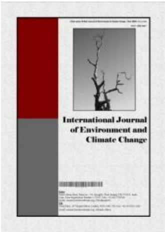

International Journal of Environment and Climate Change

12(10): 305-313, 2022; Article no.IJECC.86350
ISSN: 2581-8627
(Past name: British Journal of Environment & Climate Change, Past ISSN: 2231–4784)

Impacts of Future Climate and Land use Change on Water Yield in Arpa Catchment

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Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

Article Information

DOI: 10.9734/IJECC/2022/v12i1030799

Open Peer Review History:
This journal follows the Advanced Open Peer Review policy. Identity of the Reviewers, Editor(s) and additional Reviewers, peer review comments, different versions of the manuscript, comments of the editors, etc are available here: https://www.sdiarticle5.com/review-history/86350

Original Research Article

Received 24 February 2022
Accepted 03 May 2022
Published 07 May 2022

ABSTRACT

Studying the interaction between hydrology, land use, and climate change is necessary to support sustainable water resources management. In this study, we assessed the effects of both land use and predicted climate change on the Arpa Catchment water yield using the ArcSWAT model. The influence of changing climate on water yield was evaluated for different emission scenarios using CMIP6 Global Climate Models (GCM). Three GCM namely BCC-CSM2- MR, EC-Earth3-Veg and NorESM2-LM were ensemble and used for this study. Two 'Shared Socioeconomic Pathways' (SSP) scenarios (SSP.2_4.5, and SSP.5_8.5) were used for future climate prediction in the current study area. Land use land cover, meteorology and soil type data used as inputs to analyze the spatial and temporal pattern of water yield in the Arpa catchment from 1990 to 2020 and the impact of land use change on water yield in the basin simulated with ArcSWAT Model. Water yield compare to baseline scenario (1990) increased by 98.36 mm (18.48%) in decadal year 2000, increased by 144.51 mm (27.15%) in year 2010 and in decadal year 2020 water yield increased by 154.20 mm (28.98%). Climatic scenario (SSP2_4.5 and SSP5_8.5) changes in water components were simulated with ArcSWAT model. Model was run for three future time slices i.e. Near future (2030s), Mid future (2060s), and Far future (2090s). Water yield with reference to baseline period (646.02 mm) increased by 71.69% under SSP2_4.5 during 2090s. Similarly, under SSP5_8.5 water yield increased by 106.87% for the far future (2090s).

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Keywords: Water yield; land use land cover; Arpa catchment; global climate models and climate change.

1. INTRODUCTION

The hydrological processes in the watershed are greatly affected by land use/cover (LULC) and climate interchange. For water resource management, understanding influence of the changes in on the distribution output is essential. Changes in LULC have a direct effect on ecosystems and the favor they provide, usually water yield. Water yield is the entire amount of water that flow on the ground in a given area. The regular distribution of water yield is critical to the hydrological balance, because a decrease can lead to water scarcity, while a sharp increase can lead to flooding (Suxiao et al.,2018) [1].

Climate and land use/land cover (LULC) changes have a significant impact on water yield [2,3]. Climate change affects precipitation and evapotranspiration (solar radiation, temperature, and precipitation) in watershed [4], affecting the regional water cycle, infiltration processes, water holding model, and hence water yield [5].

Remote sensing (RS) and Geographic Information Systems (GIS) have long been recognised as important and powerful tools for assessing LULC changes at different spatial scales [6]. To extract evidence from remotely sensed data, several change detection techniques and image analyses have 3 been used [7,8]. Geographic Information Systems, on the other hand, combines Remote sensing data to produce a clear understanding of LULC modelling [9]. Remote sensing and Geographic Information Systems have proved to be very useful tool for the detection of LULC patterns [7,10]; Chen et al., [11]; Nunez et al., [12]; Rahman et al., [13]. Moreover, the combined use of satellite RS and GIS has proved to be a robust and cost-effective method for monitoring LULC changes Lambin et al., [14]; Poyatos et al., [15]; Herold et al., [16]; Hazarika et al., [17]. With the development of RS and GIS techniques, LULC mapping has become a detailed and useful tool for improving the selection of areas for various uses ((Selcuk et al., (2003); Rawart et al., [18]; Rawart et al., [19])).

The Coupled Model Intercomparison Project's sixth phase (CMIP6) is the most recent modelling effort for general circulation models to simulate and project various aspects of climate change. Many of the CMIP6 participating General Circulation Models (GCMs) provide archived output that can be used to calculate effective climate sensitivity (ECS) and forecast future temperature change based on emissions scenarios from several Shared Socioeconomic Pathways(SSPs) [20]. Future GCM climate projections of temperature and precipitation under various climate scenarios were examined in this study, have been used as inputs to hydrological watershed models (SWAT) to simulate the response of water yield to the effects of changing climate.

2. MATERIALS AND METHODS

2.1 The Study Area

The Arpa River is a major tributary of the Mahanadi River, which provides irrigation to the state of Chhattisgarh. The watershed of Arpa has been chosen for this study. The study will be conducted at the Ghatora gauging station in the Arpa basin, which has long-term data on climate, hydrology, and land use. Khondari Khongsara, near Pendra (tehsil) in Bilaspur district, is the source of the Arpa river. Arpa is around 147 kilometers long. The river Kharang is an important tributary of the Arpa. The water flows from north-west to south direction. The study area lies between $81^0$47’12” E to 8 $82^0$14’48” E and 21^0 49’29” N to 22^0 45’27” N with a latitude ranges from 171 - 1076 m above mean sea level (MSL). The total catchment area for the Arpa river is 3192.28 sqkm. The climate of the Arpa watershed is sub-tropical, with an average annual rainfall of 1350 mm, with a maximum temperature of 44.360°C in the summer and a minimum temperature of 16.60°C in the winter. Location map of study area shown in Fig. 1.

2.2 Data Processing for the Model

The meteorological data have been processed using standard methods for preparation of daily rainfall (*.pcp) and temperature (maximum and minimum) (*.tmp) input file following the recommended format in the database (.txt/ .dbf format). Some of the data like relative humidity, solar radiation and wind velocity were prepared in *.wgn file.

Various maps, such as DEMs, soil maps, and land use/land cover maps, were generated with ArcGIS 10.5 and the data from each map was entered as an attribute value in the GIS to create

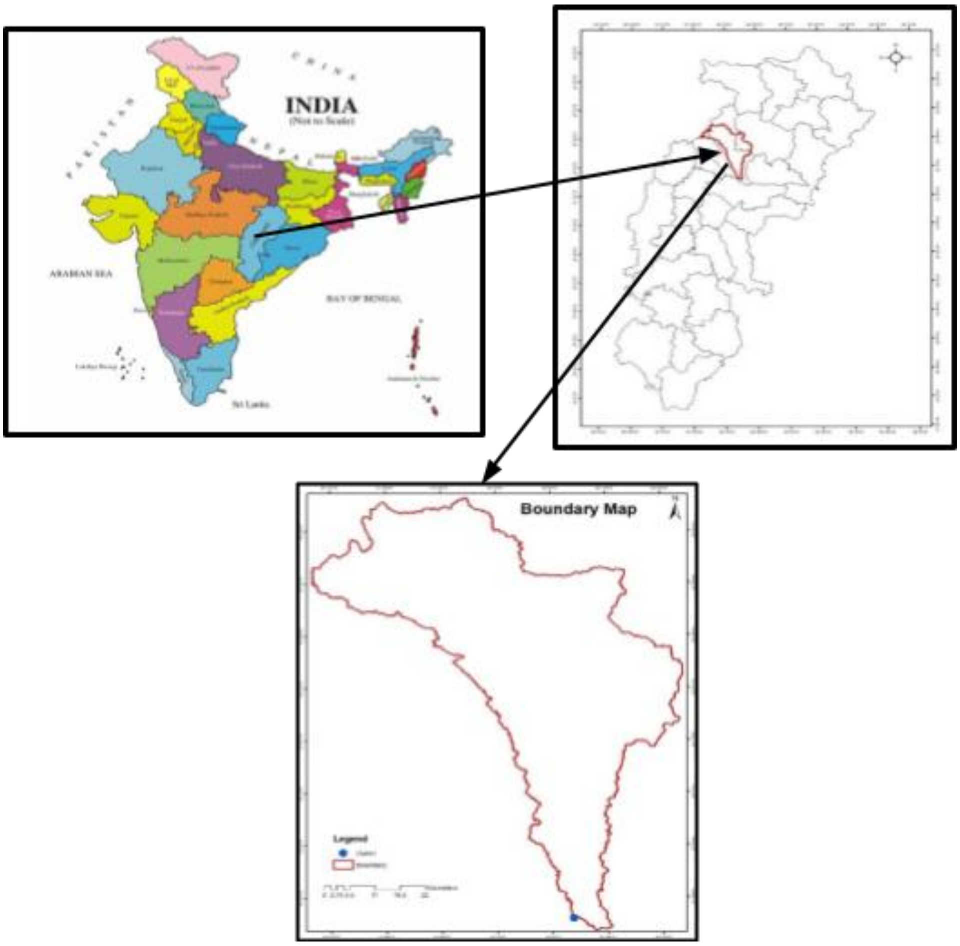

Fig. 1. Location map of Arpa catchment

the database for a specific themed map. The ArcSWAT model employed the attribute values associated with each thematic map to extract various information and parameters about the study area.

2.3 Land Use/ Land Cover Change

The cloud free LANDSAT imagery pertaining to year 1990, 2000, 2010 and 2020 which covers the study area was downloaded from Earth Explorer website. The land use/cover map of the study area was generated using ERDAS IMAGINE 2015. Most common land use classification method, the supervised classification was used in this study.

2.4 Global Climate Model

Global climate model data were downloaded from Zenedo, CERN Data Centre (2021)0. These model data consist biased corrected data of precipitation, maximum temperature, and minimum temperature data. Each model includes five scenarios (historical, ssp126, ssp245, ssp370, and ssp585). Out of this five scenarios taken two scenario for water yield analysis. Three GCM namely BCC-CSM2- MR, EC-Earth3-Veg and NorESM2-LM were ensemble and used for this study.

Climate forcing in the SWAT model was based on daily precipitation, maximum and minimum temperature data for the baseline climate and forecast years (2020-2100). To compare changes in hydrological variables to the baseline climate, the SWAT model was run for three future time slices (2030s, 2060s, and 2090s) and for the baseline climate. Daily time series values of the three selected climate models were averaged to obtain one dataset (ensemble). These climate data were used as climate input in SWAT model to obtain various other hydrological variables under baseline as well as future periods.

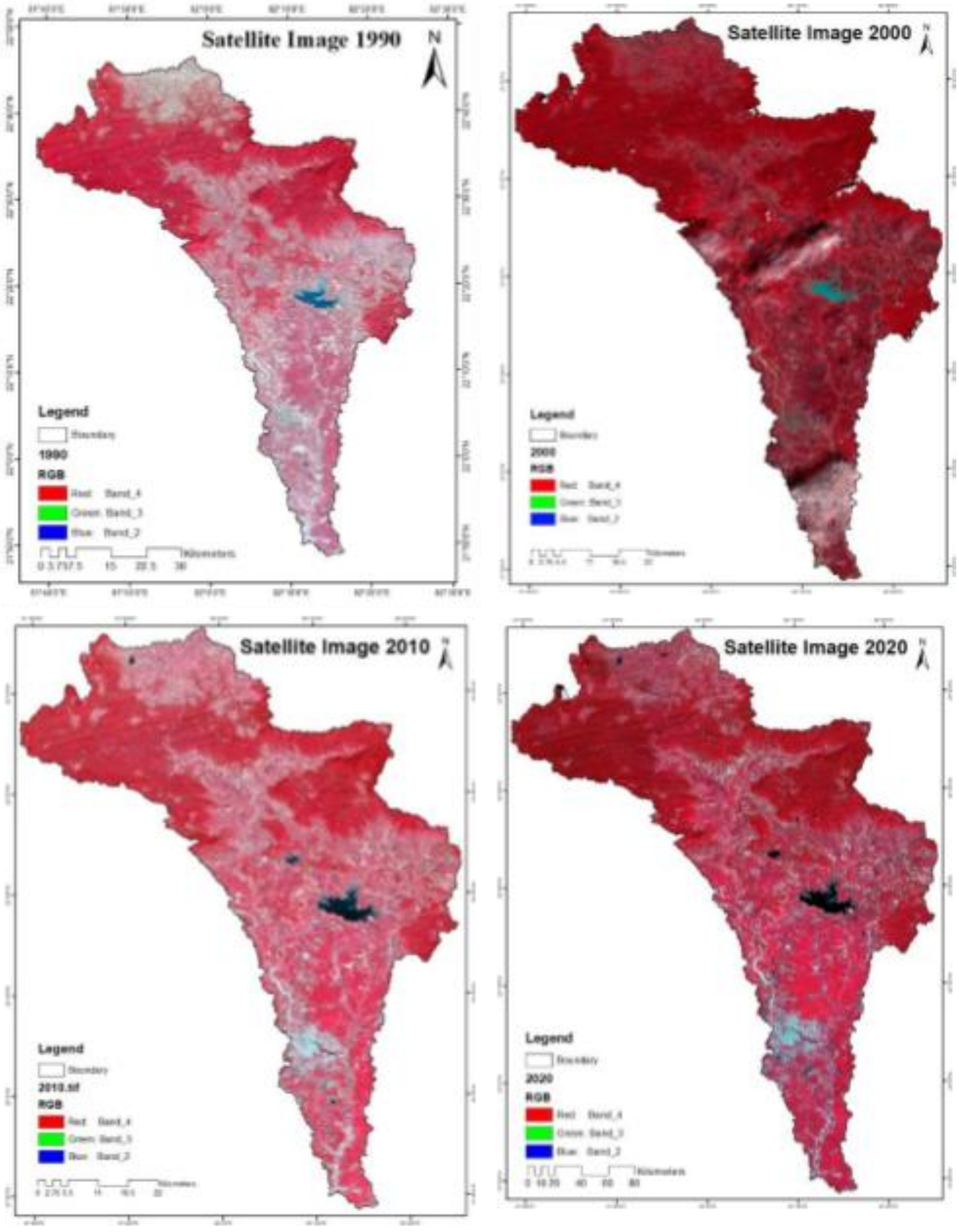

Fig. 2. Satellite imagery of study area

3. RESULTS AND DISCUSSION

3.1 Land use/ Land Cover Change Impact on Water Yield

The land use/cover map of the study area was generated using ERDAS IMAGINE 2015. Most common land use classification method, the supervised classification was used in this study. The decadal year (1990, 2000, 2010 and 2020) land-use maps were classified into ten classes. Water yield compare to baseline scenario increased by 98.36 mm (18.48%) in decadal year 2000, increased by 144.51 mm (27.15%) in year 2010 and in decadal year 2020 water yield increased by 154.20 mm (28.98%). Impact of land use changes on water yield given in Table 1.

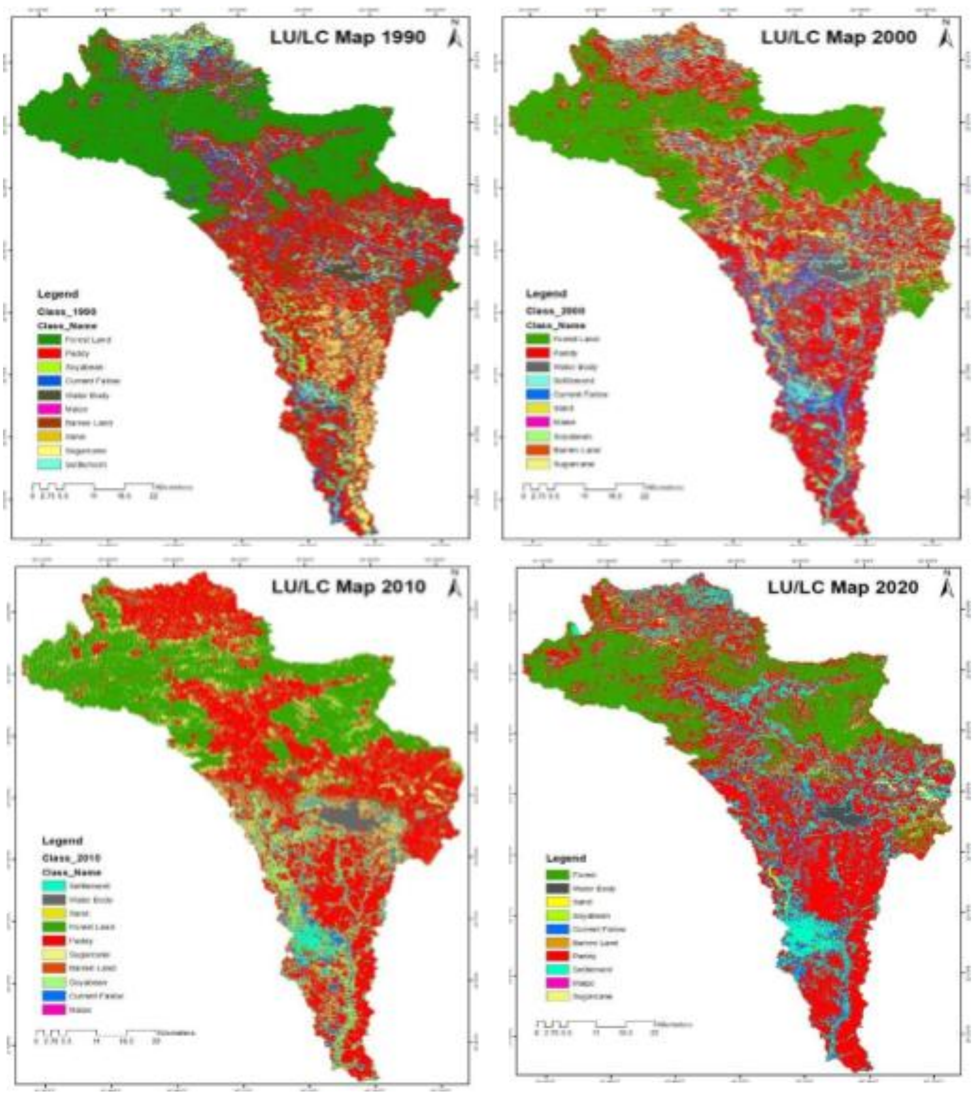

Fig. 3. Land use land cover map of study area

Table 1. Land use/cover changes impact on water yield

Water Yield (mm)							
Arpa Catchment	**Baseline**	**Land use Scenarios**			**% Change compare to baseline**		
Months	1990	2000	2010	2020	2000	2010	2020
Jan	2.29	7.40	6.72	18.41	223.92	194.11	705.53
Feb	3.68	2.76	5.38	13.44	-24.87	46.40	265.64
Mar	2.72	3.55	2.02	37.36	30.35	-25.88	1272.06
Apr	1.24	0.57	0.79	55.35	-54.48	-36.23	4348.60
May	6.45	0.58	1.51	67.45	-90.97	-76.58	945.68
Jun	44.09	36.31	54.64	61.20	-17.64	23.93	38.82
Jul	150.73	163.00	193.98	101.57	8.14	28.70	-32.61
Aug	119.88	172.93	195.65	132.46	44.26	63.21	10.50
Sep	116.11	145.16	135.11	92.05	25.02	16.36	-20.72
Oct	54.05	60.87	54.50	54.66	12.61	0.84	1.14
Nov	22.85	25.92	20.61	28.48	13.39	-9.82	24.63
Dec	8.07	11.49	5.76	23.91	42.34	-28.67	196.30
Sum	532.17	630.53	676.68	686.37	18.48	27.15	28.98

3.2 Climate Change Impact on Water Yield

Water yield with reference to baseline period (646.02 mm) increased by 31.96%, 45.56% and 71.69% under SSP_245 during 2030s, 2060s and 2090s, respectively. Similarly, under SSP_585 water yield increased by 31.96%, 45.89% and 106.87% for the 2030s, 2060s and 2090s. respectively. Percentage change in water yield in GCM scenario SSP_245 and SSP_585 compared to baseline given in Table 2 and 3 respectively. Trends in long term average annual total water yield under scenario SSP_245 and SSP_585 shows in Fig. 4. and Fig. 5. respectively.

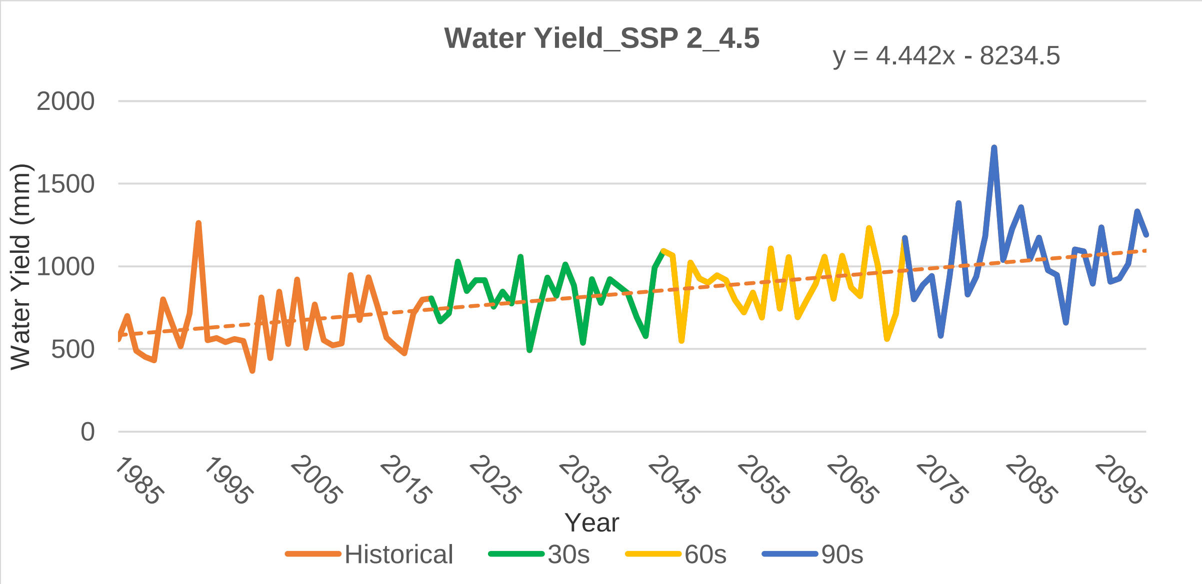

Fig. 4. Trends in long term average annual total water yield in SSP 2_4.5 scenario

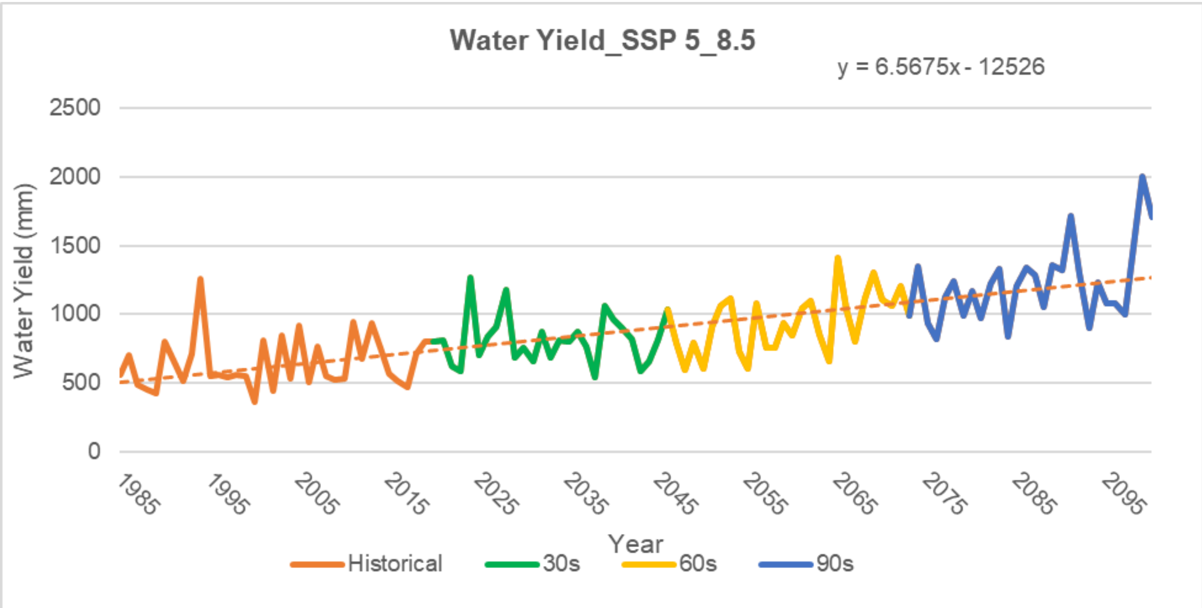

Fig. 5. Trends in long term average annual total water yield in SSP 5_8.5 scenario

Table 2. Percentage change in water yield in GCM Scenario SSP 2_4.5 compared to baseline

Month	Water Yield (mm)				% Change		
	Base Line (1985-2020)	**2030s**	**2060s**	**2090s**	**% 2030s**	**% 2060s**	**% 2090s**
Jan	10.58	15.32	19.25	22.15	44.73	81.83	109.29
Feb	8.09	13.84	13.57	14.48	71.00	67.65	78.93
Mar	14.08	6.87	8.10	7.92	-51.22	-42.44	-43.75
Apr	18.29	2.76	5.36	3.70	-84.92	-70.69	-79.77
May	22.94	3.37	8.14	9.23	-85.29	-64.54	-59.77
Jun	52.02	29.56	27.77	42.07	-43.18	-46.63	-19.14
Jul	144.63	215.52	206.28	229.09	49.01	42.62	58.39
Aug	165.84	232.32	290.41	333.26	40.09	75.12	100.96
Sep	116.45	164.77	168.26	226.89	41.49	44.49	94.84
Oct	55.88	88.06	111.79	121.72	57.57	100.03	117.80
Nov	24.32	52.62	53.56	57.90	116.34	120.21	138.06
Dec	12.89	27.47	27.85	40.74	113.15	116.07	216.07
Annual	646.02	852.48	940.32	1109.15	31.96	45.56	71.69

Table 3. Percentage change in water yield in GCM Scenario SSP 5_8.5 compared to baseline

Month	Water Yield (mm)				% Change		
	Base Line (1985-2020)	**2030s**	**2060s**	**2090s**	**% 2030s**	**% 2060s**	**% 2090s**
Jan	10.58	22.01	27.27	22.77	107.92	157.60	115.16
Feb	8.09	10.61	13.89	15.30	31.17	71.72	89.04
Mar	14.08	7.42	7.82	9.82	-47.25	-44.46	-30.27
Apr	18.29	3.40	3.69	3.13	-81.39	-79.82	-82.89
May	22.94	3.99	10.82	4.62	-82.59	-52.84	-79.86
Jun	52.02	28.39	46.77	57.28	-45.43	-10.10	10.11
Jul	144.63	220.96	186.74	300.39	52.77	29.11	107.69
Aug	165.84	229.58	274.21	413.94	38.43	65.35	149.60
Sep	116.45	156.14	170.27	265.07	34.08	46.21	127.62
Oct	55.88	87.31	110.63	130.80	56.24	97.97	134.06
Nov	24.32	51.98	54.96	71.61	113.71	125.97	194.40
Dec	12.89	30.68	35.39	41.70	138.05	174.60	223.51
Annual	646.02	852.48	942.46	1336.42	31.96	45.89	106.87

4. CONCLUSIONS

In this study, the ArcSWAT model was used to assess the water yield changes in the Arpa Catchment under the infuence of climate and land use changes from 1990 to 2020. The results show that the water yield in the Arpa Catchment has been increasing from 532.17 mm in 1990 to 686.37 mm in 2020. The land use map of 2020 and ArcSWAT calibrated parameter range kept constant then ArcSWAT model was run for GCM climate change scenario (SSP 2_4.5 and SSP 5_8.5) representing the three future time slices viz. near future (2030s), mid future (2060s) and far future (2090s). Impact of climate change on water yield with reference to baseline period 1985-2020 increased by 31.96%, 45.56% and 71.69% under SSP 2_4.5 during 2030s, 2060s and 2090s, respectively. Similarly, under SSP 5_8.5 water yield increased by 31.96%, 45.89% and 106.87% for the 2030s, 2060s and 2090s. respectively.

ACKNOWLEDGEMENT

The authors would like to thank Central Water Commission, Bhubaneshwar, for authorizing the use of data essentially for study and research purposes. The authors would also like to thank to Zenedo, CERN Data Centre for free downloading of CMIP6 Global Climate Models data.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

REFERENCES

1. Hyandye CB, Worqul A, Martz LW, Muzuka ANN. The impact of future climate and land use/cover change on water resources in the Ndembera watershed and their mitigation and adaptation strategies. Environ Syst Res. 2018;7:7. Available:https://doi.org/10.1186/s40068-018-0110-4.
2. Xu J, Xiao Y, Li N, Wang H. Spatial and temporal patterns of supply and demand balance of water supply services in the Dongjiang Lake Basin and its beneficiary areas. J. Resour. Ecol. 2015;6:386–396.
3. Sun SL, Ge S, Caldwell P, McNulty S, Cohen E, Xiao JF, Zhang Y. Drought impacts on ecosystem functions of the U. S. National Forests and Grasslands: Part II Assessment results and management implications. For. Ecol. Manag. 2015;353:269–279.
4. Legesse D, Vallet-Coulomb C, Gasse F. Hydrological response of a catchment to climate and land-use changes in Tropical Africa: Case study South Central Ethiopia. J. Hydrol. 2003;275:67–85.
5. Sharp R, Tallis HT, Ricketts T, Guerry AD, Wood SA, Chaplin-Kramer R, Nelson E, Ennaanay D, Wolny S, Olwero N, et al. InVEST 3.2.0 User's Guide. The Natural Capital Project, Stanford University, University of Minnesota, The Nature Conservancy, and World Wildlife Fund; 2015. Available:https://naturalcapitalproject.stanford.edu/software/invest (accessed on 15 March 2021).
6. Dewan A, Corner R. Dhaka Megacity. Geospatial Perspectives on Urbanization, Environment and Health, Springer Science & Business Media: Berlin, Germany; 2014.
7. Lu D, Mausel P, Brondizio E, Moran E. Change detection techniques. Int. J. Remote Sens. 2004;25:2365–2407.
8. Lu D, Moran E, Hetrick S, Li G. Land-use and land-cover change detection. In Advances in Environmental Remote Sensing: Sensors, Algorithms and Applications, Weng, Q., Ed., CRC Press: Boca Raton, FL, USA. 2011;273–291.
9. Mesev V. Integration of GIS and Remote Sensing, Wiley: Chichester, UK; 2007.
10. Attri P, Chaudhry S, Sharma S. Remote Sensing and GIS based Approach for LULC Change Detection—A Review. Int. J. Curr. Eng. Technol. 2015;5:3126–3137.
11. Chen X, Vierling L, Deering D. A simple and effective radiometric correction method to improve landscape change detection across sensors and across time. Remote Sens. Environ. 2005;98:63–79.
12. Nuñez MN, Ciapessoni HH, Rolla A, Kalnay E, Cai M. Impact of land use and precipitation changes on surface temperature trends in Argentina. J. Geophys. Res; 2008.
13. Rahman A, Kumar S, Fazal S, Siddiqui MA. Assessment of land use/land cover change in the North-West District of Delhi using remote sensing and GIS techniques. J. Indian Soc. Remote Sens. 2011;40:689–697.
14. Lambin EF, Geist H, Lepers E. Dynamics of land use and cover change in tropical regions. Annu. Rev. Environ. Resour. 2003;28:205–241.

15. Poyatos R, Latron J, Llorens P. Land-use/land-cover change after farmland abandonment—The case of a Mediterranean mountain area (Catalan PrePyrenees). Mt. Res. Dev. 2003;23:362–368.
16. Herold M, Goldstein NC, Clarke KC. The spatiotemporal form of urban growth measurement, analysis and modelling. Remote Sens. Environ. 2003;86:286–302.
17. Hazarika N, Da AK, Borah SB. Assessing land-use changes driven by river dynamics in chronically flooding affected Upper Brahmaputra plains, India, 147 using RS-GIS techniques. Egypt. J. Remote Sens. Space Sci. 2015;18:107– 118.
18. Rawart JS, Biswas V, Kumar M. Changes in land use/cover using geospatial techniques: A case study of Ramnagar town area, district Nainital, Uttarakhand, India. Egypt. J. Remote Sens. Space Sci. 2013;16:111–117.
19. Rawart JS, Kumar M. Monitoring land use/cover change using remote sensing and GIS techniques: A case of Hawallbagh block, district Almora, Utterkland, India. Egypt. J. Remote Sens. Space Sci. 2015;18:77–84.
20. McBride LA, Hope AP, Canty TP, Bennett BF, Tribett WR, Salawitch RJ. Input and Output Files EMGC, Zenodo; 2021. Available:https://doi.org/10.5281/zenodo.4300780.

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