Deciphering the Water-Forest-Climate nexus through long-term hydro-climatic trends in watersheds of Narmada River

Singh, M., Srikar, R., Sinha, B., Bisaria, J., and Thomas, T.

EGU26-1239| PICO2.4| BG3.44| 8 May 2026 |Virtual

Study funded by: Ministry of Environment, Forest & Climate Change, Govt. of India (R&D Projects/17/2021-2022)
Conference participation supported by EGU Early Career Scientist's Travel Support

Institute: Centre for Climate Change Studies, IIFM, Bhopal | University: Forest Research Institute DU, Dehradun, India

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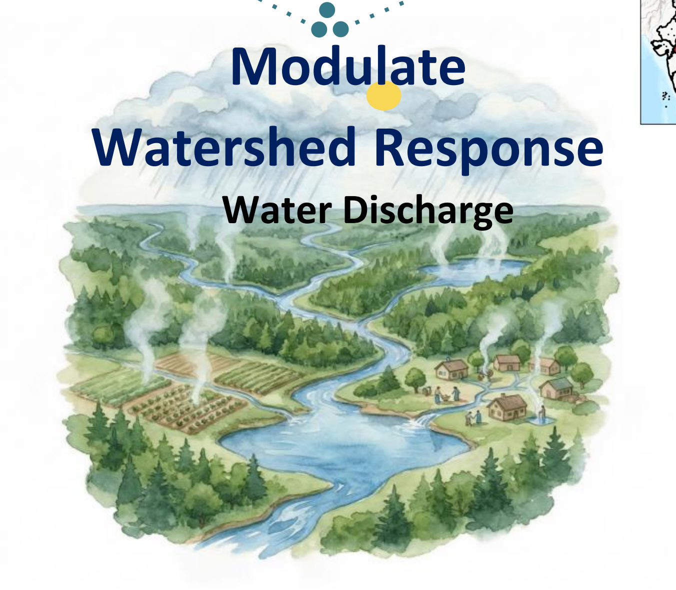
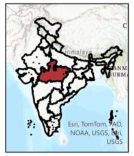
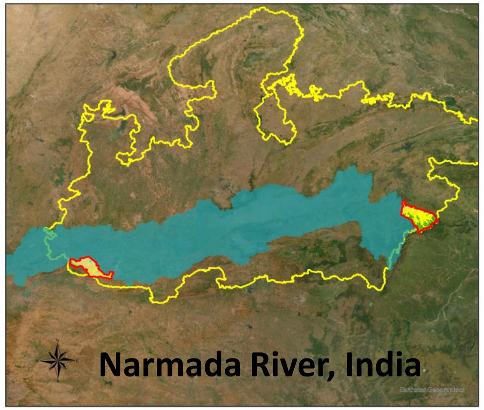
Climate
Precipitation, AET, PET, Temperature

Forest
Forest cover, Forest type, NDVI, EVI

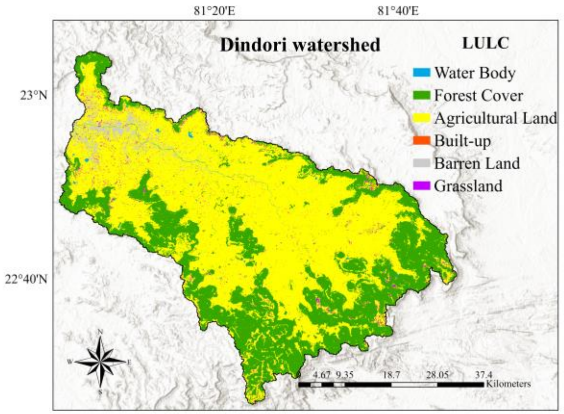
Topography & Soil
DEM, Slope, Aspect, Soil moisture

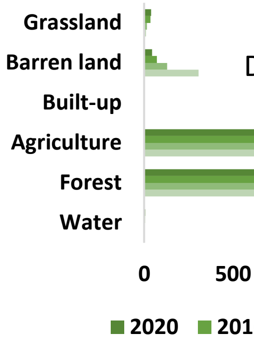




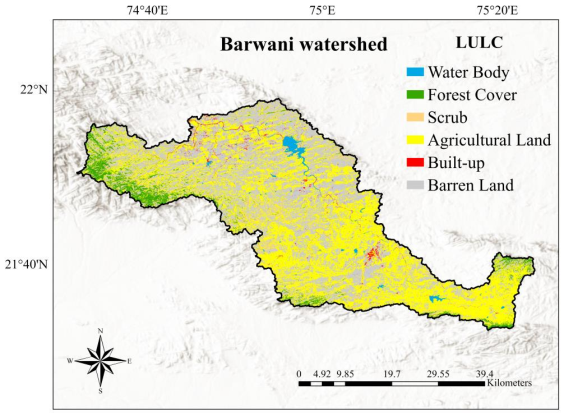


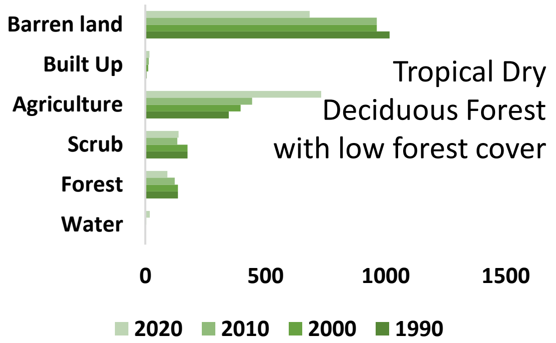
Forest Cover ↓
Agriculture ↑





Tropical Moist Deciduous Forest with higher forest cover



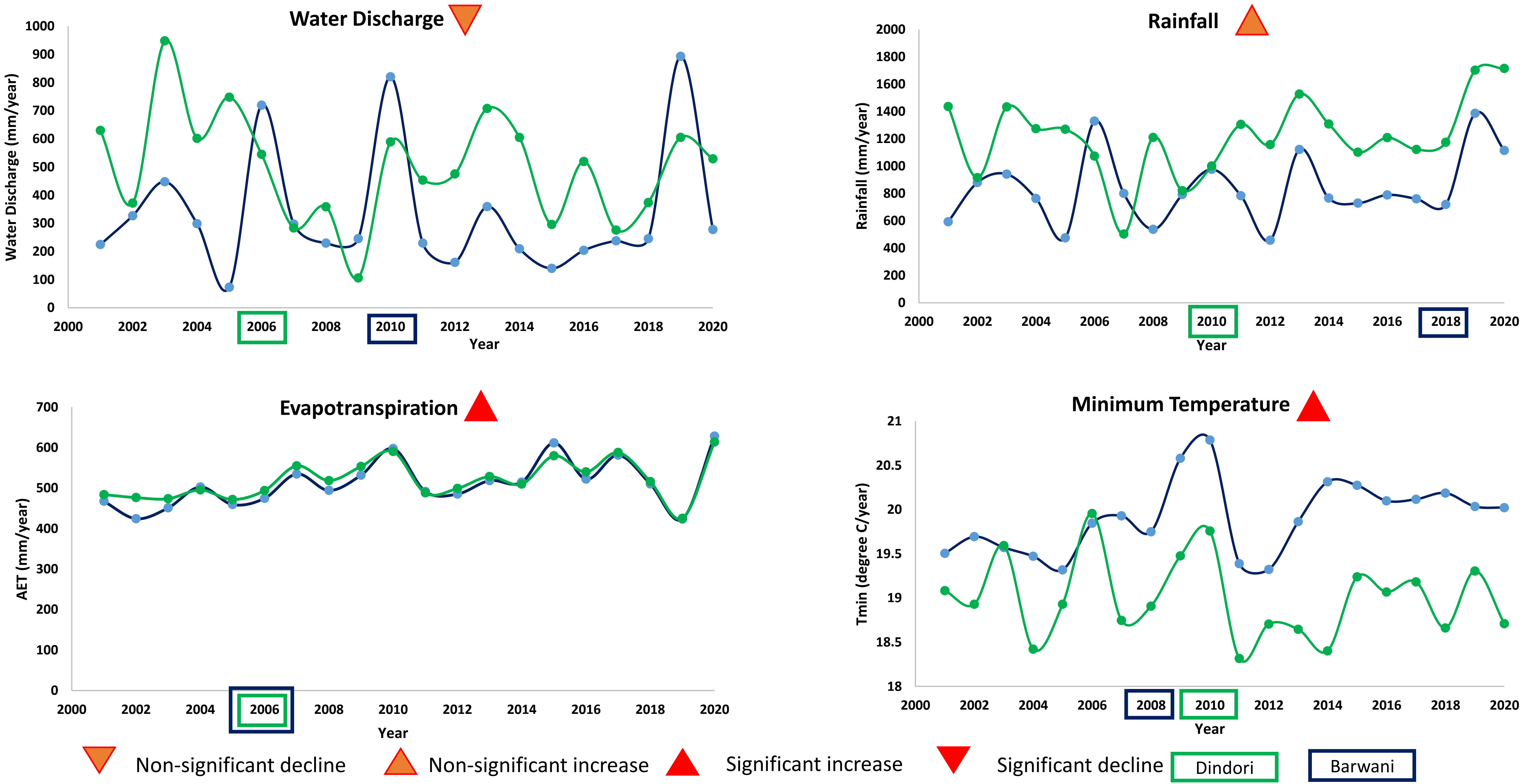


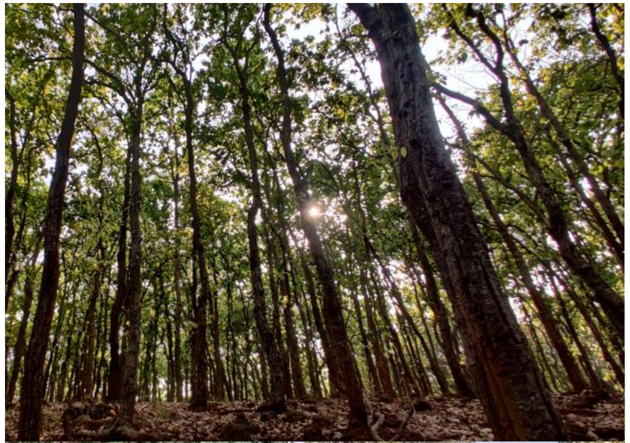
Tropical Dry Deciduous Forest with low forest cover

- **Background:** Changes in climate & vegetation create imbalances for eco-hydro-meteorological patterns impacting sustainable water flow in forested watersheds.
- **Gap:** Lack of studies focused on integrating hydro-climatic variability with forest and vegetation changes in India.
- **Approach:** Analysed long-term trends of eco-hydro-meteorological variables of distinctly forested tropical watersheds of a Central Indian River.

Any further information needed? Contact email: msinghfri19@iifmbhopal.edu.in | srikar.rishabh@gmail.com

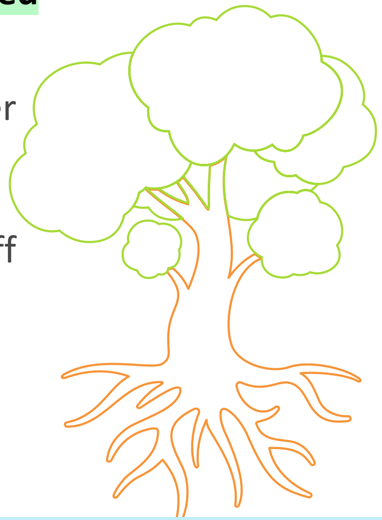
Contrasting watershed hydrological sensitivity under varying forest conditions





Dindori Watershed

- Higher water availability
- Stable runoff patterns
- Denser vegetation



Barwani Watershed

- Low water availability
- Increasing water stress
- Risk of desertification

The importance of forests in watersheds may increase substantially as freshwater resources become increasingly scarce

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Continue for Detailed Presentation

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Research Background & Gap → Study Area → Methods & Data → Results → Conclusion → Limitations

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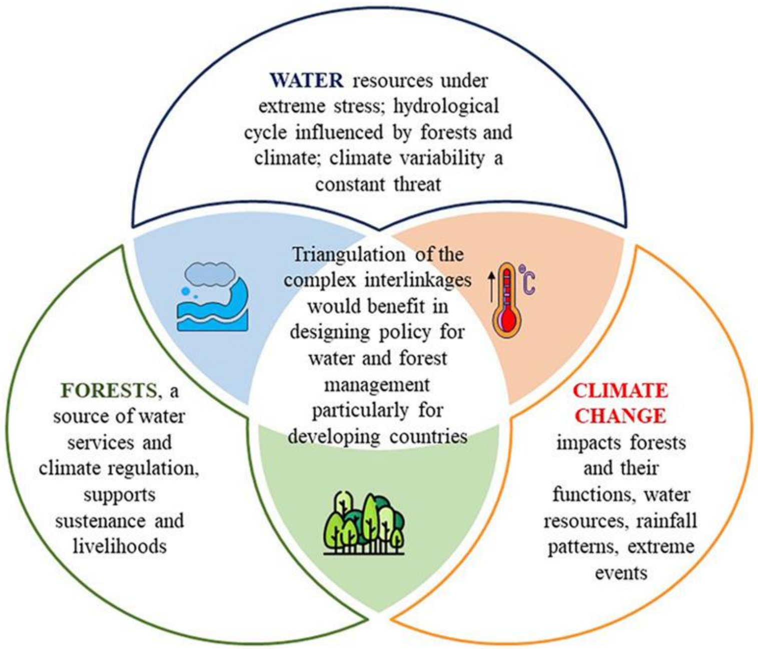
प्रगतेः मूलं प्रकृतिः

Research Background & Gap

Climate change intensifying floods, droughts, shifting precipitation patterns, fueling sea-level rise

Changing climate impact forests and regulation of water flows, influencing the availability of water resources

Forest water relationship critical for high proportion of domestic, agricultural, industrial and ecological water supply



Complexities of forest, water and climate (Singh et al., 2022)

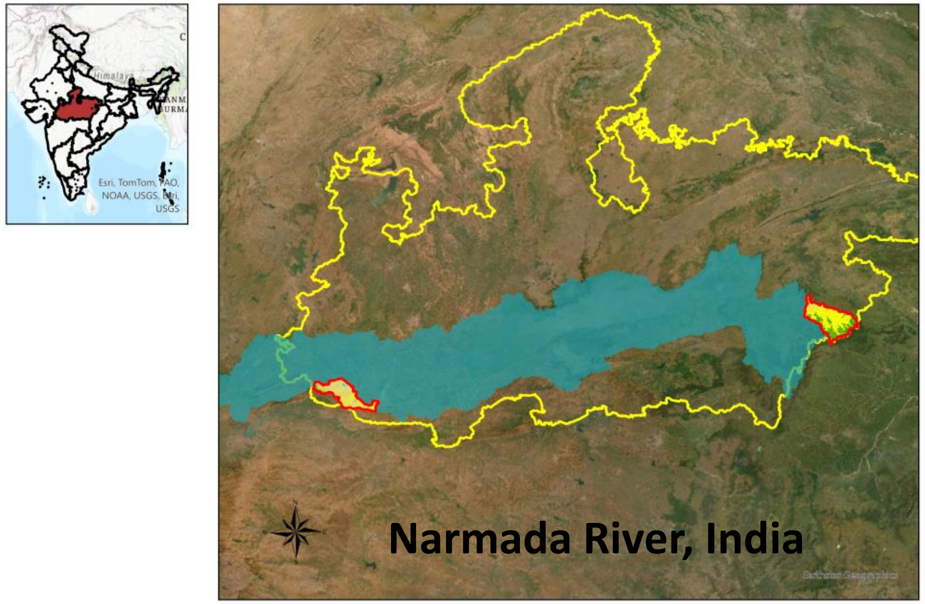
Water regulation and security influenced by changing forest cover & climate change

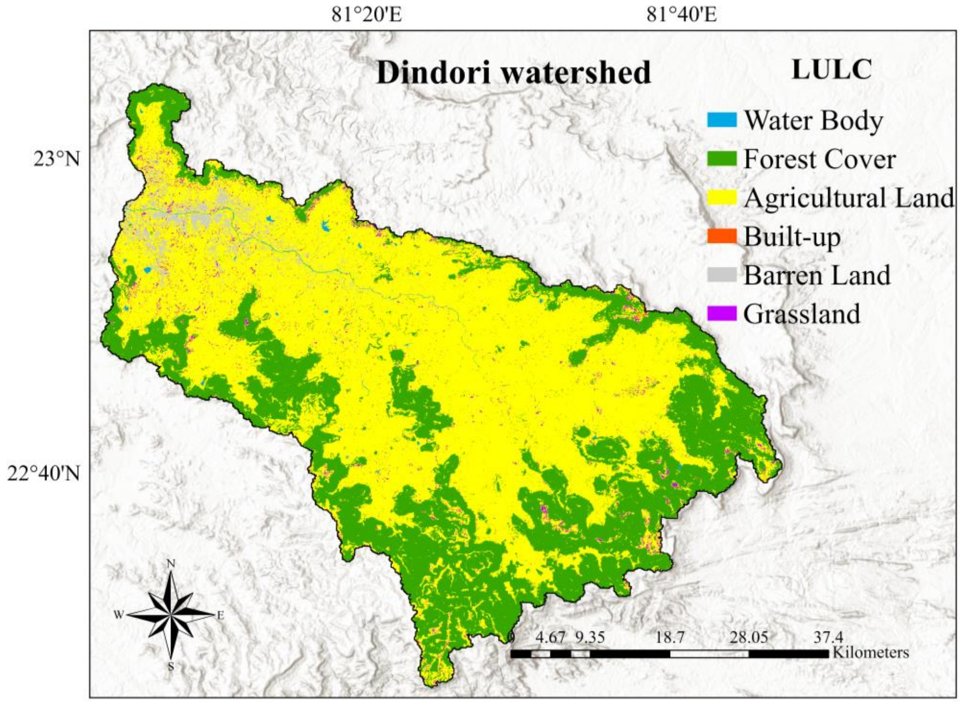
Lack of studies focused on integrating hydro-climatic variability with forest & vegetation changes in India

OBJECTIVE Therefore, our study focuses on analyzing long-term temporal trends of eco-hydro-meteorological variables of two distinctly forested tropical watersheds of Central Indian River

Singh, M., Sinha, B., Bisaria, J., Thomas, T., & Srivastava, P. (2022). Understanding synergies and tradeoffs between forests, water, and climate change. WIREs Water, 9(6), e1614. https://doi.org/10.1002/wat2.1614

Study Area

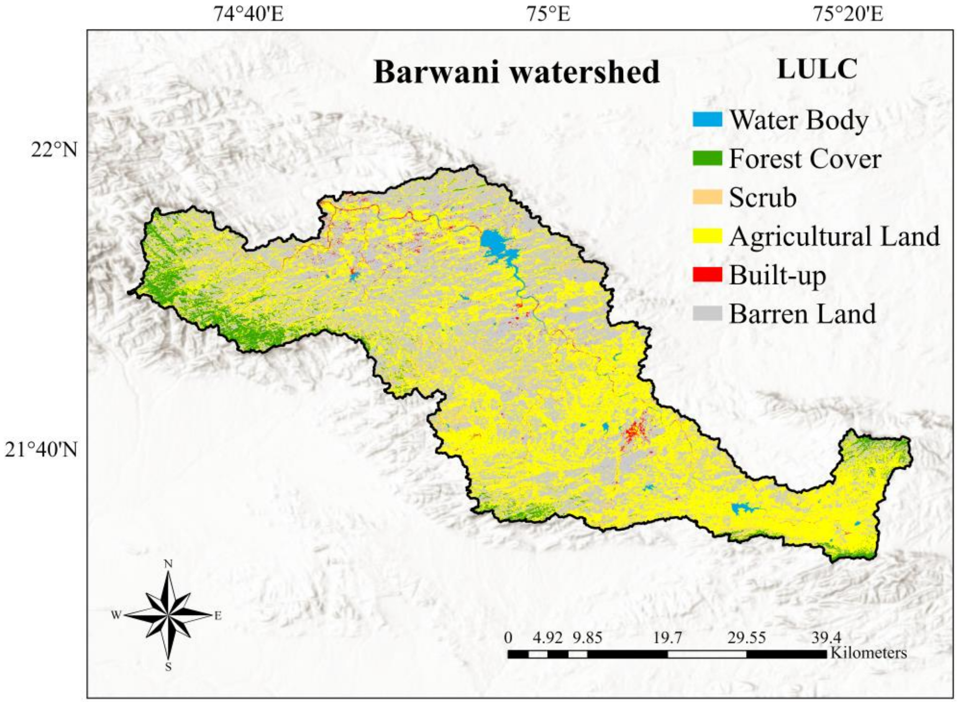




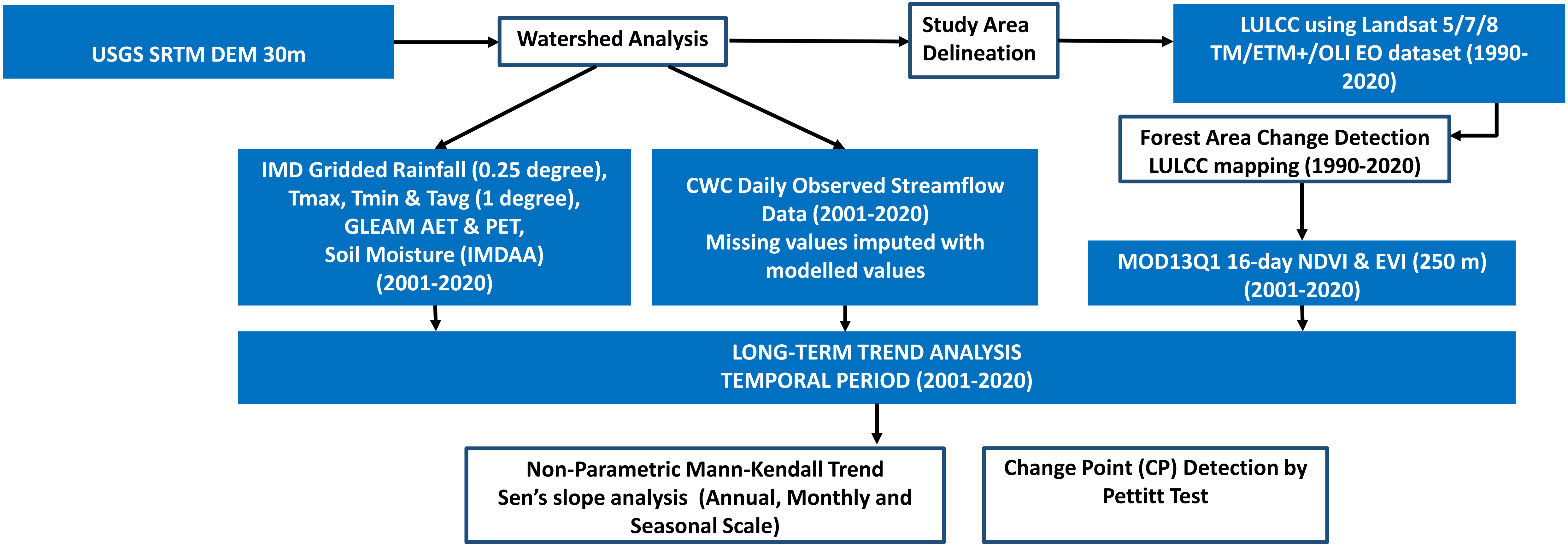
Forest cover	Higher (33%)
Forest Type	Tropical Moist Deciduous
Forest Density	Very dense & Mod. dense
Location	Upper catchment
Climate	Sub-humid

- Narmada river catchment with 33% forested area has ecological, economic, and socio-cultural importance for over 16 million people across four Central Indian states.
- Dindori and Barwani watersheds were selected in the upper and middle zones with different forest cover, density, and type.

Forest cover	Low (6%)
Forest Type	Tropical Dry Deciduous
Forest Density	Scrub Forest
Location	Middle catchment
Climate	Semi-Arid

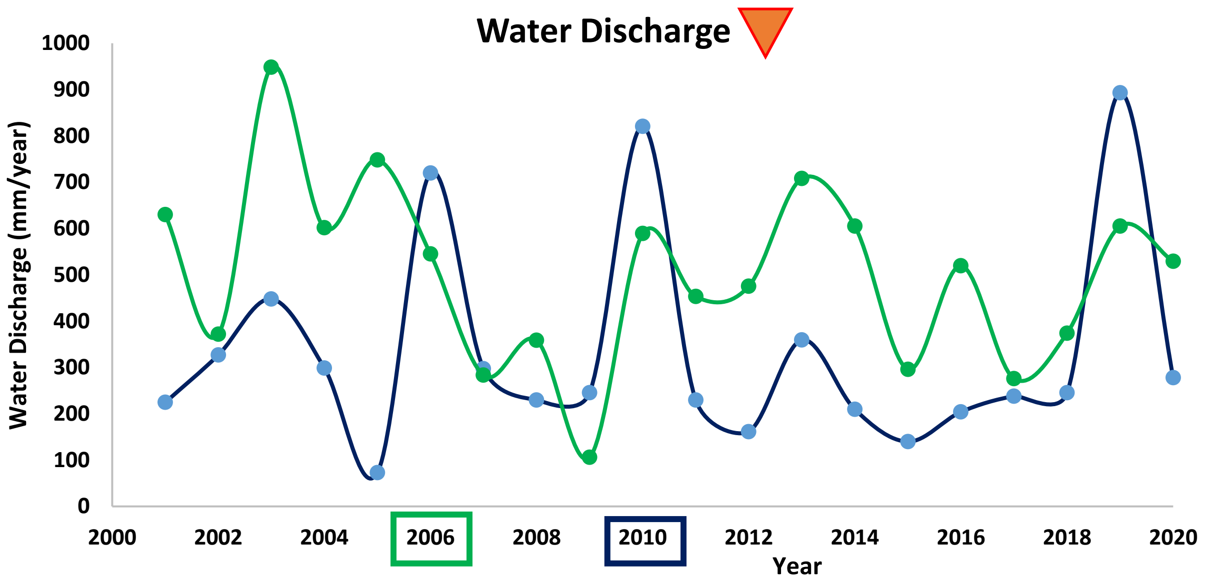


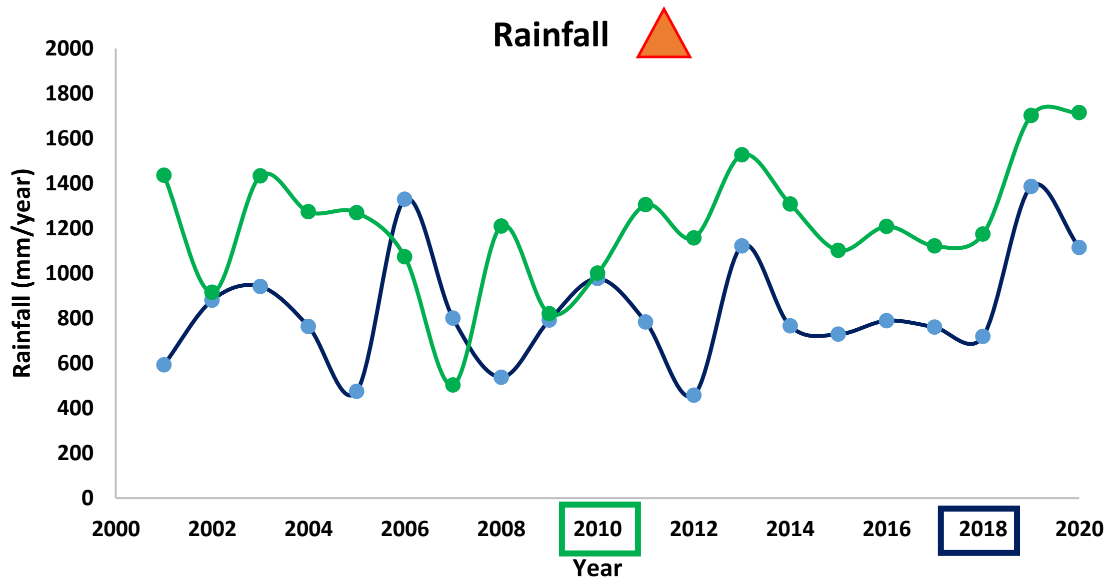
Method and Data Details

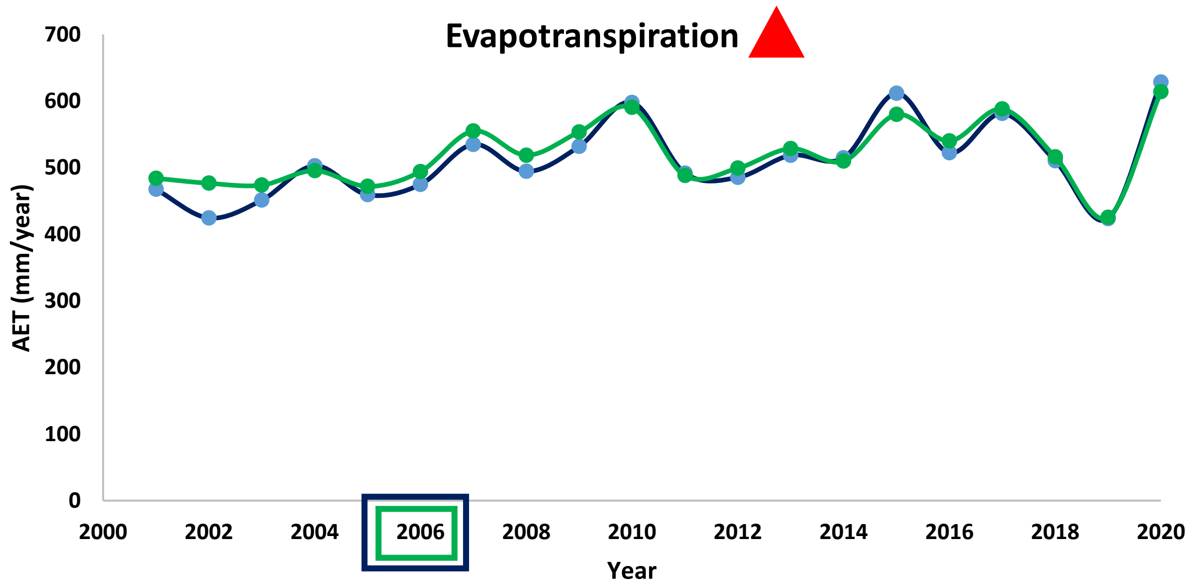


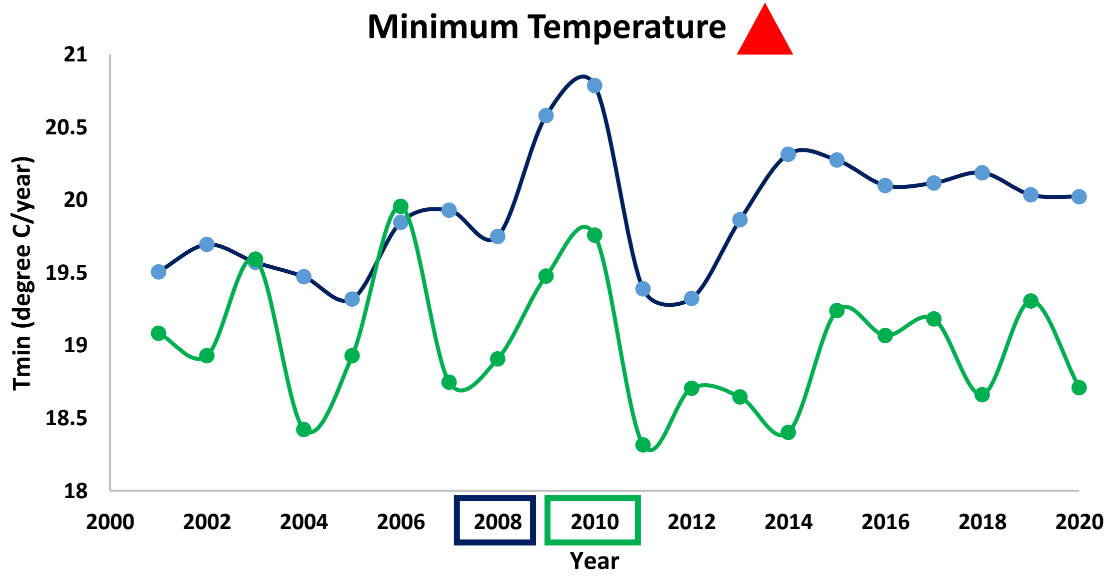
Results

Contrasting watershed hydrological sensitivity under varying forest conditions









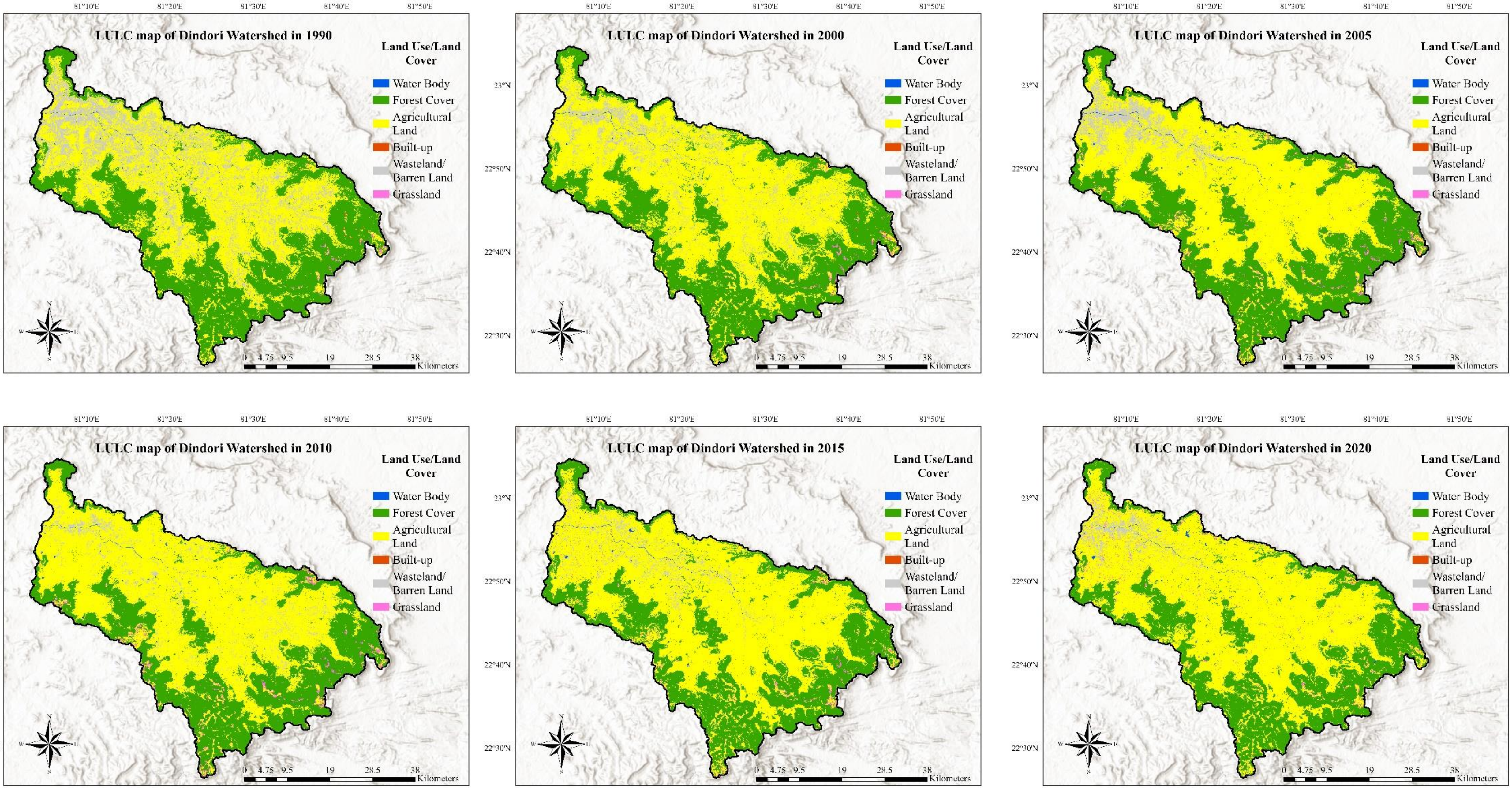
Non-significant decline | Non-significant increase | Significant increase | Significant decline | Dindori | Barwani

Results

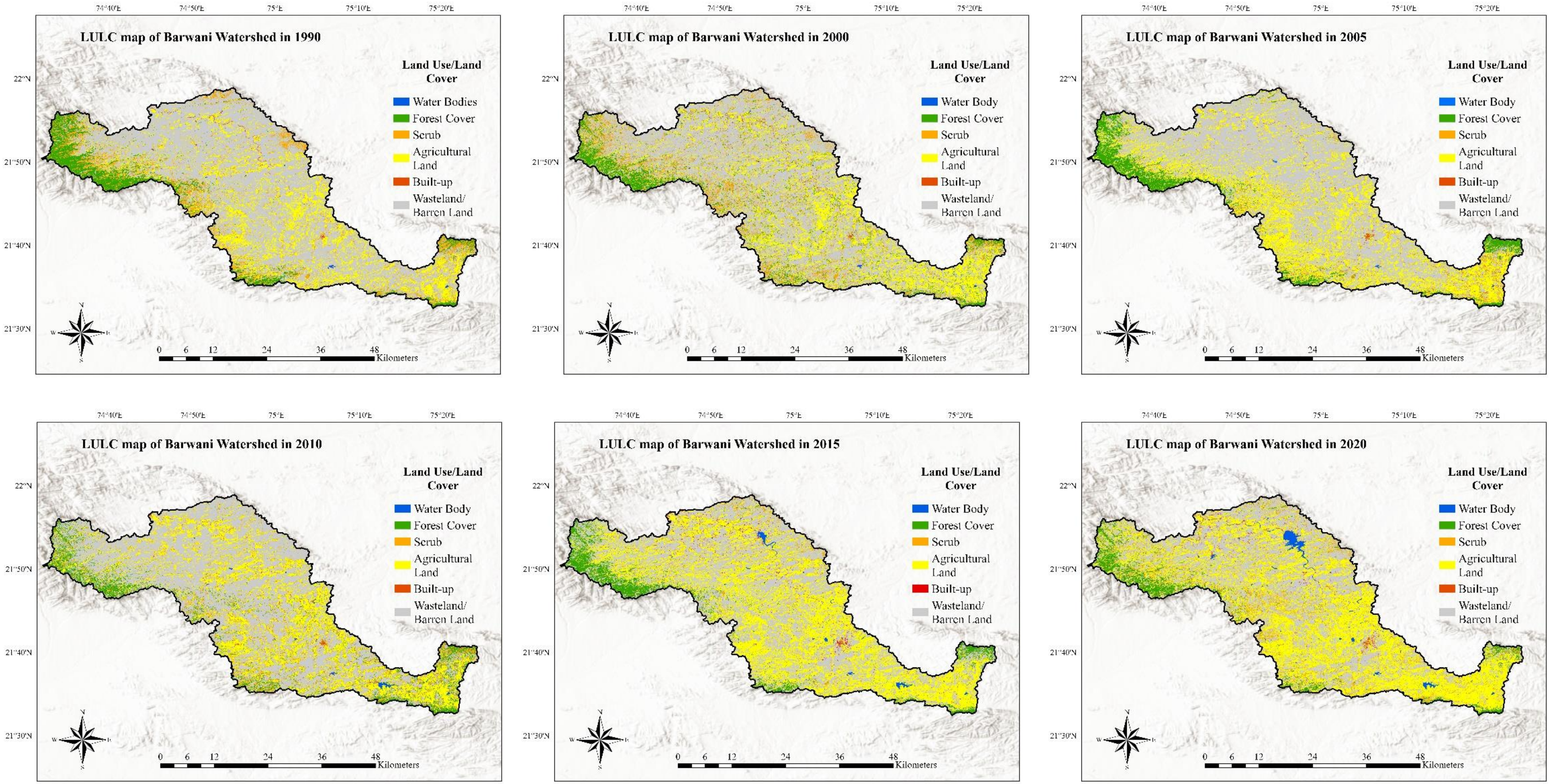
- Mann-Kendall trend test and change point analysis show significant variability in minimum temperature, average temperature, evapotranspiration and decline in water discharge for both watersheds
- Warming hydro-climatic conditions and increasing evaporative stress
- Forest cover reduction and increase in agriculture area observed in both watersheds according to lulcc mapping.
- NDVI increase attributed to the increase in agriculture area & intensification
- Hydro-climatic conditions exhibited variability across the two watersheds, with Barwani showing a warming tendency, particularly in minimum temperature, while Dindori exhibited relatively moderate climate variability
- Forest condition and watershed characteristics influence how rainfall is converted into streamflow.

Dindori	MK_Z	Trend	Sen_slope	CP_Year
Rainfall	0.88	no trend	12.70	2010
Tmax	-0.81	no trend	-0.01	2010
Tmin	-0.62	no trend	-0.01	2010
Tavg	-0.75	no trend	-0.02	2010
PET	0.03	no trend	0.04	2018
AET	2.24	increasing	3.95	2006
CWC_Q	-0.88	no trend	-6.61	2006
NDVI_Forest	0.55	no trend	0.00	2003
NDVI_NonForest	2.50	increasing	0.00	2008
EVI_Forest	0.75	no trend	0.00	2012
EVI_NonForest	3.21	increasing	0.00	2008
SM_L1	1.85	no trend	0.13	2011
SM_L3	0.16	no trend	0.05	2002

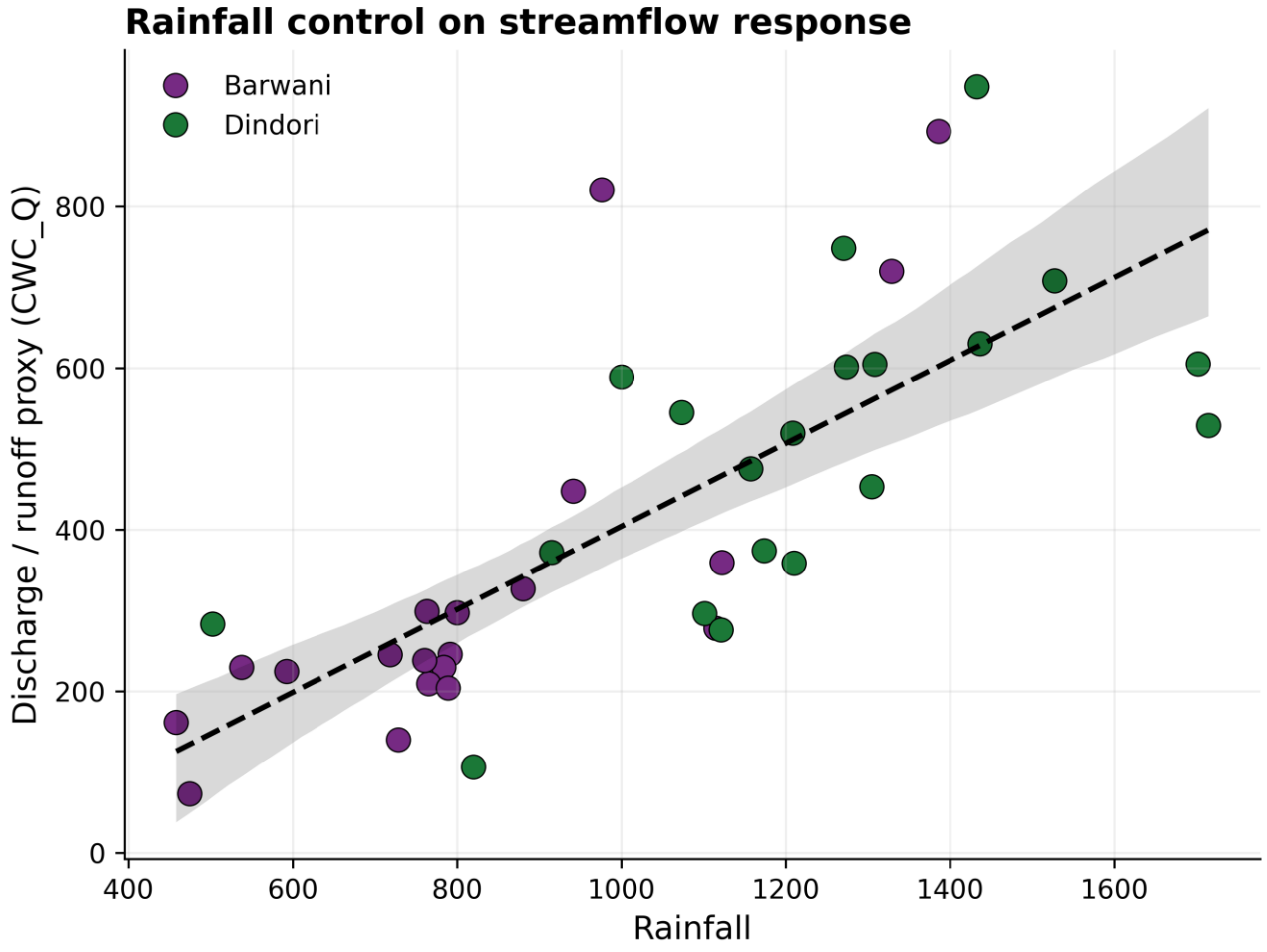
Barwani	MK_Z	Trend	Sen_slope	CP_Year
Rainfall	0.29	no trend	4.69	2018
Tmax	0.16	no trend	0.01	2018
Tmin	1.98	increasing	0.03	2008
Tavg	0.55	no trend	0.01	2013
PET	-0.10	no trend	-0.14	2018
AET	2.37	increasing	5.45	2006
CWC_Q	-0.29	no trend	-1.34	2010
NDVI_Forest	3.21	increasing	0.00	2008
NDVI_NonForest	4.44	increasing	0.00	2009
EVI_Forest	3.86	increasing	0.00	2009
EVI_NonForest	4.77	increasing	0.00	2009
SM_L1	2.24	increasing	0.13	2005
SM_L3	0.55	no trend	0.35	2007

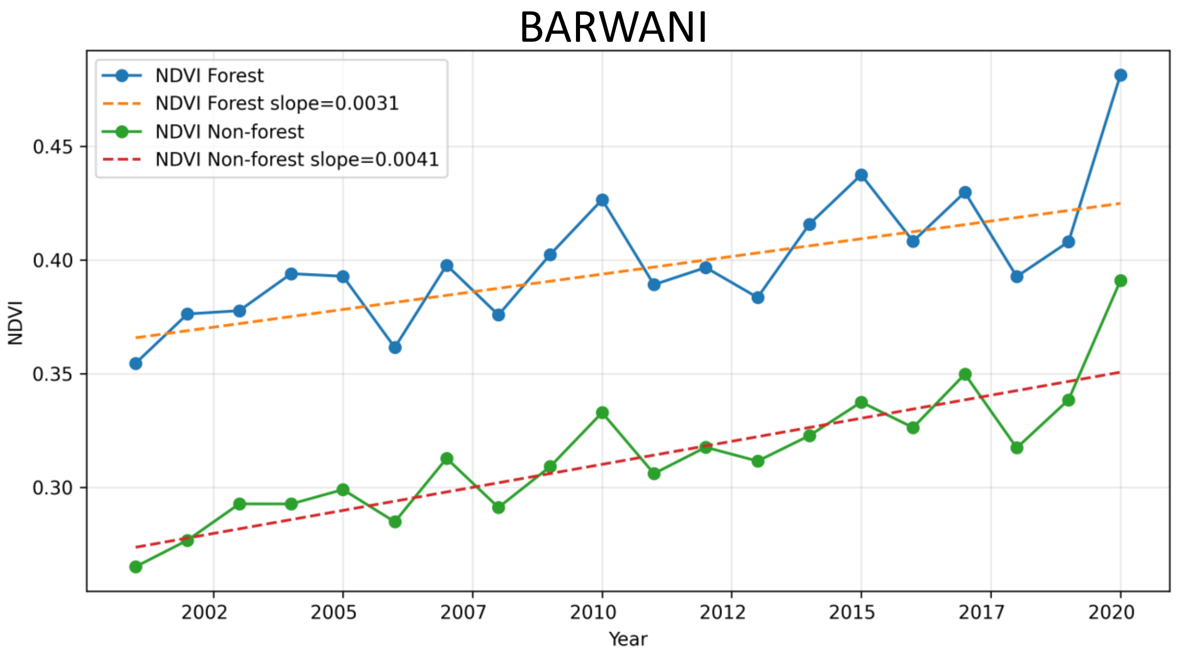


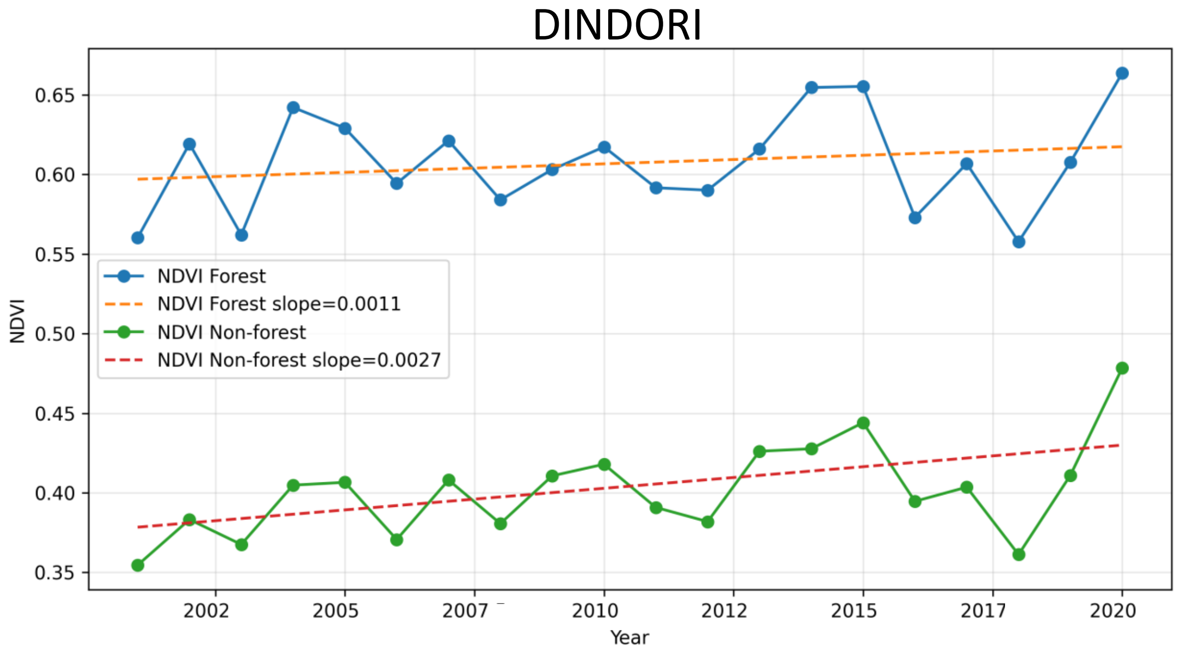
LULC DINDORI Watershed (1990-2020)



LULC BARWANI Watershed (1990-2020)







Discharge response is mainly rainfall driven in both watersheds but forested watershed depict hydro-climatic stability and buffered hydrological response

Conclusions

- The research undertaken highlights differentiated hydro-climatic response of tropical forested watershed and an alternative approach to explore the complexities of watershed dynamics.
- The changes are more pronounced in Barwani when compared to Dindori, as forested watershed indicate a better regulated hydrological regime.
- The long-term & descriptive analysis of the variables characterises Dindori watershed with higher runoff efficiency, better moisture retention with denser vegetation, and a balanced ET-runoff relationship depicts resilience, but this is subject to change due to rising AET.
- While in Barwani, low water availability compounded by higher ET losses proportional to rainfall indicates increasing water stress, which will further intensify due to rising temperatures.
- The drying impact is a concerning factor for the energy and water balance in an already water-limited region (Barwani), as this could pose the risk of desertification in future.

Limitations

- The study relies on trend analysis of twenty year of continuous eco-hydro-climatic data but increasing the temporal period will lead to more reliable trends as variations are sensitive to the temporal spread of data
- The inferences drawn are based on observational variations with MKT trend and change point analysis, the actual causation factors needs to be explored
- Data limitations exist both in spatial and temporal form, the work is reliant on modelled datasets for most variables

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