Setting up a new CZO in the Ganga basin: instrumentation, stakeholder engagement and preliminary observations

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February 22, 2018

Abstract

The Ganga plains represent the abode of more than 400 million people and a region of severe anthropogenic disturbance to natural processes. Changing agricultural practices, inefficient use of water, contamination of groundwater systems, and decrease in soil fertility are some of the issues that have affected the long-term resilience of hydrological processes. The quantification of these processes demands a network of hydro-meteorological instrumentation, low-cost sensors, continuous engagement of stakeholders and real time data transmission at a fine interval. We have therefore set up a Critical Zone Observatory (CZO) in a small watershed (21 square Km) that forms an intensively managed rural landscape consisting of 92% of agricultural land in the Pandu River Basin (a small tributary of the Ganga River). Apart from setting up a hydrometeorological observatory, the major science questions we want to address relate to development of water balance model, understanding the soil-water interaction and estimation of nutrient fluxes in the watershed. This observatory currently has various types of sensors that are divided into three categories: (a) spatially not dense but temporally fine data, (b) spatially dense but temporally not fine data and(c) spatially dense and temporally fine data. The first category represent high cost sensors namely automatic weather stations that are deployed at two locations and provide data at 15 minute interval. The second category includes portable soil moisture, discharge and groundwater level at weekly/ biweekly interval. The third category comprises low-cost sensors including automatic surface and groundwater level sensors installed on open wells to monitor the continuous fluctuation of water level at every 15 minutes. In addition to involving the local communities in data collection (e.g. manual rainfall measurement, water and soil sampling), this CZO also aims to provide relevant information to them for improving their sustainability. The preliminary results show significant heterogeneity in soil type, cropping system, fertilizer application, water quality, irrigation source etc. within a small catchment.

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AGU FALL MEETING
New Orleans 11-15 Dec. 2017

POSTER NO: H41G-1535

1. Preamble

- The Ganga River is ranked as the second most polluted river in the world, endangering the lives of 140 fish species, 90 amphibian species along with millions of humans.
- Many small and large scale projects were carried out to clean the river, but resulted in no significant improvements.
- The heterogeneity in current scenario needs a proper understanding of various Critical Zone processes throughout the basin.

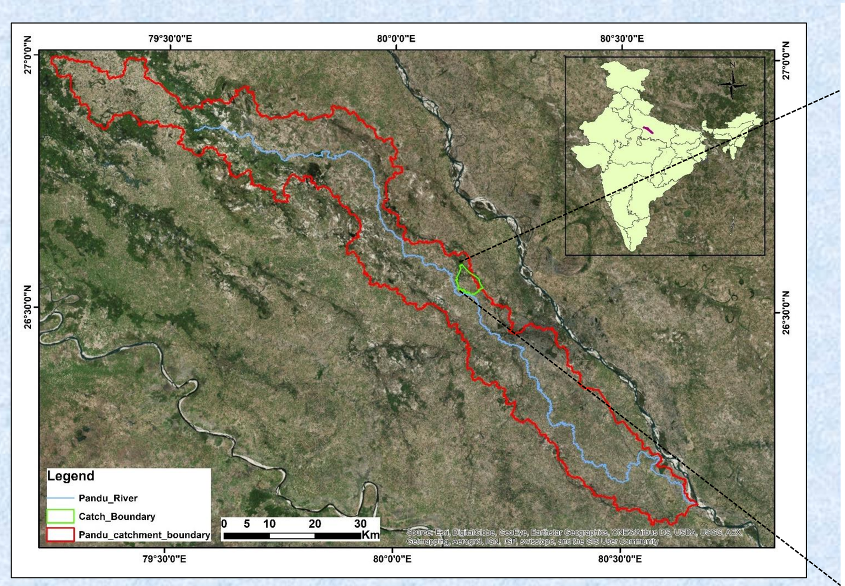
2. Importance of CZO

- Anthropogenic changes impact several interconnected systems (surface and groundwater, atmosphere, soil, vegetation etc.)
- Problems caused in these systems are difficult to solve due to current understanding of interacting processes, limited by data availability (Singh, 2015).
- The CZO aims to monitor hydro-meteorological parameters, soil physical and chemical characteristics, geochemical parameters and agricultural decision making.
- This data repository would build a platform to invite interdisciplinary research to address current problems in the Ganga basin.

3. Objectives

1. Set up a hydro-meteorological observatory in a small watershed.
2. Understand the geomorphic characteristics of the watershed using high resolution satellite images and digital elevation models.
3. Estimate water balance components for the watershed using observational data.
4. Determine soil physical and chemical characteristics and water chemistry.
5. Measure the fluxes of N and P in the watershed using geochemical approach.

4. Study Area



Area: 21 Km^2, Elevation: 67-80m, Rainfall: 821.9mm, Major land use/land cover: Agriculture (Wheat &Rice), Major physiographic Unit: Central ganga Alluvial Plain

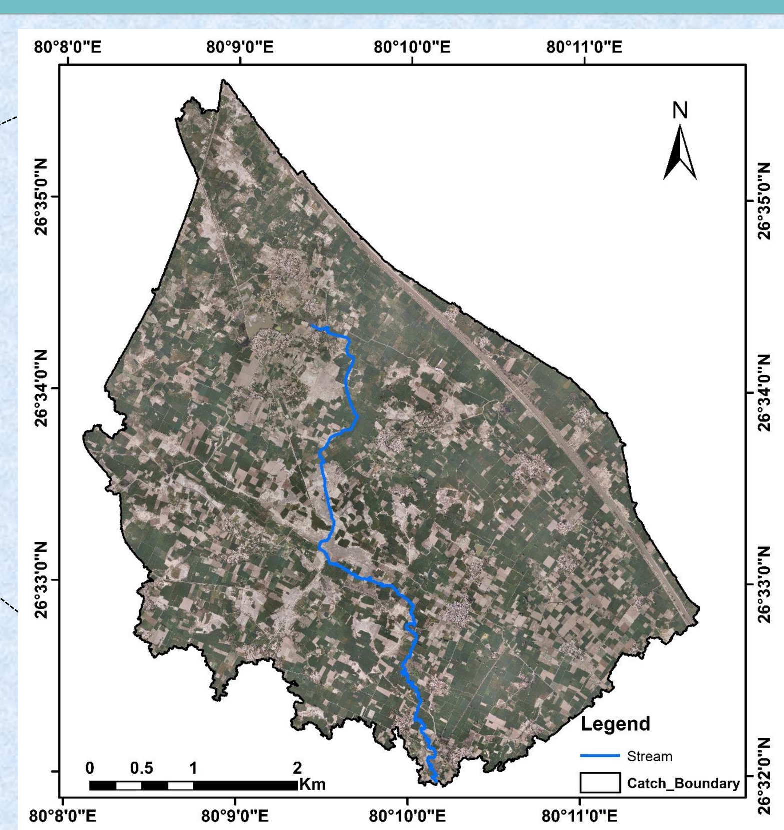


Fig. 1 Study Area

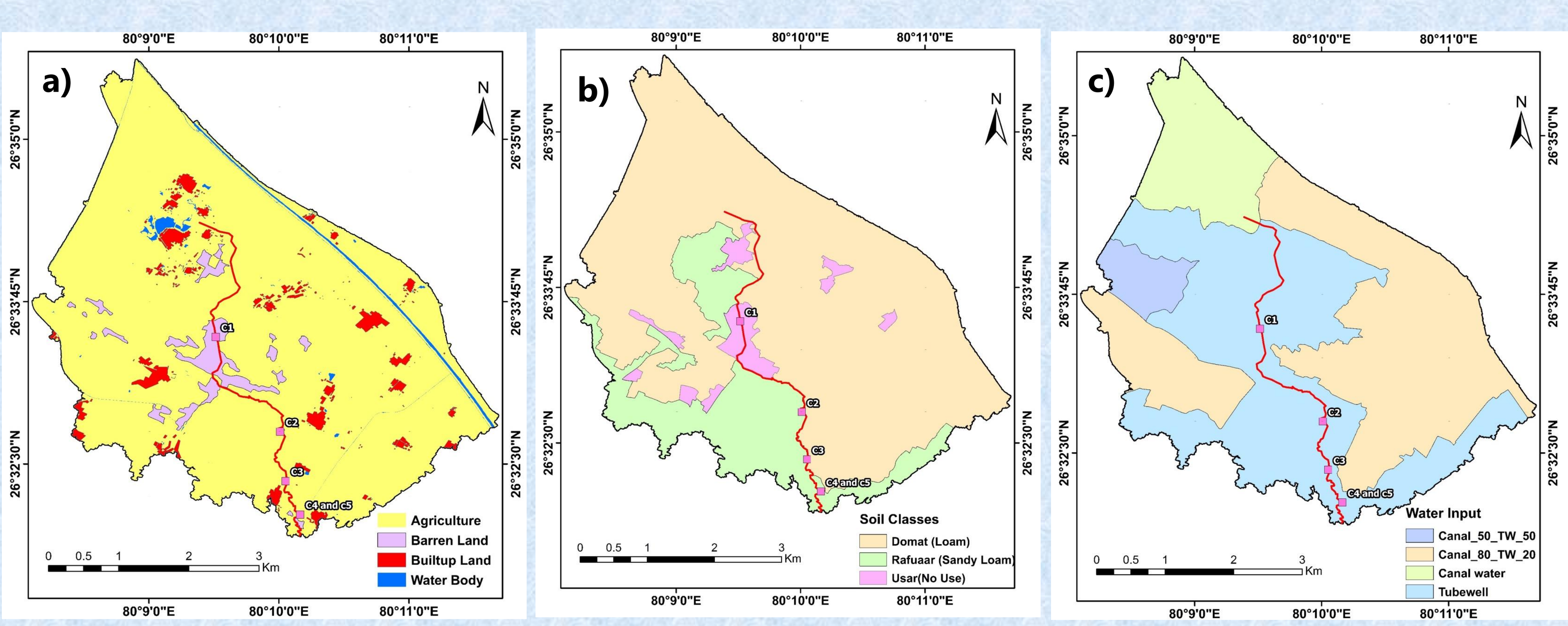


Fig. 2 a) LULC b) Soil Map c) Water Input Map

5. Methods and Approaches

Major Challenges Faced During Instruments Deployment

Technical:

- Identifying measurable hydrological and meteorological variables critical to runoff generating processes

Administrative:

- Obtaining permissions from state, district and local government officials, and police for land verification and allotment

Stakeholder Engagement:

- a) Deployed Dummy instruments on the field.
- Instrument damaged due to villagers curiosity.
- b) Interaction with the villagers for the importance of instrument deployment.
- c) With repetitive iteration, we successfully deployed various instruments.

Fig. 3 a) Dummy Instruments, b) Local Interaction, c) Instrument Deployed

Instrumentation

Purpose	Sensor	No. of Places	Time Interval
Spatially Not Dense but Temporally fine Data (High Cost)			
Meteorological Parameter (wind speed, direction, humidity, radiation, temperature, pressure, evaporation)	AWS	1. Upstream (Bansathi) 2. Downstream (Bani)	15 Minute Interval
Spatially Dense But Temporally Not Fine Data (High Cost)			
Groundwater level	Well Sounder	60 (Open Wells)	Biweekly (March 17 to present)
Soil Moisture (SM)	Theta Probe (Surface SM)	18	Weekly (August 17 to present)
	Trime Pico (1m depth)	18	
Discharge	Current meter	5 Culverts and Canal	Seasonal stream (Monsoon time)
LAI	LAI-2200	18	Weekly
Spatially Dense and Temporally Fine data (Real Time & Low Cost)			
Groundwater Level	Automatic GWL	20	15 minutes
Soil Moisture	Specmeter SM	2 locations: 8 sensors at each site	15 minutes
Rainfall	Rain gauge	8	Daily
Soil Sampling	Bore hole	4	Depends upon stakeholder

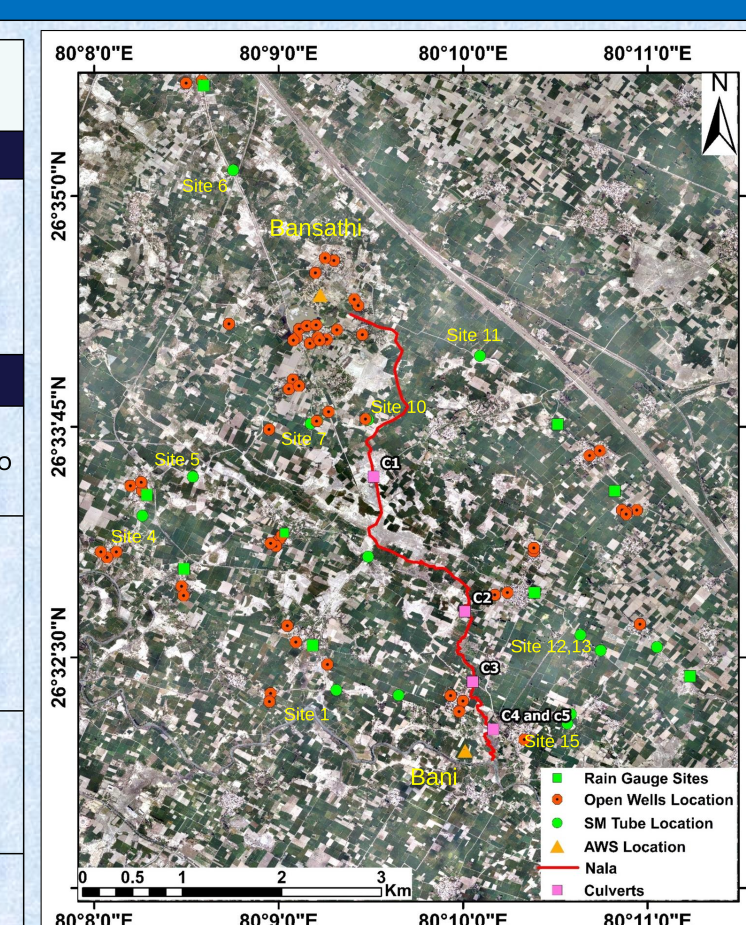


Fig.4 Locations of sensors deployed

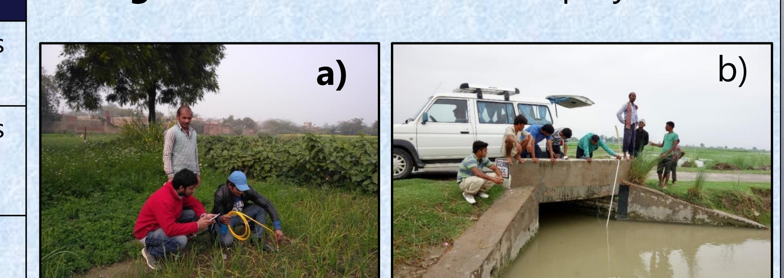


Fig. 5 a) SM Measurement b) Discharge measurement

6. Preliminary Observations

Variation of Yield with Soil Type

- **Wheat crop Yield is** 0.5-1 t/ha higher for fields irrigated by GW compared to those irrigated by canal water
- Major difference in yield due to soil type (Fig.6)

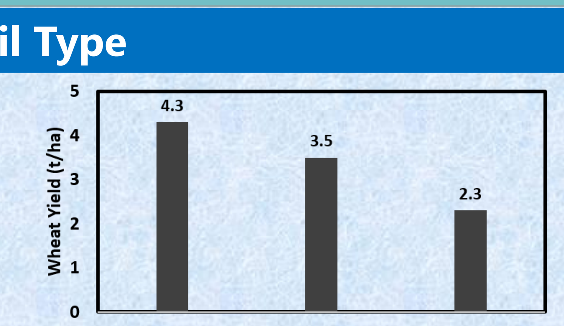
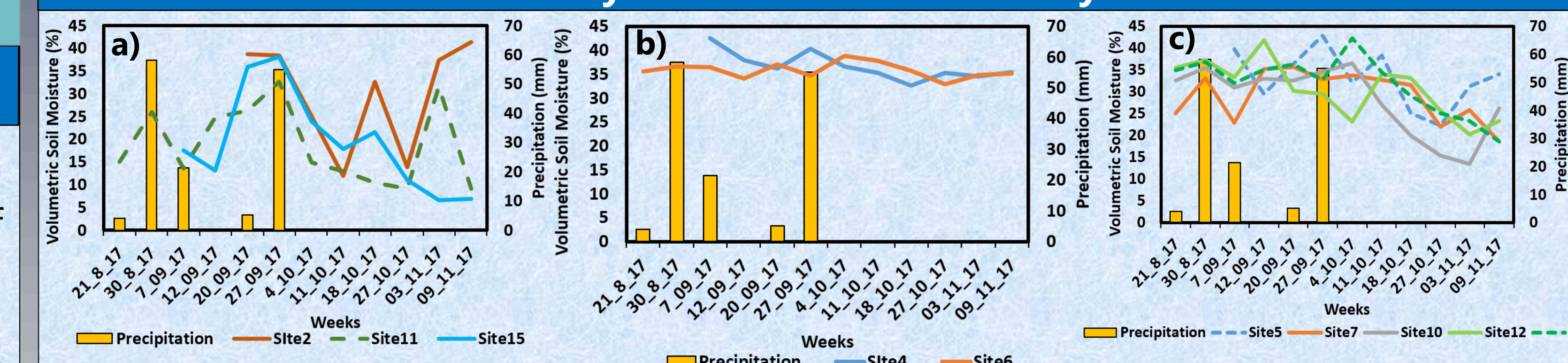


Fig.6 Soil type and Yield

Variability of Soil Moisture in Paddy Fields



- a) Irrigated by Tubewell
- Yield is 0.4 to 2.4 t/ha due to high fluctuation in SM
- b) Irrigated by Canal
- Yield is 5.6 t/ha due to constant SM
- c) Irrigated by Tubewell
- Yield is 4.8 t/ha due to maintained SM

Fig.7 Soil Moisture variability (a, b & c)

Spatial Groundwater Level Variability

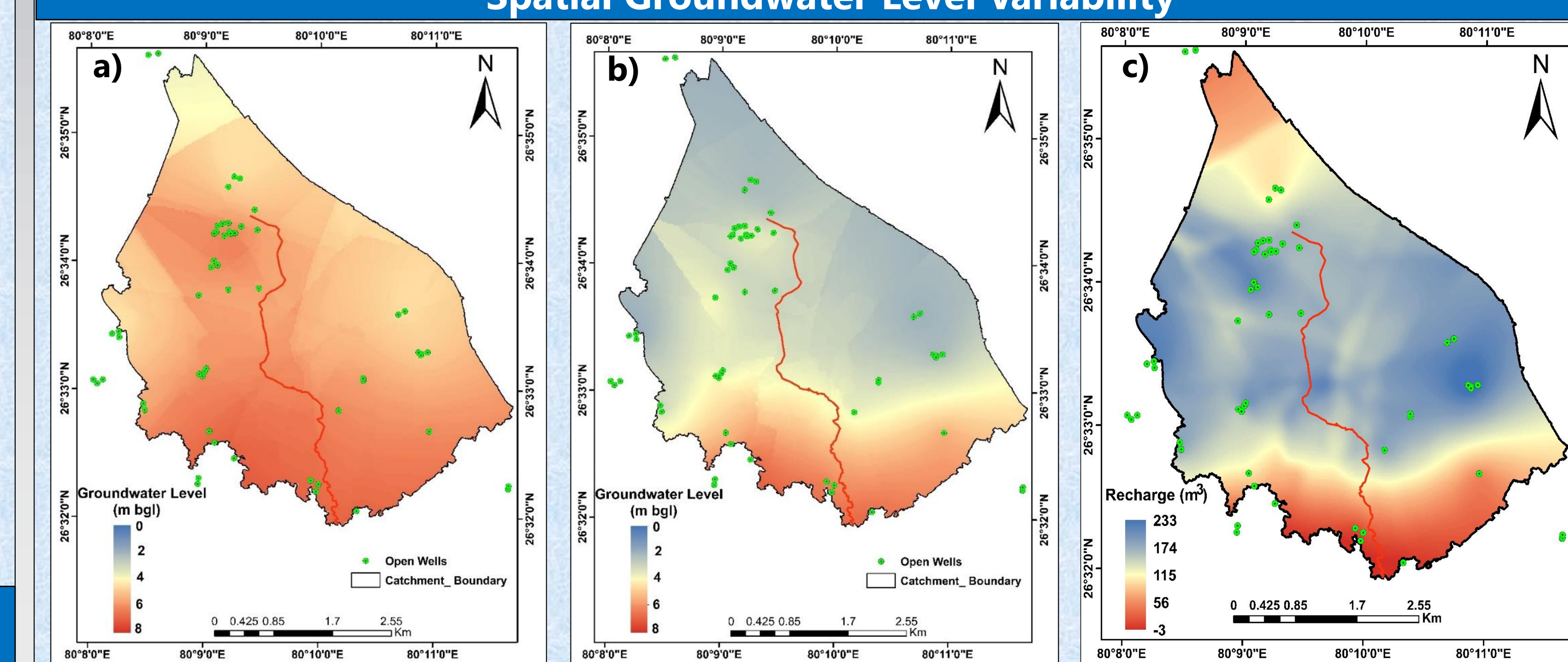
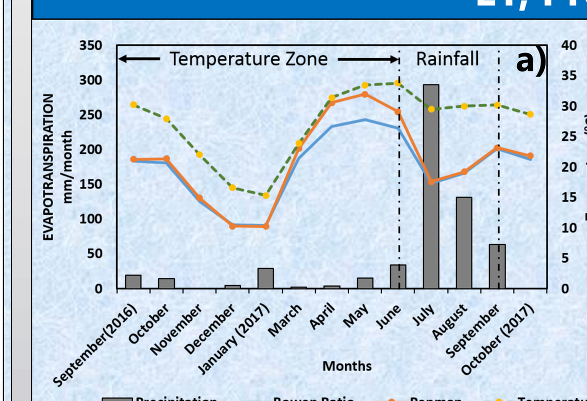


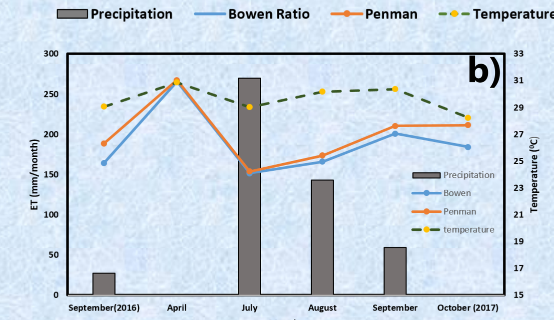
Fig.8 Spatial Groundwater Variability (a & b) and Recharge (c)

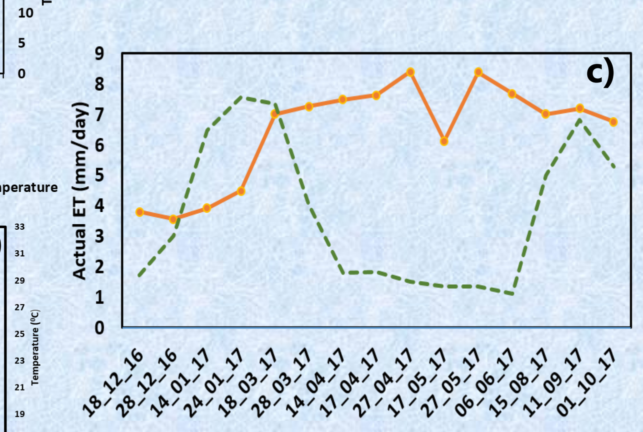
- Raster surface has been created using Kriging method.
- All the area gets recharged in post monsoon expect the downstream area.

ET, Precipitation, Temperature and NDVI



- ET calculated using Bowen (Actual) and Penman Monteith method (Potential) (Xing et al, 2008).
- ET showed high correlation with temperature in pre-monsoon months and with rainfall in post monsoon months (Fig .





- NDVI plot using Sentinel-2 data (10m resolution)
- ET showed poor correlation with NDVI (Tongdeenok et al., 2007)

Fig.9 Relationship between ET, Precipitation, Temperature (a & b) and NDVI (c)

7. Ongoing work

- Computation of the Water Balance for the Watershed.
- To observe the variation in the satellite and ground truth data for soil moisture.
- Interrelation between different measured attributes of the study area.

8. Acknowledgements

We thank Ministry of Earth Sciences, Government of India for providing us a research grant (Ref.No: MoES/PAMC/H&C/63/2015-PC-II). we would also like to say thanks to Atul Gaur (Field Engineer), Soham Adla, Vinod and Kripa Shankar Ji for their help in establishing this.

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