Integrating ecosystem based approach within the Water-Food-Energy nexus framework

Project title: Tackling the challenges of water, food and energy nexus in India and Scotland

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Find out more: http://www.hydronationscholars.scot/scholar_bio_Bhawana_Gupta.html

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Introduction and Background

Why-WEF Nexus?

- Addressing the scale of the nexus in a large growing economy such as India is a challenge, but this is a country where the nexus problem is very "real".
- Investment in irrigation technology (when available) is driving a change in crop production to more high value commodities at the expense of staples .
- Subsidised energy and fuel potentially drive over exploitation of groundwater resources.
- Urbanisation will significantly impact on the supply markets and chains
- Understanding the tensions between desirable centrally planned 'sustainability' targets and the economic realities that individuals/farmers face (that in turn drive resource consumption and choices) are critical.

Why-ecosystem integrity for sustainability of WEF nexus?

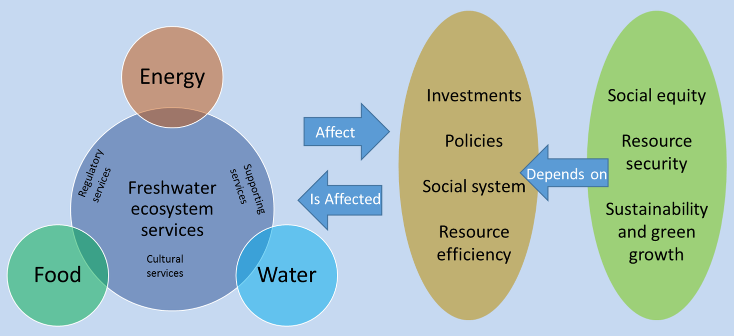

Figure 1: Diagram showing the role of ecosystem services for maintaining long term socio-economic and environmental benefits

- Provisioning and supporting ecosystem services are the resource base for water, food and energy and regulating services provides carbon sink.
- Human interventions posing threats on ecosystems and deteriorating the ecosystem services leading to resource insecurities and increased competition between sectors.

Research structure and methods

Aim	Method
1. To assess the impact of small and large water structures on natural water flow regime under the current socio-economic scenario.	i) Hydrological method-Application of Indicators of Hydrological Alterations (IHA)
2.To assess the alterations in the natural flow regime under different socio-economic pathways and identify the risks of different levels of alterations in study catchments.	i) Hydro-economic model- Application of GWAVA model for simulating the daily mean flows for future socio-economic scenarios. ii) Classify catchments from severely impacted to un-impacted catchments
3. To analyse the spatial variability in the water,food,energy demand and production system across the Cauvery river basin	i) Develop a typology of river catchments where variables are- population growth, gridded power demand and consumption, renewable energy demand, cropping pattern, and source of irrigation using the secondary data ii) Selecting representative catchments under each type for further investigation
4. To analyse the trade-offs between water withdrawal and energy demand in different catchments identified in step 3 and simulate the energy demand under different future scenarios of land use and land cover	i) Application of System dynamic model or Economic model for simulating energy demand* *The method for this step has not been decided yet as the research is in its initial stages

Current Stage

Indicators of Hydrological Alterations (IHA)

The natural hydrologic regime is the characteristic pattern of water quantity, timing and variability in a natural water body. A river's hydrologic, or flow, regime consists of environmental flow components, each of which can be described in terms of its magnitude, frequency, duration, timing and rate of change. The integrity of freshwater systems depends on the natural dynamic character of these flow components to regulate ecological processes.

Anthropogenic alteration of the natural hydrologic regime is a major contributor to the global freshwater biodiversity crisis. Major causes of hydrologic alteration include dams, withdrawals, climate change and land use.

Environmental flows are the quantity and timing of water flows required to maintain the components, functions, processes and resilience of aquatic ecosystems and the goods and services they provide to people. Unlike the natural flow regime, the environmental flow regime allows for some degree of hydrologic alteration. However, environmental flows are intended to mimic the patterns and ecological outcomes of the natural flow regime.

The IHA method assesses 67 ecologically-relevant statistics derived from daily hydrologic data. These statistics are grouped into 5 broader categories–

i) Magnitude of monthly water conditions

Ii) Magnitude and duration of annual extremes

Iii) Timing of annual extremes

Iv) Frequency and duration of high and low pulses

V) Rate and frequency of change in conditions

Comparative analysis of these statistics can then help statistically describe how these patterns have changed for a particular river or lake, due to abrupt impacts such as dam construction or more gradual trends associated with land- and water-use changes.

Issues identified in the study area during field visit

This PhD project has been designed to examine the application of socio-ecological systems modelling approach to investigate the trade-offs between water, food and energy sector in Peninsular India and aims to provide a novel evaluation of potential future options for management. In order to refine the objectives of the proposed PhD study, a scoping field visit to Karnataka and Tamil Nadu (basin states) in India was made in June 2017. The visit was undertaken with the aims of understanding the current issues related to water management and farming practices, establishing trust with local stakeholders and scoping the PhD research. Some of the important issues identified are below:

Figure 2: *Mettur Dam, Karnataka*

Figure 3: *Dry river streams and canals downstream of Mettur Dam*

Figure 4: *Dry coconut trees and poor harvest in a farm in Cauvery-middle sub-basin*

Figure 5: *Farmers deepening the dugwell in the coconut farm*

Figure 6: *Paddy field in the Cauvery-lower sub-basin (delta region)*

Figure 7: *Traditional food grain crops– Millets have been replaced by other crops with more economic returns. Irrigation management training institute in Tamil Nadu is advocating farmers to shift back to traditional crops with less water requirement.*

Study Area Description

Table 1: *Number of large scale water development projects in Cauvery river basin*

Water structure	Number
Dams	96
Power houses	24
Barrages	10
Weir/Anicuts	16
Irrigation projects	91

- Area- 85,626km²
- Mean annual rainfall- 1075 mm
- Area under irrigation projects- 24095.5km²

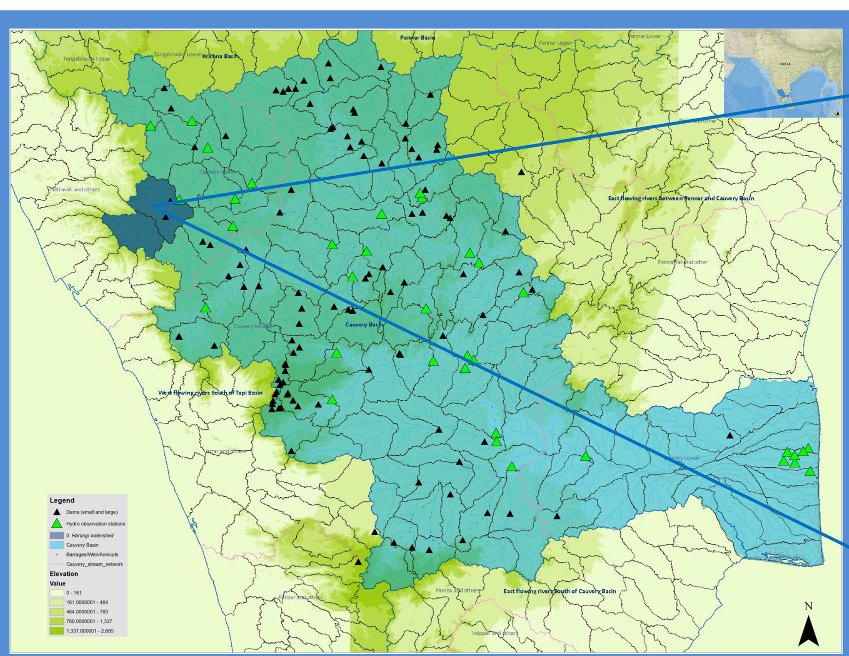

Figure 8: *Map showing location of dams and hydro-meteorological stations in micro-catchments and river streams in the Cauvery river basin*

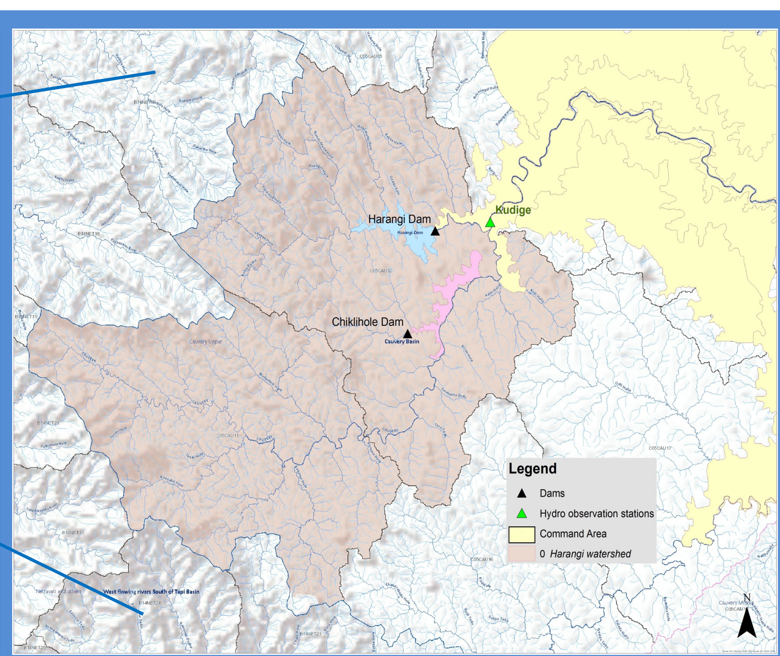

Figure 9: *Map showing the location of Dams, hydro-observatory station and command area in the Harangi river catchment*

Table 2: *Number of water interventions in the Harangi river catchment*

Structure Type	Water Structure	Number
Large Scale	Dams	2
Small scale	Dugwells	52
	Shallow tubewells	37
	Surface lift schemes	187
	Surface Flow schemes	370

- Area of the catchment- 1757.633 km²
- ***Table 3:*** *Distribution of rainfall across seasons and mean rainfall during different periods*

Period	Pre-monsoon (%)	SW monsoon (%)	Post-monsoon (%)	Mean (mm)
1972-81	9.34	77.03	13.63	1412.39
1982-91	8.93	74.21	16.86	1186.64
1992-01	8.04	72.58	19.38	1388.55
2002-12	9.43	71.59	18.97	1302.45

Source: Deepthi, K.A, 2015

Pre-monsoon- January to May, first 22 standard weeks

South-west monsoon- June to September, 23rd to 39th standard weeks

Post-monsoon- October to December, 40th to 52nd standard weeks

[1] Barrage- A structure built across a river, for diverting water into a canal or for providing a small storage pond. It comprises a series of gates for regulating the river flow and water level, while keeping the afflux during floods within, acceptable limits. The structure may or may not have a raised sill. It is constructed to regulate the water-surface level and to divert the water flow from upstream of the gates.

[2] Weir/ Anicut-An ungated barrier across a stream or a river for the purpose of: measuring its discharge, or raising, controlling and maintaining the water level, and/or, diverting part or all the water from the stream/river into a canal or conduit.

[3] Command Area- It is the area which can be physically irrigated from the irrigation scheme and is fit for cultivation

[4] Surface lift scheme-Lift irrigation is a method of irrigation -in which water is not transported by natural flow (as in gravity-fed canal systems) but is lifted with mechanical means.

[5] Surface flow scheme-Under such schemes, fields are irrigated from canals, by flow under gravity alone.

Future

- Preliminary analysis for all the Hydro-meteorological stations in the basin.
- Classification of river catchments on the basis of hydrological alterations in the baseline scenario.
- Hydrological modelling for simulating the changes in the flow regime in future due to climate change and land use change.
- Comparative analysis of river flow regime under different future scenarios

Results from preliminary analysis

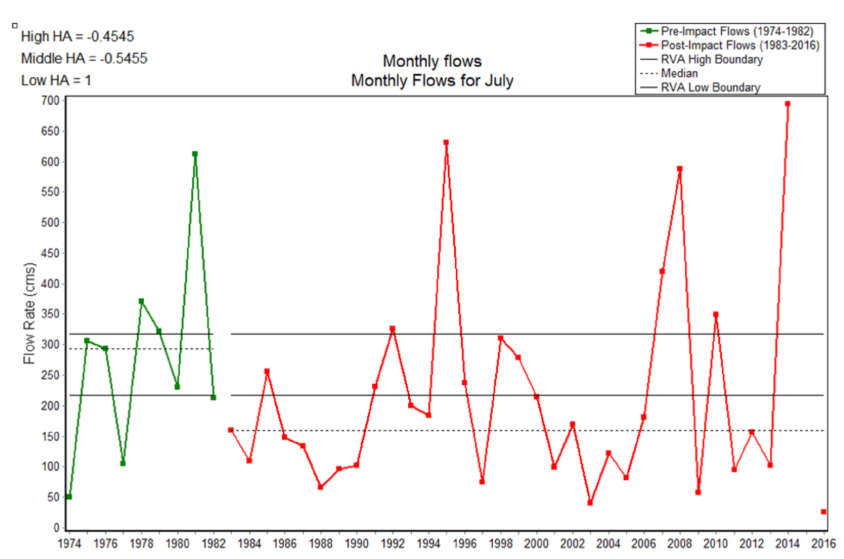

Figure 10

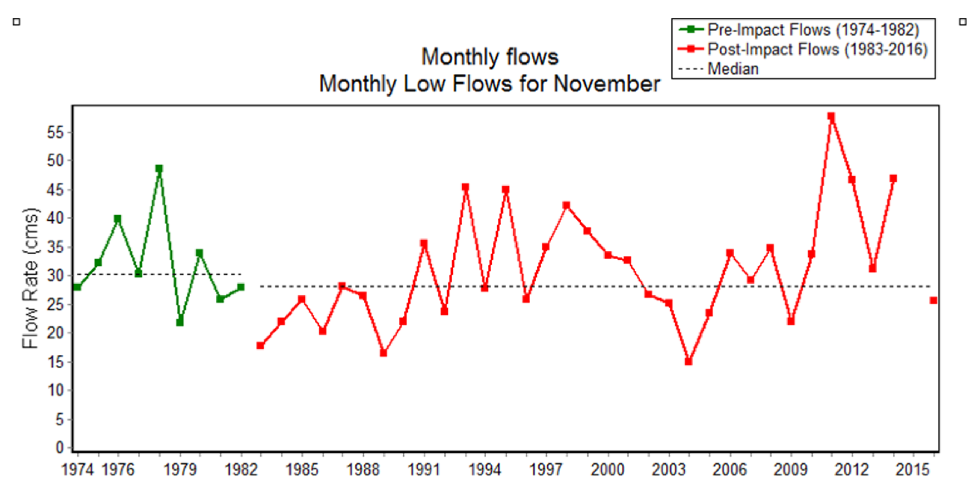

Figure 11

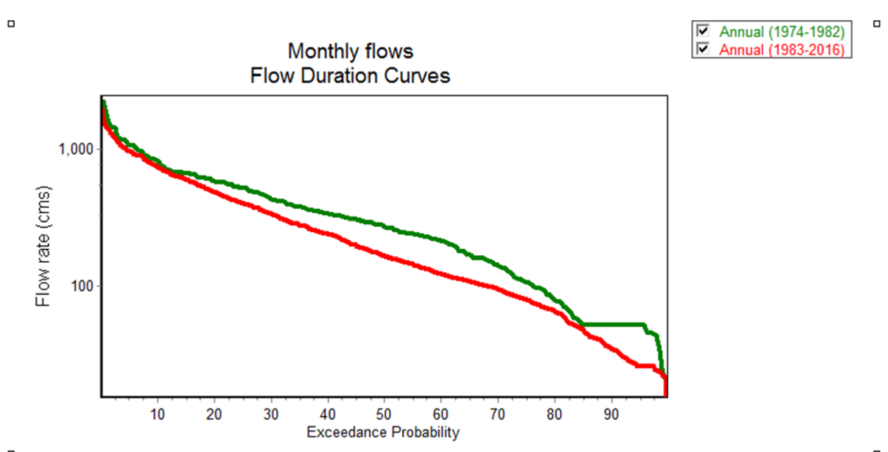

Figure 12

Fig 10: Hydrograph representing the monthly mean flows for the month of July before the construction of Dams (pre-impact) and after the construction of dams (post-impact). The figure also shows the Range of Variability (RVA) - RVA analysis divides the graph into 3 categories, for the pre-impact period the boundaries between categories are based on percentile values. In this case the category boundaries are placed 17 percentiles from the median, meaning– lowest category contain all values less than or equal to 33rd percentile; middle category contains 34th-67th percentile and highest category contains all values greater than 67th percentile. It then calculates the Hydrologic Alteration factor (HA). HA in this case is negative in high and middle categories which means that the frequency of post-impact values within these RVA categories has decreased.

Fig 11: The graph represents the monthly low flows for the month of November (post-monsoon) for the pre-impact and post-impact periods. Monthly low flows– All the flows less than or equal to the low flow threshold which is equal to the 25th percentile of all daily flows

Fig 12: The graph represents two-period Non-parametric flow duration curve where exceedance probability is the probability that a given flow (y-axis) will be equal to or exceed that % of time (x-axis)

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