

# Indo-Gangetic Basin in India: Groundwater Issues Groundwater Governance Project, February 2006

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## 1. Introduction and background

The purpose of this report is to give a background on groundwater issues in the Indo-Gangetic basin in India.

## 2. Description of groundwater setting/problems

The Indus basin consists of the main river Indus and its major tributaries, the Kabul, the Swat and the Kurram from the west and the Jhelum, the Chenab, the Ravi, the Beas and the Sutlej from the east (Figure 5). The Indus river is distributed in 5 Indian states- Jammu and Kashmir (60%), Himachal Pradesh (16%), Punjab (16%), Haryana (3%) and Rajasthan (5%) respectively. The catchment area of the Indus is 1.165 million sq. km out of which 321,290 sq. km.



Figure 1. Indus basin rivers (Sikka, 2004)

The Ganga basin is joined by the river Yamuna from the west at Allahabad, then the rivers Ramganga, Gomti and Tons from the north and the Chambal, Betwa, Sinda and Ken from the south (Figure 6). In India the Ganges basin covers 8 states: Uttar Pradesh (34.2%), Himachal Pradesh (0.5%), Haryana (4%), Rajasthan (13%), Madhya Pradesh (23.1%), Bihar (16.7%), West Bengal (8.3%) and Delhi (0.2%). The catchment area of the Ganga basin is 1.06 million sq. km. out of which 861,404 sq. km. lies in India.



Figure 2. Ganges basin rivers (Sikka, 2004)

Physiographically, the Indo-Gangetic Plains in India can be divided into 3 parts: a) The Himalayan ranges and the Siwaliks to the north and north-west, b) the plains that range from east to west, and c) the highlands comprising the Malwa plateau, the Bundelkhand uplands, the Vindhyachal-Baghelkhand plateau and the Chotanagpur plateau (Figure 3 and Figure 4).

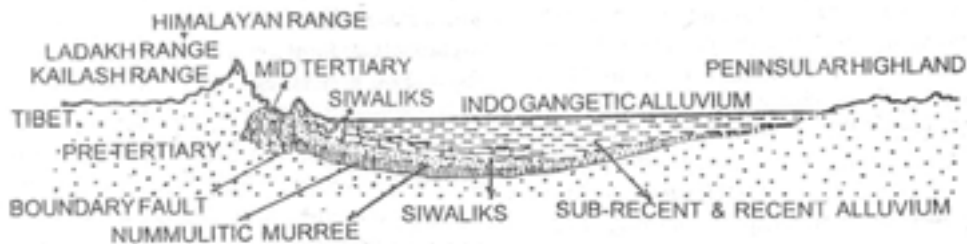


Figure 3. Representative north-east to south-west cross-section of the Indo-Gangetic Basin (not to scale) (Tiwari 2003)

The rainfall distribution across the basin shows a general increase in average annual rainfall from east to west (Figure 5). The average annual rainfall ranges from 400-500 mm from parts of Punjab to 1200 mm in West Bengal. Parts of the plateau highlands in the south also receive high rainfall as much as 2000 mm annually.



Figure 4. Indo-Gangetic Basin in India: Physical features (Berkoff 1990)



Figure 5. Indo-Gangetic Basin in India: Mean Annual Rainfall (Berkoff 1990)

Groundwater development is most suitable in the vast plains area of the basin. Aided by development of canal networks that have induced recharge into the alluvial aquifers of the plains, rapid groundwater development has been experienced all across the plains areas in the past 50 years. The pattern of concentration of well density and availability of groundwater show variation across the plain areas. Freshwater parts of the western plains have shown high degree of development and there is extensive depletion of groundwater over vast areas, whereas saline groundwater areas in the western plains are showing signs of rising water tables. Towards the eastern plains, there is lesser intensive and profitability in exploiting groundwater, therefore, the degree of development is not as high.

In the highlands areas of Madhya Pradesh, Chattisgarh and West Bengal states that lie within the basin, the geology is comprised of primarily Crystalline terrain that is unsuitable for storage of groundwater on the whole. There are local variations where intermontane deposits aid local storage of groundwater through recharge from surrounding hills. Also, some highly localized fractured and weathered terrain assist

development of groundwater. But apart from this, groundwater flow and availability is highly localized as opposed to the plain areas.

Saline tracts of groundwater exist in the western parts of the Indus basin and in central parts of the Ganga basin plain areas (Figure 6). Problems of fluoride contamination exist in the western, central and southern parts of the IGB basin areas (Figure 7). The eastern parts of the basin are affected by arsenic contamination and some areas have high iron content in groundwater (Figure 6).

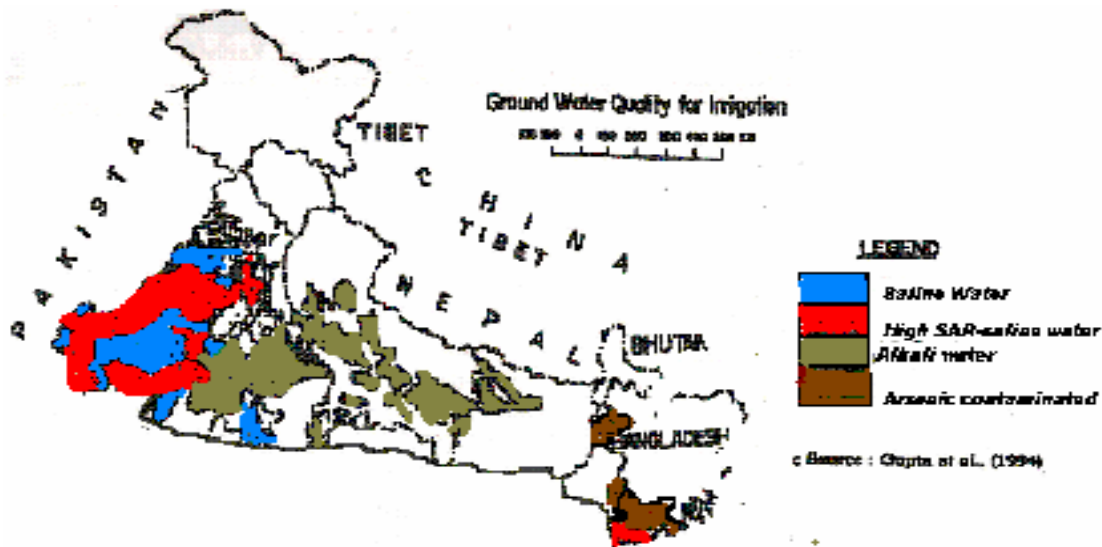


Figure 6. Salinity-affected and Arsenic-affected groundwater in Indo-Gangetic basin



Figure 7. Distribution of Fluoride in shallow groundwater of Indo-Gangetic basin in India

Energy availability in rural areas shows a division across the basin areas. There is relatively abundant availability of cheap to free electricity in the western states of Punjab and Haryana whereas rural electricity for irrigation purposes is dysfunctional in eastern parts of the basin such as West Bengal and Bihar. Parts of the MP basin areas are quite backward in development and do not have access to good supply of electricity. In areas where there is poor availability of electricity for well-irrigation, diesel pumpsets are the

common mode of accessing groundwater. One can see the gradual variation of groundwater access mechanisms from western to eastern parts of the plain areas.

Population density is highest in the plain areas which are also marked by smaller land ownings. In general, the eastern parts have smaller landholdings than the western parts of the basin and are characterized by greater population density and greater poverty. There is also a high rate of migration of rural poor from the eastern parts such as Bihar, part of which is towards the agriculturally prosperous western regions which attract agricultural labor. Part of the reason is also high flood-proneness of the eastern plains, especially northern parts of Bihar (Figure 8).

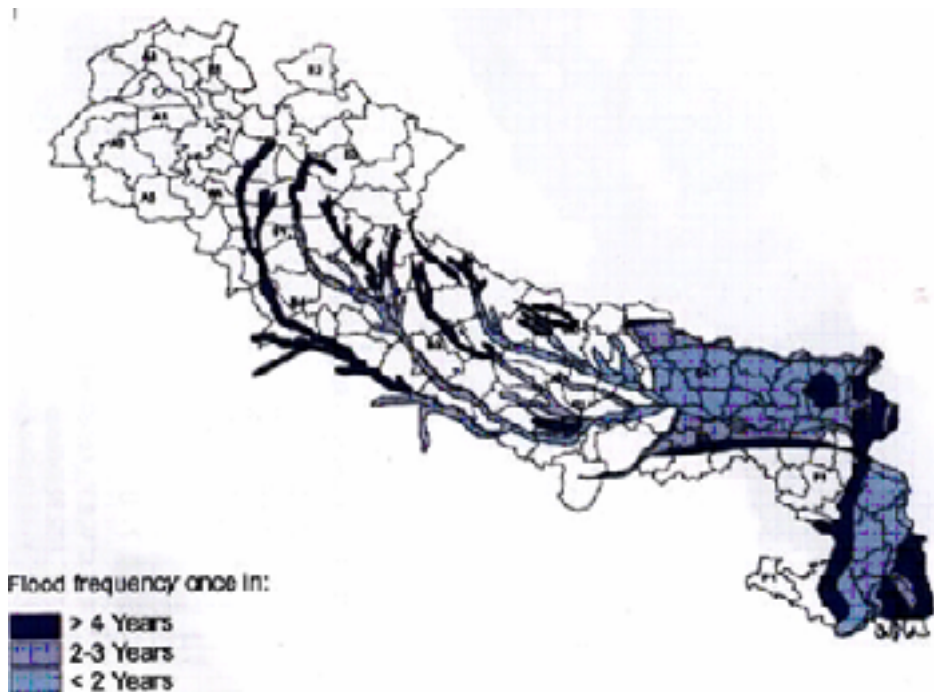


Figure 8. Frequency of flood in parts of the Indo-Gangetic basin

In the plain areas, the rice-wheat cropping system is the most common. Productivity of agriculture is higher in the western areas as compared to the eastern areas per unit land and water applied. This can be attributed to various reasons. In general, the western regions are lesser dependant on rain-fed farming due to poorer rainfall. Therefore, there is greater reliance on irrigation from canal and from groundwater – both of which are relatively more reliable than the rains. This combined with the Warabandi system (fixed time period canal water allocation based on landholdings), better availability of energy for groundwater irrigation, natural factors such as lesser monsoon cloud cover (more sunny days per year) and being lesser prone to floods – are factors that have contributed to the relative economic prosperity of the western agricultural region. Certainly, political and social factors also add texture to this picture.

The entire plain areas show a vast presence of local markets for groundwater. The presence of these local water markets combined with availability of tube well technology and energy availability (diesel, electricity) have contributed to the boom in groundwater development.

The questions in managing groundwater are several and are region dependant:

1. Addressing groundwater depletion in fresh groundwater areas of the west (Figure 9),
2. Addressing groundwater tables rise in saline areas of the west and central parts of the plain (Figure 10),
3. Bringing about local groundwater management to develop irrigation in hilly areas of the south,
4. Addressing drinking water problem in areas affected by high Fluoride, high Arsenic and high Salinity and for local communities whose social and economic conditions deprive them of basic water needs,
5. Utilizing groundwater development as a means to sustain and improve agricultural water and land productivity in the eastern parts of the basin,
6. Using direct means such as laws for regulating drilling of new wells and indirect measures such as electricity pricing for controlling volumetric use of groundwater for governing groundwater over the region.

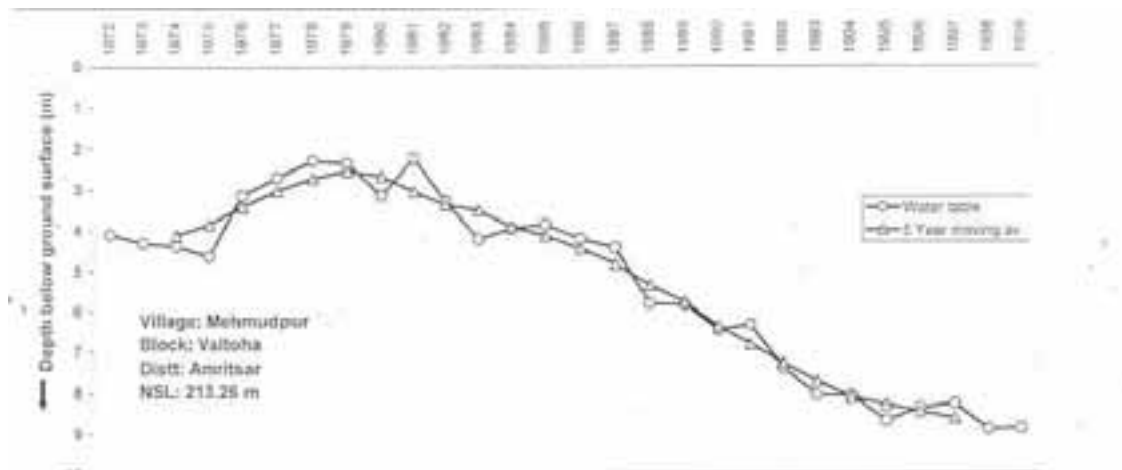


Figure 9. Falling water table in fresh groundwater area of Punjab

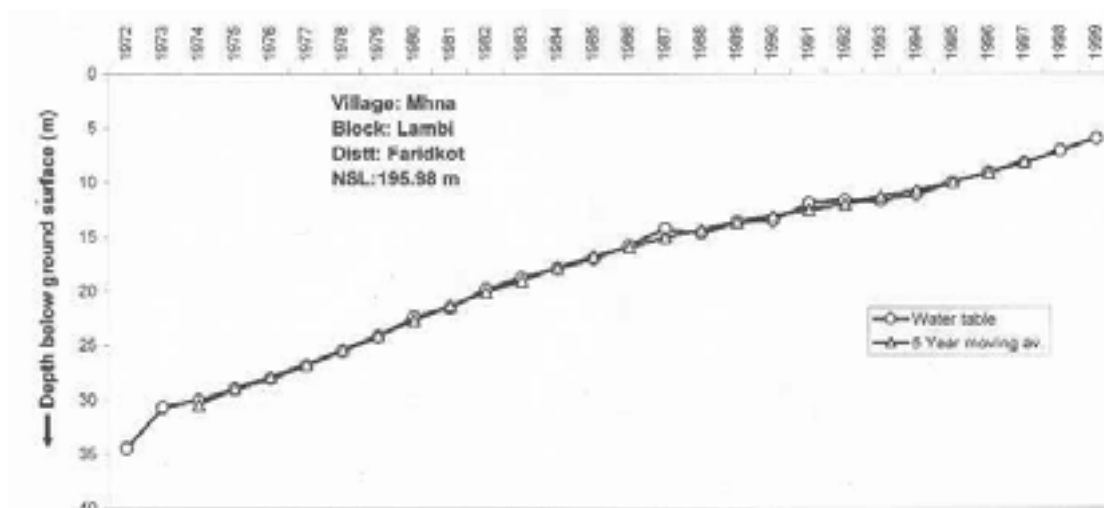


Figure 10. Rising water table in saline groundwater area of Punjab

#### **4. Major institutions involved in groundwater research and management, their relative role and importance and some key issues in this respect**

Since 1999, IWMI has developed a fairly strong presence on the Indian groundwater scene. In 2001, IWMI and Sir Ratan Tata Trust, Mumbai collaborated to establish the IWMI-Tata Water Policy Program. One key area of IWMI-Tata research in India has been groundwater economics, institutions and policies. Over the years, this work has filled an important gap in the understanding of the groundwater socio-ecology of India, notably the Indo-Gangetic basin. This has helped IWMI establish close rapport with some key national level institutions in charge of policy making on groundwater issues. Because of this history, and because IWMI groundwater theme was based in India until 2005, the Project did not plan a special sensitization trip in India as it did in other project countries. The national body in charge of groundwater management in India is the Central Groundwater Board (CGWB) which is a part of the Ministry of Water Resources, Government of India. The CGWB was established in mid 1970's essentially as a groundwater research and monitoring organization. The CGWB is therefore staffed principally by hydro-geologists and modelers. The Board has five regional offices, each mandated to monitor groundwater resources and quality in their respective zones. In addition, many states have their own Groundwater Departments. Both the state groundwater departments as well as CGWB have their own observation wells on what water levels are recorded twice every year, before and after the monsoon. Together, some 50,000 observation wells are being monitored.

As groundwater development has occurred at a runaway pace, there is increasing demand for the CGWB to play a larger resource management and regulatory role beyond just resource monitoring. In response to a Public Interest Appeal, the Supreme Court of India designated the CGWB as the country's Central Groundwater Authority mandated to control rampant groundwater depletion and contamination. The CGWA has tried, without much success, to fill this new role expected of it. However, it requires a cultural and organizational overhaul before it can meet the Supreme Court's expectations. In response to growing concerns about groundwater abuse and depletion, the Parliament mandated the Planning Commission of India to appoint a high-powered expert group to recommend a suitable plan of action for strengthening groundwater governance in India. IWMI is represented on this important expert group which provides a powerful channel to translate its research into useful guideline for strategic action. The working group also provides IWMI access to highest levels of decision making in India's water sector, including the chairman, CGWA, Secretary, Ministry of Water Resources, Government of India and several key states; Member, Planning Commission (Water and Power). IWMI's research so far—and to be carried out under the CP project—is of direct relevance and interest to the CGWA; therefore, the Project researchers have kept the Authority brought up to speed from time to time on the progress of the project. The chairman of the CGWA himself has assured support to and participation in the Project.

The Project researchers have developed limited contacts with state level groundwater departments, especially in the IGB states. Moreover, many states also have tubewell corporations. While public tube well programs are either extinct or being phased out, these corporations still have some role and face some challenges of interest to the CP projects.

During 2000-2005, Government of India and five states operated a World Bank funded National Hydrology Project whose aim was to improve the groundwater monitoring system and make for wider dissemination of groundwater data. The Project researchers have some contact with the Hydrology Project. However, now it has been phased out. Even so, the data base generated by it can be accessed and used for the benefit of the CP project.

IWMI organized a pre-proposal consultation in Calcutta during 26-27 August, 2003 to seek ideas and feedback on the research proposal on Groundwater Governance in IGB and YRB that IWMI-Tata researchers were developing. The workshop was funded by the IWMI Tata Program and IWMI's theme on Sustainable Groundwater Management. The workshop brought together researchers and policy makers mostly from India and Bangladesh (list of participants in Annexure 1). ITP subsequently also supported another workshop at Roorkee in 2004 where IWMI scientists had opportunity to interact with some of the researchers and research centers in the IGB (list of participants attached). Finally, after the project was approved, a project inception workshop organized in Delhi provided one more opportunity to develop an overview of ongoing groundwater research in India.

These interactions suggested that three types of groundwater research is being carried out in India almost independently of each other in three different types of research institutions:

[a] *Hydro-geology and groundwater modeling*: in National Institute of Hydrology and Indian Institute of Technology, Roorkee; various IITs and regional engineering colleges; and select ICAR centres such as the one at Patna;

[b] *Groundwater and agronomy*: in the ICAR system under a variety of Co-ordinated Research Projects that involve agricultural universities; and

[c] *Social science of Groundwater*: in ICSSR research centres in several states such as Rajasthan, Gujarat, Madhya Pradesh, Bihar, West Bengal, Tamilnadu, etc; moreover, several Agro-economic Research Centres too carry out studies on the economics of groundwater irrigation. In the Indo-Gangetic basin, there are around a dozen such centres and individual researchers (such as Niranjana Pant). IWMI has contact with some of these; but under the CP project expand its ambit and bring more such centres under coverage.

The bulk of the mainstream research related to groundwater falls in hydro-geology and modeling with very little taking place in social science of groundwater use in agriculture.

A major shortcoming of Indian knowledge-base on groundwater is that these three segments remain mutually exclusive with little synthesis occurring at any level. As a result, even at the top-most policy making levels, a synthetic, well-rounded understanding of the issues involved in managing a complex resource economy is often lacking. In understanding the challenge of sustainable groundwater management in India, it is critical to blend three distinct perspectives: [a] the characteristics and behaviour of groundwater resource (resource perspective); [b] the characteristics and behaviour of resource user communities (user perspective); and [c] the institutional frameworks under which the resource is appropriated and used (institutional perspective) (see figure 1). IWMI's work on groundwater in India has evolved under the premise that the national knowledge development as well as capacity building on groundwater use in agriculture so far is dominated by 'resource perspective'; and the critical value-adding contribution is to be made in expanding global knowledge and capacity in user and institutional perspectives. Undergraduate and Masters' courses on hydro-geology in India, for instance, spend less than 10% of teaching time on economics and sociology. When their students grow up as researchers and policy makers in groundwater sectors, their worldview tends naturally to get dominated by the resource perspective. And since economists and sociologists seldom foray into groundwater research, user and institutional perspectives have remained largely unexplored in the existing groundwater knowledge base.

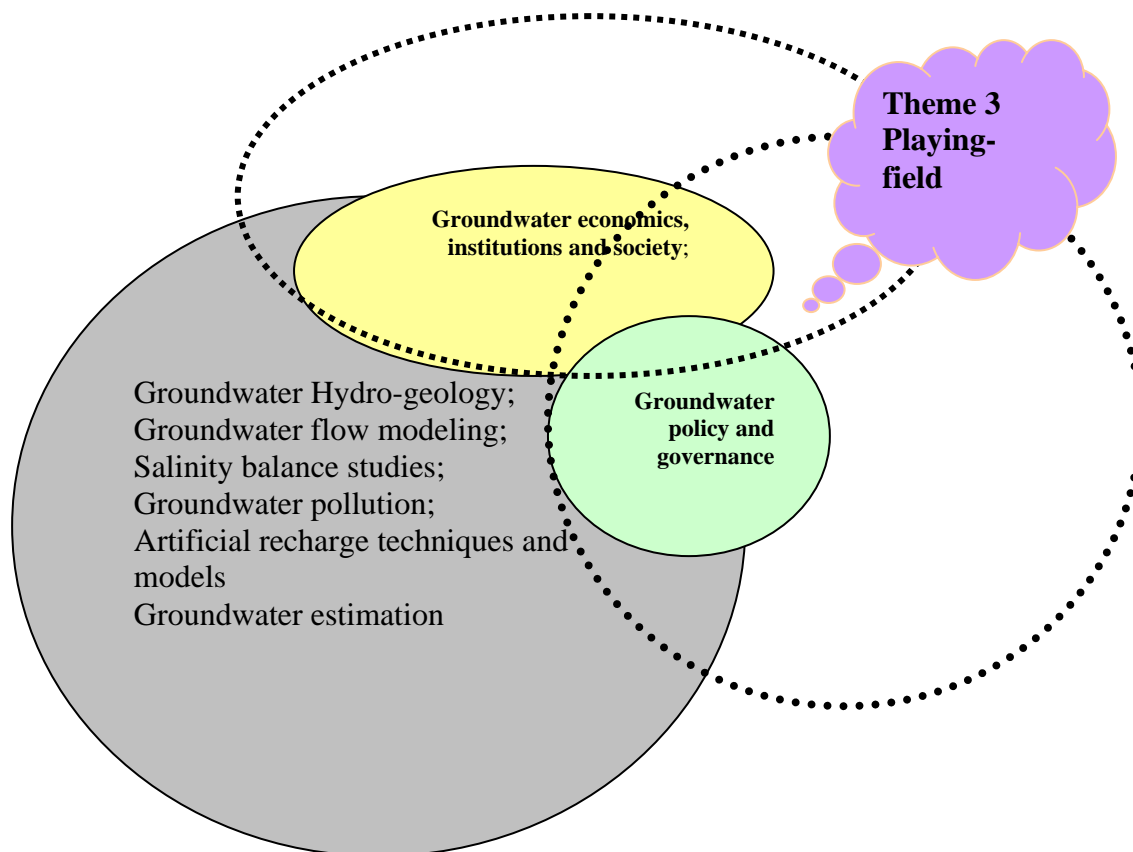


Figure 11. The knowledge development challenge of groundwater management

It is not surprising therefore that books and journals containing groundwater research in India present scientific interactions amongst mostly hydro-geologists, water resource engineers and modelers with little contribution from sociologists, economists, researchers in policy sciences and public administration. There is growing recognition of the need to blend these perspectives to create a broad, well-rounded understanding of groundwater governance issues. And since the CP project on GwG directly addresses this need, it is expected to generate enthusiastic response from managers and policy makers at various levels in India.

## 6. Conclusions and recommendations

Unlike other CP project countries, India has a large research establishment to work on groundwater science. The key to research for effective action is to support practical, problem oriented research rather than hard science. The suggestion then is that CP GwG should apply a rather broad and 'inclusive' notion of 'policy research' to understanding the groundwater challenge facing Asian governments.

1. Research aiming explicitly to draw attention to the **Big Picture**. This may include an assessment, say, of the potential for conjunctive management of ground and surface water and a policy framework to make that happen in a sub-basin, say of Sharda. Or the impact of new electricity policy in Uttar Pradesh.

2. Research in **whistle-blowing format**: Does the new World Bank supported project for river basin management in Uttar Pradesh lead to integrated management of ground and surface water at the catchment level?

3. Research aimed at **seeding large-scale new action initiatives**: Is there scope to improve the efficiency and equity impacts of government programs such as Million Well subsidy scheme? Is there an effective low cost filter to minimize health hazard of arsenic-contaminated groundwater?

4. working with NGOs and grassroots groups in an **action research** mode. We may support a small study of NGO's working on arsenic.

5. Practical research on **"Institutional design"**. An interesting issue may be the Punjab Chief Minister's plan to wean his farmers away from the rice-wheat system. Or the effectiveness of West Bengal's efforts to contain groundwater overdraft.

6. **"Impact Research"**: Public health impacts of arsenic contamination in West Bengal.

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