Sustaining Water Resources for Food, Energy & Ecosystem Services in India
Workshop Report
Bangalore, India
11-12 March 2015

Background

This workshop brought together UK and Indian researchers to address priorities for sustaining water resources to inform the Newton- Bhabha call Sustaining Water Resources for Food, Energy & Ecosystem Services in India. Day 1 focused on highlighting short term priorities and the discussions on Day 2 centred on identifying longer term goals.

Rapid development (demographic and economic change) is increasing stress on India's water resources (rivers, lakes and groundwater) resulting in declining water quantity and quality. These demands on India's water resources are predicted to continue to grow and to be exacerbated by climate change. There is an urgent need to understand the 'safe operating spaces' for river and groundwater which will provide the necessary services for food, energy and ecosystem health, and the aim of this programme is to support the research needed underpin sustainable basin-wide integrated water management and contribute to economic development and social welfare in India, in line with the Newton-Bhabha Fund's objectives.

The UK and India have established strong research collaborations on the water cycle over the past few years, including 2 NERC/MoES funded programmes Changing Water Cycle and Drivers of Variability in the South Asian Monsoon, and this Newton-Bhabha activity on water resources provides an opportunity to further develop this successful partnership and lay the foundations for future joint activities. The potential scope of the research is broad with research questions to be considered including:

- How can we further improve our capacity to model, understand and predict the hydrological cycle using a 'whole-system' approach?
- What is the relationship between water quality, river flow, groundwater status and terrestrial and aquatic ecosystem services?
- How do we define environmental flows?
- What is the sustainability of groundwater in the major Indian river basins?
- How water storage is distributed seasonally and spatially in a basin?
- How to quantify drivers of hydro-meteorological variability and change and their uncertainties?
- How hydro-meteorological fluxes differ for different land use types and different climate regimes?

- How do the above change over time in response to the environmental drivers?

Up to £3m is available for the UK contribution to the Sustaining Water Resources for Food, Energy & Ecosystem Services in India programme, which will be match funded by MoES in terms of research effort. Given the wide range of potential research challenges further scoping was needed to determine the priorities for the planned research call and the primary aim of the workshop was to bring the UK and Indian communities together to discuss what the priorities for this activity should be, how best to address them, and how to ensure that the outcomes of the research support long-term sustainable growth in India.

Workshop Format

The workshop took place over two days (11-12 March 2015).

Day 1 (11 March 2015)

The aim of Day 1 was to identify short term priorities to inform the Newton-Bhabha Fund call. The morning session consisted of an introduction to the Newton- Bhabha Fund presented by Dr Nafees Meah followed by a presentation by Dr Ruth Kelman and Dr Vijay Kumar explaining the background and overview of the aims and objectives of the workshop. Dr Vijay Kumar gave an overview of the interests of the Indian Ministries and Missions with responsibilities for water resources.

Following introductory presentations on the Newton-Bhabha Fund and the funder's vision for this call, the workshop participants discussed the priorities for the call. Each participant was asked to put forward three science questions relating to the call topic.

These questions were then clustered into the following main ideas:

- Urban water- the effect of urbanisation on water resources; how water demand will change with increase in urbanisation.
- Uncertainties- reduction of uncertainties at different spatial/time scales; what thresholds exist for key species which have important roles for ecosystem services; big data for model building.
- System approaches- system dynamics models for basin level management; dynamic ecosystem modelling; how ecosystems respond to anthropogenic changes.
- Water quality- land cover/land use interactions on hydrology and water quality; forestation impacts on water quality.
- Meteorological- assessment of rainfall with observations; hydrological response to meteorological changes.
- Climate change- Improving prediction by climate models; inter-annual climate change variability impacts on water availability.
- Sediment- basin scale water sediment discharge; sediment delivery and ecological consequences.
- Groundwater/surface water- deep water aquifers; surface/ground water interaction along major rivers.

- User/stakeholder engagement- social impact on water allocation; ecosystems approach to water management; translating outcomes of research into knowledge.
- Flooding/extreme events- how does land use change affect flood generation; restoration of degraded systems.
- Cryosphere- long term changes in glacier extent and its influence on river systems.
- Environmental flows- development of standards for eflow assessment; impact of infrastructure on eflows.

The complete list of suggested priorities can be found in Annex A.

Building on these ideas, breakout groups discussed to achieve priority resources challenges for the call. The areas identified in the earlier session were to help lead the discussions. Each breakout group was asked to come up with 3 - 5 research questions. The participants were then asked to vote on which 2 questions should be included in the call. The 4 top choices were:

- How should water flows in a river system be ordered so that the river performs its basic natural functions?
- Constraining uncertainties in hydrological and meteorological observations and models for improved inferences.
- How does the distribution of storages and fluxes within heterogeneous catchments affect water availability, crop production, and energy and ecosystem services?
- What is the impact of urbanisation (urban centres/ land use changes) on surface water and groundwater?

The complete list of questions resulting from this discussion session can be found in Annex B.

Day 2 (12 March)

Dr Pradeep Mujumdar gave a presentation on the Report of the Sub-committee on Technology Interventions in the Water Sector t from the Scientific Advisory Council to the Prime Minister . He highlighted that Interdisciplinary research on water resources is necessary to help inform policy decisions. Dr Rajiv Sinha gave a presentation on the health of rivers in India. Dr Sinha emphasised the importance of the river systems for the public as they provide hydropower, irrigation water and water supply. Socio- economic changes could threaten the flows in the rivers system and it is important to adapt a more holistic management approach. The idea of a virtual Joint Centre on Water Resources which would be useful for networking and engagement with end-users as well as place for dialogue between researchers was presented to the group.

The aim of Day 2 was to identify long-term priorities for future UK- India collaborations in the area of sustainable water resources. Each group was asked to identify important research questions that would shape longer-term collaboration between the UK and India and what the best way to address water resource management in the future would look like. A common theme resulting from these

discussions was the need to address questions using a systems approach. Outcomes included addressing drivers of change, extreme events and the importance of models and observations.

The following additional points were highlighted during the discussion:

- It is necessary to engage with stakeholders and end users throughout the programme.
- The hydrological model needs to be at a very high standard to include the whole system and must have predictive capability.
- The economic implications and the monetary value of ecosystem services needs to be considered.
- It is necessary to have the ability to model hydrologic systems based on atmospheric drivers and be able to link atmosphere and hydrological cycle.
- Food and energy need to be taken into account along with the links between water, food and energy.
- It is important to be able to develop spatially specific database of land use that promotes a healthy system- water, and food security.

Wrap up

NERC and MoES thank the workshop delegates for their participation and thoughtful discussions. The inputs over the two days were excellent and will be incorporated into the upcoming call and future work. The Announcement of Opportunity for the call is expected to be issued in early summer 2015.

Attendees

Name	Institution	Contact
Prof Vinod Gaur	CSIR Centre for Mathematical Modelling and Computer Simulation	gaur@cmmacs.ernet.in
Prof AK Keshari	IIT Delhi	akeshari@hotmail.com
Prof Adebayo Adeloye	Heriot-Watt University	a.j.adeloye@hw.ac.uk
Prof Alex Densmore	Durham University	a.l.densmore@durham.ac.uk
Dr Ana Mijic	Imperial College London	Ana.mijic@imperial.ac.uk
Prof Anil Kulkarni	IISc Bangalore	anilkukarni@caos.iisc.ernet.in
Dr Anne Priest	NERC	annpri@nerc.ac.uk
Dr Arindam Chakraborty	IISc Bangalore	arch@caos.iisc.ernet.in
Dr Ashis Mitra	NCMRWF, Noida	akm@ncmrwf.gov.in
Prof B.N. Goswami	Institute of Science Education and Research, Pune	goswami@iiserpune.ac.in
Prof CSP Ojha	IIT Roorkee	cojhafce@iitr.ernet.ac.in cspojha@gmail.com
Dr Chris Jackson	British Geological Survey	crja@bgs.ac.uk

Prof David Gilvear	Plymouth University	David.gilvear@plymouth.ac.uk
Dr Dewashish Kumar	NGRI, Hyderabad	dewashishkumar@ngri.res.in
Prof GS Bhat	IISc, Bangalore	bhat@caos.iisc.ernet.in
Dr Gwyn Rees	Centre for Ecology & Hydrology	hgrees@ceh.ac.uk
Prof Ian Holman	Cranfield University	i.holman@cranfield.ac.uk
Prof Indu Mehrota	IIT Roorkee	Imehrotra46@gmail.com
Dr J Chandrashekar Iyer	Central Water Commission, Bangalore	Jchandra69@gmail.com
Dr J Iwan Jones	Queen Mary University	j.i.jones@qmul.ac.uk
Prof Jagdish Krishnaswamy	ATREE	jagdish@atree.org
Ms Jean- Marion	South Asia Research Hub	
Dr John Mathei	NCESS, MoES, Thiruvananthapuram	mathaicess@gmail.com
Prof K Srinivasan	IIT Madras	ksrini@iitm.ac.in
Prof Krishna Achuta Rao	IIT Delhi	akrishna@cas.iitd.ac.in
Dr Lindsay Beevers (Smith)	Heriot-Watt University	l.beevers@hw.ac.uk
Dr M Rajeevan	MoES	Rajeevan61@yahoo.co.in
Dr Mark Everard	University of West England	Mark.everard@uwe.ac.uk
Prof Michele Clarke	University of Nottingham	Michele.clarke@nottingham.ac.uk
Mr Murtaza Khan	Science & Innovation Network	
Dr Nafees Meah	RCUK India	Nafees.meah@rcuk.ac.uk
Dr D Nagesh Kumar	IISc, Bangalore	nagesh@civil.iisc.ernet.in
Dr Naresh Krishna	NIT Rourkela	vissan@nitrkl.ac.in
Dr Nayana Deshpande	IITM, MoES, Pune	nrdesh@tropmet.res.in
Dr Nick Chappell	Lancaster University	n.chappell@lancaster.ac.uk
Dr P.N. Vinayachandran	IISc, Bangalore	vinay@caos.iisc.ernet.in
Dr Pradeep Mujumdar	IISc, Bangalore	pradeep@civil.iisc.ernet.in
Prof Rajiv Sinha	IIt Kanpur	rsinha@iitk.ac.in
Dr Ravi Bhalla	FERAL, Pondicherry	bhalla@feralindia.org
Prof Ravi Nanjundiah	IISc, Bangalore	ravi@caos.iisc.ernet.in
Dr Rita Sharma	Science & Innovation Network	
Prof Rob Ward	British Geological Survey	rswa@bgs.ac.uk

Dr Ruth Kelman	NERC	rkel@nerc.ac.uk
Prof S Dutta	IIT, Guwahati	subashisa@iitg.ernet.in
Dr S.P Rai	NIH Roorkee	Sspr@nih.ernet.in
Prof Sekhar Muddu	IISc, Bangalore	muddu@civil.iisc.ernet.in
Ms Shalini Singh	RCUK India	Shalini.singh@rcuk.in
Dr Sharad K Jain	NIH Roorkee	skj@nih.ernet.in
Dr Shrinivas Badiger	ATREE, Bangalore	Ssbadiger@atree.org
Prof Subimal Ghosh	IIT Bombay	Ssubimal.ghosh@gmail.com
Mr Sunil Kumar	Science & Innovation Network	
Dr Surinder Kaur	MoES	Surinderkaur.imd@gmail.com
Dr Swati Basu	MoES	Sswati.basu@nic.in
Dr Timothy Jones	Lancaster University	t.jones1@lancaster.ac.uk
Dr Vandana Chaudhary	MoES	v.chaudhary@nic.in
Dr Vijay Kumar	MoES	vVijay.kumar66@nic.in
Dr V.V Srinivas	IISc, Bangalore	vvs@civil.iisc.ernet.in
Prof SK Satheesh	IISc, Bangalore	Ssatheesh@caos.iisc.ernet.in
Prof M.S. Mohan Kumar	IISc, Bangalore	Ms.mohankumar@gmail.com
Dr. Sumit Sen	IIT, Roorkee	sensumit2@gmail.com

Annex A

Sustaining Water Resources: Post-it notes from India workshop (10-11 March 2015)

URBAN WATER

Integrating energy fluxes from urban land surface to atmospheric system.

Urban heat island effect- scientific understanding of problem of high intensity precipitation in urban areas.

Urban water models link catchment for water security and sharing nutrient rich waste water.

How the changing land use in urban centres located in a river basin affect the groundwater and surface water?

What are the relationships of water and contaminant plumes between stream and aquifer in a river basin?

Better monitoring and use of satellite image for development of LDAs towards better hydrologic forecast.

Impacts of urbanisation and peri-urban demand on hydrological process.

Urbanisation effects on water resources.

What is the extent of future urban expansion and how the water demand will change?

Importance of urbanisation on hydrological cycle.

How can we quantify the links between demand and supply between various sectors on a systems level?

Urban to basin scale hydro and water quality interaction. How deo we integrate these scales and represent these within basin wide models to understand the processes (to inform management and policy development)?

UNCERTAINITIES

Quantification and reduction of uncertainties in assessment of hydrologic change at different spatial/ time scales.

What is the safe operating space for ecology in river basins- i.e. what thresholds/tipping points exist for key species which have important roles for ecosystem services?

Constraining uncertainties in observations due to sampling limits and due to uncertain process descriptions in models.

Given the spatio-temporal variability in groundwater, soil water etc, what is the optimum monitoring network design to support improved systems-based models.

Big data for model building.

Large scale coastal aquifer problems.

SYSTEMS APPROACHES

System dynamics models for basin level water resources management.

What is the trade-off between food security and ecological flows under current and future scenarios of water-use efficiency and climate change?

What are the short and long term impacts of river basin on estuaries and deltas and dependent ecosystems?

Basin wide assessment of components of hydrologic cycle.

A need to apply the ecosystem service concept to water resources and catchment and river systems. Need to identify hot spots and hot moments and fluxes.

Dynamic ecosystem modelling involving demand and supply chain.

Modelling and assessing water stresses at spatial scale in river basins and its feedbacks on crop productivity.

To strengthen hydro-geological inputs into values of ecosystem services.

How do we most effectively integrate biophysical and social and economic sciences for clear policy messages?

How do we communicate complex class scale issues (catchment implications of nested small scale interactions) for coherent policy communication?

Understanding the implications of scaling-up more efficient irrigation methods to the basin-scale, food production and expansion of irrigation.

Better assessment and prediction to improve food security under the usage of higher irrigation energy with low efficiency? Role of Water Governance?

What is the impact of transformed flow regimes, sediment and nutrient fluxes on threatened freshwater ecosystems and ecosystem services?

How ecosystem responds to hydrometeorologic and anthropogenic changes and assessment of environmental flows?

Fundamental natural science linking meteorological processes to groundwater response to river generation.

Can e-flow and ecosystem service concept be amalgamated?

WATER QUALITY

Water quality impairment and its impact on human and ecosystem health; technologies to improve water quality.

Quantifying forestation impacts on sustaining water quality.

Land cover/Land use interactions and impacts on hydrology and water quality.

METEOROLOGICAL

Assessment of rainfall with observations

Hydrological response to meteorological fluxes and vice versa.

How do we address scale and resolution disparities in hydro/met research and watershed restoration?

Estimation of hydro-met fluxes for different land uses.

Prepare rainfall, soil moisture datasets by combining satellite and in situ observations.

CLIMATE CHANGE

Inter-annual climate change variability impacts on water availability,

Improving prediction of precipitation by climate model.

Segregating the contribution of land use and climate change on hydrology.

SEDIMENT

Basin scale water sediment discharge- how can we do this?

Better quality soil erosion and sediment flux pathways from agricultural systems in terms of reservoir siltation and aquifer ecosystem quality.

Link sediment delivery to ecological consequences.

Determine the role of land use change versus climate change in sediment delivery to rivers.

GROUNDWATER/SURFACE WATER

Dynamics of deep aquifer- quantification of aquifer storage; quality of aquifer; recharge of deep aquifer; recharge rate of aquifer.

Surface water- groundwater: interaction of optimal water use policy at basin level.

Model surface flow with land surface model. JULES validate model with observations.

Surface water- Groundwater interaction along major rivers during floods.

How do we identify or define reporting conditions for river/stream or groundwater in forms of ecosystem /enviro health?

Integrated management of coastal water resource systems considering risk of saline intrusion to groundwater.

Physical process- interaction between surface and groundwater (quantify supply).

Quantification of water availability at sub basin and aquifer scales at multiple temporal scales.

Groundwater is key to future increased food production but interactions between climate variability and subsurface heterogeneity are likely to be linear and may limit food production and impact on energy use and CO2.

USE/STAKEHOLDER ENGAGEMENT

Mechanisms to match the scale of bio-physical models with the scale at which policy decisions are made (e.g. state/district).

Ecosystems approach to water resource management/ allocation including changing water use practices (equity and efficiency).

How does one scientifically validate community knowledge on watershed management (specifically structural measures)?

How do we translate the outcomes of research into a practical structure for delivering water resource management?

What is the social impact on water allocation?

How do we valuate ecosystem services from the perspective of stakeholders in large basisn with complex caste/class/community structure?

Valuation to address cross-scale and beneficiary issues: what values do catchments produce? What are the distributional impacts? How do we reshape the formal and informal policy environment to optimise cross-service/beneficiary values?

What is the trade-off among various water uses and ecosystem services and what should be its role in optimal water allocation/use?

FLOODING/EXTREME EVENTS

Extreme events- identification of flood/drought events- mitigations

Thorough quantification of forestation impacts on flood flow and low flows. Including role of groundwater, watersheds- Himalayas.

Comparative hydrological process studies (Interactions, transpiration, forest flow) between difference ecosystems.

Runoff prediction under degraded ecosystem conditions.

Restoration of degraded ecosystems.

Understanding the ecological response to extreme flows- role of change in clime and land use in propagation of extremes.

Changes in the rainy period of a place. Non monsoonal events and use of rainfall during these.

How does effect of land use change for flood generation?

Basin scale characterisation of floods and droughts and the effect of climate change.

Spatial and temporal evolution of meteorological drought and translation to agricultural and hydrological droughts.

CRYOSPHERE

Long term changes in glacier extent and its influence on water availability in Himalayan rivers.

How much is loss of glacier mass and future changes in mass loss?

How much is glacier stored water in the Himalayas?

Can we project glacier mass balance and its influence on river flows?

Understanding cryogenic processes and influence downstream water resources.

E-FLOWS

Estimation of ecological flows.

Modelling tools for environmental/ base flows in river basins.

How do we define e-flows in the context of climate change?

Assessment of env flows and ecosystem.

Development of standards for eflow assessment.

Modelling hydrological processes and environmental eflows in river basins to gain fundamental knowledge on the processes.

Improve understanding of the morphological adjustment of rivers to dwindling flows and ascertain if the response is beneficial or leads to adverse consequences.

Impact of human infrastructure / practice on soil loss, sediment transport, pollutant transport and eflows/ecosystems.

Annex B

Questions arising from discussion session on Day 1.

How best to engage stakeholders so that scientific research is useful, usable and used.

Identifying options for value retention across the water cycle for optimal societal benefit?

- Treatment of effluent/ land waste interface/groundwater and surface water recharge
- Water governance for optimal food- water- energy outcomes

How can we place value on the changes in ecosystem services that result from changes in flow?

Understanding the trade-offs and demand management controls arising from societal and sectorial policy on water resources at the basin scale.

Constraining uncertainties in hydrological and meteorological observations and models for improved inferences.

What are the tipping points and thresholds in coupled agro-hydrological and eco-hydrological systems?

How do we identify in space and time aquatic ecosystem tipping points due to water abstraction and regulation that adversely affect the supply of ecosystem services to society?

How does the spatial and temporal variability of hydrological cycle impact agriculture and ecosystem?

What is the relationship of water and contaminant fluxes between glaciers/river/groundwater?

What are the ecological and livelihood responses to environmental and anthropogenic change?

- Urban and rural land use impacts
- Implications for sustainable water and rural policy

What are the adaptation strategies in agriculture and ecosystems to global changes?

What level of complexity is required to manage groundwater in different hydrogeological settings?

Can meteorological parameters (rain/snow/temp) be predicted at different basin scales 5-10 years ahead?

Given meteorological parameters can we partition inflows into a basin from rainfall and snow/ice melt?

What can scenario analyses tell us about outcomes at nested temporal and spatial scales (continental to local rural/urban)?

- Optimal use of satellite products and in situ measurements, combined in models appropriate to different scales.
- Difference outcomes for “business as usual”, recharge/regeneration * other scenarios.
- Accounting for uncertainties and how they should inform decision makers.
- Integrated systems dynamics approach at variable spatial and temporal scales.

How do we characterise the impacts of episodic events on catchment dynamics & ecosystem services?

-Hydrological modelling and forecasting; Implications for catchment through to local scales.

How much is the influence of Himalayan cryosphere in spatial and temporal distribution of water in the Himalayan basin system. Specifically in terms of food security and energy security.

What are the recharge processes of deep aquifers and how can this help in sustainable management of ground water resources?

What is the impact of urbanisation on surface water/groundwater?

How will the urban centres influence/impact hydrological cycle of a river basin?

How does the distribution of storage within heterogeneous catchments affect water availability, crop production and energy use?

Attributing water quality change to anthropogenic and atmospheric drivers.

What are the trade-offs between water allocation to human and natural ecosystems under difference LU –LC and climatic scenarios?

How do large scale LULC changes affect hydrological services?

Can we quantify the influence of human interventions, climate change and their interaction on hydrological cycle of a river basin?

How far can integrated management and operation of surface and groundwater resources go in alleviating water stress at the basin scale and in the best and worst scenarios of water availability and demand?

How do we allocate flows in a river system so that the river performs its basic functions?

Basin wide system dynamics modelling of important threatened basins.

What are the minimum spatio-temporal requirements of E flows that support society’s demand for ecosystem services? – In gauged and ungauged basin?