Effects of land use change on the water resources of the Basoda basin using the SWAT model

By

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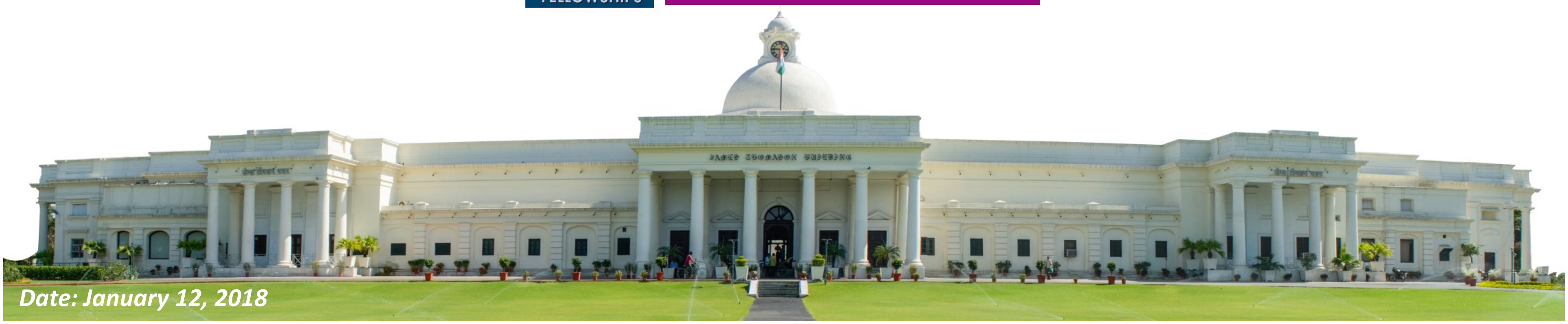

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INTRODUCTION

- Land use change information has great importance to understand the consequences of natural resources at spatial and temporal scales.
- For a river basin, land use is an important factor significantly influencing the hydrological cycle by affecting water balance components.
- Moreover, the adequate use of land and water resource is essential to provide desired goods and services without adversely affecting natural resources.
- Adaptive land and water resources management strategies are also prerequisite for sustaining food productivity.
- Nowadays, the SWAT model has been widely used to study different water balance components, and it turned out to be an effective tool to assess the land use change impact in a river basin area.

MOTIVATION OF THE STUDY

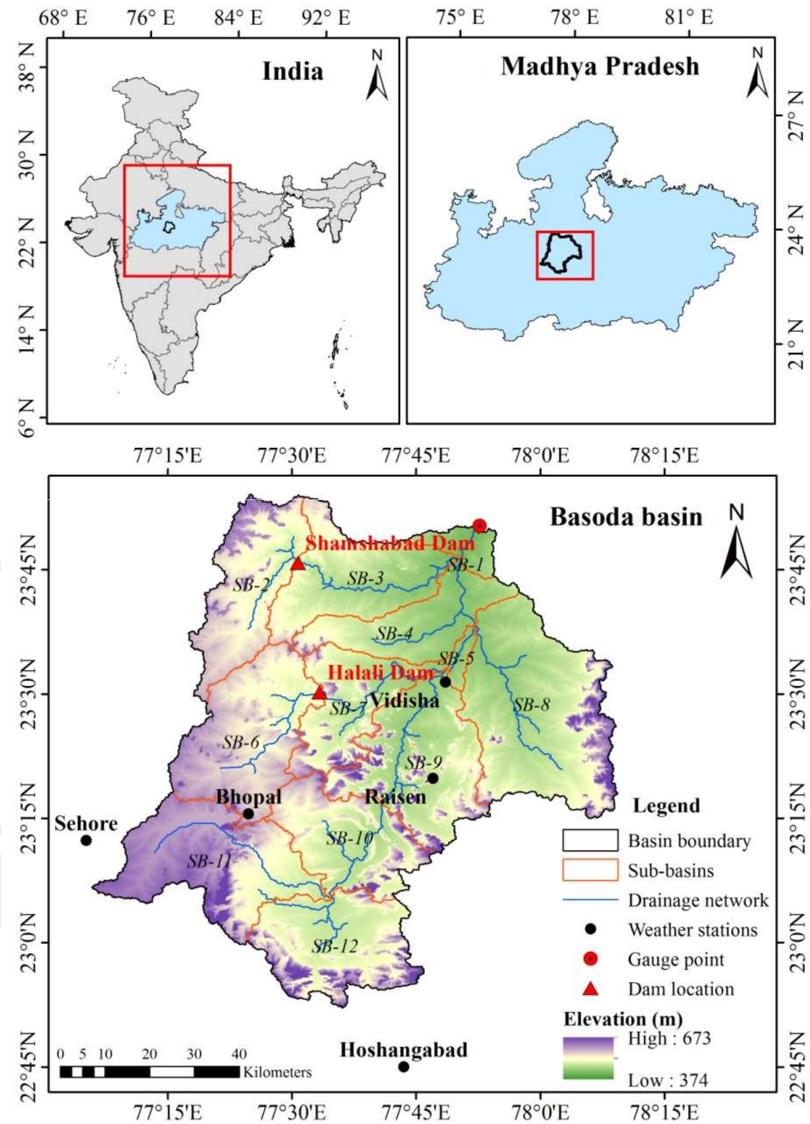
- Indian river basins are among the most sensitive natural systems, and are yet experiencing a variety of challenging issues in the land resources management due to rapid growth of population, urbanization and industrialization.

- In many parts of India, rapid land use changes alter the environment, resulting in pronounced impacts on the water balance. Therefore, the study of land use change impact is vital for sustainable land and water resources management.

- In the Central India, water resources are increasingly used for agriculture production. Moreover, urbanization nearby the capital city Bhopal affects the vegetation cover. Therefore, the present study is planned to identify the effects of major land use change on water balance of the Basoda basin.

STUDY AREA: Basoda basin

- Basoda is located near the local Betwa river, a tributary of the Yamuna river (which is tributary of Ganga river) in Central India.
- A gauging station at Basoda is controlled by the Central Water Commission (CWC) to measure gauge and discharge, since 1976.
- The Basoda basin area, upper part of the Betwa river basin, has spatial extends from latitude 22° 52' 5" N to 24° 54‘ 5" N and longitude 77° 05‘ 45" E to 78° 09' 31"E. Total area of the Basoda basin is about 6755 km^2.
- The range of elevation is about 374 m to 673 m above mean sea level. It has undulating topography with the land slope varying from 0 to 47%.
- The average annual rainfall varies from 700 to 1,200 mm with an average annual rainfall of 1,138 mm. The daily mean temperature ranges from a minimum of 8.1°C to a maximum of 42.3°C.
- Wheat, gram, paddy, oilseeds, pulses, sorghum, maize, vegetables and fodder are the major crops grown in the study area.



DATA

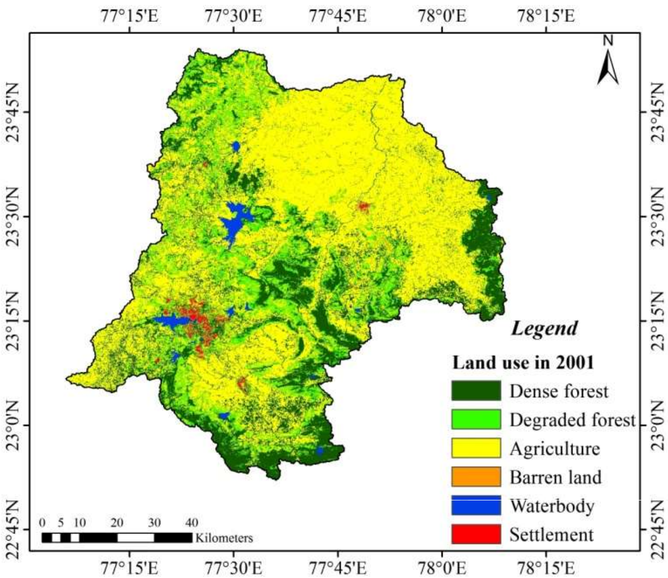
Data type	Data Source
Digital Elevation Model (DEM) data	• Shuttle Radar Topography Mission (SRTM) data of 30 m spatial resolution from Earth Explorer website (https://earthexplorer.usgs.gov/)
Satellite imagery data (Landsat 7 ETM+ and landsat-8 OLI)	• United States Geological Survey (USGS) Global Visualization (GloVis) website (http://glovis.usgs.gov/)
Observed climate data*	• India Meteorological Department (IMD) Pune
Soil data	• National Bureau of Soil Survey & Land Use Planning (NBSS & LUP), Nagpur, India
Discharge data**	• Yamuna Basin Organization (YBO), Central Water Commission (CWC), New Delhi
ArcSWAT model & SWAT-CUP	• Soil & Water Assessment Tool (SWAT) website (http://swat.tamu.edu/software/)

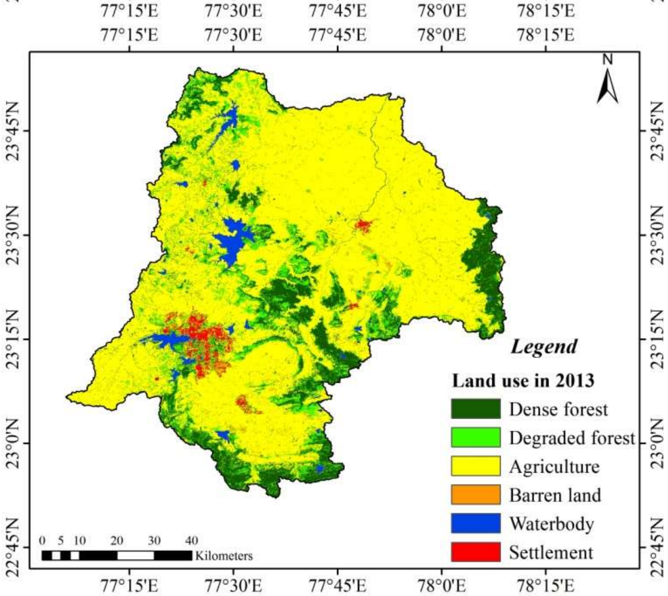
* IMD stations: (rainfall and temperature)

Sr. No.	Station
1	Bhopal
2	Hoshangabad
3	Raisen
4	Sagar
5	Vidisha

** CWC station: Basoda HO 676

LAND USE MAP PREPARATION





- Satellite imagery data has been used to prepare the land use maps using maximum likelihood classification method for the years 2001 and 2013.
- Accuracy assessment showed overall kappa coefficient values 0.72 and 0.78, and overall classification accuracies 78% and 82% respectively for the years 2001 and 2013.

Land use class	Indicator	Classification accuracy (%) 2001	2013
Dense forest	Producers accuracy	93.33	93.75
	Users Accuracy	70.00	75.00
Degraded forest	Producers Accuracy	83.33	77.27
	Users Accuracy	75.00	85.00
Agriculture area	Producers Accuracy	65.79	80.65
	Users Accuracy	83.33	83.33
Barren land	Producers Accuracy	66.67	58.33
	Users Accuracy	80.00	70.00
Waterbody	Producers Accuracy	100.00	100.00
	Users Accuracy	90.00	90.00
Settlement	Producers Accuracy	90.00	100.00
	Users Accuracy	70.00	90.00

SWAT model

Water balance equation used in the SWAT model:

$$SW_t = SW + \sum_{t-1}^{t} (R - Q - ET - P - QR)$$

where, SW_t = final soil water content (mm),

SW = initial soil water content (mm),

t = time (days),

R = amount of rainfall (mm),

Q = amount of surface runoff (mm),

ET = amount of evapotranspiration (mm),

P = percolation (mm) and

QR = amount of return flow (mm).

SWAT model run (2001-2013)

At monthly time-scale

2 warm-up years (2001-2002),

7 calibration years (2003-2009), and

4 validation years (2010-2013)

- **SWAT-CUP**
  - ➢ SUFI-2 algorithm used for the model calibration and validation.
  - ➢ Sensitivity analysis
    1. One-at-a-time sensitivity analysis
    2. Global sensitivity analysis

✓ **SWAT model inputs**

- DEM data
- Land use data
- Soil data
- Slope
- Weather data
- Reservoir data

✓ **Sensitive parameters to Discharge**

Rank	Parameter	Description	Fitted value
1	CN2.mgt	Soil conservation service runoff curve number for moisture condition II	-0.169
2	GW_DELAY.gw	Groundwater delay (days)	31.697
3	SURLAG.bsn	Surface runoff lag coefficient	1.642
4	SOL_AWC().sol	Available water capacity of the soil layer	0.082
5	GDRAIN.mgt	Drain tile lag time	0.625
6	ALPHA_BF.gw	Baseflow alpha factor (days)	0.414
7	GWQMN.gw	Treshold depth of water in the shallow aquifer required for return flow to occur (mm)	0.067
8	ESCO.hru	Soil evaporation compensation factor	0.579
9	RCHRG_DP.gw	Deep aquifer percolation fraction	0.364

SWAT model: Evaluation criteria

✓ **Coefficient of determination (*R*²)**

$$R^2 = \left[\frac{\sum_{i=1}^{n} (x_i - \bar{x})(y_i - \bar{y})}{\sqrt{\sum_{i=1}^{n} (x_i - \bar{x})^2} \sqrt{\sum_{i=1}^{n} (y_i - \bar{y})^2}} \right]^2$$

✓ **Nash-Sutcliffe coefficient (*NSE*)**

$$NSE = 1 - \frac{\sum_{i=1}^{n} (x_i - y_i)^2}{\sum_{i=1}^{n} (x_i - \bar{x})^2}$$

✓ **Percent Bias (*PBIAS*)**

$$PBIAS = \left[\frac{\sum_{i=1}^{n} (x_i - y_i) \times 100}{\sum_{i=1}^{n} (x_i)} \right]$$

✓ **Ratio of the RMSE to the standard deviation of measured data (*RSR*)**

$$RSR = \frac{\sqrt{\sum_{i=1}^{n} (x_i - y_i)^2}}{\sqrt{\sum_{i=1}^{n} (x_i - \bar{x})^2}}$$

where, x_i = observed values,

y_i = simulated values,

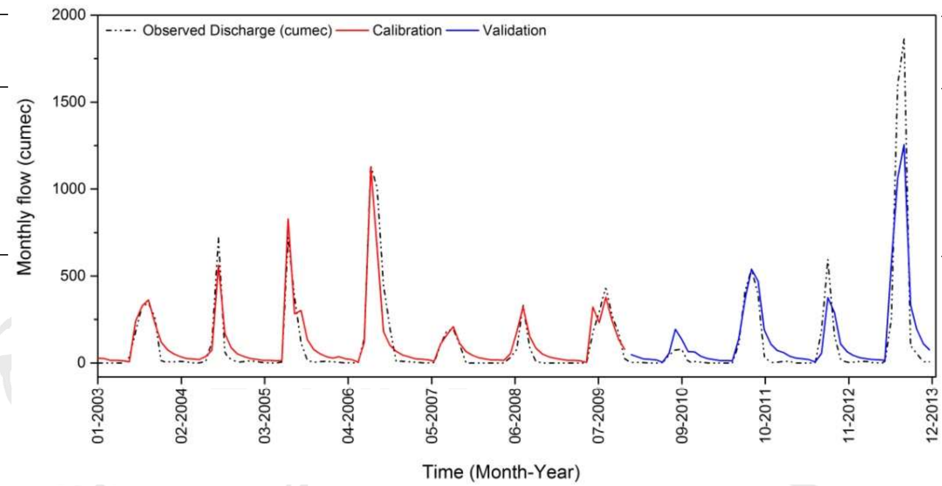
n = total number of values, and

$\bar{x}$ and $\bar{y}$ = are the mean values of observed and simulated values respectively.

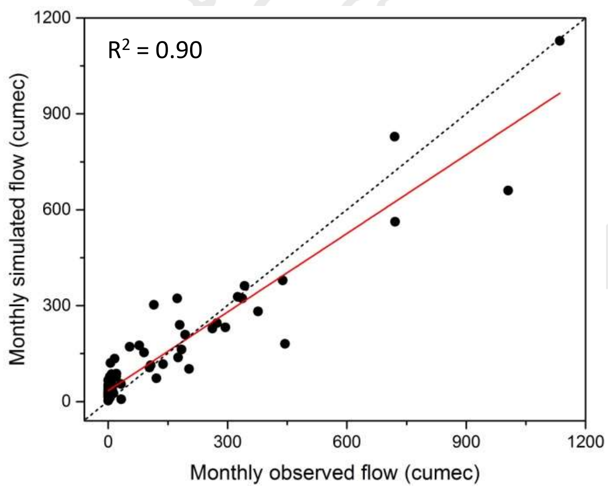
SWAT model: Monthly calibration & validation

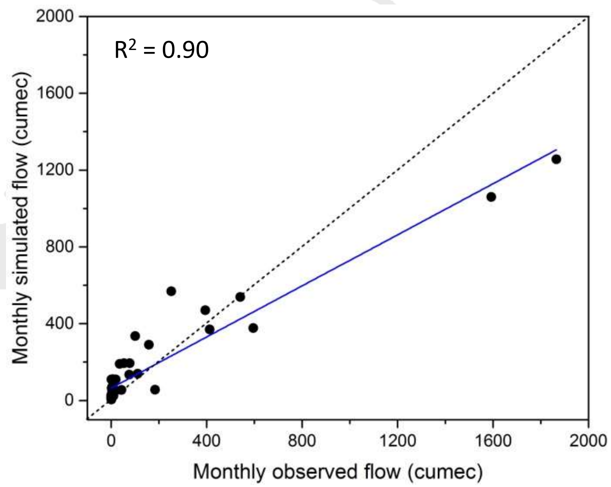
SWAT model monthly performance in the study area *(Moriasi et al., 2007)*

Evaluation Criteria	Calibration	Performance
R^2	0.90	
NSE	0.88	Very good
PBIAS	-14.20	Good
RSR	0.34	Very good



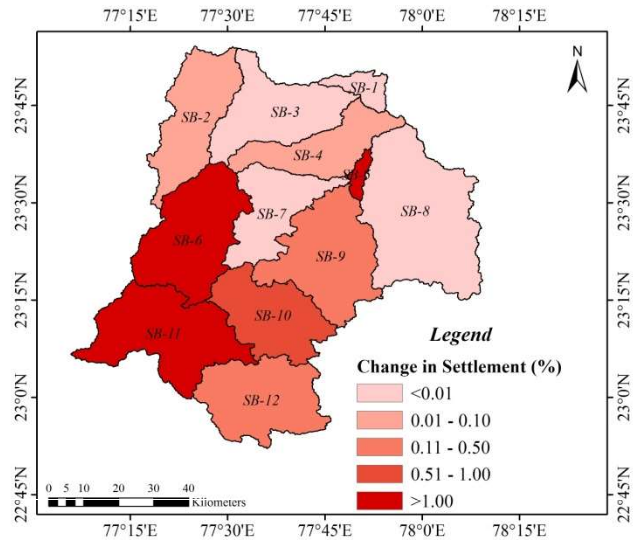
Evaluation Criteria	Validation	Performance
R^2	0.90	
NSE	0.84	Very good
PBIAS	-13.60	Good
RSR	0.41	Very good

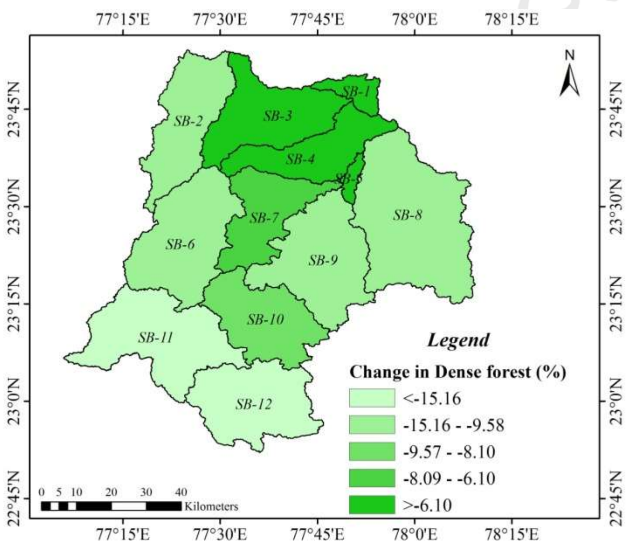


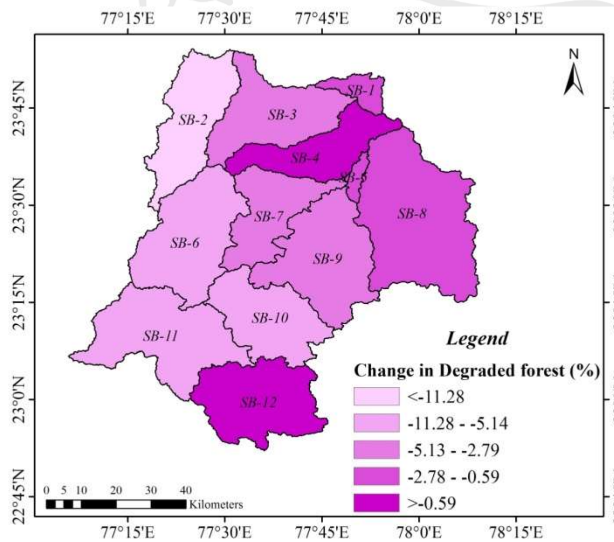


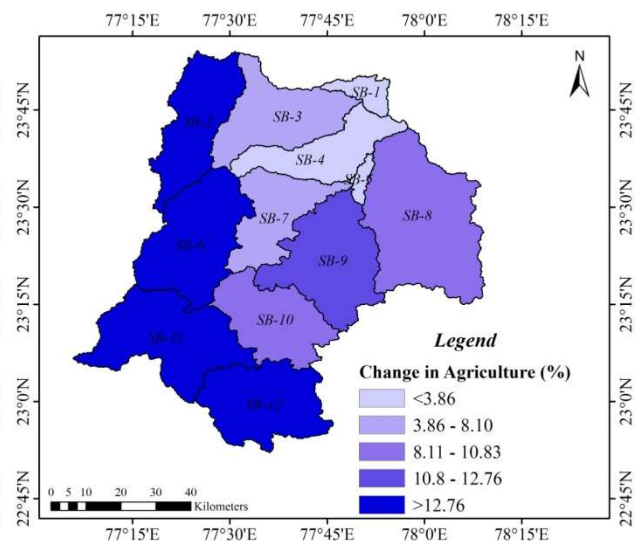
Land use change during 2001-2013

Land use class	Area (%)		Land use change (%)	Remark
	2001	2013		
Dense forest	24.76	14.50	-10.26	Decreased
Degraded forest	13.23	9.25	-3.98	Decreased
Agriculture	59.50	71.19	11.69	Increased
Barren land	0.31	1.33	1.02	Increased
Waterbody	1.46	2.57	1.11	Increased
Settlement	0.74	1.16	0.43	Increased
Total	100	100		









Land use change impact during 2001-2013

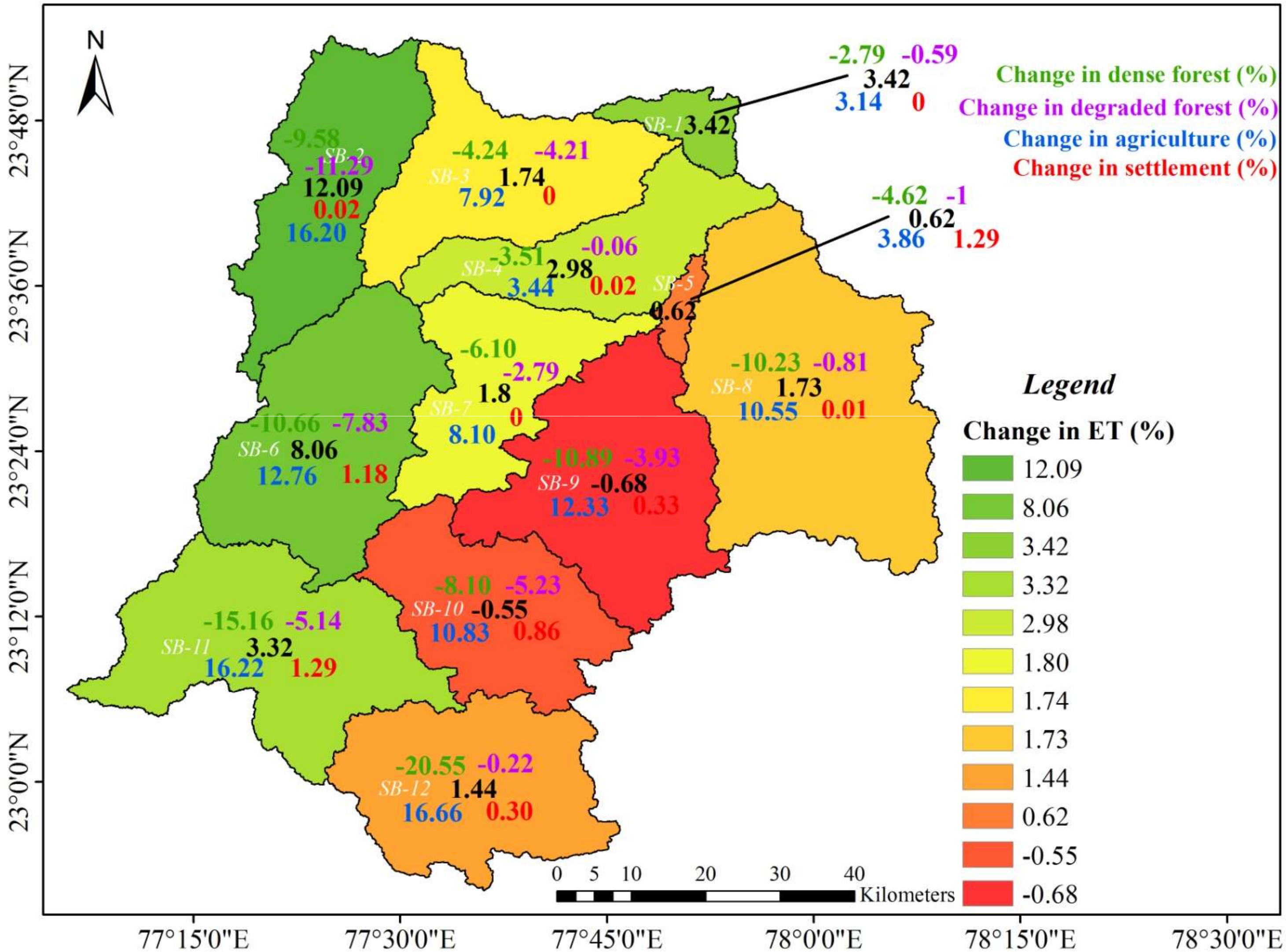
Method: **Delta approach**

Two model runs were performed with two different land use maps.

Water balance components	Before Land use change (mm)	After Land use change (mm)
Precipitation	986.10	986.10
Surface Runoff	229.34	229.85
Percolation	297.96	288.08
Evaporation and Transpiration	**467.70**	**482.60**
Deep Recharge	108.21	104.75
Total Water Yield	**525.96**	**518.57**

Water balance ratios	Bafore Land use change	After Land use change
Streamflow / Precip	0.43	0.42
Baseflow / Total flow	0.46	0.45
Surface runoff / Total flow	0.54	0.55
Percolation / Precip	0.30	0.29
Deep recharge / Precip	0.11	0.11
ET / Precipitation	0.47	0.49

Land use change impact on ET



Land use change impact on ET

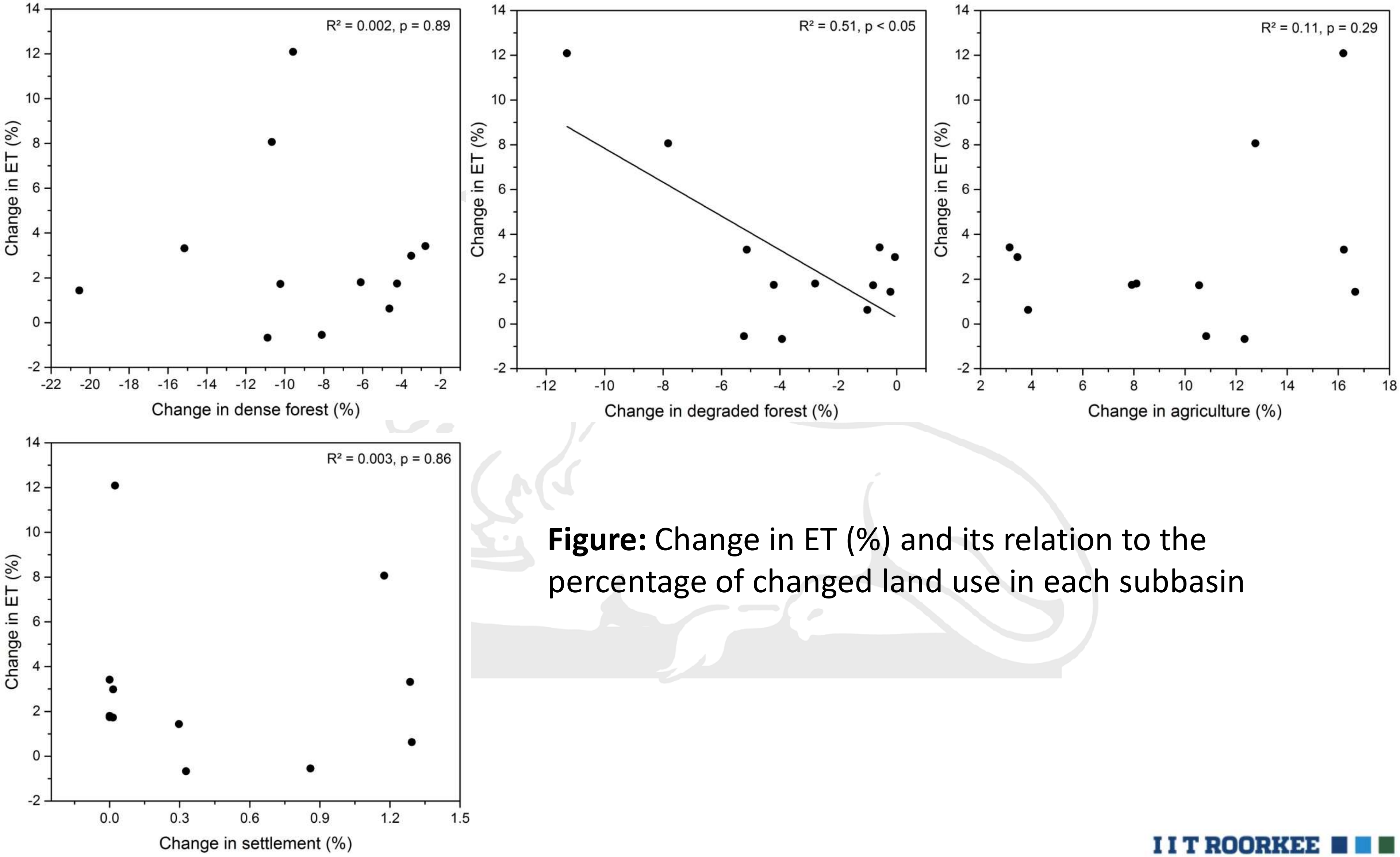
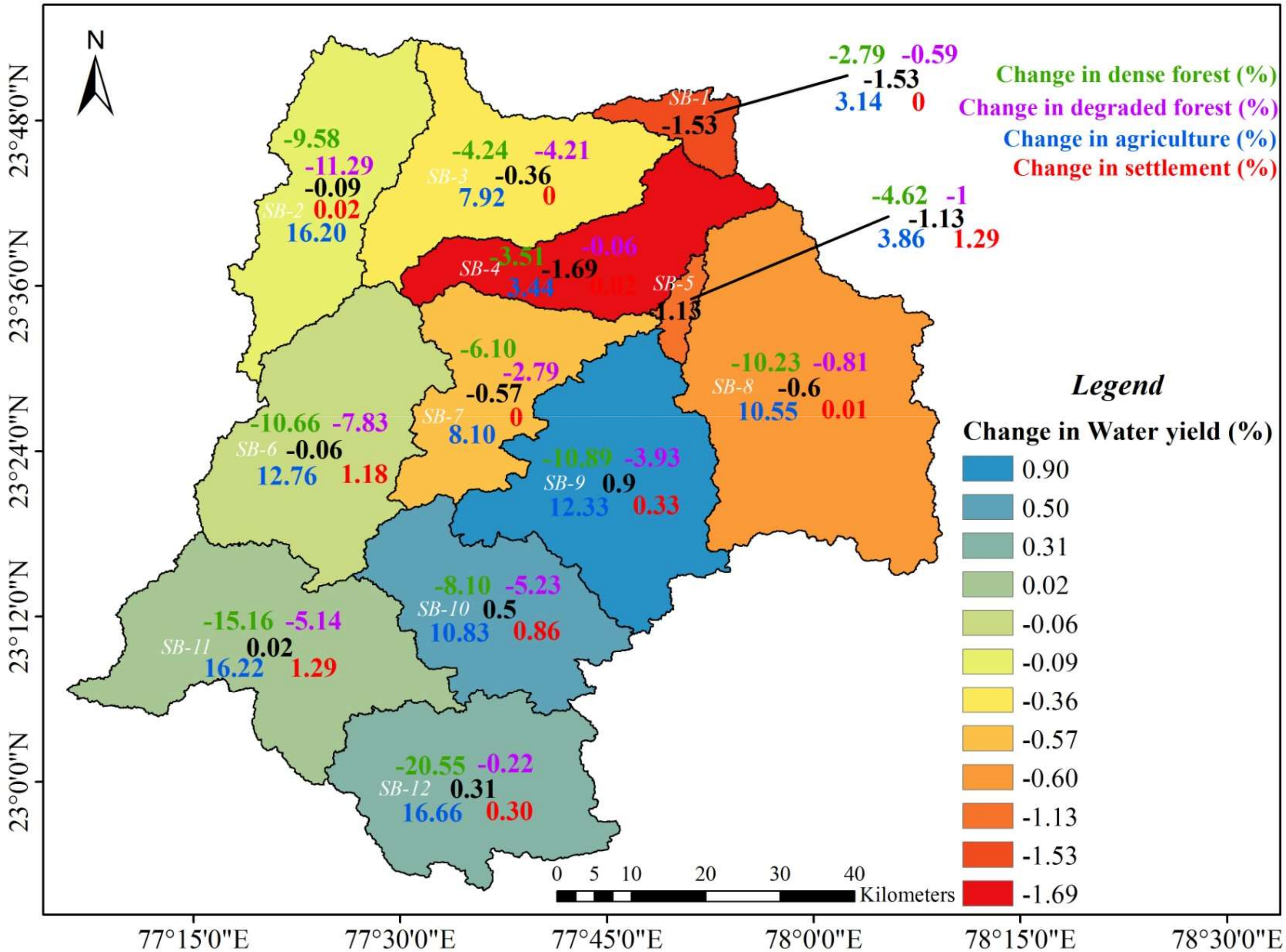


Figure: Change in ET (%) and its relation to the percentage of changed land use in each subbasin

Land use change impact on Water Yield



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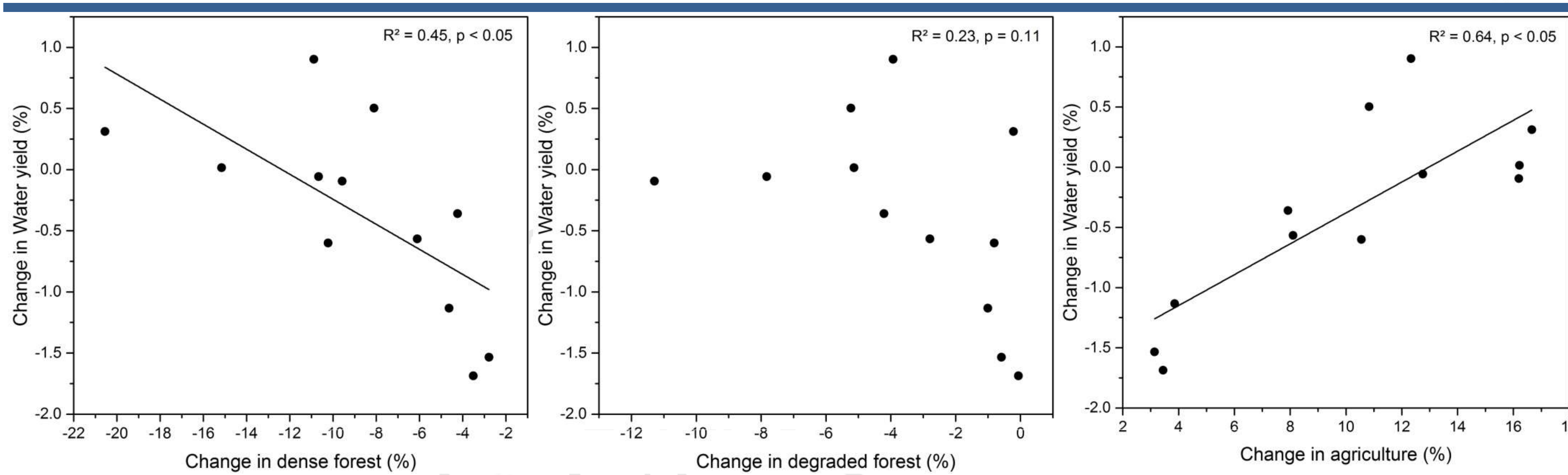
Land use change impact on Water Yield



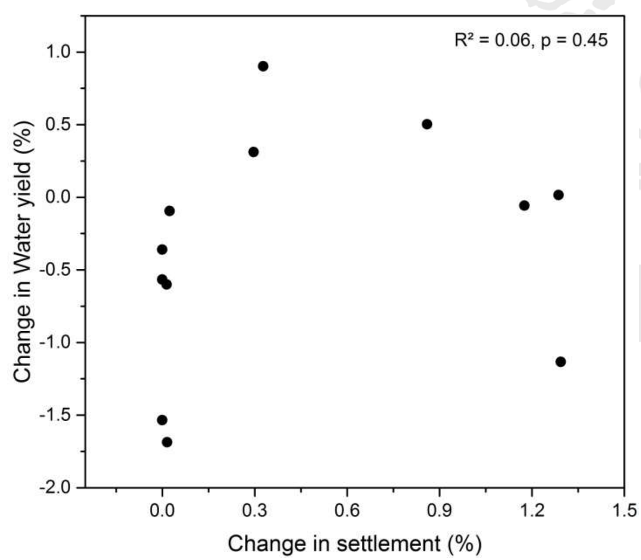


Figure: Change in water yield (%) and its relation to the percentage of changed land use in each subbasin

CONCLUSION

- This study highlights the role of vegetation dynamics affecting evapotranspiration and water yield at basin and subbasin level.
- SWAT simulation helps to understand the effects of land use changes on water balance components of the Basoda river basin.
- The major land use changes in the dense forest (decreased by 10.26%) and agriculture area (increased by 11.69%) have significant impacts on the simulation. At sub-basin level, the significant effect of degraded forest change on ET varied depending on changes in the vegetation cover.
- Overall, this study reveals that land use change is an important driver for changes in water balance of the Basoda river basin. Thus, proper management is required to conserve and sustain land resources in Central India.

THANK YOU…!