Water and Agricultural Transformation in India
A Symbiotic Relationship -- II[1]

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This is the second part of a paper (in two parts) in which we present the argument for twin propositions: (a) that solving India's water problem requires a paradigm shift in agriculture (Part I) and (b) that the crisis in Indian agriculture cannot be resolved without a paradigm shift in water management and governance (Part II). In the first part of the paper (EPW - - -), we outlined the constituent elements of the existing paradigm of agriculture, explained why it needs to be transformed and then described the nature of the paradigm shift required.

In this second part of the paper, we describe the paradigm shift needed in water, which includes rejuvenation of catchment areas of rivers, a shift towards participatory approaches to water management, focus on green water and protective irrigation, widespread adoption of water-saving seeds and technologies, while building trans-disciplinarity and overcoming hydro-schizophrenia in water governance.

The paradigm shift required in water[5]

Just as the Green Revolution paradigm fundamentally misrecognises the essential nature of soils as living eco-systems, the dominant policy discourse on water fails to acknowledge the principal characteristics of water as an intricately inter-connected, common pool resource. The multiple crises of water in India today could be said to stem from this essential misapprehension. Atomistic and competitive over-exploitation of aquifers and the inability to manage catchment and command areas of large dams are the biggest examples of how the water crisis has got aggravated.

What makes things worse – but also creates an opening for a new beginning – is the fact that definite limits are being reached for any further construction of large dams or

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[1] This is the second part of the revised version of a paper originally commissioned by the Food and Agriculture Organisation and presented at the National Dialogue *Indian Agriculture Towards 2030* organised by the NITI Aayog in January 2021. We are extremely thankful to Jean Dreze for taking out time to give us detailed comments on the paper.

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[5] This section relies heavily on both Shah (2013) and Shah *et al* (2016), where these arguments are fleshed out in fuller detail

groundwater extraction. Thus, the strategy of constructing large dams across rivers is increasingly up against growing basin closure. In addition, the possibilities of further extraction of groundwater are reducing, especially in the hard rock regions, which comprise around two-thirds of India's land mass.

1. Participatory irrigation management in the irrigation commands

India has spent more than INR. 4 trillion on the construction of dams, but trillions of litres of water stored in these reservoirs is yet to reach the farmers for whom it is meant. There is a growing divergence between the irrigation potential created (113 million hectares) and the irrigation potential actually utilised (89 million hectares). While this gap of 24 million hectares reflects the failure of the irrigation sector, it is also low-hanging fruit: by focusing on this, India can quickly bring millions of hectares under irrigation. Moreover, this can be achieved at less than half the cost of building new dams, which are becoming increasingly unaffordable. There are massive delays in the completion of projects and colossal cost over-runs, in addition to which there are humongous human and environmental costs.[6] Major river basins like Kaveri, Krishna, Godavari, Narmada and Tapti have reached full or partial basin closure, with few possibilities of any further dam construction.

There is, therefore, an urgent need for reforms focused on demand-side management, jettisoning the over-emphasis on ceaselessly increasing supply. These reforms have already been tried and tested in many countries across the globe. There are also significant successful examples of reform pioneered within India. These successes have now to be taken to scale. Reforms in this context imply a focus on better water management and last-mile connectivity. This requires the de-bureaucratisation or democratisation of water. Once farmers themselves feel a sense of ownership, the process of operating and managing irrigation systems undergoes a profound transformation. Farmers willingly pay irrigation service fees to their Water Users Associations (WUAs),

[6] The old engineering maxim of not letting river water flow "wastefully" into the sea stands badly discredited today. Indeed, recent scientific research advises caution in tampering with run-off from major rivers. The 2014-2020 multi-institution Ocean Mixing and Monsoon (OMM) Programme of the Ministry of Earth Sciences has confirmed that flows of river water into the Bay of Bengal lead to fundamental changes in the response of the Bay of Bengal sea surface temperature to tropical cyclones and the monsoons. Reduction of flows from major rivers would affect the salinity and depth of the upper mixed layer, and modify the temperature of the Northern Bay of Bengal. This could impact variations of rainfall, including rainfall carried inland by monsoon low-pressure systems and depressions born in the Bay of Bengal. It is, therefore, almost certain that tampering with run-off from major rivers will impact monsoon rainfall, in unknown and unanticipated ways (https://incois.gov.in/omm/index.jsp)

whose structure is determined in a transparent and participatory manner. Collection of these fees enables WUAs to undertake proper repair and maintenance of distribution systems and ensure that water reaches each farm.

This kind of participatory irrigation management (PIM) implies that the State Irrigation Departments only concentrate on technically and financially complex structures, such as main systems, up to secondary canals. The tertiary-level canals, minor structures and field-channels are handed over to the WUAs, which enables better last-mile connectivity and innovative water management. This includes appropriate cropping patterns, equity in water distribution, conflict resolution, adoption of water-saving technologies and crop cultivation methods, leading to a rise in India's overall water-use efficiency, which is among the lowest in the world.

PIM, it must be acknowledged, is not a magic bullet; studies across the world reveal specific conditions under which it works. These need to be carefully adhered to. While these are issues for state governments to tackle, the Centre also has a critical role to play in incentivising and facilitating the former to undertake these reforms. Release of funds to states for large dam projects must be linked to their progress on devolutionary reforms and empowering WUAs. States committed to the national goal of *har khet ko paani* (water for every farm) will not view this as an unreasonable imposition. In order to allay any apprehensions, the Centre should also play an enabling role, helping officers and farmers from different states to visit pioneering PIM proofs-of-concept on the ground sites, so that they can learn and suitably adapt them to their own command areas.

2. Participatory groundwater management

In a classic instance of vicious infinite regress,[7] tubewells, which were once seen as the solution to India's water problem, have tragically ended up becoming the main cause of the crisis. This is because borewells have been indiscriminately drilled, without paying attention to the nature of aquifers or the rock formations within which the groundwater is stored. Much of India is underlain by hard rock formations, with limited capacity to store groundwater and very low rates of natural recharge. Once water is extracted from them, it takes very long for it to regain its original level.

[7] Where the presumed solution to a problem not only fails to provide a solution but instead continues to only aggravate the problem (Stanford Encyclopaedia of Philosophy, 2018)

For decades, aquifers have been drilled everywhere at progressively greater depths, lowering water tables and degrading water quality. It is also not often understood that over-extraction of groundwater is perhaps the single most important cause of the peninsular rivers drying up. For these rivers to keep flowing after the rains stop, they need base-flows of groundwater. But when groundwater is over-extracted, the direction of these flows is reversed and `gaining' rivers get converted into `losing' rivers. Springs, which have historically been the main source of water of the population in mountainous regions, are also drying up in a similar way.

Reversing this dire situation requires a careful reflection on the nature of groundwater and a recognition that it is a common-pool resource. By its very nature, it is a shared heritage. While the land under which this water is located can be divided, it is not possible to divide the water, a fugitive resource that moves in a fluid manner below the surface. Competitive and individual extraction leads to a mutually destructive cycle, where each user tries to outdo the others in drilling deeper and deeper, till the point where virtually no groundwater left. Indeed, this point is being reached in many aquifers in India today. How, then, can India protect and continue to use its single most important natural resource without driving it to extinction?

One commonly proposed solution is to meter and license the use of groundwater. While this might make sense for the few very large consumers, such as industrial units, it would be impossible to implement on a large-scale, bearing in mind that India has more than 45 million wells and tubewells. Fortunately, there are a few examples that show the way forward. A million farmers in the hard rock districts of Andhra Pradesh have come together to demonstrate how groundwater can be used in an equitable and sustainable manner (World Bank, 2010). With the co-operation of hydro-geologists and civil society organisations, facilitated by the government, these farmers clearly understood the nature of their aquifers and the kinds of crops that could be grown with the groundwater they had. Careful crop-water budgeting enabled them to switch to less water-intensive crops, more suited to their specific agro-ecology. It needs to be noted that this initiative required a strong mooring in both science and social mobilisation. Such examples have mushroomed all over India, especially in Maharashtra, Madhya Pradesh, Kutch and Sikkim. All of them are based on collective action by farmers, who have come together to jointly manage their precious shared resource. They have developed protocols for pumping of water, sequencing of water use, distance norms between wells and tubewells and strictly adhere to them, once they understand that this is the only way they can manage to meet both their farm and domestic requirements.

Taking these innovations to scale requires massive support from the government. Paradoxically, as groundwater has become more and more important, groundwater departments, at the Centre and in all the states, have only become weaker over time. This trend needs to be reversed urgently and state capacities strengthened in a multi-disciplinary manner. The Twelfth Plan saw the initiation of the National Aquifer Management Programme and the government recently launched the *Atal Bhujal Yojana*. While both of these are pioneering initiatives, the likes of which the world has never seen before, they are yet to take off. The primary reason is that the requisite multi-disciplinary capacities are missing within government. Besides, they cannot be implemented by the government alone. They demand a large network of partnerships with stakeholders across the board: universities, research centres, panchayati raj institutions and urban local bodies, civil society organisations, industry and the people themselves.

3. Protecting and Rejuvenating India's catchment areas

There is a pressing need to understand that the health of the country's rivers, ponds and dams is only as good as the health of their catchment areas. In order to protect the country's water sources, the areas from where they `catch' their water need to be protected and rehabilitated. A 2018 study of 55 catchment areas (Sinha *et al.*, 2018) shows that there has been a decline in the annual run-off generated by major river basins, including Baitarni, Brahmani, Godavari, Krishna, Mahi, Narmada, Sabarmati and Tapi, and this is not due to a decline in rainfall but because of economic activities destructive of their catchment areas. The fear is that if this trend continues, most of these rivers will almost completely dry up.

All over the world, including in China, Brazil, Mexico, Costa Rica and Ethiopia, attempts are being made to pay for the eco-system services provided for protecting catchment areas, keeping the river basin healthy and green. If the channels through which water flows into rivers are encroached upon, damaged, blocked or polluted, the quantity and quality of river flows are adversely affected. The natural morphology of rivers has taken hundreds of thousands of years to develop. Large structural changes to river channels can lead to unforeseen and dangerous hydrological, social and ecological consequences.

How, then, is the imperative of economic development and its negative impacts on water availability and river flows to be reconciled? This is possible only by adopting a completely different approach to development, one where interventions are woven into the contours of nature, rather than trying to dominate it. Most of India gets its annual rain within intense spells in a short period of 40-50 days. The speed of rainwater as it rushes over the ground needs to be reduced by carefully regenerating the health of catchment areas, treating each part in a location-specific manner, as per variations in slope, soil, rock and vegetation. Such watershed management helps recharge groundwater and increase flows into ponds, dams and rivers downstream. This can generate multiple win-wins: soil erosion is reduced, forests regenerated, water tables rise, rivers are rejuvenated, employment generated, farmer incomes improve, thereby reducing indebtedness, and bonded labour and distress migration gradually eliminated. The most important success factor is building capacities among the local people so that they can take charge of the watershed programme from planning, design and implementation right up to social audit.

4. Water saving seeds and technologies

Through careful micro-level trials and experimentation by their field centres, the Indian Agricultural Research Institute (IARI) and state agricultural universities have developed several crop varieties, which require less water than conventional Green Revolution seeds. For example, the low-irrigation wheat varieties Amar (HW 2004), Amrita (HI 1500), Harshita (HI 15231), Malav Kirti (HI8627) and Malav Ratna (HD 4672), developed at the IARI Wheat Centre in Indore, give fairly good yields at a much lower level of water consumption (Gupta *et al.*, 2018). These varieties are also prescribed by the ICAR-NICRA (Indian Council for Agricultural Research-National Innovations on Climate Resilient Agriculture) project, through their district-level drought adaptation plans.[8] Adoption of these varieties by farmers would need training and facilitation by *Krishi Vigyan Kendras* (KVKs) so that they are able to understand the new agronomic practices that these varieties would involve. Their large-scale adoption could go a long way in reducing the water footprint of water-intensive crops.[9]

Adoption of water saving practices can also achieve the same result (as summarised in Table 12). System of Rice Intensification is a combination of practices,

[8] http://www.nicra-icar.in/nicrarevised/index.php/ state-wise-plan

[9] Three thousand varieties of rice were being cultivated in eastern India before the Green Revolution (Shiva and Prasad, 1993). If revived, this rich agro-diversity could play a big role in reducing water demand.

which together reduce heavy input use in rice. Conservation agriculture and tillage refers to methods where the soil profile is not disturbed by tilling. Drip irrigation takes water application closer to the root systems of plants (Narayanamoorthy, 2004). Direct Seeding of Rice enables sowing of rice without nurseries or transplanting. Uneven soil surface affects the germination of crops, reduces the possibility of spreading water homogenously and reduces soil moisture. Therefore, land levelling within farms[10] is a precursor to good agronomic, soil and crop management practices.

Table 1: Impact of water saving practices on blue water use in different states

	State	Practices	Crops	Blue Water Saved Compared to Conventional Practices (%)	Reference
1	Andhra Pradesh	System of Rice Intensification	Rice (Kh)	50	Ravindra *et al.*, 2011
2	Bihar	Conservation Agriculture[11]	Rice (Kh)	24	Laik et *al.*, 2014
	Bihar	System of Wheat Intensification	Wheat (Rb)	17.5	Kumar, *et al.*, 2011
3	Gujarat	System of Rice Intensification	Rice (Kh)	33	Mevada *et al.*, 2016
	Gujarat	Drip Irrigation	Wheat (Rb)	48	Singh, 2013
4	Haryana	Laser Land Levelling	Rice (Kh)	30	Ladha, 2009
	Haryana	Conservation Tillage and Soil Residue Cover	Wheat (Rb)	18	Ladha, *et al.,* 2016
5	Karnataka	Direct Dry Seeding of Rice	Rice (Kh)	46	Soriano *et al.*, 2018
6	Maharashtra	Drip Irrigation	Sugarcane (Annual)	57	Pawar *et al.*, 2013
7	MP	Drip Irrigation	Wheat (Rb)	28.4	Chouhan *et al.*, 2015
8	Punjab	Laser Land Levelling	Rice (Kh)	25.0	Ladha, 2009
	Punjab	Drip Irrigation	Wheat (Rb)	21.1	Suryavanshi *et al.*, 2016
9	Rajasthan	Deficit Irrigation	Wheat (Rb)	17	Rathore, et *al.*, 2017
10	Tamil Nadu	Young seedlings, wide spacing with alternate wetting and drying irrigation	Rice (Kh)	79.8	Oo, et *al.*, 2018
11	Telangana	System of Rice Intensification	Rice (Kh)	50	Ravindra *et al.*, 2011

Note: Kh: kharif; Rb: rabi

[10] Quite unfortunately, however, what has got emphasised in Punjab is land levelling outside farms, resulting in a loss of natural topography and drainage systems through the destruction of the small hillocks or *tibbas*. For an account of the impact of this on Punjab's water crisis, see Kulkarni and Shah (2013)
[11] Conservation agriculture can also minimise risk to climate extremes (Aryal *et al.*, 2016)

5. Reversing the neglect of rainfed areas: Focus on green water and protective irrigation

One of the most deleterious consequences of the Green Revolution has been the neglect of India's rainfed areas, which currently account for 54 percent of the sown area.[12] The key to improved productivity of rainfed farming is a focus on soil moisture and protective irrigation. Protective irrigation seeks to meet moisture deficits in the root zone, which are the result of long dry spells. Rainfed crops can be insulated to a great extent from climate variabilities through two or three critical irrigations, complemented in each case by appropriate crop systems and *in situ* water conservation. In such a scenario, provision needs to be made for just about 100-150mm of additional water, rather than large quantities, as in conventional irrigation.

Lal (2012) provides a comprehensive list of options for increasing green water in rainfed farming:

> "(i) increase water infiltration; (ii) store any runoff for recycling; (iii) decrease losses by evaporation and uptake by weeds; (iv) increase root penetration in the subsoil; (v) create a favorable balance of essential plant nutrients; (vi) grow drought avoidance/adaptable species and varieties; (vii) adopt cropping/farming systems that produce a minimum assured agronomic yield in a bad season rather than those that produce the maximum yield in a good season; (viii) invest in soil/land restoration measures (i.e., terraces and shelter belts); (ix) develop and use weather forecasting technology to facilitate the planning of farm operations; and (x) use precision or soil-specific farming technology using legume-based cropping systems to reduce losses of Carbon and Nitrogen and to improve soil fertility. Similarly, growing crops and varieties with better root systems is a useful strategy to reduce the risks in a harsh environment. The root system is important to drought resistance"

This kind of approach to rainfed areas, with a strengthening of the agricultural extension system on a participatory basis, would make a major contribution to the paradigm shift needed in farming to solve India's water problem.

6. Building trans-disciplinarity in water

Both at the Centre and in the states, government departments dealing with water resources include professionals predominantly from the disciplines of civil engineering, hydrology and hydrogeology. There is an urgent need for them to be equipped with multi-disciplinary expertise covering all the disciplines relevant to the paradigm shift in water

[12] Rainfed areas provide 89 percent of national millet production, 88 percent of pulses, 73 percent of cotton, 69 percent of oilseeds and even 40 percent of rice production. It has been shown that there is a strong overlap between the incidence of poverty and rainfed regions. Thus, requisite emphasis on these regions could make a huge contribution to both poverty reduction and nutritional security in India (Expert Committee, 2019).

management that this paper proposes. This multi-disciplinary expertise must also cover water management, social mobilisation, agronomy, soil science, river ecology and ecological economics. Agronomy and soil science would be needed for effective crop water budgeting, without which it will not be possible to align cropping patterns with the diversity of agro-ecological conditions. To develop practices to maximise the availability and use of green water, soil physical and plant biophysical knowledge will need to be harnessed. What will also be needed is a better understanding of river eco-system dynamics, including the biotic inter-connectedness of plants, animals and micro-organisms, as well as the abiotic physical and chemical exchanges across different parts of the eco-system. Ecological economics would enable the deep understanding and necessary valuation of the role of eco-system services in maintaining healthy river systems. Without an adequate representation of social science and management expertise, sustainable and equitable management of water resources to attain democratisation of water will not be possible. Social science expertise is also required to build a respectful dialogue and understanding of the underlying historical cultural framework of traditions, beliefs and practices on water in a region-specific manner, so that greater learning and understanding about water could be fostered.

Since systems such as water are greater than the sum of their constituent parts, understanding whole systems and solving water problems necessarily requires multi-disciplinary teams, engaged in inter-disciplinary projects, based on a trans-disciplinary approach, as is the case in the best water resource government departments across the globe.

7. Overcoming hydro-schizophrenia

Water governance and management in India has generally been characterised by three kinds of hydro-schizophrenia: that between (a) surface and groundwater, (b) irrigation and drinking water and (c) water and wastewater. Government departments, both at the Centre and in the states, dealing with one side of these binaries have tended to work in isolation from, and without co-ordination with, the other side. Ironically, groundwater departments have tended to become weaker over time, even as groundwater has grown in significance in India. A direct consequence of surface water and groundwater being divided into watertight silos has been that the inter-connectedness between the two has neither been understood nor taken into account while understanding emerging water problems. For example, it has not been understood that the post-monsoon flows of India's peninsular rivers derive from base-flows of groundwater. Over-extraction of groundwater in the catchment areas of rivers has meant that the many of the larger rivers are shrinking and many of the smaller ones have completely dried up. A reduction in flows also adversely affects river water quality. Treating drinking water and irrigation in silos has meant that aquifers providing assured sources of drinking water tend to get depleted and dry up over time, because they are also used for irrigation, which consumes much higher volumes of water. This has had a negative impact on the availability of safe drinking water in many parts of India. When the planning process segregates water and wastewater, the result generally is a fall in water quality, as wastewater ends up polluting supplies of water. Moreover, adequate use of wastewater as a resource to meet the multiple needs of water is not sufficiently explored.

Without bridging these silos into which we have divided water, it will be impossible to address the grave water challenges facing the country.

8. Building multi-stakeholder partnerships

The paradigm shift in water can only be built on an understanding that wisdom relating to it is not the exclusive preserve of any one sector or section of society. It is imperative, therefore, that the state and central governments take the lead in building a novel architecture of enduring partnerships with the primary stakeholders of water.[13]

This is also critical because the challenges of groundwater management, catchment area treatment and river rejuvenation, as also ensuring that the last farm gets water in command areas, requires people's participation and true democratisation of water. This involves building respectful and lasting dialogue based on a process of mutual learning. Water governance and management at all levels must be informed by, and involve the understanding of, perspectives and experience on water that all primary stakeholders bring to the table. The indigenous knowledge of Indians with a long history of water management is an invaluable intellectual resource that must be fully leveraged.

It is also necessary to ensure that the participation of primary stakeholders must not be nominal, passive or merely consultative, as has tended to happen in the past. Their participation must be both empowering and empowered, so that stakeholders are able to

[13] Nesshover *et al* (2017) clearly show that for nature-based solutions (of the kind suggested in this paper) to succeed, multi-stakeholder partnerships are an essential pre-condition

take into account all available information and expertise while making decisions, and their voice has a definite bearing and influence on processes and outcomes.[14]

Conclusion

The unprecedented COVID-19 pandemic provides an urgent context to the discussion in this paper. It has reminded everyone, like never before, of how circumscribed the economy necessarily is by the nature of the larger eco-system governing it. It is not merely a matter of realising the constraints within which everyone operates but of re-envisioning the response: moving from a paradigm of linear mechanics to thinking in terms of complex dynamics. As the imprint of humans on the planet grows ever larger in the epoch of the Anthropocene, this shift becomes imperative. Change now is no longer going to be uni-vocal or uni-directional. The harder we impact the Earth, the more impossible becomes our dream of command-and-control over it. We need, more and more, to learn to deal with the unforeseen and the inherently unpredictable. The pandemic forces everyone to acknowledge that this is now imperative, not just for greater prosperity but also for the very survival of human life on Earth.

According to Kate Brown, MIT Professor of Science, Technology and Society:

> "Within the uniform predictability of modern agriculture, the unpredictable emerges . . . Two-thirds of cancers have their origins in environmental toxins, accounting for millions of annual fatalities . . . we inhabit not the Earth but the atmosphere, a sea of life; as swimmers in this sea, we cannot be biologically isolated . . . Biologists have begun questioning the idea that each tree is an "individual"—it might be more accurately understood as a node in a network of underworld exchanges between fungi, roots, bacteria, lichen, insects, and other plants. The network is so intricate that it's difficult to say where one organism ends and the other begins."[15]

More specifically, it is clear that

> "There is a large list of deadly pathogens that emerged due to the ways in which we practice agriculture, among which are: H5N1-Asian Avian Influenza, H5N2, multiple Swine Flu variants (H1N1, H1N2), Ebola, Campylobacter, Nipah virus, Q fever, hepatitis E, Salmonella enteritidis, foot-and-mouth disease, and a variety of influenzas" (Altieri and Nicholls, 2020).

This necessitates a paradigm shift in our structures of thought, to be able to grasp complex adaptive systems[16] (where the complexity of the behaviour of the whole system cannot be completely grasped by an understanding of its individual parts), of which farming and the water cycle both are important examples. Thus, an appreciation of inter-

[14] Agarwal (1994) offers a very useful typology of the ways in which participation occurs in development programmes and enunciates the conditions under which it is truly meaningful

[15] https://councilontheuncertainhumanfuture.org/the-pandemic-is-not-a-natural-disaster/

[16] Holland (1998); Gal (2012)

connectedness becomes essential to understanding the nature of the problem and to suggesting meaningful solutions.

It is this understanding that underlies the paradigm shifts in water and agriculture advocated in this paper. Ironically, those resisting this change claim to be speaking the language of science, while completely ignoring how both best practice and theory are evolving globally. All of the policy prescriptions advocated in this paper rely on nationally and globally tried and tested best practices in both water and farming – practices that range from technological advances to management systems and governance reform.

If farming continues to be as water-intensive as it is in India today, there will be no way for the country to meet the drinking water and livelihood requirements of its people. If farming methods pay no attention to the soil that sustains them, then food security will be in ever-greater danger. If the exclusive focus on rice and wheat in the support provided to farmers continues, India will be completely unable to tackle the twinned syndemic of malnutrition and diabetes.

We cannot continue to mindlessly extract groundwater without realising how that is destroying the resource itself, as also the rivers that both feed and are being fed by it. We cannot go on building dams without being mindful of what that could mean for the very integrity of India's monsoon cycle. We cannot continue to destroy our catchment areas and still hope for our rivers to survive and sustain us. If India's river basins survive, we also will. Otherwise like many great river valley civilisations of the past, we too will perish!

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