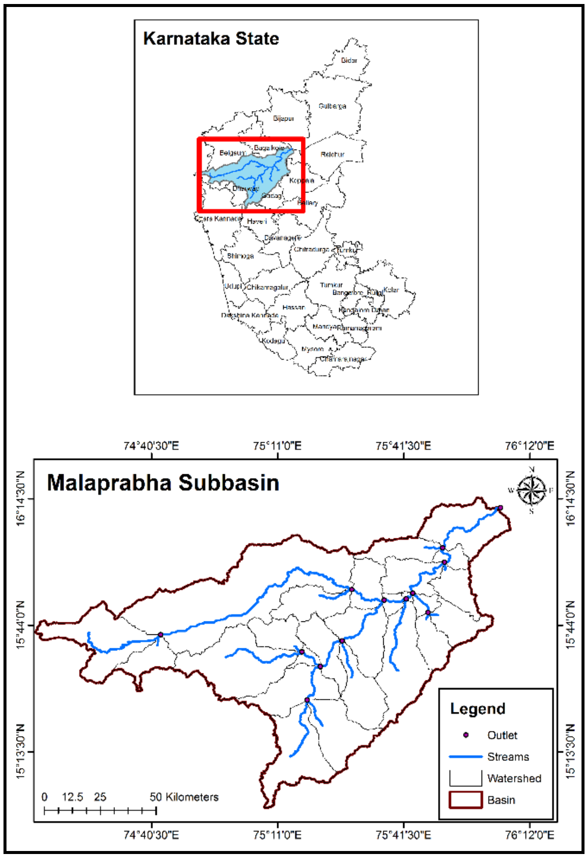

Figure 1: Map of Malaprabha Sub-basin

3. METHODOLOGY

3.1 Hydrological modelling

Many researchers in the past have successfully applied geostatistics for water quality modelling (Jat and Serre, 2016; Jat and Serre 2018) however hydrological models are more common for big hydrological structure where no data are available. Hydrological models can be labelled as shortened mathematical demos of a real hydrological structure mainly river basin or a portion of it. These models are foremost attires for hydrologist applicable for various resolves for example water resource management etc. Hydrological models have been categorised differently pointing to make the models certainly understandable and can be functioned effortlessly. Generally, these models are labelled by using various terms from 3 prime categories such as simulation basis, spatial representation and temporal representation. Further these are been fragmented into subcategories.

SWAT is a semi-distributed watershed model programed by the Agricultural Research Service of the United States Department of Agriculture (USDA) have been adopted for the study. SWAT requires a substantial amount of information and parameters for execution and calibration. The foremost use of SWAT is the identification of runoff (Williams and Arnold 1993; Arnold et al. 1998). Due to highly documentation it is easy in understanding and application. Usually SWAT runs by opting a single watershed, and the isolating it into various sub-basins. These sub-basins are then broken into various unique land use, soil and slope combinations which is known as Hydrological Response unit (HRUs).

The hydrologic cycle as simulated by SWAT is oriented on the water balance equation,

$$S_{wt} = S_{wo} + \sum_{/-1}^{t} \left(R_{day} - Q_{surf} - E_a - W_{seep} - Q_{gw} \right) \qquad Eq.(1)$$

Where
S_{wt} is the final soil water content (mm),
S_{wo} is the initial soil water content on day (mm),
t is the time (days),
R_{day} is the amount of precipitation on day (mm),
Q_{surf} is the amount of surface runoff on day (mm),
E_a is the amount of evapotranspiration on day (mm),
W_{seep} is the amount of water entering vadose zone from the soil profile on day (mm),
Q_{gw} is the amount of return flow on day (mm).

3.2 Data Required

The various kinds of datasets and its source are used in this study (shown in below table 1) are DEM, Land use land cover, Soil, meteorological data, RCM data and Observed data. To setup and execute SWAT model these data are prepared accordingly. Firstly, the DEM data is used to delineate the watershed, and it is obtained from Cartosat 1 Ver. 3R1 which is of 32m resolution, the maximum and minimum elevation ranges from 360m to 680m in the Malaprabha sub basin. The Land use land cover data for the study area obtained from Global land use land cover facility, soil data obtained from Food and Agricultural Organization, land use land cover and soil data are used for Hydrologic Response Unit (HRU) analysis during modelling. The precipitation (0.5x0.5deg.) and temperature (1x1deg.) gridded data are obtained from IMD, Pune. Impact assessment for the study area carried out using RCM data which is of 0.5x0.5deg. resolution.

Table 1: Data and its sources

Sl. No.	Data	Source
1.	Digital Elevation Model (DEM)	Cartosat 1 Ver. 3R1 (32m resolution)
2.	Land use land cover	Global land use land cover
3.	Soil map	Food and agricultural organization (FAO)
4.	Meteorological data (Precipitation, Temperature)	India Meteorological Department (IMD, Pune)

5.	Regional Climate Model (RCM) data	Indian Institute of Tropical Meteorology (IITM, Pune)
6.	Observed discharge data	Water Resource Information System, India

3.2.1 Weather data

WCRP developed Coordinated Regional Climate Downscaling Experiment (CORDEX) for the regions of south Asia is delivered to enhance studies concerning climate variation impacts at regional scale. The dataset comprises dynamically downscaled projections of 10 scenarios and models for which day-to-day scenarios were formed and spread under CMIP5.CORDEX dataset contains downscaled climate scenarios which is been derived from the Atmosphere-Ocean coupled General Circulation Model (AOGCM).CORDEX RCM outputs of South Asia are being shared by modelling partners and published by IITM (Indian Institute of Tropical Meteorology).Future projection data are been taken from the IITM website from the year 2041 to 2060. RCM Grid have been laid over study area. The precipitation and temperature data have been extracted from datasets using ArcMap 10.1. Fig 5 shows the CORDEX RCM grid, the grid points inside the Sub-basin are opted for the extraction purpose.

4. RESULTS AND DISCUSSIONS

4.1 SWAT Calibration and Validation

The monthly discharge output from the model (Simulated) have been compared with the monthly observed discharge of study area and found to be not satisfactory. Hence the calibration is required. The variance among the simulated and observed discharge observed by coefficient determination R^2. Desirable limits of R^2 (>0.6 & <1.0) & NSE (>0.5 & <1.0). Before calibration correlation coefficient (R^2) and Nash Sutcliffe Coefficient (NSE) value are found to be 0.5352 and 0.7383 respectively. As R^2 value doesn't fit into desirable limit hence calibration and validation is carried out.

4.1.2 Calibration

SWAT_CUP (SUFI-2) is used for calibration and validation of the model. Calibration is an art of matching up stimulated and observed discharge data. Calibration has been carried out from the year 1988 to 1998(11 years). Initially 4 basic parameters are preloaded in the SWAT_CUP. Based on literature and understanding parameters are added up. The Parameters used for the calibration and its ranges are given in the table 2. With the parameters added, software is run for various number of iteration with 300 simulations for each iteration. The parameter values will be fitted and further these parameter ranges are imported for the next iteration until the desired limits of R^2 and NSE is obtained. The desirable values of R^2 and NSE are achieved and model is initiate to be satisfactory. Figure 2 shows the comparison of simulated and observed discharge during calibration and figure 3 shows the scattered plot observed and simulated during calibration. During calibration period the R^2 value is found to be 0.67 and NSE values is found to be 0.867.

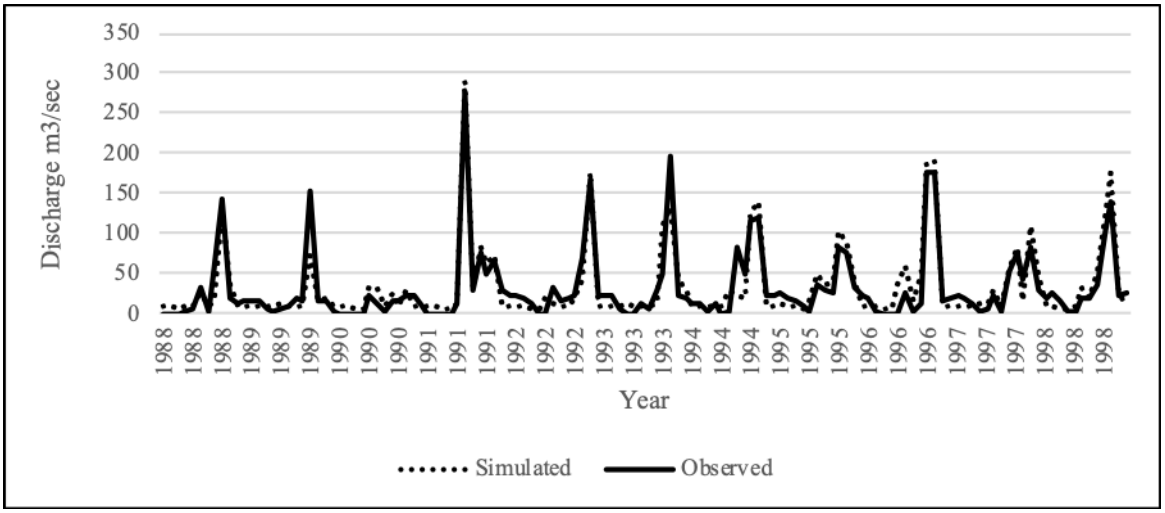

Figure 2: Comparison of simulated and observed discharge during calibration

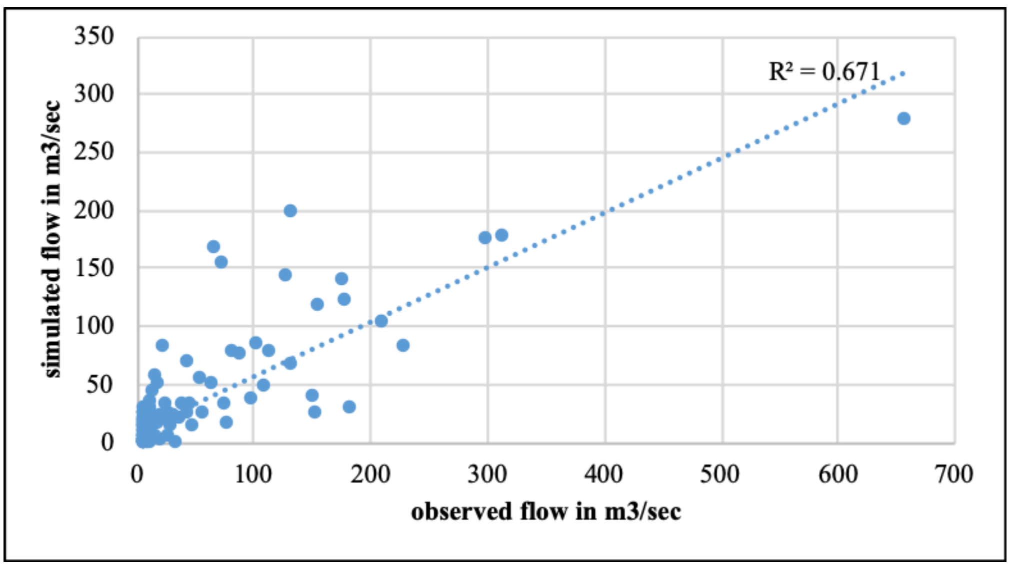

Figure 3: Scattered graph of simulated and observed discharge during Calibration

Table 2: Parameters Ranges during Calibration

Sl. No.	Parameter	Fitted value	Min. value	Max. value
1	R_CN2.mgt	-0.252	-0.3216	0.0840
2	V_ALPHA-BF.gw	1.014	0.8000	1.2760
3	V_GW_DELAY.gw	28.015	12.6310	33.7056
4	V_GWQMN.gw	1759.000	1300.0000	3000.0000

5	R_CH_K2.rte	3.792	2.6025	3.804069
6	R_CH_N2.rte	0.0021	-0.0033	0.006259
7	R_EPCO.bsn	0.944	0.87733	1.242
8	R_ESCO.bsn	0.2599	0.12059	0.3206
9	R_GW_REVAP.gw	1.1279	0.8690	1.2442
10	R_RCHRG_DP.gw	0.1372	0.07190	0.3831
11	R_REVAPMN.gw	43.0000	40.0000	100.0000
12	R_SOL_AWC.sol	-0.3458	-0.5563	-0.1435
13	R_SOL_K.sol	0.25	0.2500	0.2500
14	R_SURLAG.bsn	6.3904	5.4125	7.6867

4.1.3 Validation

Validation is the procedure of checking whether the calibration has been fitted properly for the next set of years. SWAT-CUP does not have other procedure for the validation purpose, it is carried out by inputting the same set of parameters and their ranges which are used during the calibration. The number of simulation given during the calibration period should be same during the validation process. The values of R^2 and NSE are found to be 0.7092 and 0.9346 respectively and as the values fit into the desirable limit the model is satisfactory and the further analysis can be carried out. Figure 4 shows the comparison of simulated and observed discharge and figure 5 shows the scattered plot for observed and simulated discharge during validation.

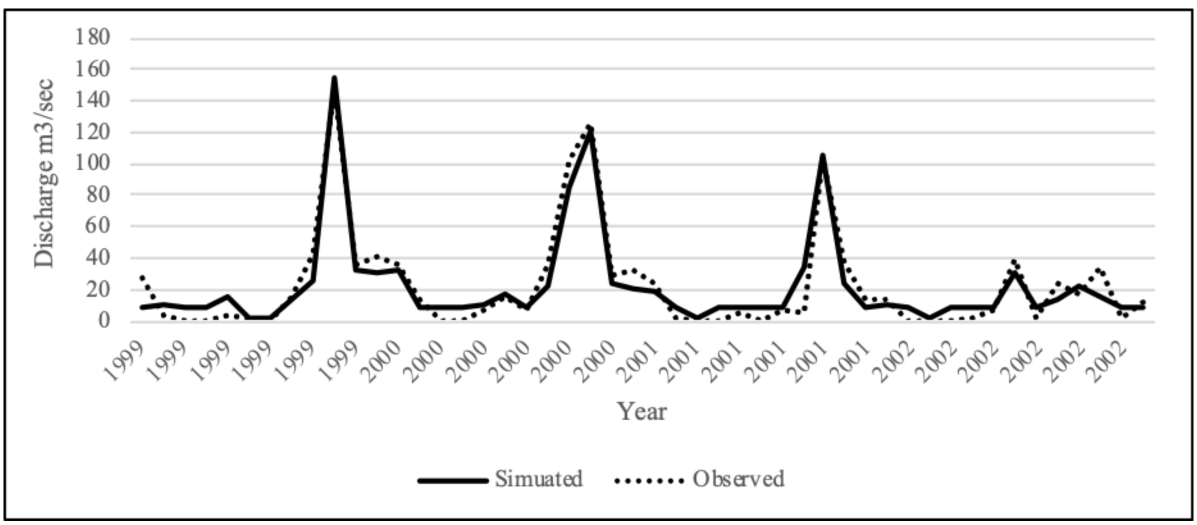

Figure 4: Comparison of simulated and observed discharge during Validation

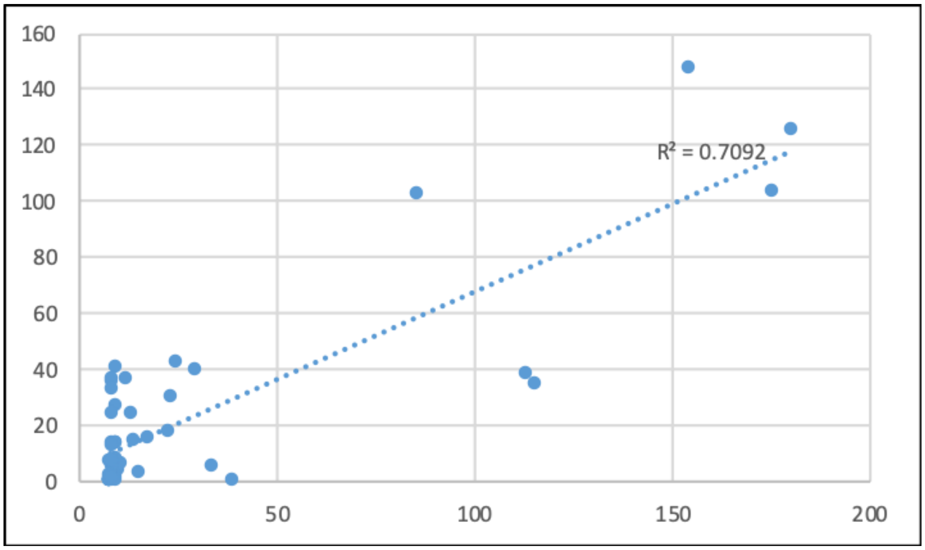

Figure 5: Scattered graph of simulated and observed discharge during validation

4.2 Climate Change Analysis

The model was run from the year 1985 to 2005. As 3 years have been given as warmup period during the execution. The output is obtained from the year 1988 to 2005 (18years). From the year 1988 to 2002 (15 years) results are considered as baseline scenario for the evaluation of future predicted surface runoff, Temperature and Precipitation. For the future prediction as revealed earlier CORDEX data been extracted from the year 2041 to 2060 (20 years) as each dataset are of 10 years. For the analysis of impact, future predicted data from year 2046 to 2060 (15 years) have been employed as future scenario.

4.2.1 Precipitation

Precipitation can be defined as any water constituents falling from atmosphere to earth surface. Precipitation includes Rainfall, snow, hail and sleet etc. Precipitation plays a vital role and has direct influence on the surface runoff. Surface runoff is accommodated by the subsurface which is the main reason for the flow of surface runoff when the rainfall is less observed in the region. Increase in precipitation increases surface runoff and wise versa. The results table 3 shows that in the year 2047 highest precipitation of 3614.9mm maybe be observed and lowest precipitation of 1464.3 mm may be observed in the year 2058.

Table 3: Comparison of Baseline scenario and future scenario for Precipitation

Baseline Scenario		**Future Scenario**		**Change In mm**
Year	Precipitation(mm)	Year	Precipitation(mm)	
1988	472.6	2046	1592.2	1119.6
1989	380.6	2047	3614.9	3234.3
1990	436.8	2048	3495.1	3058.3
1991	1051.3	2049	2196.4	1145.1
1992	417.7	2050	2396.3	1978.6
1993	629.9	2051	1898.3	1268.4
1994	538.1	2052	1884	1345.9

1995	738.4	2053	2291.8	1553.4
1996	821.5	2054	2649.4	1827.9
1997	667.4	2055	1740.1	1072.7
1998	803.5	2056	2734.1	1930.6
1999	572.6	2057	2318.2	1745.6
2000	554.1	2058	1464.3	910.2
2001	541.5	2059	2402.3	1860.8
2002	454.9	2060	2568	2113.1
AVG	**605.3**	**AVG**	**2349.6**	**1744.3**

4.2.2 Temperature

A simple definition for the temperature can be given as "The degree or intensity of heat present in a substance or object". Temperature also performances as an important part in surface runoff and it has direct relationship. As the temperature increases the Evapo-transpiration process will also tend to increase causing the decrease in the surface runoff as the losses by the evapotranspiration happens but warmer atmosphere can grasp additional moisture producing higher precipitation. From the given table 4 below in the forthcoming years there maybe increase of the atmosphere temperature by an average of 1. 670C. From the future predicted data, we would come to know that the highest average temperature is observed in the year 2050 of 28.03^{0}c and lowest in the year 2052 of 27.14^{0}C.

Table 4: Comparison of Baseline scenario and future scenario for average Temperature

Baseline Scenario		**Future Scenario**		**Change** (degrees Celsius)
Year	Average Temperature (degrees Celsius)	Year	Average Temperature (degrees Celsius)	
1988	26.09	2046	27.46	1.37
1989	25.91	2047	27.98	2.07
1990	25.69	2048	27.87	2.19
1991	26.02	2049	27.79	1.77
1992	25.85	2050	28.03	2.18
1993	25.66	2051	27.63	1.97
1994	25.92	2052	27.41	1.49
1995	26.21	2053	27.71	1.50
1996	26.02	2054	27.79	1.77
1997	26.03	2055	27.63	1.59
1998	26.52	2056	27.78	1.26
1999	25.93	2057	27.68	1.74
2000	25.94	2058	27.60	1.67
2001	26.12	2059	27.88	1.76
2002	26.55	2060	27.28	0.73
Average	**26.03**	**Average**	**27.70**	**1.67**

4.2.3 Surface Runoff

Surface Runoff can be termed as the "portion of the water cycle that runs over land as surface water without being percolated into groundwater. Runoff is that quantity of the precipitation that appears in unrestrained surface streams, rivers, lakes and ponds". The estimation of the flow that occurs in the upcoming years helps in designing the water structures. From the future scenario highest surface Runoff can be experienced in the year 2047 with 11600.51 m^3/sec and lowest among is observed in the year 2058 with 4233.989 m^3/sec. The table 5 shows an average change in surface flow for Baseline scenario and Future Scenario is observed to be 6456.78 m^3/sec.

Table 5: Comparison of Baseline scenario and future scenario for Surface Runoff

Baseline Scenario		Future Scenario		Change
Year	Surface Runoff In m^3/sec	Year	Surface Runoff In m^3/sec	
1988	280.85	2046	880.038	599.188
1989	296.96	2047	2040.51	1743.55
1990	241.84	2048	1972.61	1730.77
1991	620.89	2049	1262.62	641.73
1992	417.46	2050	1320.29	902.83
1993	408.17	2051	1060.79	652.62
1994	468.18	2052	1027.88	559.7
1995	343.09	2053	1348.78	1005.69
1996	498.94	2054	1580.9	1081.96
1997	383.75	2055	690.96	307.21
1998	472.43	2056	1508.85	1036.42
1999	331.81	2057	1297.64	965.83
2000	431.54	2058	780.98	349.44
2001	223.49	2059	1328.46	1104.97
2002	151.08	2060	1392.01	1240.93
Avg	**371.365**	**Avg**	**1299.55**	**928.67**

5. CONCLUSION

Global warming and climate change is a critical issue all over the world as it comprises a negative impact on the ecology and human life. This study was conducted to understand the modification that may happen on surface runoff, temperature and precipitation in the forthcoming years at Malaprabha Sub-Basin. The model was executed for the year 1985 to 2005 and output from the year 1988 to 2002 have utilised for the analysis and is considered as Baseline Scenario. CORDEX Dataset have been adopted for the future forecast data from the 2046 to 2060 as Future scenario. The results found from the Model states that there an average increase of 1.67^{0}C temperature for the future period of time. The highest Average temperature in future scenario is observed in the year 2050 of 28.03^{0}c and highest temperature observed during baseline period is 22.55^{0}c. There is a significant increase in precipitation during future scenario compared to Baseline scenario. The highest precipitation in the future scenario is observed to be 3614.9 mm in the year 2047 and during the baseline period 1051.3 mm in the year 1991 is observed. There is a drastic variation in the surface runoff during future scenario when matched to the Baseline scenario. The highest surface runoff during future scenario is witnessed in the year 2047 with 11600.51 m^3/sec and lowest among is detected in the year 2058 with 4233.989 m^3/sec. This study gives an ideology and extent of changes that may cause on the watershed due to climate change. The analysis done can be utilized in the designing and construction of the water structures in the Sub-basin, watershed management programs, adoption of alternate crop patterns.

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