Hydrometeorological feedbacks and changes in water storage and fluxes in Northern India

Executive Summary July 2014

Hydrometeorological feedbacks and changes in water storage and fluxes in Northern India

Jointly funded by NERC (UK) and MoES (India) under the Changing Water Cycle Programmes

Addressing the scientific questions for the water needs of India in a changing world.

Bringing together a consortium of researchers from the UK and India to address some of the key scientific questions facing the country with respect to its water supplies and land management policies.

Joining together cutting edge research from climatologists, hydrologists, groundwater experts and social scientists, the project is focused on understanding the complex feedbacks of the Ganges Basin in northern India and seeks to quantify and predict the availability of water resources now and in the future.

The Consortium

Imperial College London: Wouter Buytaert, Ana Mijic, Adrian Butler, Emma Bergin, Gina Tsarouchi, Jimmy O'Keeffe & Simon Moulds

University of Reading: Andy Turner & Charlie Williams

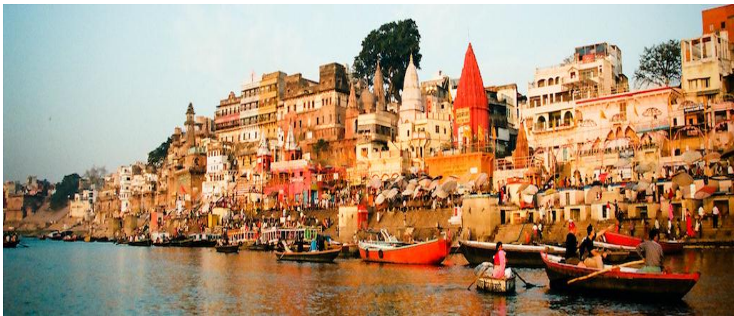
British Geological Survey: Chris Jackson, Jon Mackay & Andrew McKenzie

Pradeep Mujumdar, Muddu Sekhar, Arindam Chakraborty & Ila Chawla: **Indian Institute of Science, Bangalore**

Rajiv Sinha: **Indian Institute of Technology, Kanpur**

CSP Ojha & Rahul Garg: **Indian Institute of Technology, Roorkee**

Bhanu Neupane: **UNESCO**

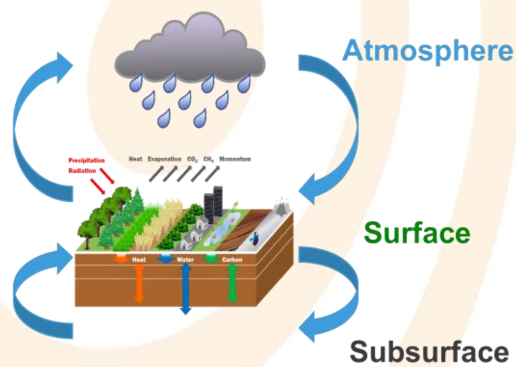


Summary of the Project

Inception Meeting
February 2012, IISc Bangalore

Land use is fundamentally changing water resources. Water extraction is drawing down water tables and lowering river levels. Meanwhile, land use change is affecting the partitioning of water flues, while changes in surface runoff and aquifer recharge will affect surface water and groundwater resources. Further feedbacks between evapotranspiration and precipitation may also be in play.

Given the interactions between different hydrometeorological processes, a systems approach is needed. This project is the first to combine both climate impacts on the hydrological regime and hydrological feedbacks on the climate. This is accomplished by using a state-of-the-art suite of data assimilation, new process understanding and integrated modeling of the atmosphere surface groundwater system.



The project specifically addresses the scope of the call, especially the themes on interactions between the surface and subsurface, water cycle drivers and mechanisms, and the water cycle-anthropogenic interface. The overall objective of the project is to provide the scientific and modelling platform the next-generation water cycle modelling of the Gangetic Plain and associated water resources and ecosystem assessments. There are four main objectives to achieve this:

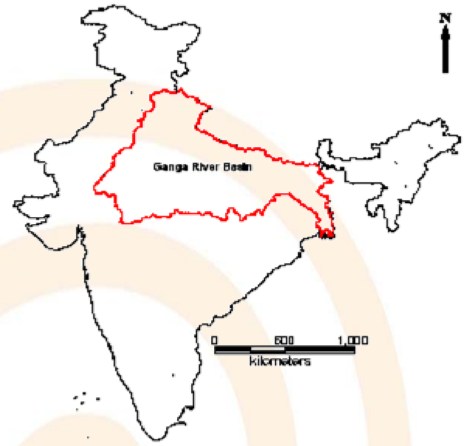
1. Quantification of the major fluxes in the Gangetic Plain and their temporal dynamics
2. Quantification of hydrometeorological feedbacks in the Gangetic Plain
3. Statistical downscaling and analysis of the predictive capacity
4. Generating and evaluating climate change projections in water resources management

This project addresses the following research questions:

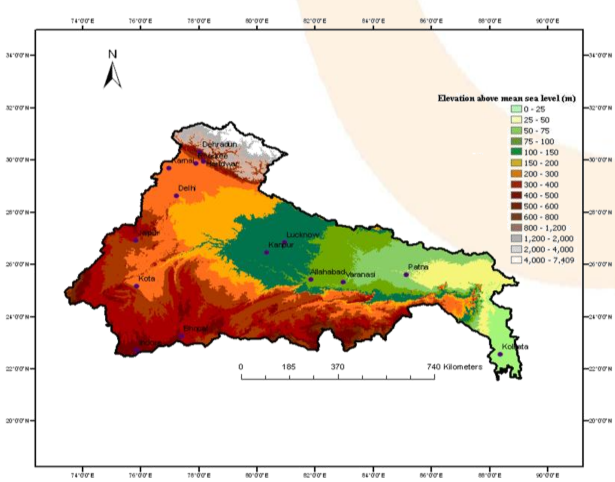
1. To what extent the large-scale, human-induced land use changes and groundwater depletion that have taken place in India feed back to the hydrological and climate system at a basin scale?

2. How should climate model outputs be disaggregated to provide the boundary conditions needed for hydrological and water resource systems modeling, and do the results of such modeling provide suitable reduction in the uncertainty of projections?

3. Can large-scale modeling studies inform localized, ecosystem-based management decisions to improve water availability and security?



The northern Indian plains have experienced land use changes and water exploitation at an unprecedented scale, posing extraordinary scientific challenges to understand, quantify and predict the availability of water resources.



The Ganga River is not only crucial for the socio-economic development of the country; it also provides a unique case of large-scale river systems dominated by groundwater resources. The project specifically addresses the scope of the call, especially the themes on interactions between the surface and subsurface, water cycle drivers and mechanisms, and the water cycle-anthropogenic interface.

Hypotheses of the Project:

1. Land use change is a significant driver of observed trends in water resources in the Gangetic Plain

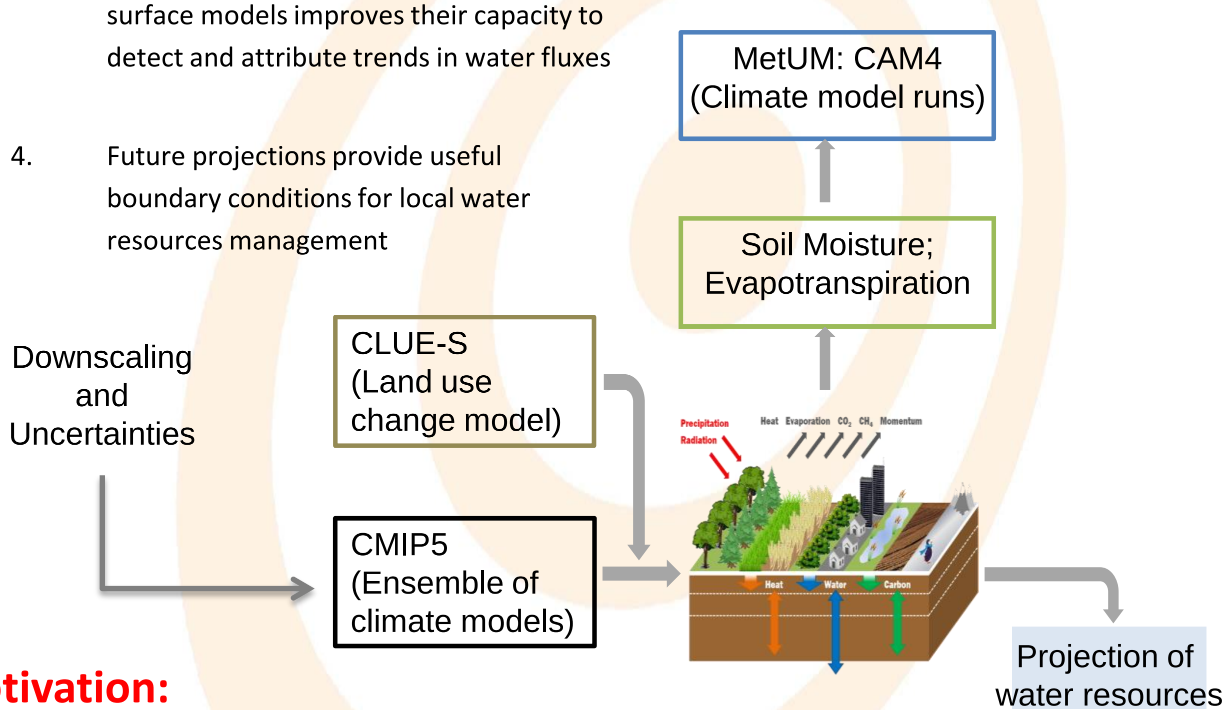
2. Changes in soil moisture patterns due to land use change significantly affect the precipitation patterns

3. Integration of satellite imagery in land-surface models improves their capacity to detect and attribute trends in water fluxes

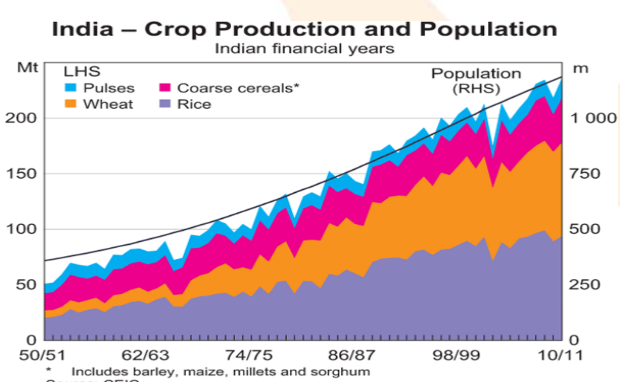
4. Future projections provide useful boundary conditions for local water resources management

Model Structure:

A systems approach with coupling between atmosphere, land surface and groundwater systems.



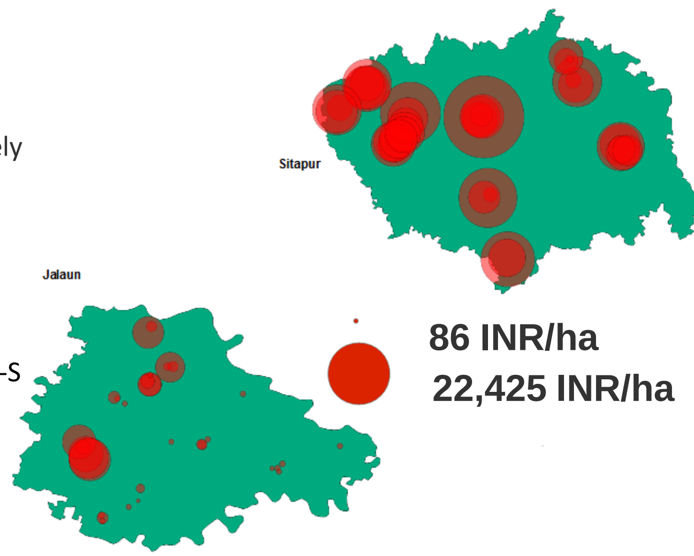
Motivation:



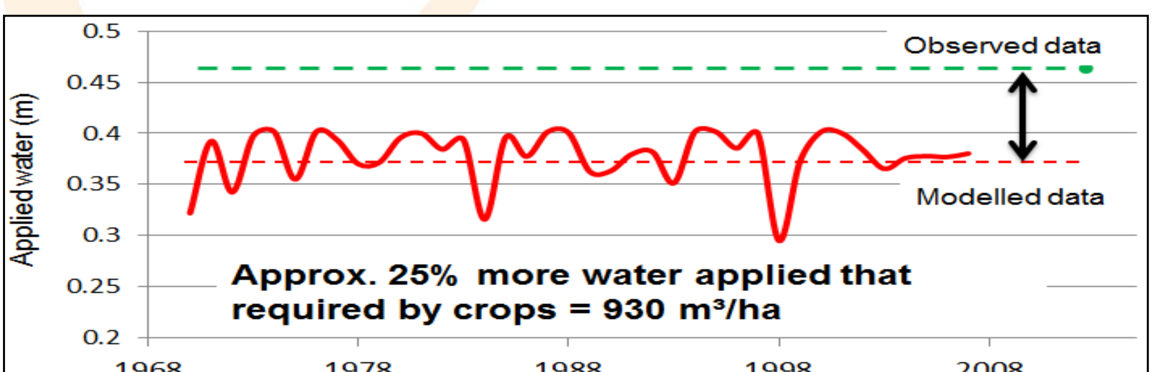
http://www.ceicdata.com/India.html

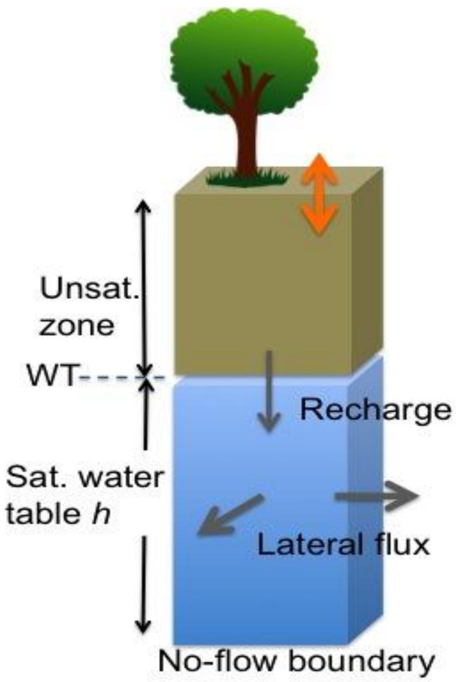
Research Highlights

Water Use in India: Imperial College, London



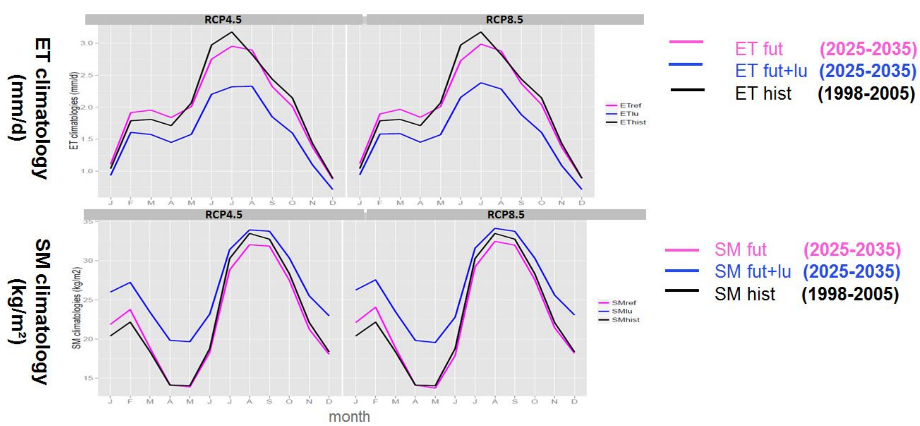
- Semi-structured interviews with approximately 100 farmers in Jalaun & Sitapur
- Participants – farmers growing rice and/or wheat
- Projecting future LU of the region using CLUE-S land surface model
- Setting up JULES hydrologic model over the Upper Ganga basin at 0.1 degree resolution
- Coupling JULES with InfoCrop to assess effect of cropping on hydrologic regime.
- Quantifying the current and historical volume of water used in irrigation and representing the heterogeneity in water use practices in the region





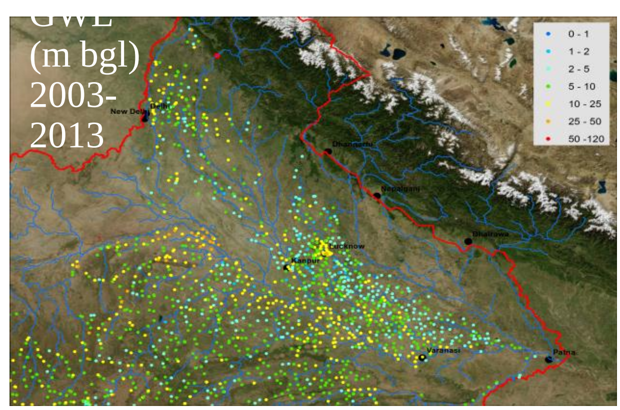
Land Surface Modelling: Imperial College, London

- The Ganga basin is groundwater dominated
- If the saturated zone is close to the surface it may influence the surface flux
- We extend the JULES domain to the aquifer base and solve the pressure-based Richards equation at the point scale (routines in R)
- Water resources are projected to decrease under climate change, particularly when projected land use changes are considered



Groundwater Modelling: British Geological Survey

- Calibration of ZOODRM and ZOOM3QD groundwater models
- Coupling of groundwater and JULES land surface models

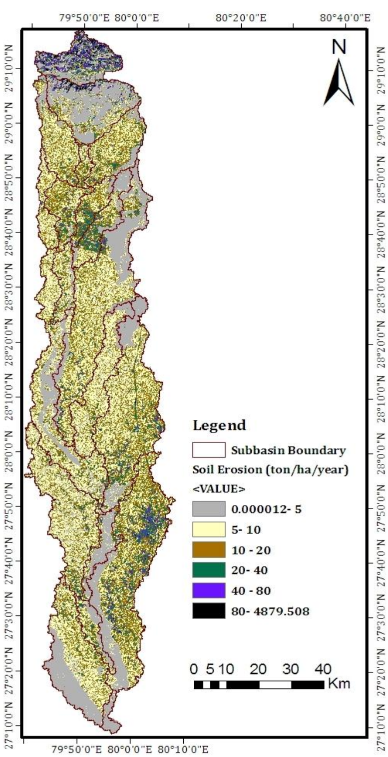


Field Measurements and Data: Indian Institute of Technology, Roorkee

Field Visit, December 2012

- Liaison between the government agencies and the research institutes involved in this project

- Facilitate procurement of streamflow data and other ancillary data from the concerned government agencies in India



Sediment Transport: Indian Institute of Technology, Kanpur

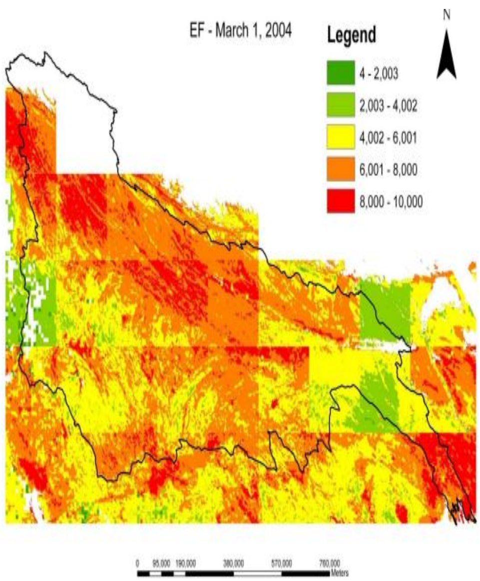
- Estimating the sediment transport capacity of the Garra basin (sub-basin of Ganga basin) using the CAESAR-LisFlood Model

- Working out environmental flow requirements and water management options

- Estimated soil erosion for the time period 1971 -2005 using ASTER GDEM for the land use conditions of 2005 (left)

Environmental Flows: UNESCO

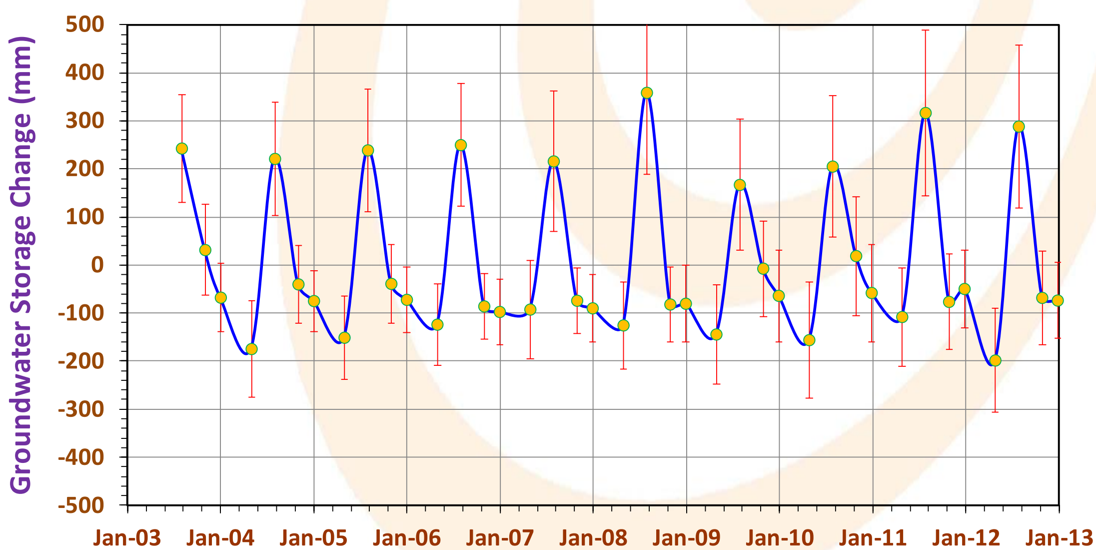
- Setting up boundary conditions through groundwater and flow data from Nepal



Groundwater Modelling: Indian Institute of Science, Bangalore

- Modelling evapotranspiration (ET)/ evaporative fraction (EF) over the Ganga basin at daily scale at 1 km resolution
- Groundwater flow modelling and coupling groundwater model with surface hydrology model
- Validating the gridded global soil moisture data from ESACCI over Indian region using the Continental Tropical Convergence Zone (CTCZ) in-situ data
- Using ESACCI soil moisture dataset to run CAM 4.0 and CML 4.0 land surface model at daily scale at 0.25 degree resolution from 1978-2010

Recharge = 259 mm (model)
Pumping = 95 mm (Survey data)
Base flow = 120 mm



Storage increase is 250 mm for May to August and storage decrease is 215 mm for August to May (*positive is rise in storage and negative is fall in storage)*

Land Use Change & Hydrological Modelling: Indian Institute of Science, Bangalore

Internal Review Meeting December 2012, IIT Kanpur

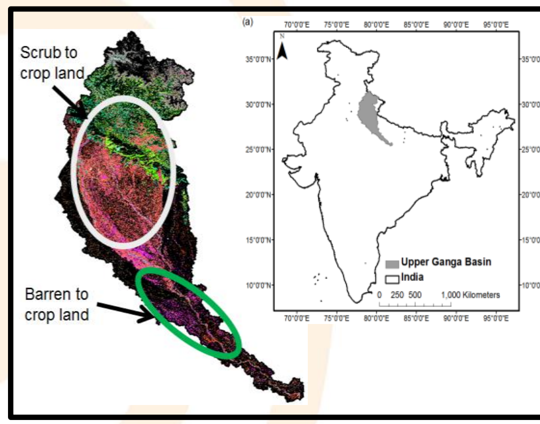
•Assessing change in Land Use of the basin using satellite images

•Setting up the Variable Infiltration Capacity (VIC) hydrologic model at 0.5 degree resolution over the Upper Ganga Basin

•Evaluating the effect of land use and climate on hydrological regime of the basin using VIC model

•Downscaling meteorological variables using CMIP 5 data and modeling uncertainties in the projections

•Modelling evapotranspiration (ET)/ evaporative fraction (EF) over the Ganga basin at daily scale at 1 km resolution

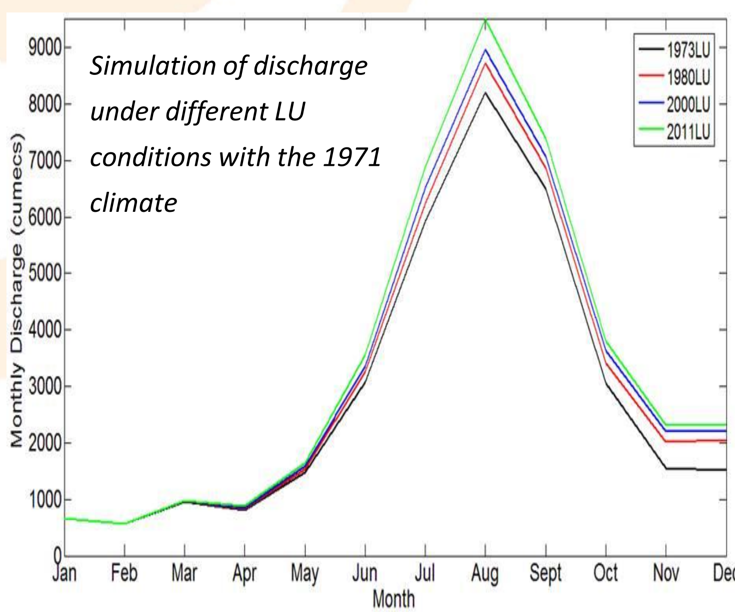


Change in LU of the basin from 1971 to 2011

- Groundwater flow modelling and coupling groundwater model with surface hydrology model

- Validating the gridded global soil moisture data from ESACCI over Indian region using the Continental Tropical Convergence Zone (CTCZ) in-situ data

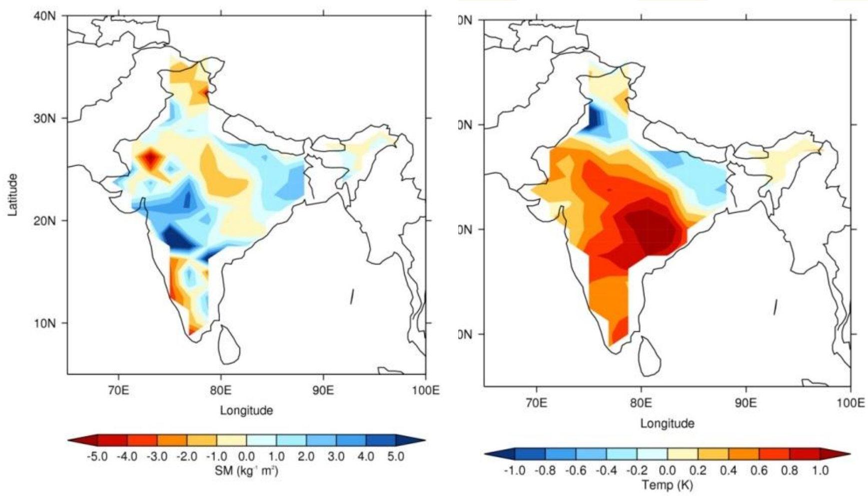
- Using ESACCI soil moisture dataset to run CAM 4.0 and CML 4.0 land surface model at daily scale at 0.25 degree resolution from 1978-2010



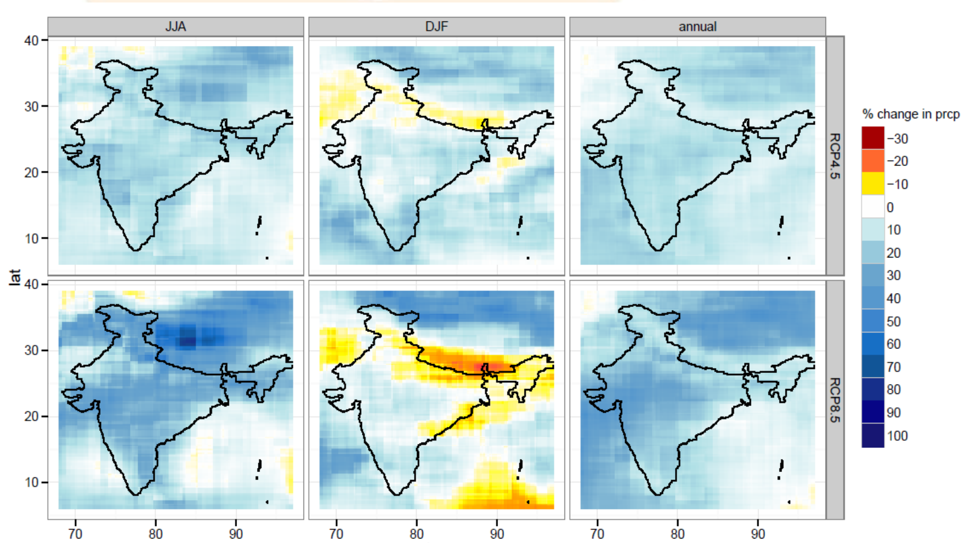
Simulation of discharge under different LU conditions with the 1971 climate

Integration of Climate Processes: University of Reading

- India has an intense monsoon season that can be linked to sea surface temperatures and air pressure in the Indian Ocean and further afield
- Simulations of future climate generally suggest an increase in monsoon rainfall on a seasonal mean, area-average basis
- Sensitivity analyses of climate processes to changes in topography and land cover improve process understanding



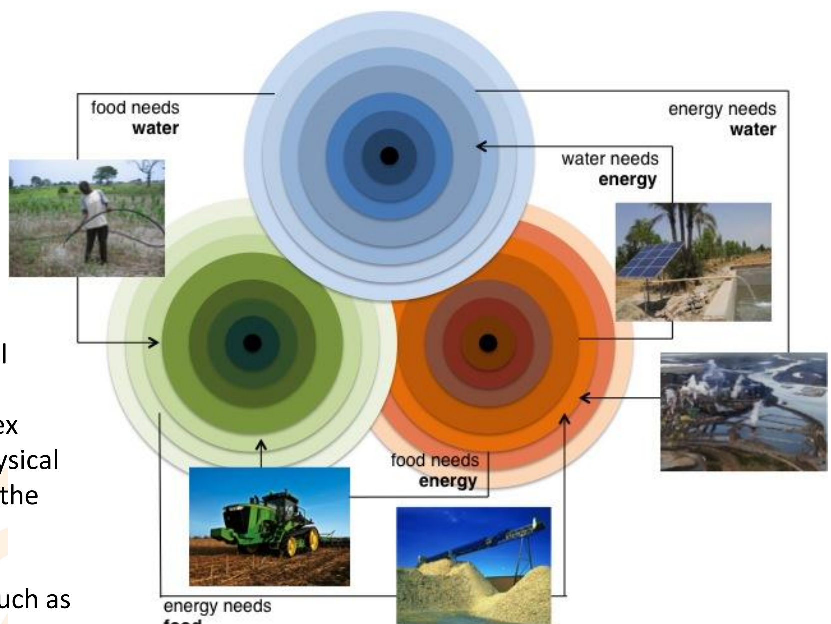
- Composites of JJAS atmospheric circulation fields from HadGEM2-ES
- Higher JJAS temp over central India when MAM SM is high
- Composite of JJAS SM (left) and temperature (right), high-low years



- Projected changes to precipitation for 1975-2005 to 2070-2100
- Coupling of land surface processes into climate models
- Link global and local scale climate processes using statistical downscaling methods

Future Work

Future food, water and energy security are interlinked via land use and demand management. The increasing demand for available resources (land and water) and inter-sectorial competition will determine the future water use in India. However, our understanding of energy-water-food interactions is in a very preliminary stage and requires more interdisciplinary research. The climate change and climate mitigation policies will further complicate the nexus.



Water demand, in particular, is determined by a variety of interacting drivers of physical, socio-economic and cultural nature.

Many of them are still poorly understood, especially in a complex socio-cultural and physical environment such as the Indian subcontinent.

Large-scale models, such as those under development within current NERC/MoES CWC portfolio of projects (although being a large step towards understanding and modelling water availability) cannot capture finer scale heterogeneity or interannual variability, which are essential drivers of larger scale processes. Therefore understanding the behaviour and decision-making, and how these vary spatially and temporally are crucial for improved quantification of the future risk for water shortages and crises.