

# CRITICAL ANALYSIS OF HYDROLOGICAL MASS VARIATIONS OF NORTHWEST INDIA

Mira Shivani S<sup>1\*</sup>, S Srivastava<sup>2</sup>, A Singh<sup>1</sup>

<sup>1</sup>Centre for Wireless Network & Applications (WNA), Amrita Vishwa Vidyapeetham, Amritapuri, India

<sup>2</sup>Amrita School for Sustainable Development, Amrita Vishwa Vidyapeetham, Amritapuri, India



## 1. Project goals and Motivation

### • Primary goal

To analyze the behavior and the **Spatio-temporal trend** of Total water storage (TWS) from 2002 to 2021.

### • Project Motivation

The major economy of India is from the **agriculture industry** and the production of **water-intensive** crops like paddy, wheat, cotton, sugarcane, has been suggested as one of the major reasons for **groundwater depletion** in the country, specifically north-western states.

**Explained: Two reports, 2 decades apart, predicted Punjab's desertification in 25 years. Here's why they are both right**

Punjab is drawing more water than is being replenished, as a result of which the water table is going down.



### Behind India's sugar dominance lies a hidden water crisis in Uttar Pradesh

Villagers living in the state's sugar belt are bearing the brunt of poorly implemented environmental regulations.

**Water woes are peaking in Bundelkhand and it's a 'bigger crisis than Covid can ever be'**

For nearly two dozen years, water scarcity is a big issue every summer. While hand pumps and wells are giving no support, Covid-19 has only heightened the stress.

**Politics of Suttej-Yamuna Link Canal Water Crisis in Punjab and Haryana**

After the Green Revolution, Punjab and Haryana have become water-scarce states due to the introduction of paddy as the main kharif crop, a massive increase in cropping intensity, and rapid urbanisation and industrialisation. However, the real issue of moving to sustainable cropping patterns and improving water-use efficiency remains unaddressed. An improvement of 15% to 20% in water-use efficiency from the present level can provide each state with the increased water that it is demanding.

The whole of north-west India, especially Punjab, Haryana and Rajasthan, are facing an acute water shortage. This crisis has intensified after the Green Revolution. Roughly, 80% of the total demand for water comes from agriculture. The rest is used in domestic consumption, industry and commerce, and the power sector. Water use in agriculture has increased many times over due to the excessive tillage and the introduction of water-intensive crops such as rice.

**Lockdown gives birth to acute water crisis in Rajasthan's Bikaner, locals left running from pillar to post**

There has been an acute water crisis in rural Bikaner in Rajasthan. Lockdown due to Covid-19 infection has made it worse, leaving villagers running from pillar to post to fill their pitchers.



**Delhi Is Running out of Water, and It Is Everybody's Problem**

In six months from now, by the year 2020, 21 Indian cities, including Delhi, are feared to run out of groundwater.

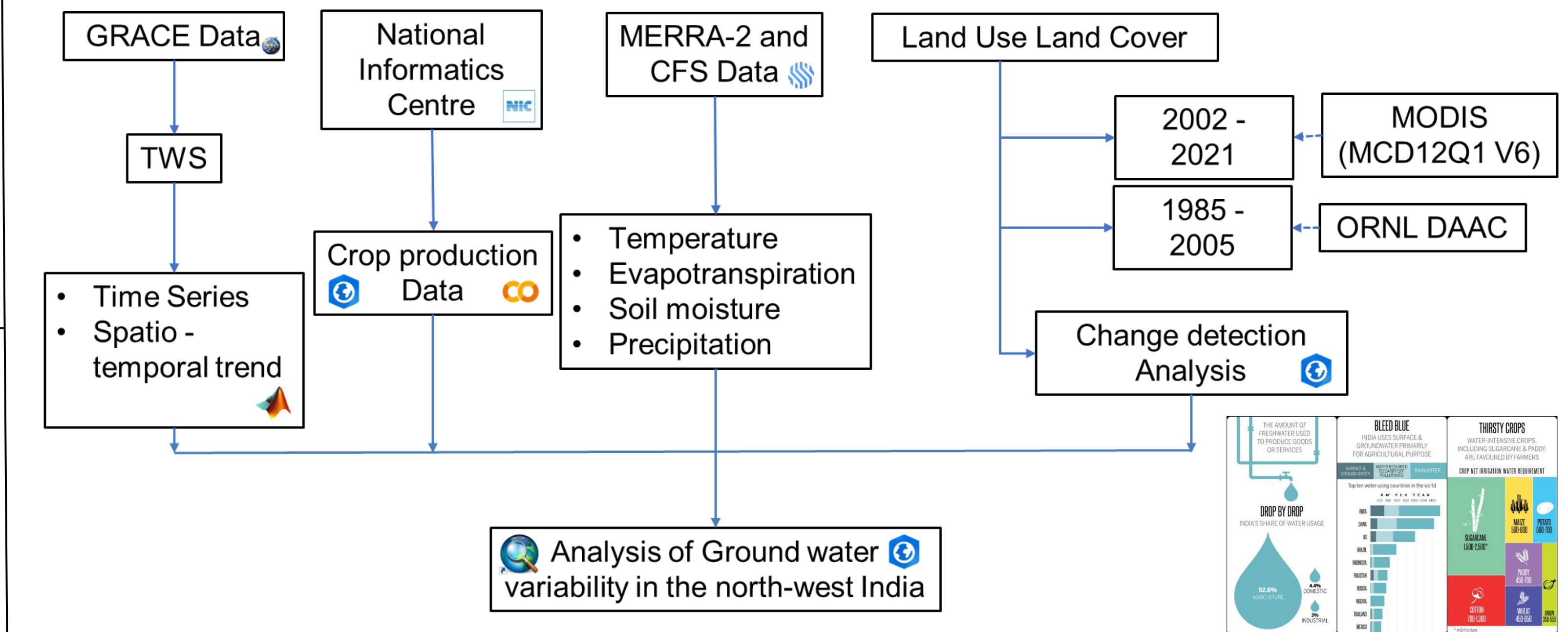
## 2. Objectives

- To analyze the **trend** of TWS from GRACE (Gravity Recovery and Climate Experiment) data.
- To analyse **groundwater availability** in northwest India.
- To identify the **predominant cause** of groundwater variability in the region.



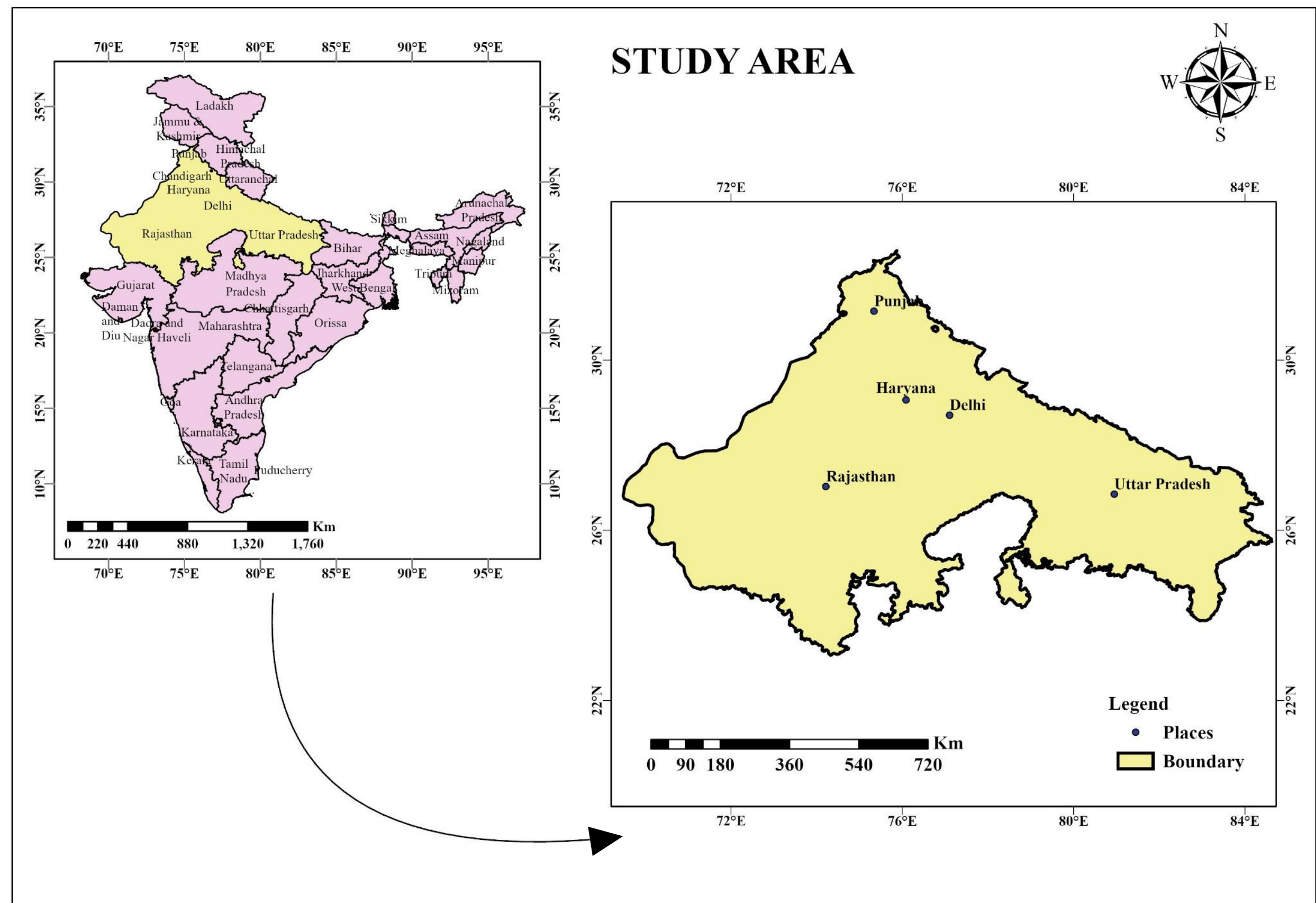
## 4. Methodology

GRACE data had gaps which were filled with the estimated seasonality and trend in **MATLAB** after which, the time series and spatial trend were analyzed. While carrying out change detection analysis in **ArcGIS Pro – Change detection wizard tool**, more importance was given to the features which got converted to croplands and built up. Crop production data from NIC was obtained, data wrangling and **statistical analysis** was done using **Google Colab**. Then, the **spatial analysis** of crop production trend was derived using **ArcGIS Pro** for the water-intensive crops (cotton, rice, sugarcane, and wheat). Other factors like temperature, evapotranspiration, soil moisture and precipitation obtained from Modern-Era Retrospective analysis for Research and Applications, Version 2 (MERRA -2) and Climate Forecast System (CFS) were analyzed in **Climate Engine's research App**.



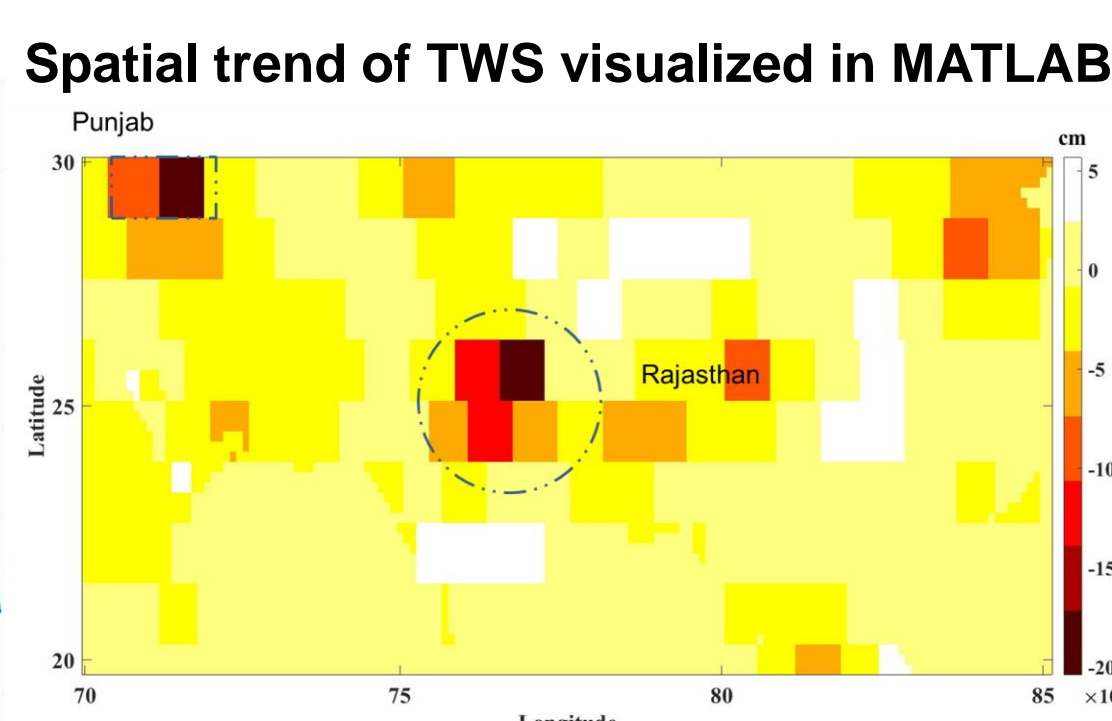
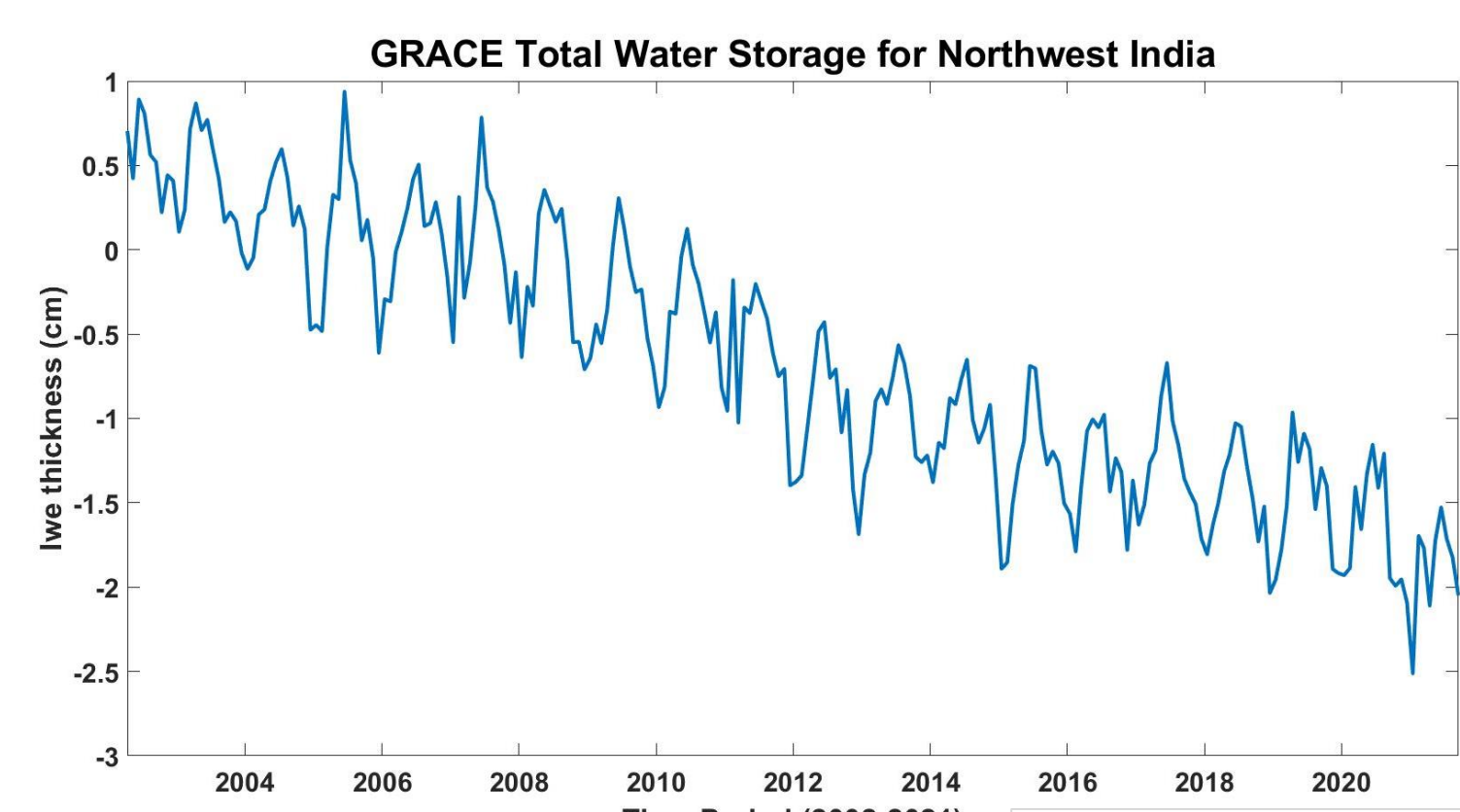
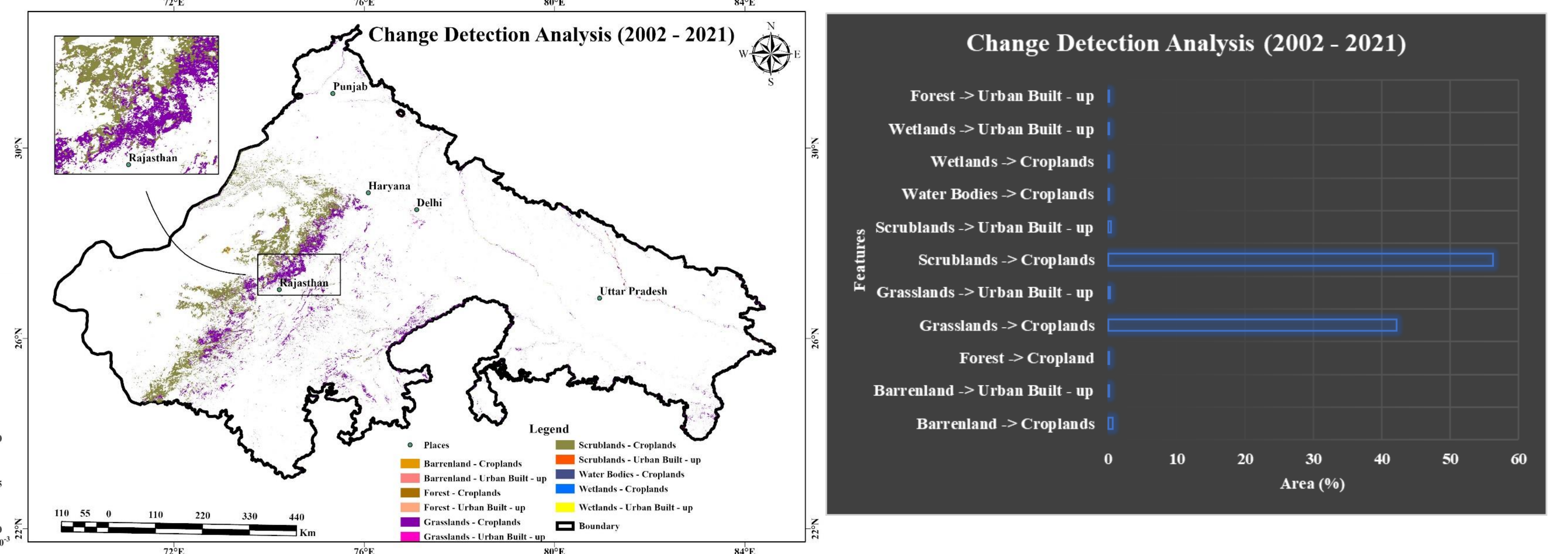
## 3. Study Area

The region receives an average rainfall of **700mm** annually and has rivers like Yamuna, Chambal, Son, etc., The groundwater in the region is withdrawn continuously for the purpose of irrigation **exceeding the recharge rate** [1], [2] which leads to depletion of groundwater in the region.

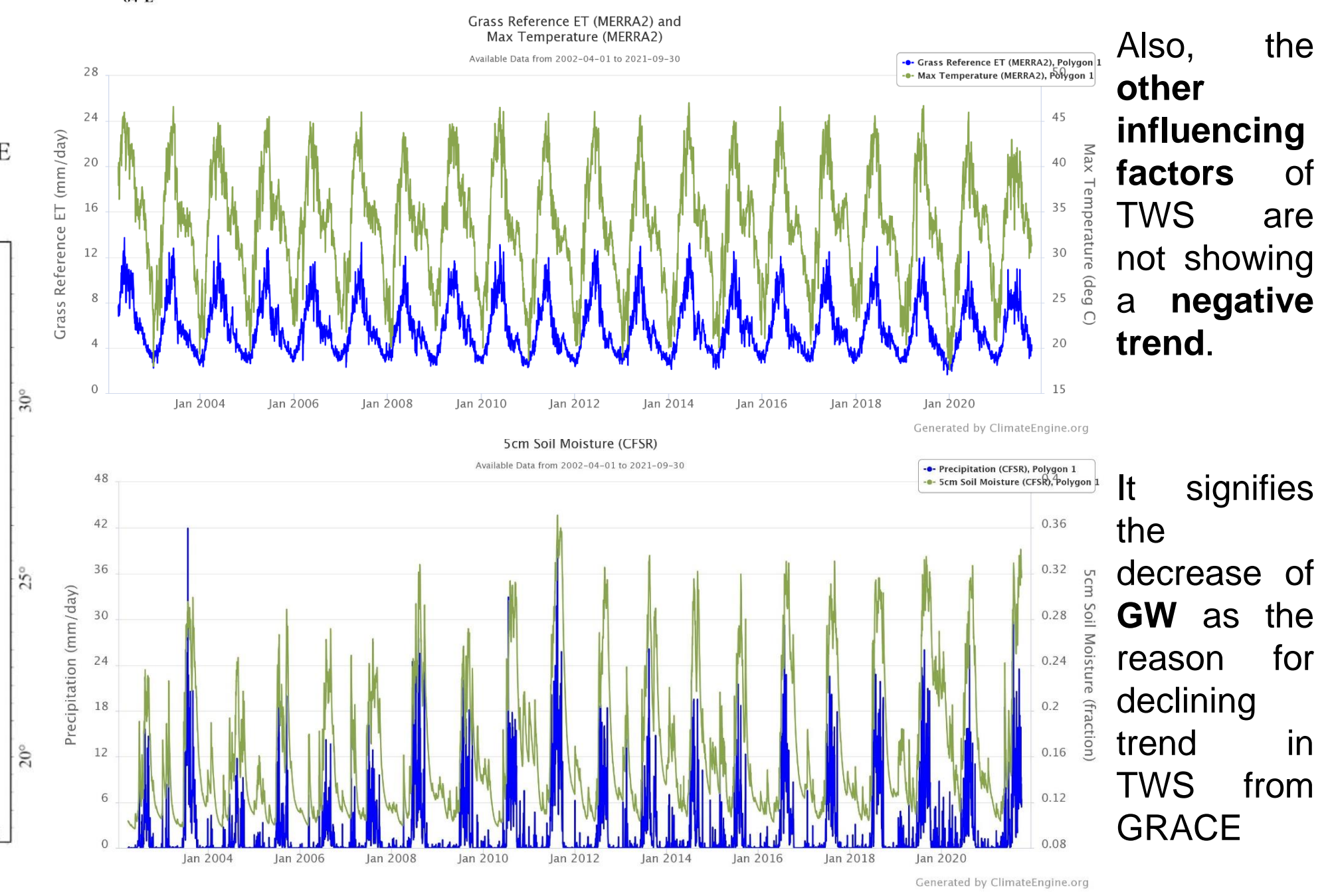
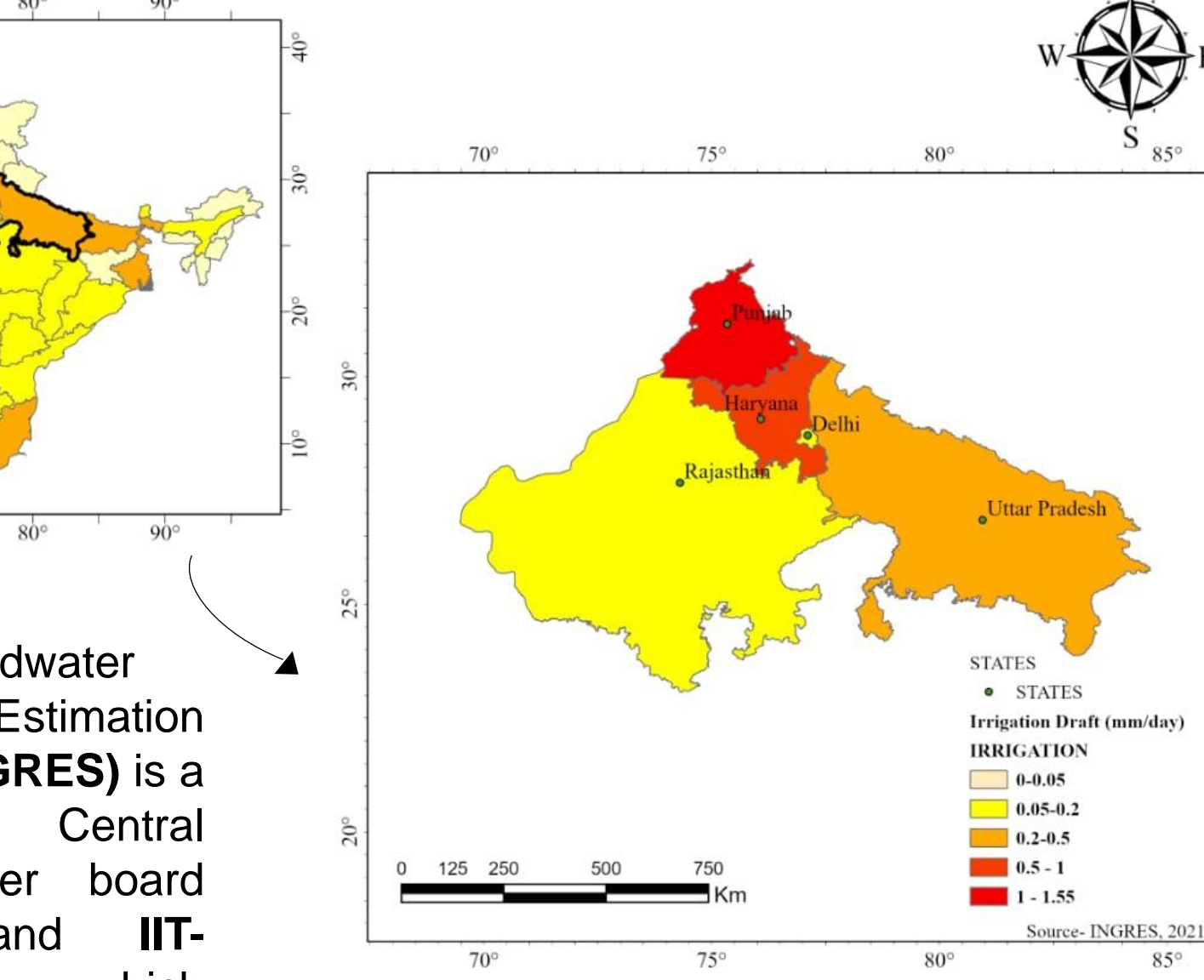


## 5. Results

- The **time series** plot of **GRACE** data clearly shows a **declining** trend in the TWS of the region, it is around **+1cm** in 2002 and significantly drops to **-2 cm** in 2021.
- From the change detection for the year 2002 and 2021, the **increase of croplands** can be witnessed which could be a reason for the negative trend of TWS as groundwater is extracted at a large scale for **irrigation** purpose.
- The **irrigation draft** data obtained from IN-GRES and processed in **ArcGIS Pro** shows very high draft values for the study area in the year 2021.
- Water intensive crop** production has also increased in the region which can be seen from crop production maps.
- As there is **no significant change in climatic variables**, change in TWS can be attributed to predominant increase in cropland and population growth.



### Groundwater Draft for Irrigation (2021)



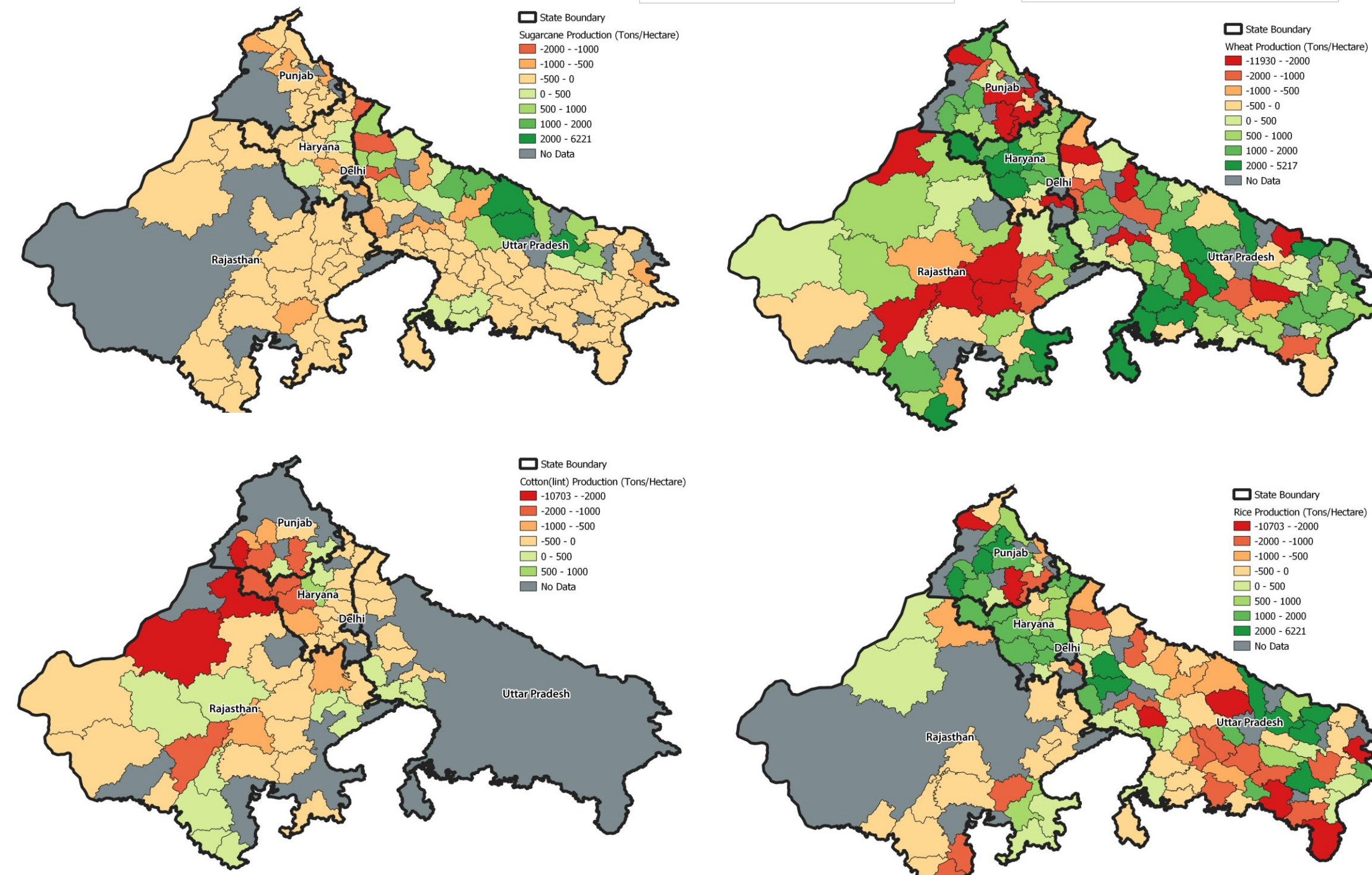
The annual crop production rate for the period **2002 - 2018** in the north-western part of India (Haryana, Punjab, Uttar Pradesh and Rajasthan and Delhi) has been demonstrated and the maps show a **positive** trend for four water intensive crops



INDIA-Groundwater Resource Estimation System (IN-GRES) is a portal by Central ground water board (CGWB) and IIT-Hyderabad which provides GW data.

Also, the other influencing factors of TWS are not showing a negative trend.

It signifies the decrease of GW as the reason for declining trend in TWS from GRACE



## 6. Conclusions

- The **growing trend of croplands** is evident from the change detection analysis.
- In all the crop production maps, it is obvious that the crop production (**water-intensive crops**) in north-western part of India is gradually **increasing**.
- Thus, it can be concluded that the **declining trend of TWS**, is due to over exploitation of groundwater in the region for the purpose of irrigation which can be considered as one of the **predominant reason**.
- On the other hand, **population** is shooting up and **demands** are escalating for food, land and water resources which urges for a **better management** of natural resources in order to lead a **sustainable living**.
- Re-aligning cropping pattern** with available water resources and **precision irrigation** can be few measures that can be taken.

## Future Directions of Research

- By utilizing **in-situ groundwater** data, the depletion can be seen explicitly.
- Adding one more spatial layer – **SMAP** (Soil Moisture Active Passive) data for improving accuracy.
- Land subsidence studies** which can be correlated to ground water depletion in a region.
- Generating a **machine learning** or a **deep learning model** with all the influencing factors for GW and carry out the analysis in a efficient manner.

[1] D. Long et al., "Have GRACE satellites overestimated groundwater depletion in the Northwest India Aquifer?," *Sci Rep*, vol. 6, no. 1, p. 24398, Jul. 2016, doi:10.1038/srep24398.  
[2] M. Rodell, I. Velicogna, and J. S. Famiglietti, "Satellite-based estimates of groundwater depletion in India," *Nature*, vol. 460, no. 7258, pp. 999–1002, Aug. 2009, doi:10.1038/nature08238.

**Acknowledgment:** We acknowledge the financial support from **DST SERB project SRG/2021/001746** and also thank **Mr. Rajarajan V** (PhD scholar, WNA, Amrita Vishwa Vidyapeetham) for his valuable suggestions and support during the project.