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HYDROLOGICAL IMPACT ASSESSMENT OF LAND USE CHANGE IN AN UNGAUGED SEMI-ARID RIVER BASIN OF RAJASTHAN, INDIA

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CONTENTS

INTRODUCTION

- Over 70% of earth's land surface has now been impacted by human development(IPCC, 2019).

- The current extent of human footprint on land and water resource is unprecedented in human history.

- Spatio-temporal changes in land use and land cover, at basin level significantly affects the hydrologic processes and the water balance components of the basin.

- It is projected that by 2025, 1.8 billion people will be living in the countries or regions with absolute water scarcity (FAO, 2013).

- India is the second most populated country in the world, current demographic pressure, urbanization, agricultural expansion and socio-economic drivers are causing large scale land conversions in the country.

INTRODUCTION

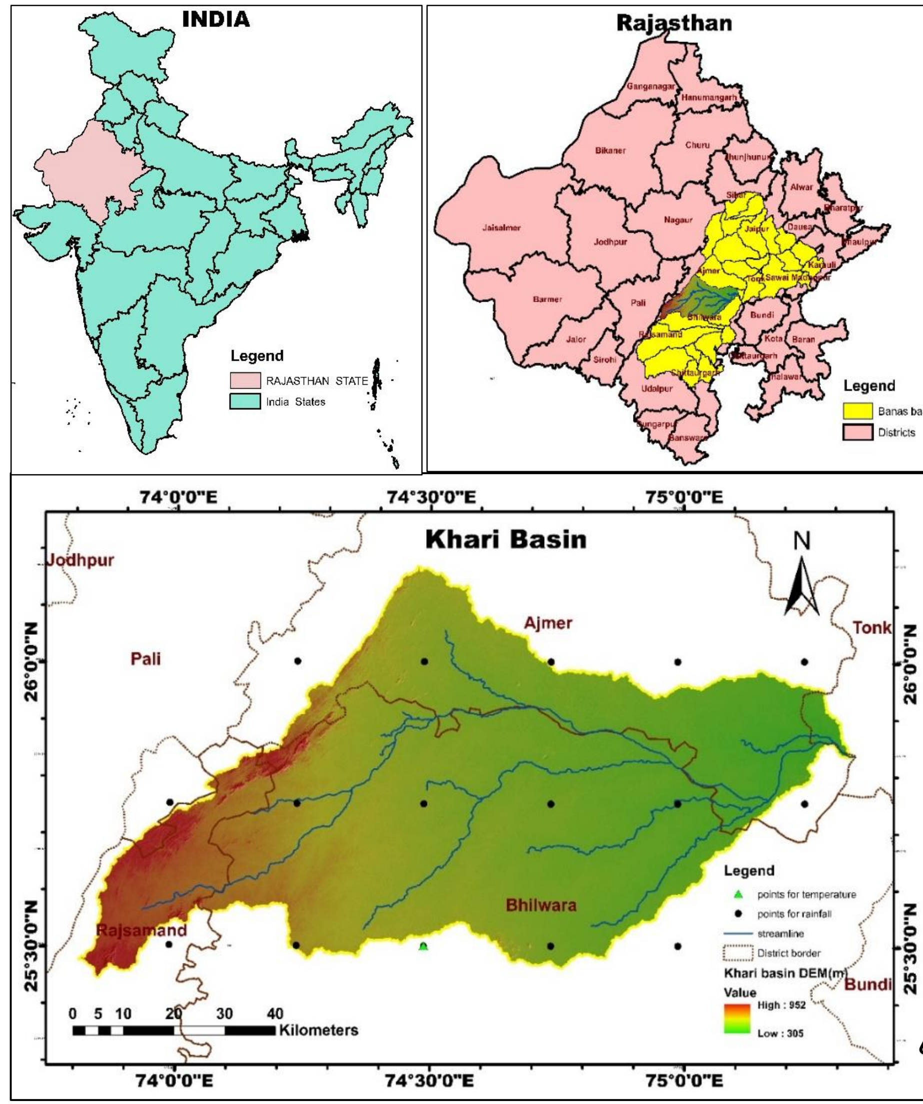
- Land use change has become one of the major concerning factor for Indian river basins beside climate change.
- Nearly all the rivers of India are severely affected by human interferences, land use change and are in over-exploited condition.
- The implications are extreme in semi-arid and arid regions where most of the rivers are ephemerals, water resources is very limited and the climate is dry.
- Khari river is an ungauged river. An important local drainage of central Rajasthan tributary of Banas river. The river is degrading due to encroachments, mining and land conversions.
- Hydrological model SWAT and GIS based digital capabilities can play the key role in basin scale water resource assessment and management specially for ungauged basins where streamflow data is not available.

OBJECTIVE

- To assess hydrological impacts of land use change (1990-2015) in Khari river basin, Rajasthan.

STUDY AREA

- The Khari River basin lies between central and south eastern part of state Rajasthan.
- It covers 6173 Km square area, across three districts Ajmer, Bhilwara, and Rajsamand.
- Khari river is a tributary of Banas, It provide important source of freshwater for Bisalpur Dam which is considered as the life line of central Rajasthan.
- The river originates in the hills near Deogarh in Rajsamand and flows in north east direction for about 192 Km before joining Banas river



STUDY AREA

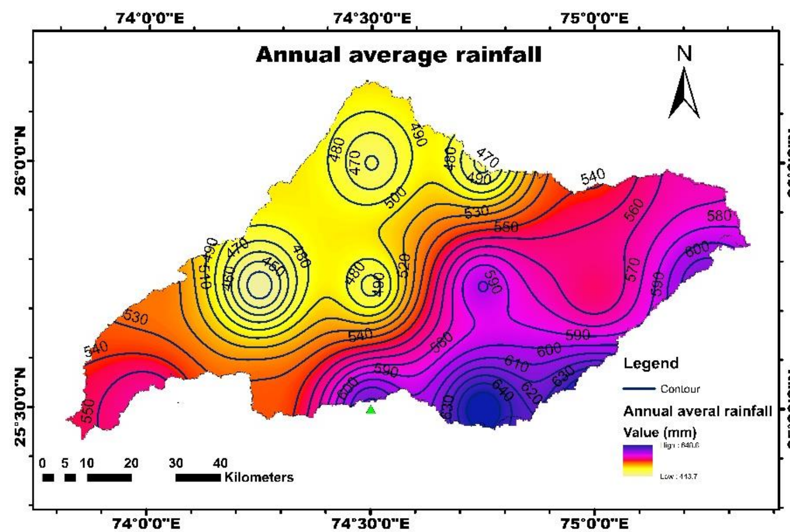
- The climate is semi-arid with annual average rainfall varies from 640 mm to 443 mm, maximum temperature reaches up to 44˚C in summer and minimum temperature reaches up to 3˚C. The basin receive rainfall only in monsoon season.

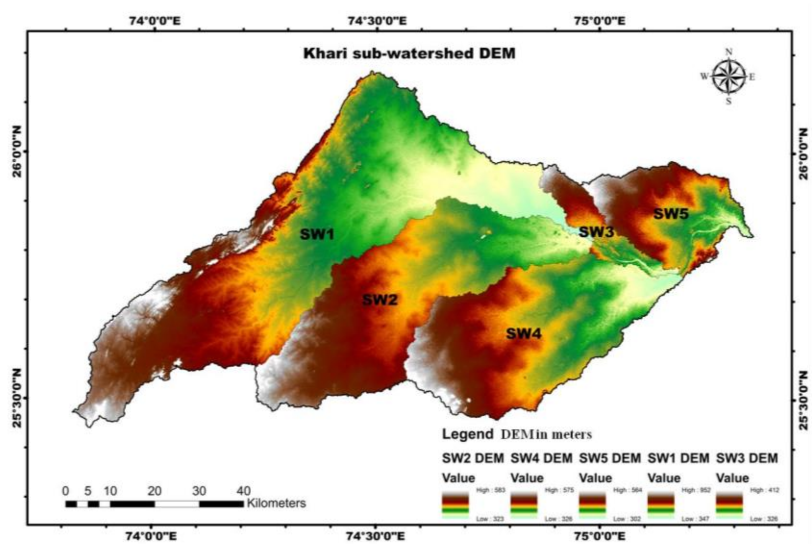
- Soil texture can be described as loam, loamy sand and clay.

- Land use can categorized in open land and agriculture, built-up area, water body and scrubland. Major crops are wheat, mustard, gram.

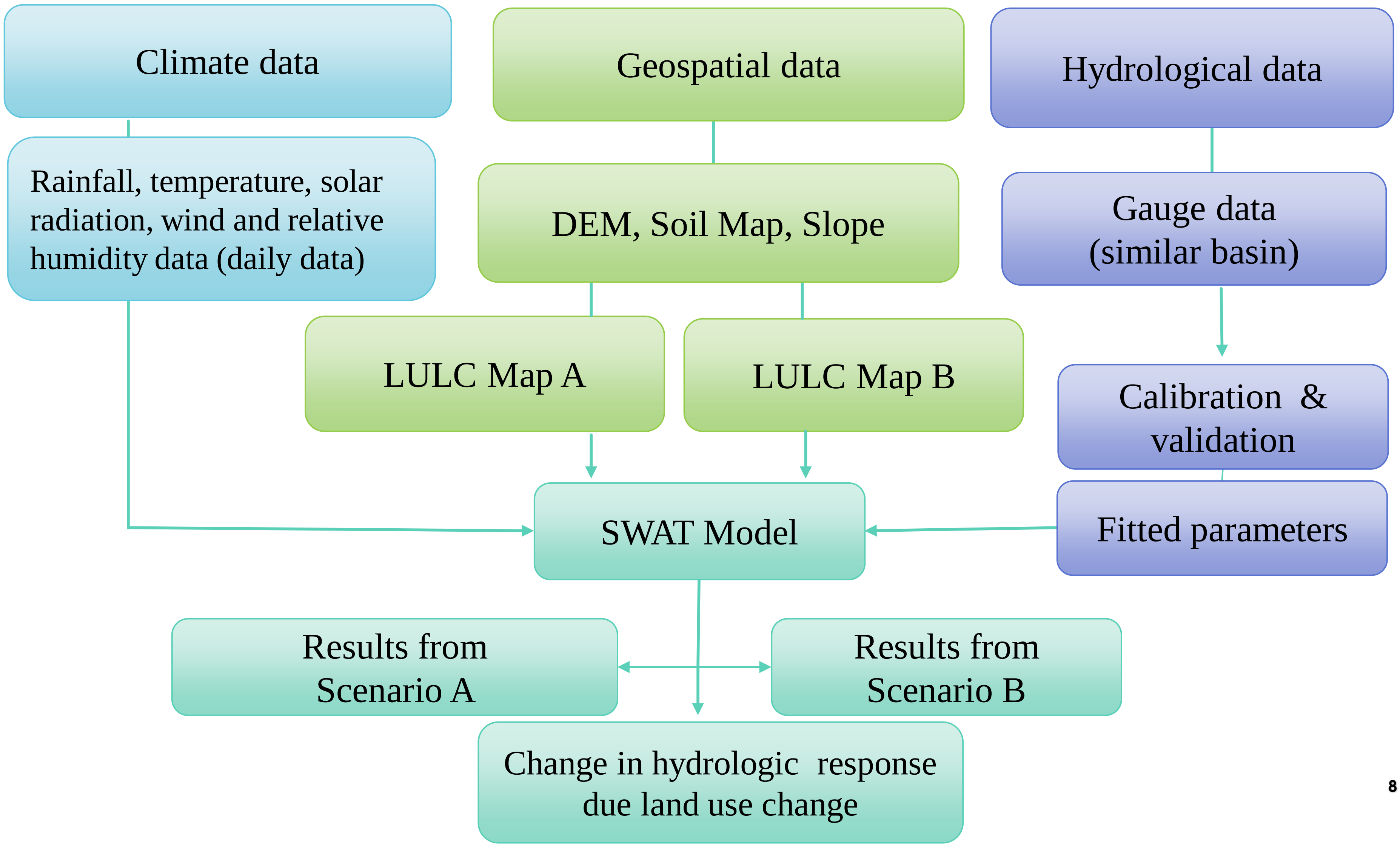
- The basin is crucial for surface and ground water in the region. Majority of population dependent upon agriculture.

- In basin further divided in five sub basins for impact assessment .





METHODOLOGY



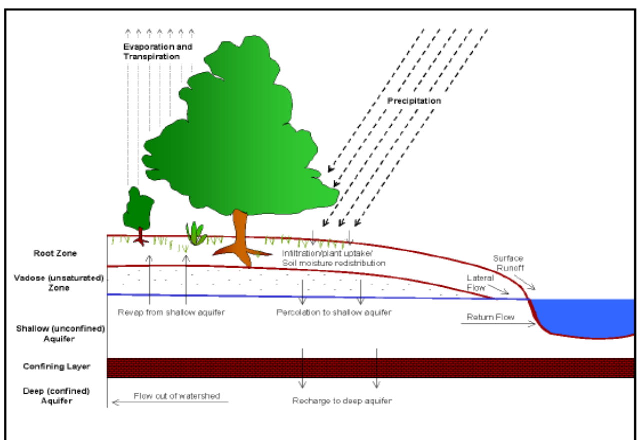
SOIL AND WATER ASSESSMENT TOOL (SWAT)

- Soil and Water Assessment Tool (SWAT) was developed by Jeff Arnold (1998) U.S. Department of Agricultural Research Service (USDARS) to quantify the impact of land management practices in large, complex watersheds.

- It is a physically based, basin-scale, semi-distributed, continuous-time watershed model that is flexible and can be integrated with GIS.

- It is a computationally efficient model commonly used for Land Use change impact assessment studies.

- Physically based approach in SWAT is beneficial for watersheds with no monitoring data and widely used in hydrological assessment studies.



$$SW_t = SW_0 + \sum_{i=1}^{t} (R_{day} - Q_{surf} - E_a - w_{seep} - Q_{gw})$$

SW_t is the final soil water content (mm H_2O)

SW_0 is the initial soil water content on day i (mm H_2O)

E_a is the amount of evapotranspiration on day i (mm H_2O).

Q_{surf} is the amount of surface runoff on day i (mm H_2O)

w_{seep} is the amount of water entering the vadose zone from the soil profile on day i (mm H_2O)

t is the time (days)

R_{day} is the amount of precipitation on day i (mm H_2O)

Q_{gw} is the amount of return flow on day i (mm H_2O).

SWAT INPUT DATA

CLIMATIC DATA

Data type	Source
Daily Rainfall data .25˚x .25˚ grid (1979-2013)	Indian Meteorological Department (IMD)
Daily Maximum Temperature, Daily Minimum Temperature data 1˚x 1˚ grid (1979-2013)	Indian Meteorological Department (IMD)
Other Daily climatic data- wind, relative humidity and solar radiation, (1979-2013)	Global weather data https://globalweather.tamu.edu/

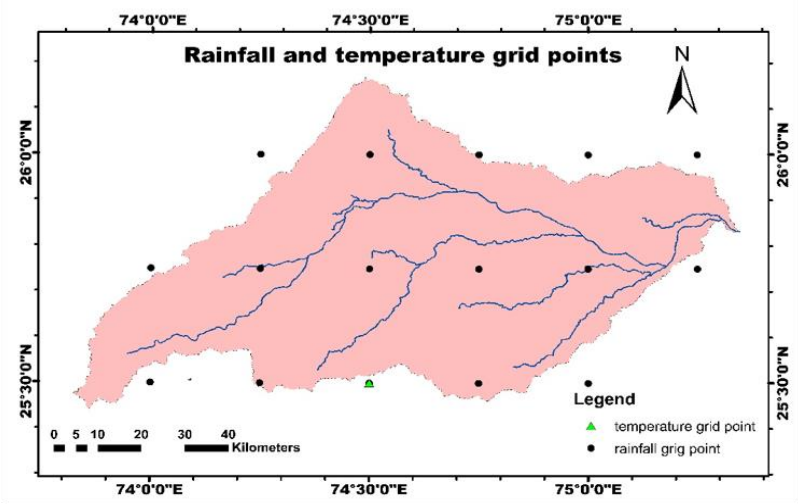
GEOSPATIAL DATA

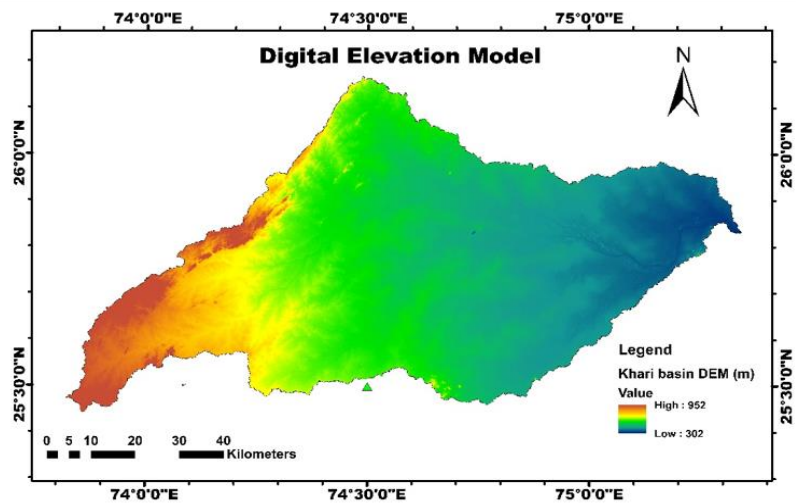
Data type	Source
Digital Elevation Model	Shuttle Radar Topography Mission (SRTM) spatial resolution 30m Earth explorer website
Satellite Image for land use map(year 1990 and year 2015)	LANDSAT 5TM and LANDSAT 8OLI Earth explorer website
Soil Map	Soil Map from(Govt. of INDIA , GANGA consortium of IIT's project, unique code NRCS/WISE /FAO)

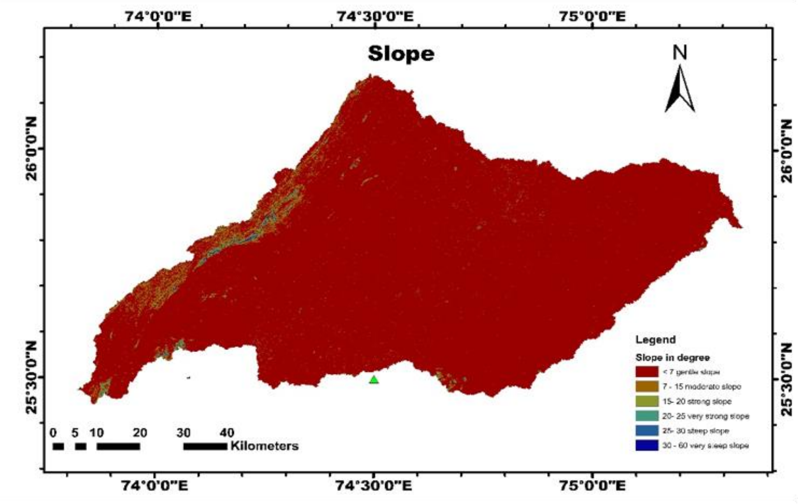
HYDROLOGICAL DATA

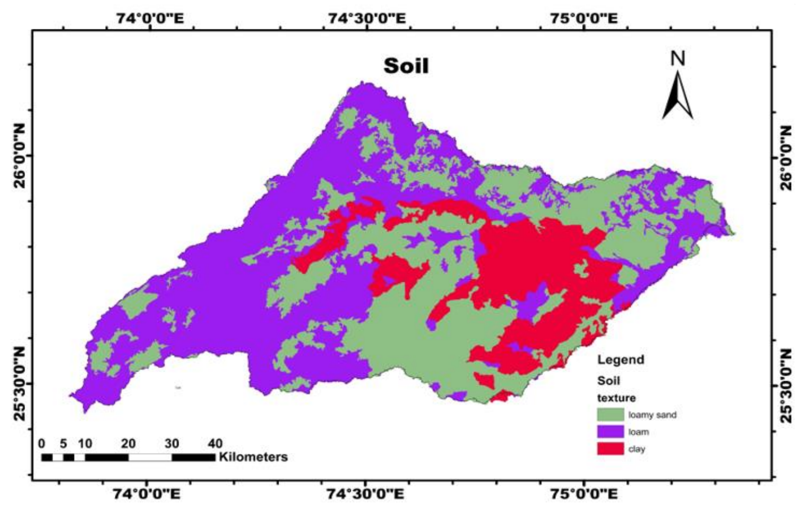
Data type	Source
Monthly stream flow data from Bigod gauge station situated at downstream from the study area is obtained for the period of year 1982-1991. 1982-1987 (calibration) 1988-1991(validation) The selected basin is similar in climate and basin characteristics to Khari basin	Central Water Commission, India

SWAT INPUT DATA

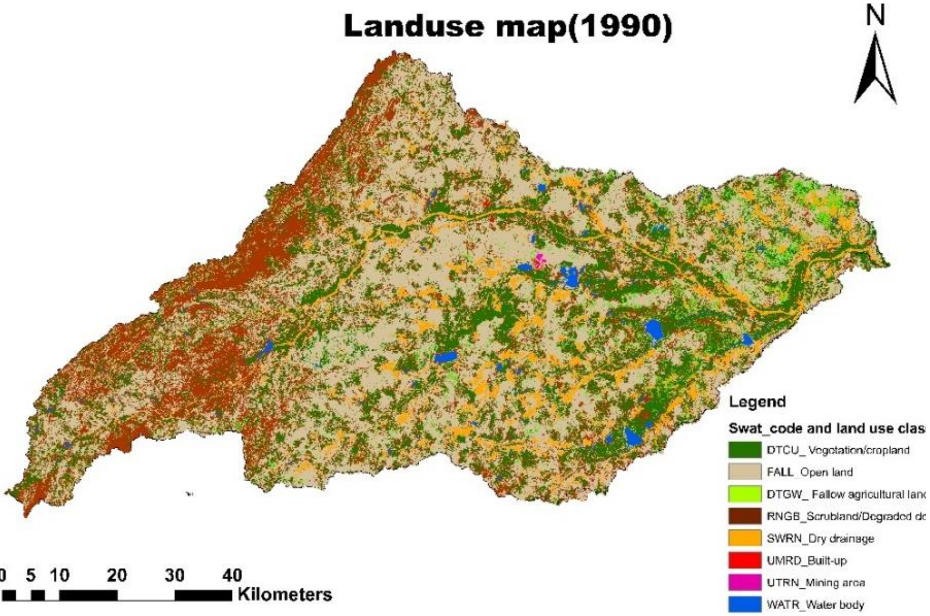


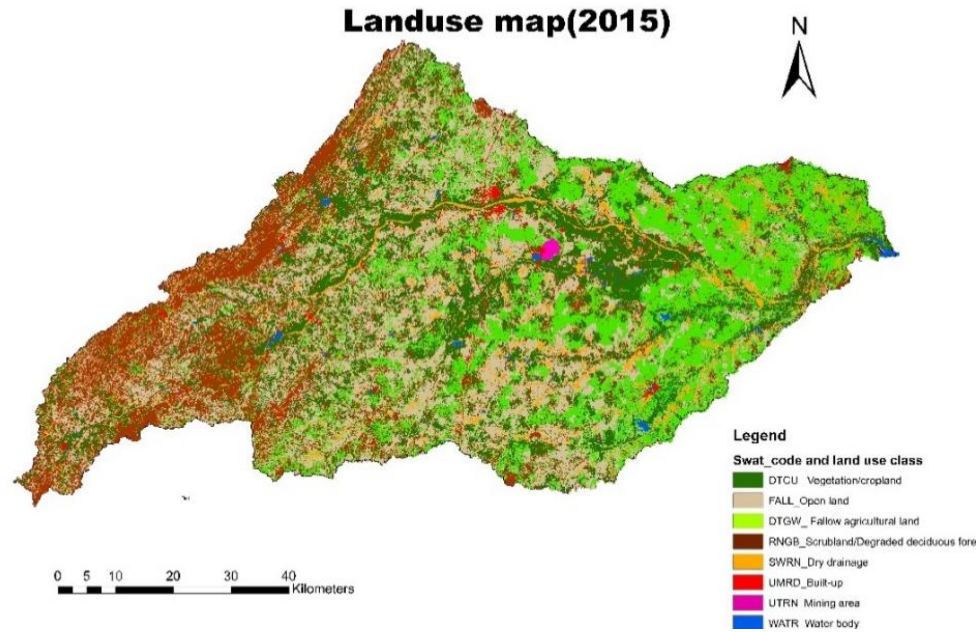






LAND USE MAP PREPARATION



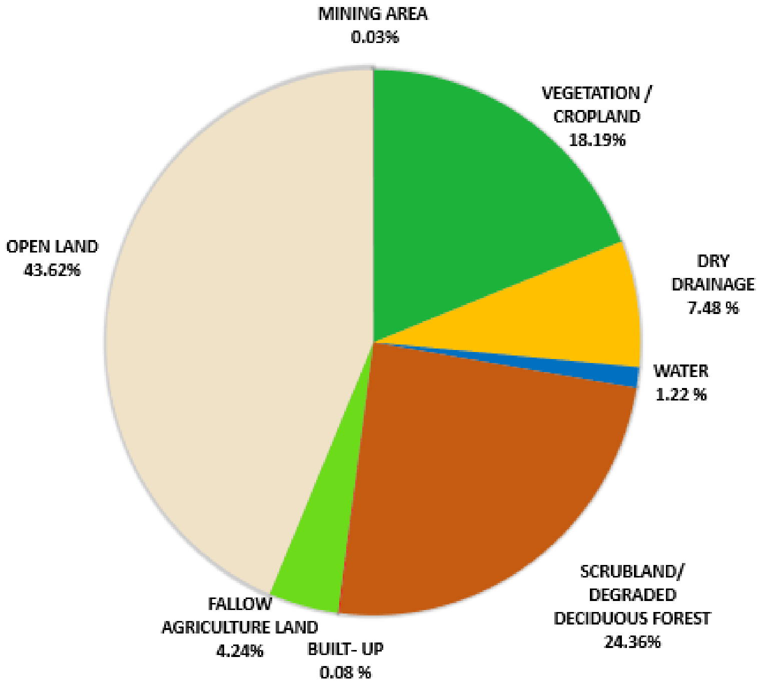


- Supervised classification with Maximum likelihood classification method is used to prepare land use map for year 1990 and year 2015.

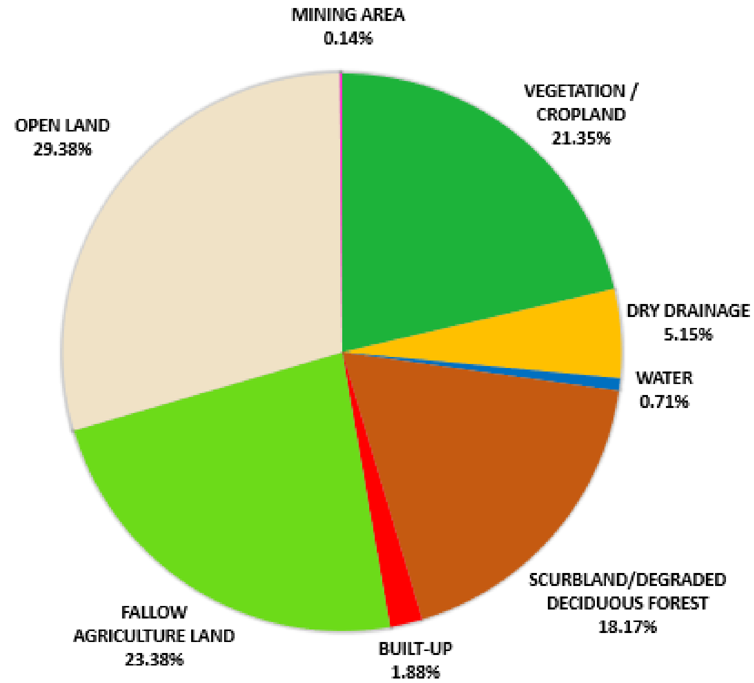
- Accuracy assessment for the two land use map shows overall accuracy of 0.92 and .0.9 and kappa coefficient of the two maps are 0.92 and 0.93. Swat codes are selected based on reference map from NRSC and IWMI and other secondary information

Land use class	Swat class	Code
Vegetation / cropland	Double triple crop conjunctive	DTCU
Open land	Fallow land	FALL
Fallow agriculture land	Double triple ground water	DTGW
Scrubland/ Degraded deciduous forest	Range land	RNGB
Dry drainage	Arid range	SWRN
Built-up	Urban	UMRD
Mining area	Urban, mine	UTRN
Water	WATER	WATR

PERCENTAGE AREA OF LAND USE CLASS



LAND USE MAP 1990



LAND USE MAP 2015

SWAT MODEL PROCESSING AND CALIBRATION STEPS

- SWAT model is set-up using two land use scenario A and B of year 1990 and 2015, keeping climate, slope and soil data same in both the Model. SWAT model is run for 32 year (1979-2013) with 3 year of warm up period.

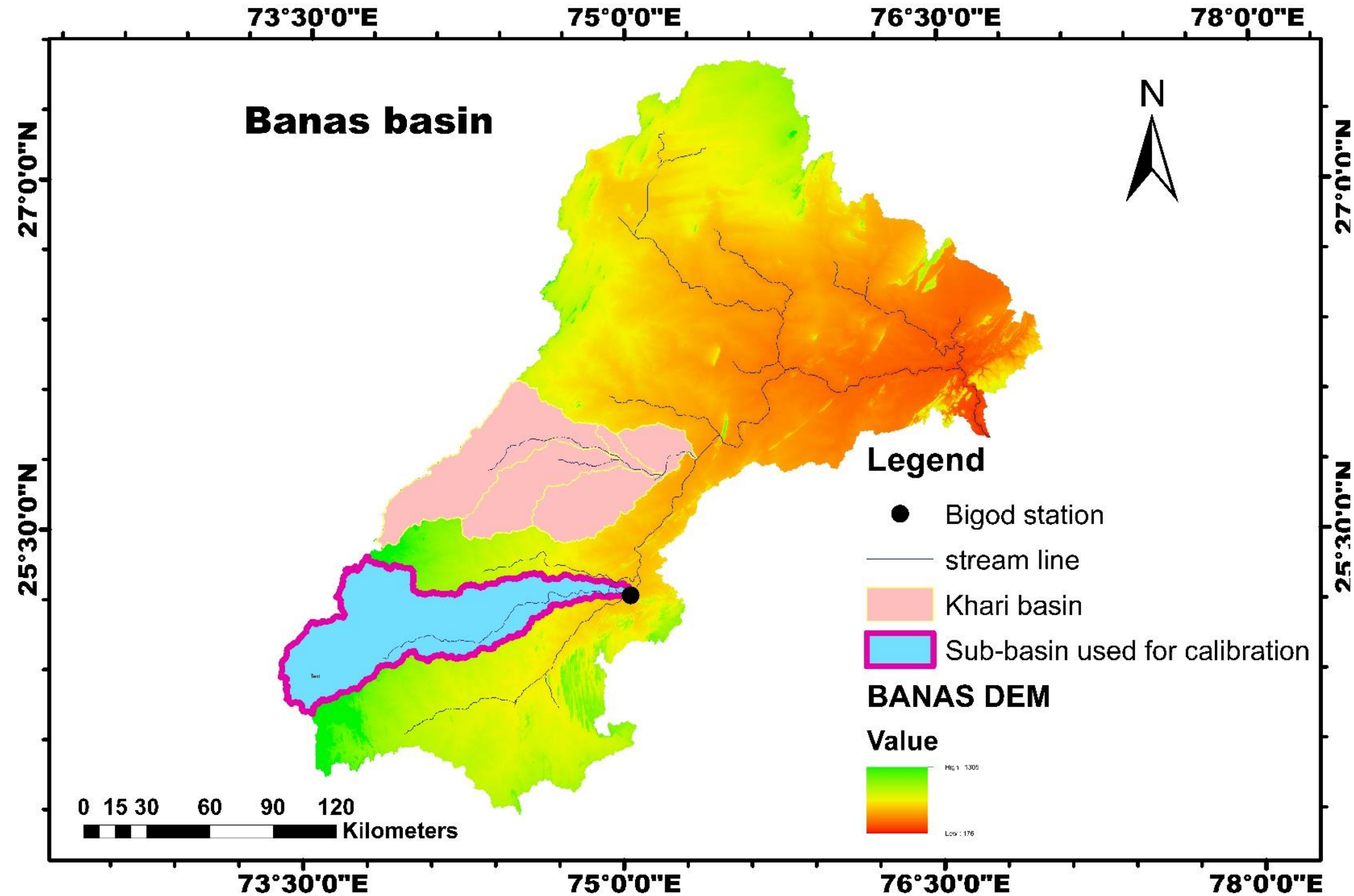
- Khari basin is an ungauged basin and the stream flow data is not available so the similar characteristic sub-basin, located downstream in the Banas basin is used for the calibration and the fitted parameters are used Khari basin.

- Monthly stream flow data of Bigod gauge station (1982 to 1991) obtained from Center Water commission India. For calibration period year 1982-87 discharge data and for validation period year 1988-91 discharge data is used.

- For model sensitivity, calibration, and uncertainty analysis SWAT-CUP interface and SUFI-2 algorithm is used.

- The model performance is analyzed based on Nash-Sutcliffe coefficient (NSE), coefficient of determination (R^2), Percentage Bias (PBIAS)

SUB-BASIN USED FOR CALIBRATION



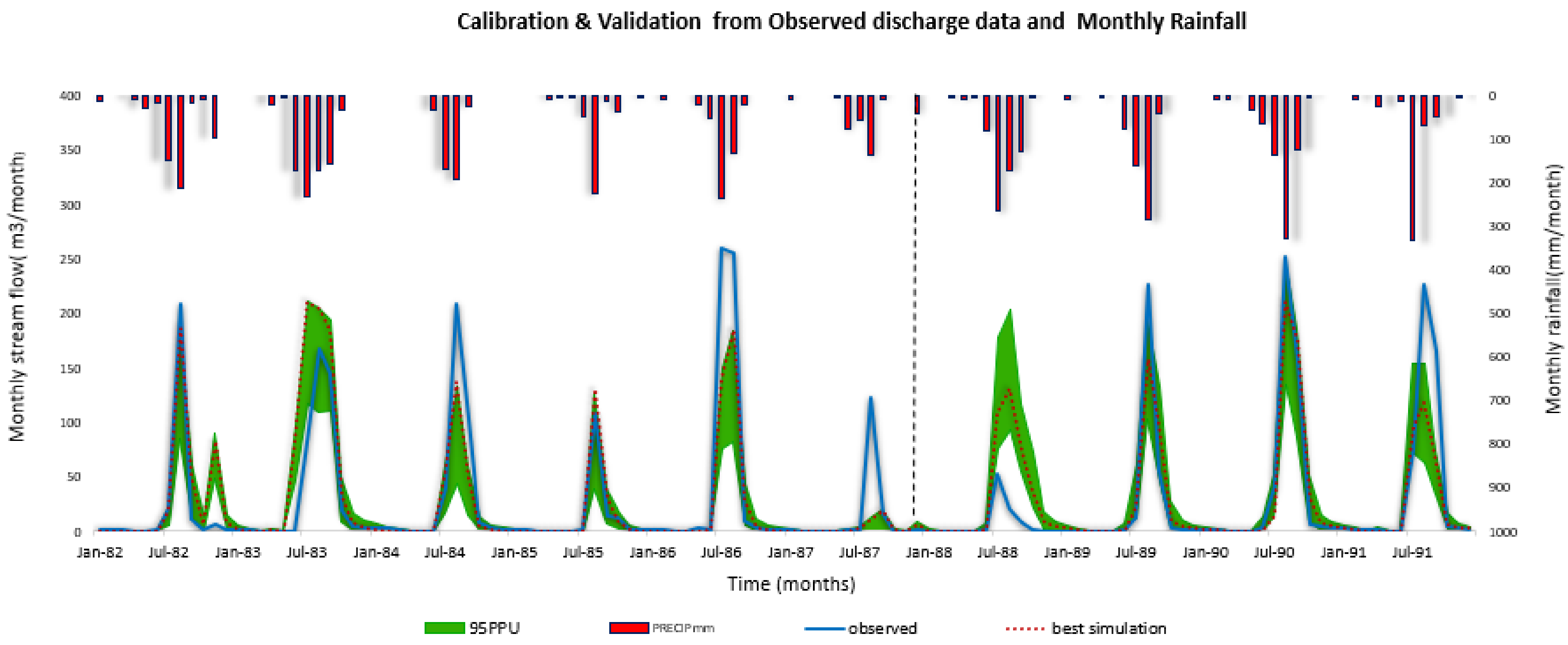
CALIBRATION AND VALIDATION

Calibration
P factor = 0.64
R factor = 0.29
R^2 = 0.72 (Good)
NSE = 0.72 (Good)
PBIAS = -1.9 (Very good)

Swat run
swat run period 1979-2013
warm up period 3 years

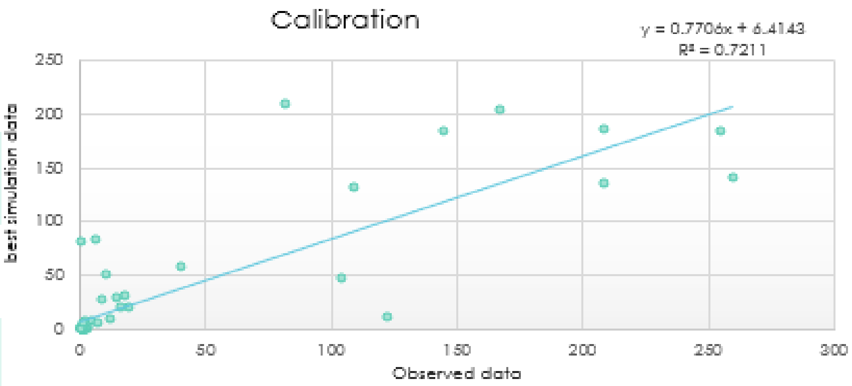
Calibration period 1982-1987
Validation period 1988-1991

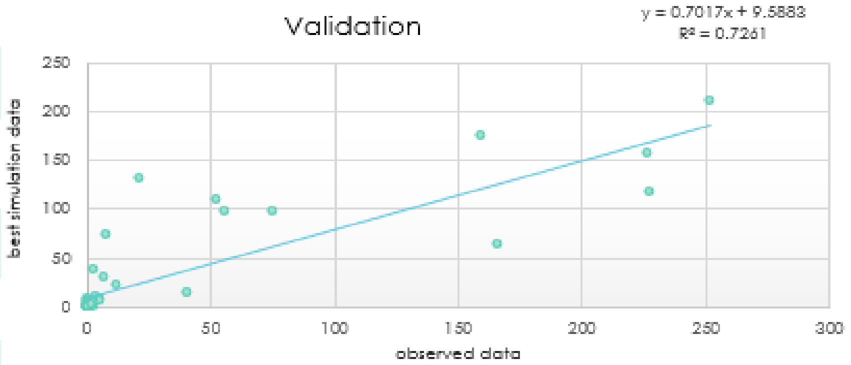
validation
P factor = 0.58
R factor = 0.40
R^2 = 0.73 (Very good)
NSE = 0.72 (Good)
PBIAS = -4.7 (very good)



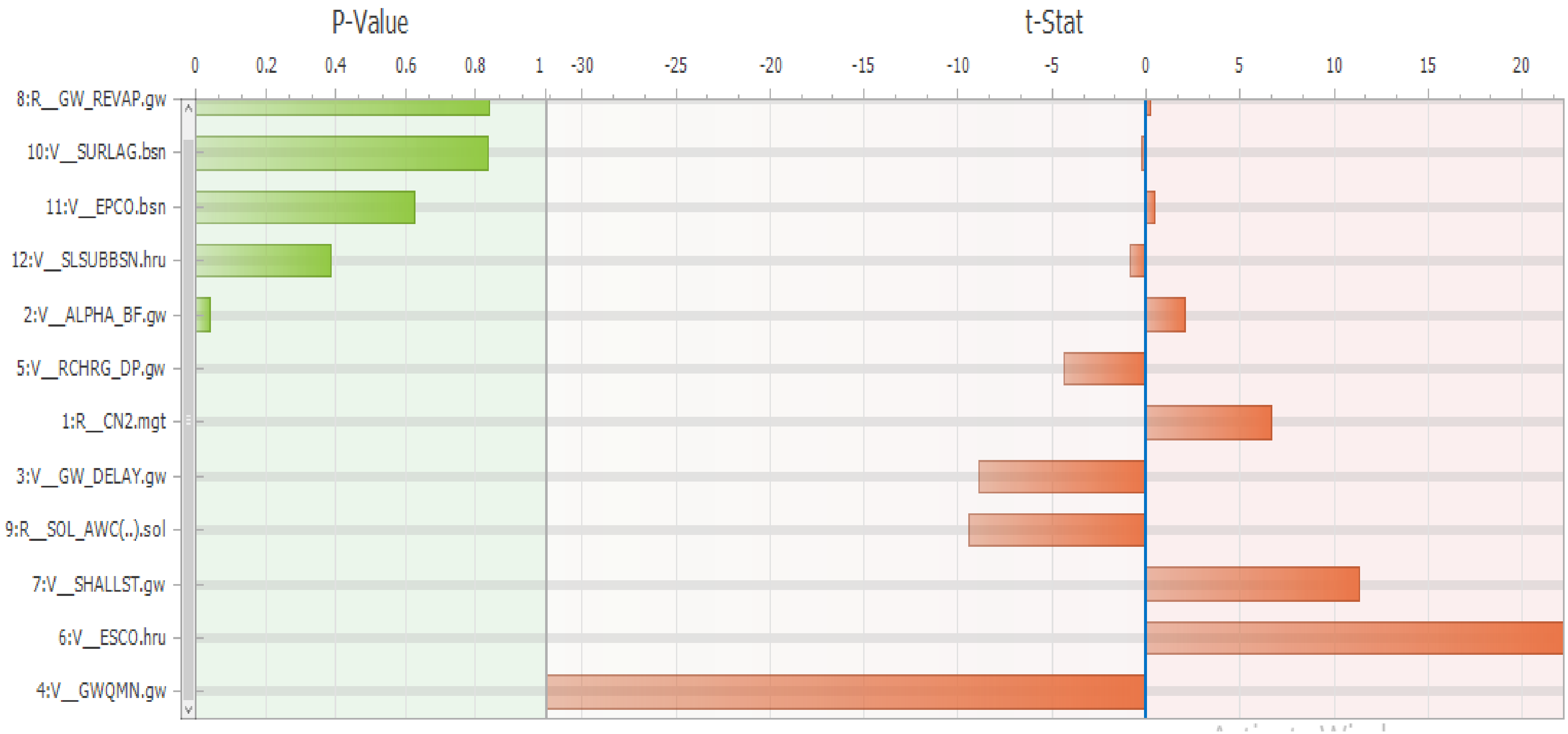
FITTED PARAMETERS

Parameter	Parameter Name	Minimum value	Maximum value	Fitted Value	Rank
V__GWQMN.gw	Threshold depth of water in the shallow aquifer required for return flow to occur, (mm)	103.8	2310.12	521.9	1
V__ESCO.hru	Soil evaporation compensation factor	0.7	1	0.963	2
V__SHALLST.gw	Initial depth of water in the shallow aquifer,, m	1863.2	2563.12	2405.9	3
R_SOL_AWC(..).sol	Soil available water storage capacity	0.101	0.379	0.186862	4
V__GW_DELAY.gw	Groundwater delay time (day)	9.372	18.17	12	5
R__CN2.mgt	Curve number for moisture condition II	-0.219	-0.085	-0.14	6
V__RCHRG_DP.gw	Deep aquifer percolation fraction	0.0496	0.256	0.091	7
V__ALPHA_BF.gw	Baseflow alpha factor	0.1789	0.535	0.408	8
V__SLSUBBSN.hru	Average slope length	10	34.97	22.22	9
V__EPCO.bsn	Plant uptake compensation factor	0.255	0.75	0.645	10
V__SURLAG.bsn	Surface runoff lag coefficient	11.549	18.28	17.422	11
R__GW_REVAP.gw	Revap coefficient	0.187	0.19	0.187	12





SENSITIVITY ANALYSIS

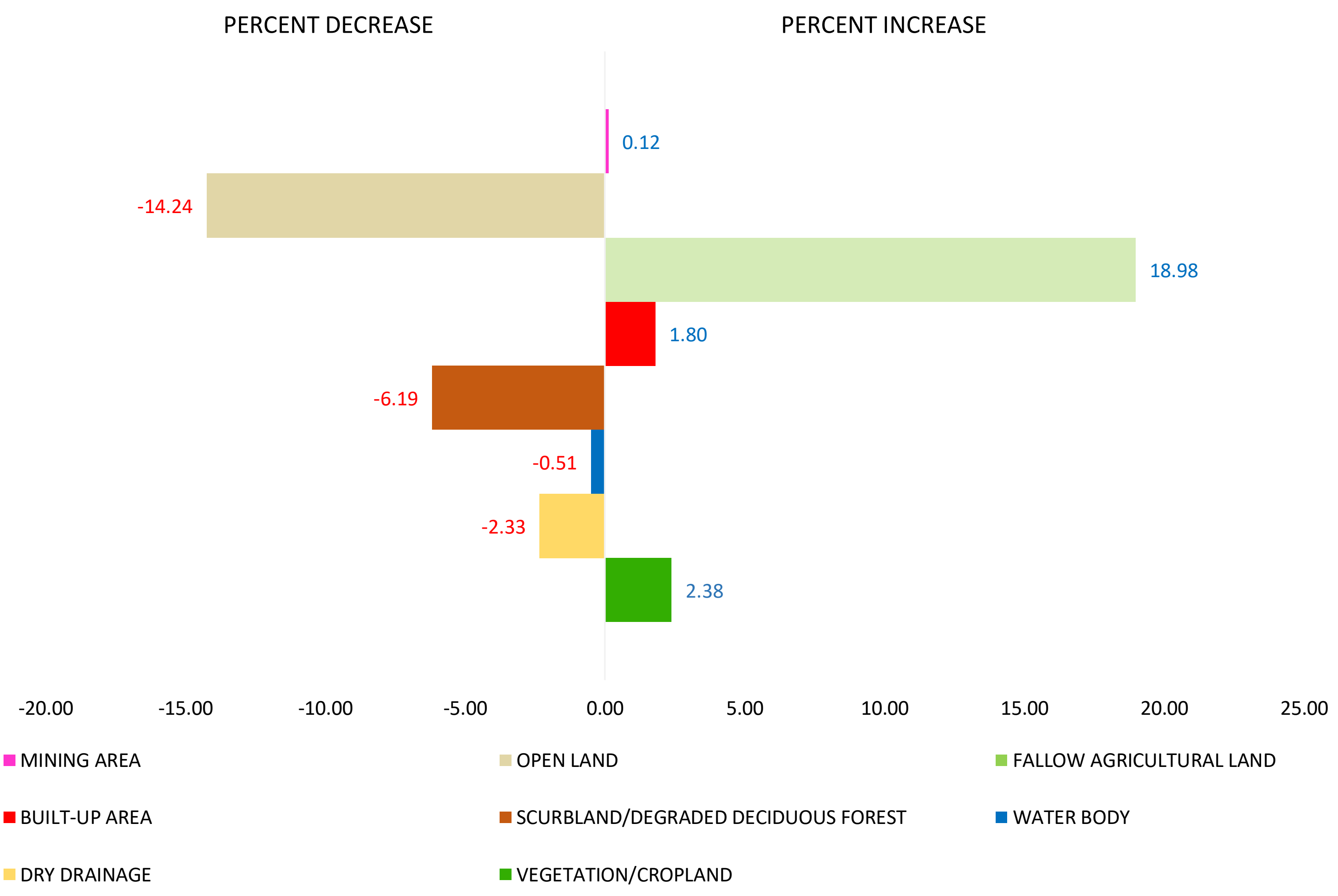


RESULTS

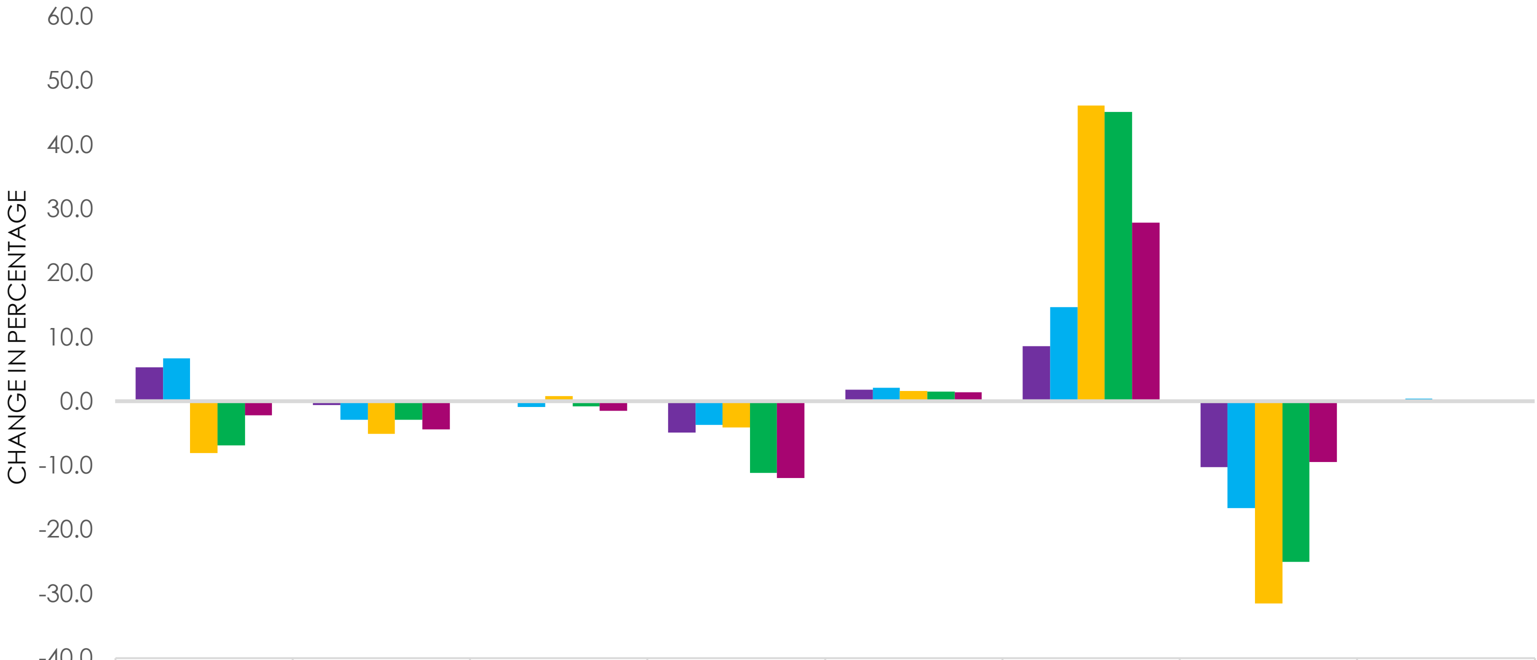
CHANGE IN BASIN LAND USE AREA (Km2)

Land Use Class	Area in Km2 land use 2015	Area in Km2 land use 1990	Change (km2)	Land use area
Vegetation/Cropland	1340.90	1191.31	149.58	Increased
Dry Drainage	323.23	469.74	-146.51	Decreased
Water Body	44.90	76.87	-31.97	Decreased
Scrubland/Degraded Deciduous Forest	1141.46	1530.08	-388.62	Decreased
Built-up Area	117.95	5.11	112.84	Increased
Fallow Agricultural Land	1458.46	266.25	1192.20	Increased
Open Land	1845.48	2739.60	-894.12	Decreased
Mining Area	8.94	1.65	7.29	Increased

CHANGE IN BASIN LAND USE AREA (%)



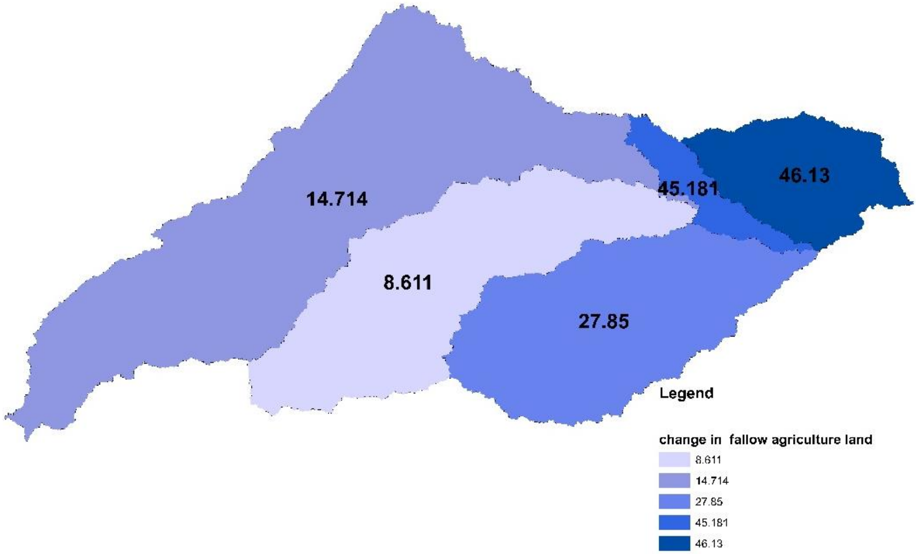
CHANGE IN SUB-BASIN LAND USE AREA (%)



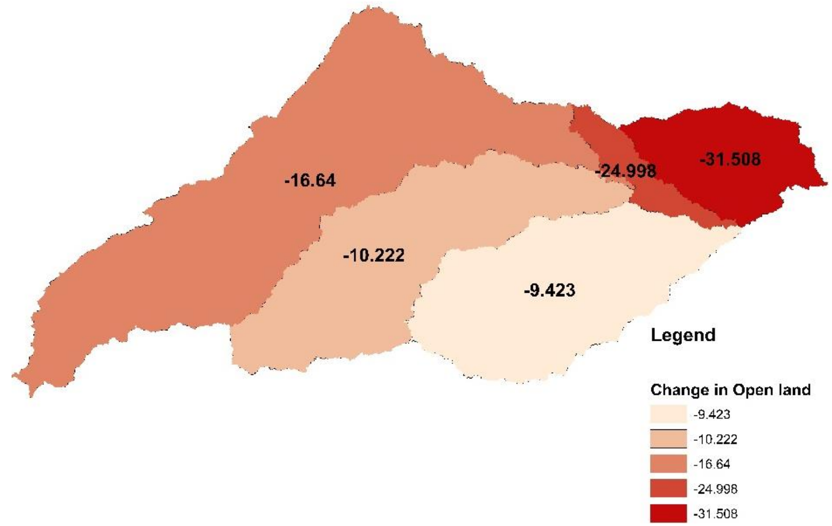
	VEGETATION/ CROPLAND	DRY DRAINAGE	WATER	SCURBLAND/ DEGRADED DECIDUOUS FOREST	BUILT-UP AREA	FALLOW AGRICULTUR AL LAND	OPEN LAND	MINING AREA
SW1	5.319	-0.571	-0.172	-4.821	1.836	8.611	-10.222	0.019
SW2	6.682	-2.837	-0.840	-3.620	2.108	14.714	-16.640	0.434
SW3	-8.047	-5.071	0.800	-4.044	1.679	46.130	-31.508	0.061
SW4	-6.867	-2.889	-0.803	-11.159	1.529	45.181	-24.998	0.005
SW5	-2.182	-4.331	-1.481	-11.930	1.490	27.850	-9.423	0.006

CHANGE IN SUB-BASIN LAND USE AREA(%)

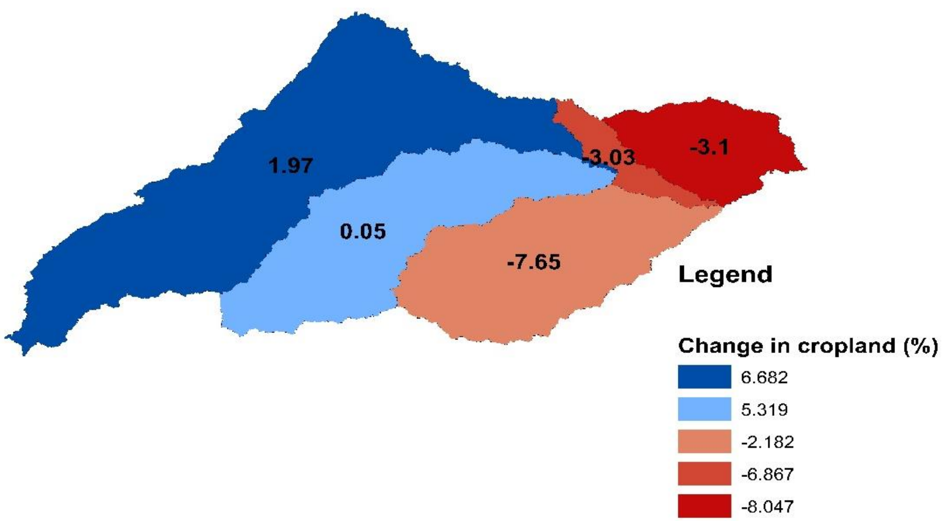
Change in fallow agriculture land (%)



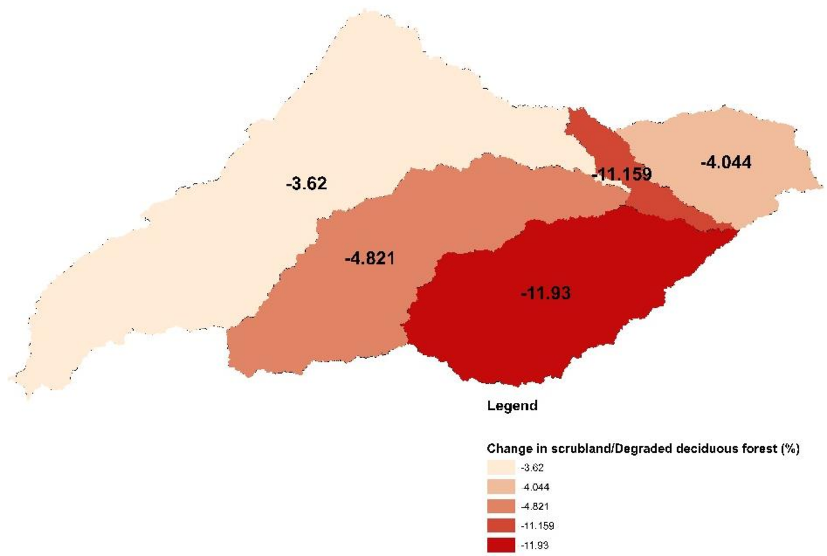
Change in Open land (%)



Change in cropland (%)



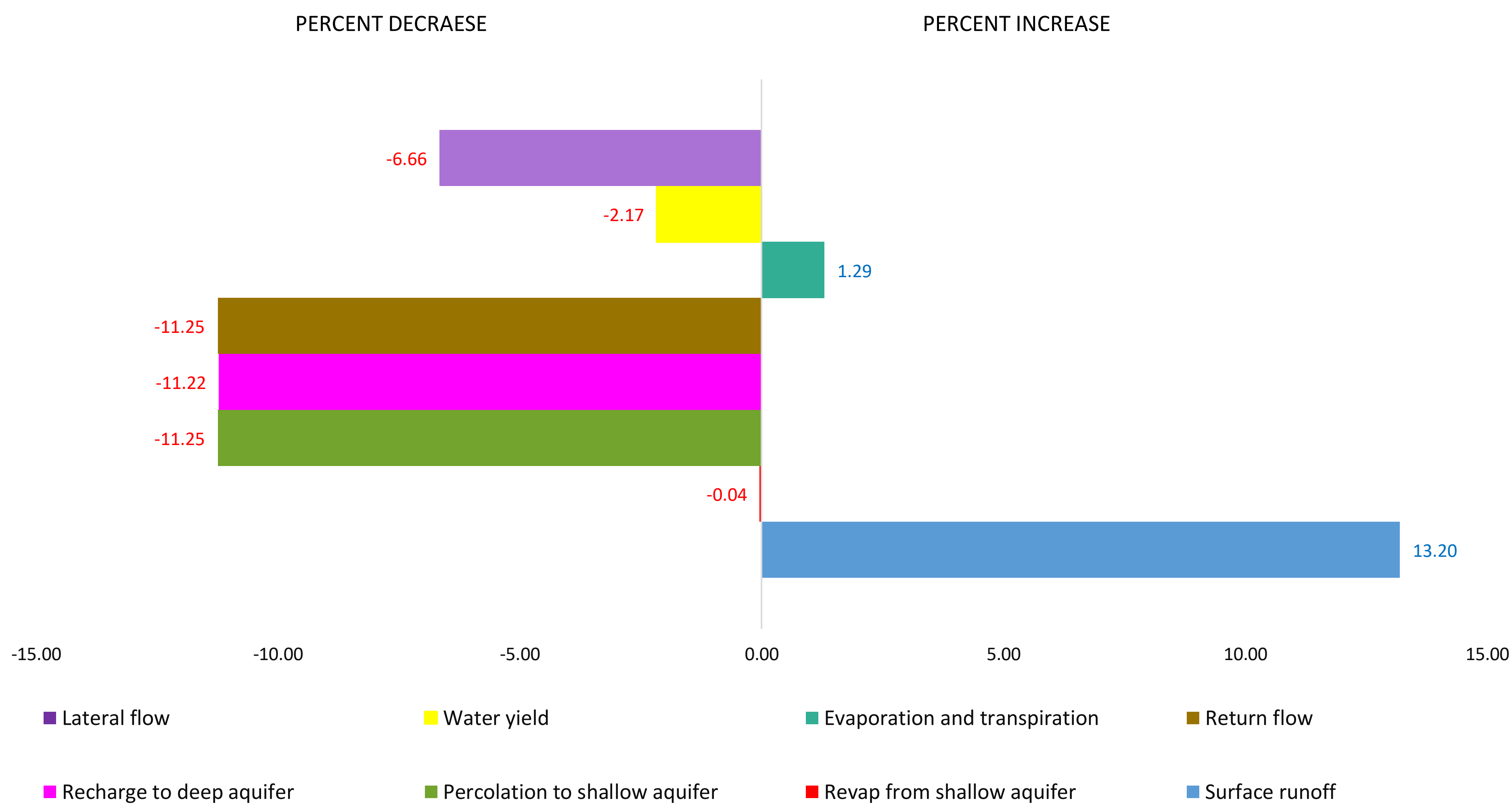
Change in scrubland/Degraded deciduous forest area (%)



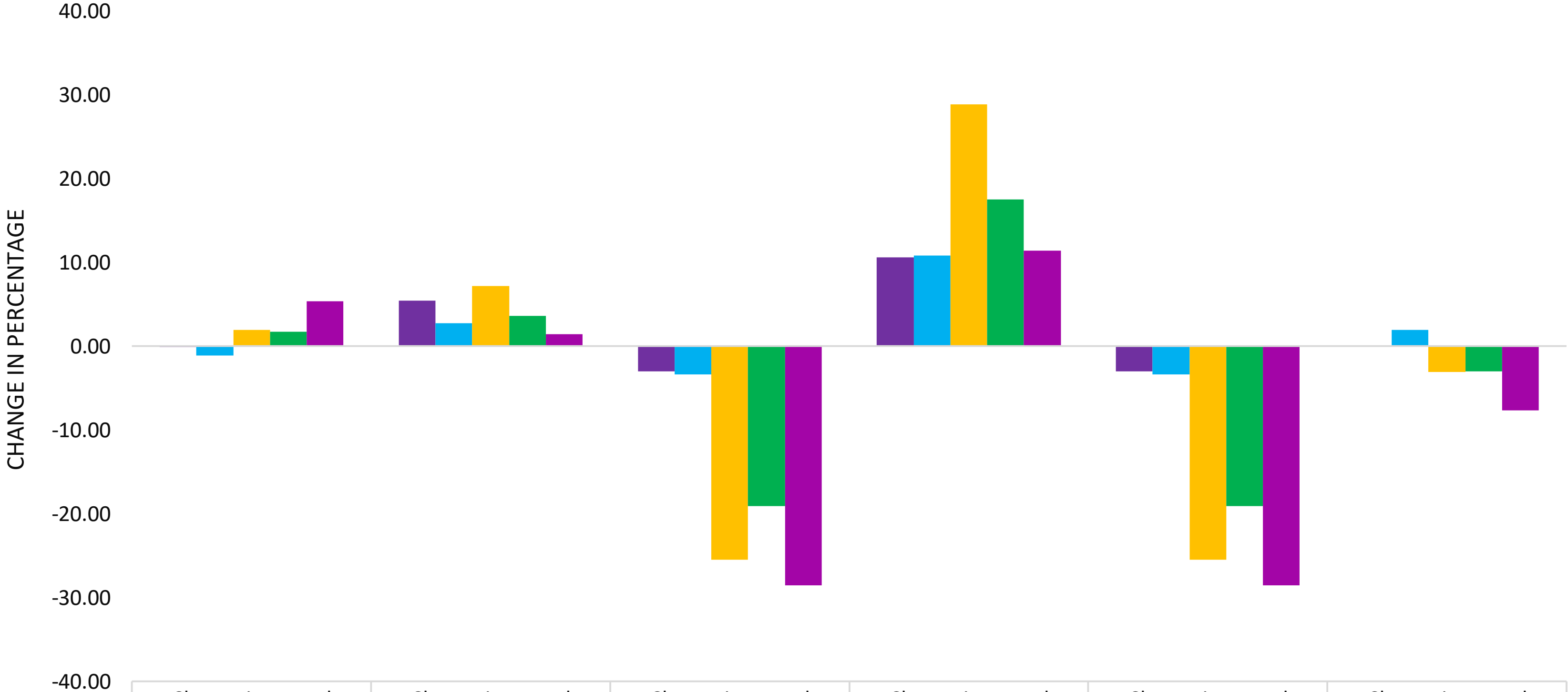
CHANGE IN BASIN WATER BALANCE COMPONENTS(mm)

Water balance component	Component value in Scenario A (LULC 1990) model Simulation (mm)	Component value in Scenario B (LULC 2015) model Simulation (mm)	Change (mm)	Result
Surface runoff	65.78	74.46	8.68	increased
Revap from shallow aquifer	46.4	46.38	-0.02	decreased
Percolation to shallow aquifer	101.98	90.51	-11.47	decreased
Recharge to deep aquifer	9.18	8.15	-1.03	decreased
Return flow	92.8	82.36	-10.44	decreased
Evaporation and transpiration	301.2	305.1	3.9	increased
Lateral flow	17.26	16.11	-1.15	decreased
Water yield	184.92	180.9	-4.02	decreased

CHANGE IN BASIN WATER BALANCE COMPONENTS (%)

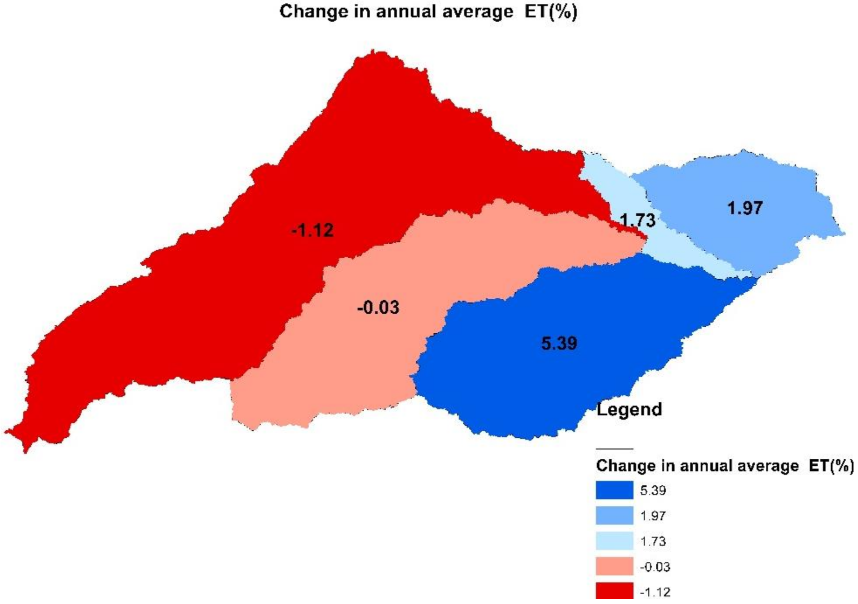


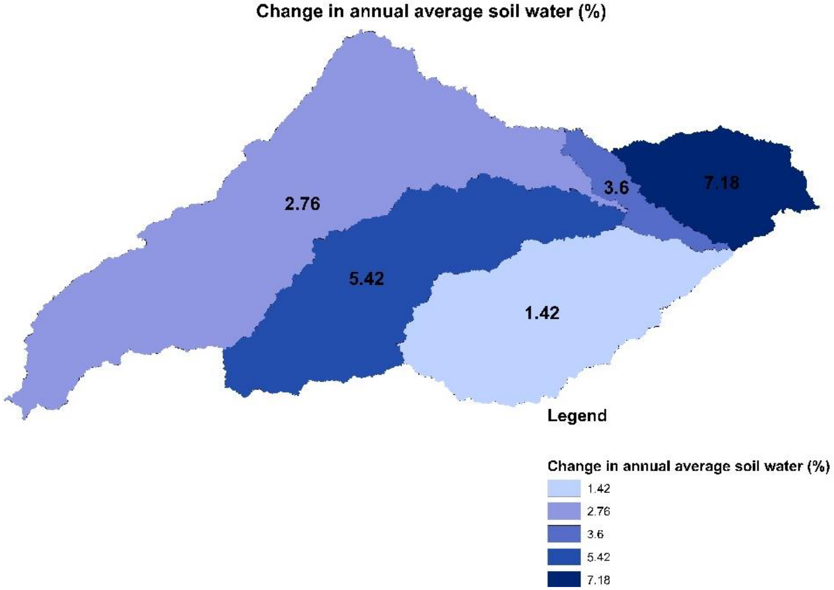
CHANGE IN SUB-BASIN WATER BALANCE COMPONENTS(%)

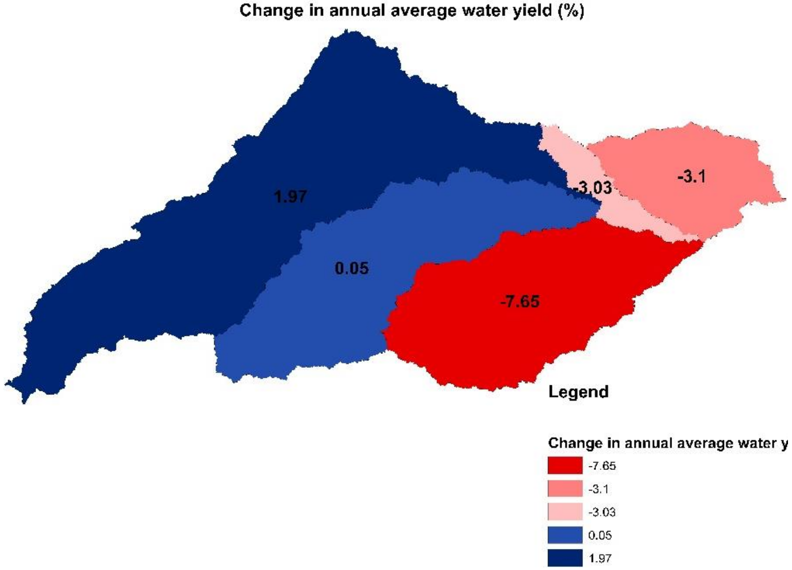


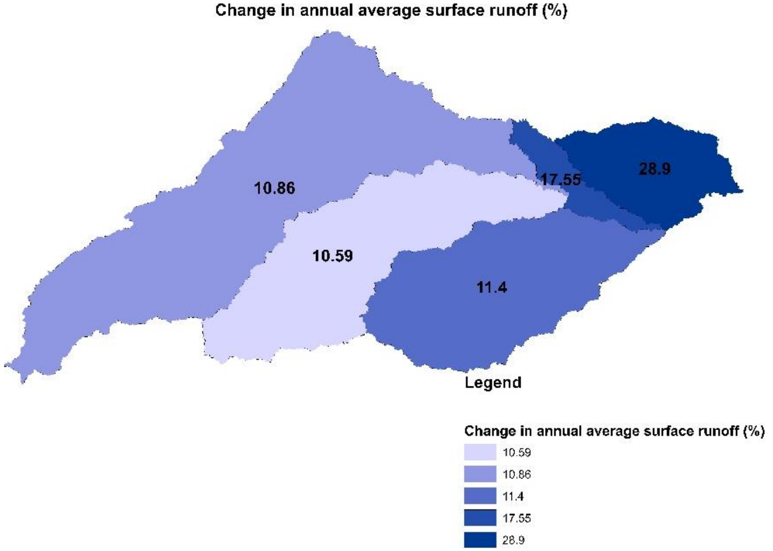
	Change in annual average ET(%)	Change in annual average SW(%)	Change in annual average PERC(%)	Change in annual average SURQ (%)	Change in annual average GW_Q(%)	Change in annual average WYLD (%)
SW1	-0.03	5.42	-3.00	10.59	-2.99	0.05
SW2	-1.12	2.76	-3.38	10.86	-3.38	1.97
SW3	1.97	7.18	-25.45	28.90	-25.45	-3.10
SW4	1.73	3.60	-19.08	17.55	-19.08	-3.03
SW5	5.39	1.42	-28.51	11.40	-28.51	-7.65

CHANGE IN SUB-BASIN WATER BALANCE COMPONENTS(%)

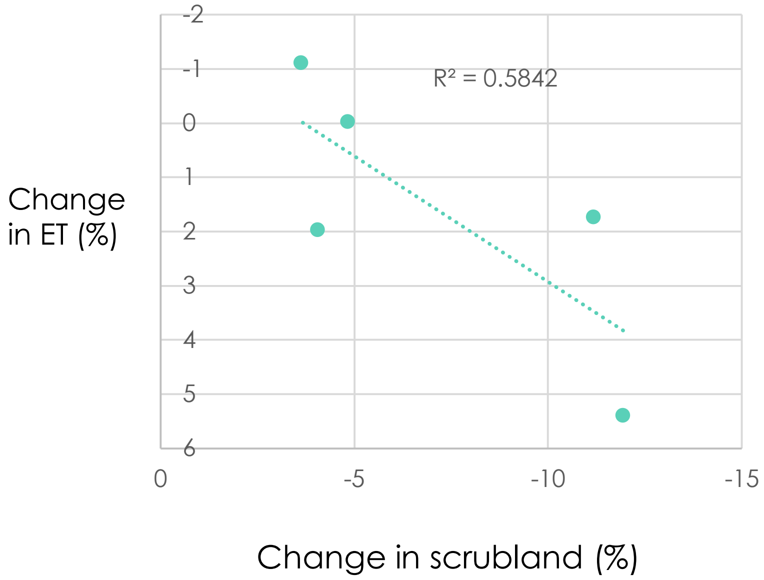


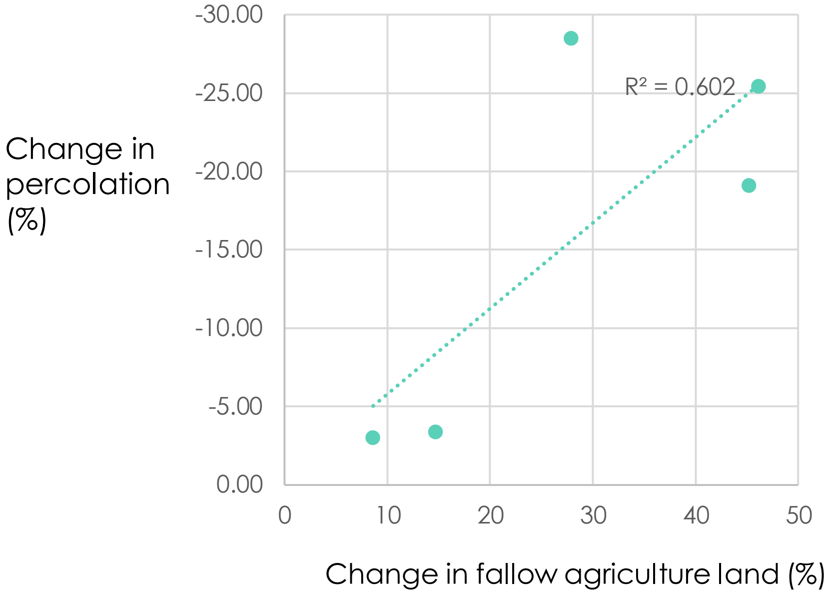






LAND USE CHANGE AND CHANGE IN HYDROLGIC RESPONSE





CONCLUSION

- Quantitative measurement of land use change and assessment of its impact on watershed hydrology provide significant information of hydrological response and land use dynamics relation.

- Physically based approach in SWAT provide capabilities to obtain critical data from an ungauged watersheds by using similar characteristics watershed gauge data.

- In the Khari basin land use there is very significant land use change in terms of change in open land and agriculture area. Open land decreased by 14 percent whereas the agriculture land increased by 18 percent .

- Hydrological response of these changes shows that there evaporation and transpiration increased by 1.29 percent and surface runoff increased by 13 percent whereas water yield decreased by 2 percent and percolation decreased by 11percent.

- The assessment shows that in all five sub-basins, the change in annual average ET (%) is shows relation with the change in scrubland (%). Similarly the change in percolation(%) shows relation with change in agriculture land (%).

THANK YOU