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Pathways for Enhancing Farmers' Income, Nutritional Security and Sustainable Food Systems

Thematic Session: WATER IN AGRICULTURE

Discussion Paper: Transforming Water and Agriculture in India

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This paper develops the argument for twin propositions: (a) that the crisis in Indian agriculture cannot be resolved without a paradigm shift in water management and governance, and (b) that India's water crisis requires a paradigm shift in agriculture. The paper traces the roots of these crises to the onset of the Green Revolution in agriculture, which has now been on-going for the past 50 years and can be said to have entered its terminal stage at the turn of the century. We suggest that if the right lessons are drawn from the experience of the Green Revolution then it is, indeed, possible to address the crisis facing India's farmers while also solving India's water problem. Not doing so would, on the other hand, leave both crises unresolved, even aggravated.

The paper outlines the constituent elements of each of the existing paradigms of water and agriculture, explains why they need to be transformed and then describes the nature of the paradigm shift required in both areas.

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I. Green Revolution: context and achievements

Recent revisionist scholarship[2] on the Green Revolution has conclusively established that the assumption of a stagnant food sector in the first two decades after independence is a myth (Balakrishnan, 2007). It also shows that neo-Malthusian fears of starvation in the Indian context were, indeed, exaggerated.[3] At the same time, there is also no denying that the Indian political leadership was deeply troubled by excessive dependence on wheat shipments under the PL-480 Food Aid Program of the United States.[4] We cannot overlook the fact that 90 percent of the food that the government distributed through the public distribution system (PDS) between 1956 and 1960 came from imports and remained as high as 75 percent even during the period from 1961 to 1965. In 1965-66, the United States of America shipped 10 million tonnes of wheat to India (Tomlinson, 2013). At that point, India had less than half the food needed to provide a basic subsidised ration to the poorest 25 percent of the population (Krishna, 1972). Hence, there was a nationalist impulse that propelled the Green Revolution and it cannot be seen as merely a conspiracy of imperialist capital, although it is certainly the case that corporations supplying key inputs to Green Revolution agriculture were major beneficiaries of this radical policy shift.[5]

What also needs to be acknowledged is that following the Green Revolution, India achieved self-sufficiency in food like never before. The buffer stock, which was hardly 3 million tonnes in the early 1970s, reached a peak of 60 million tonnes in 2012-13 (see Table 1). The single most important fact worth noting here is that in the early 1970s itself, the net sown area had almost reached 140 million hectares and this figure has remained more or less unchanged over the past five decades. During the

[2] See especially Subramanian (2015). Stone (2019) provides a good summary of the emerging work

[3] Cullather (2010, Chapter 8) brilliantly teases out how the view that "only chemical fertiliser and birth control could keep mankind off a treadmill to starvation" became dominant in the 1960s, pushing for support to the Green Revolution as the only way to save India from self-destructing through famine.

[4] Especially distressing was the introduction of the "short-tether" policy by the Lyndon Johnson administration in 1965-66, refusing to commit PL-480 wheat shipments to India more than one month in advance (Tomlinson, 2013).

[5] How politically invested the United States of America was in the Green Revolution is quite evident from this articulation by the person who coined the term: "These developments in the field of agriculture contain the makings of a new revolution. It is not a violent Red Revolution like that of the Soviets, nor is it a White Revolution like that of the Shah of Iran. I call it the Green Revolution." From *The Green Revolution: Accomplishments and Apprehensions*, address by William S. Gaud, Administrator, US Agency for International Development, 8 March 1968. How a broad-based political consensus cutting across ideological divisions emerged in the United States of America in the 1960s around the view that "economic development represented the primary defense against an evolving communist strategy of subversion and economic penetration" (p.154), has been well documented in Cullather (2010).

same period, the gross cropped area has risen steadily with the cropping intensity growing from 119 percent to 140 percent (see Table 2).

Table 1: Food grain procurement and buffer stock, 1972-2018 (million tonnes)

Year	Procurement	Buffer Stock
1972-73	7.51	2.60
1982-83	14.85	11.10
1992-93	17.16	12.67
2002-03	38.03	32.81
2012-13	72.19	59.76
2017-18	68.20	43.31

Source: DAC. 2020. https://eands.dacnet.nic.in

It can then be argued, somewhat more debatably, that without the intensification that occurred under the Green Revolution, the degradation of common lands and forests could have advanced at an even more rapid rate than it has done during this period. [6]

Table 2: All-India net sown area and gross cropped area, 1950-2015

Period	Net Sown Area ('000 ha)	Gross Cropped Area ('000 ha)	NSA/TGA (%)	GCA/TGA (%)	GCA/NSA (cropping intensity) (%)
1950-51 to 1954-55	123 248	137 874	37	42	112
1955-56 to 1959-60	130 770	149 418	40	45	114
1960-61 to 1964-65	135 908	156 387	41	48	115
1965-66 to 1969-70	137 863	159 632	42	49	116
1970-71 to 1974-75	139 587	165 438	42	50	119
1975-76 to 1979-80	140 993	171 051	43	52	121
1980-81 to 1984-85	141 467	175 604	43	53	124
1985-86 to 1989-90	139 759	178 031	43	54	127
1990-91 to 1994-95	142 505	185 650	43	56	130
1995-96 to 1999-00	142 178	189 401	43	58	133
2000-01 to 2004-05	139 073	185 602	42	56	133
2005-06 to 2009-10	140 614	192 971	43	59	137
2010-11 to 2014-15	140 806	197 405	43	60	140

Source: DAC. 2020. https://eands.dacnet.nic.in

Note: TGA: total geographical area

[6] This proposition is debatable because it is based on deeply problematic assumptions: that alternatives to the Green Revolution necessarily require more land to produce the same output and that the implications of Green Revolution farming for ecology, resilience, income stability and health are small enough to be ignored.

II. Constituent elements of the Green Revolution paradigm

Subramanian (2015) is right in arguing that that these achievements were not the result merely of moving to high-yielding dwarf varieties of seeds. Indeed, it is extremely important to recognise that the Green Revolution was a package deal, a combination of radical changes in the political economy of Indian agriculture, with several path-breaking interventions. These included the following:

i. **Higher-yielding seeds and concomitant use of chemical fertilizers and pesticides:** The consumption of fertilizers rose dramatically from 2 million tonnes in 1970-71 to more than 27 million tonnes in 2018-19 (Table 3). Similarly, synthetic pesticide consumption has grown sharply over the past decade (Table 4). Just six states (Maharashtra, Uttar Pradesh, Punjab, Telangana, Haryana and West Bengal) together accounted for about 70 percent of total chemical pesticide consumption in the country in 2019-20.

Table 3: Fertilizer consumption in India, 1950-2019

Year	Fertilizer Use ('000 tonnes)
1950-51	70
1960-61	294
1970-71	2 257
1980-81	5 516
1990-91	12 546
2000-01	16 702
2010-11	28 122
2018-19	27 228

Source: Fertiliser Association of India.

www.faidelhi.org/general/con-npk.pdf

Table 4: Synthetic Pesticide Consumption in India, 2001-2019

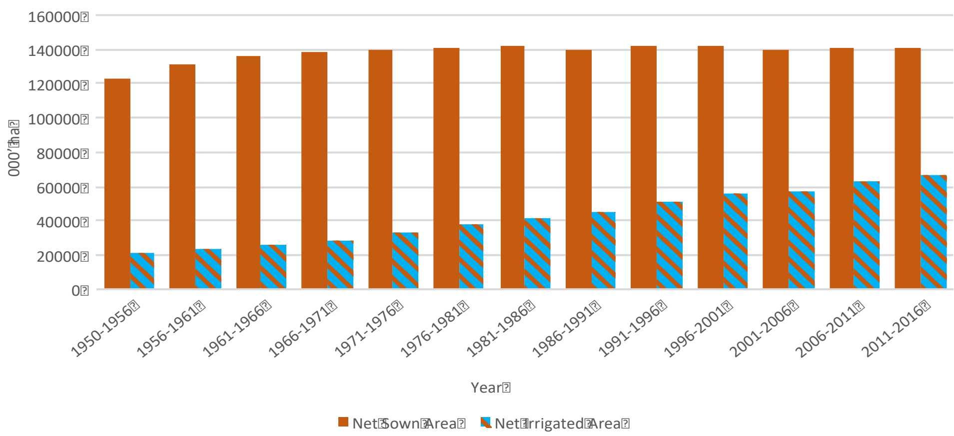
Period	Consumption ('000 tonnes)
2001-04	45.46
2004-07	41.28
2007-10	42.44
2010-13	51.38
2013-16	56.84
2016-19	60.46
2019-20	60.56

Source: Agricultural Statistics at a Glance, 2019 for 2001-19;

Directorate of Plant Protection, Quarantine and Storage, Department of Agriculture and Co-operation for 2019-20

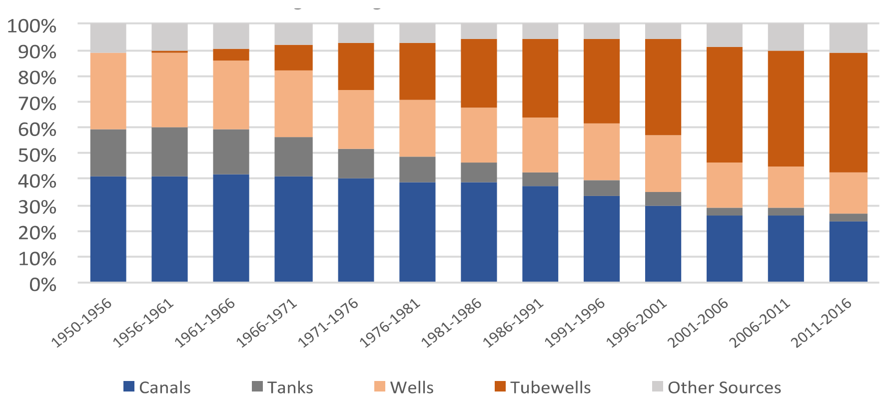
ii. **Breakthrough in irrigation:** Following the Green Revolution there was a sea-change in the extent of irrigation as well as in the way India irrigated her fields. Irrigated area more than doubled, both in absolute terms and as a percentage of net sown area (Figure 1). Over time, groundwater, especially that provided by deep tubewells, has become the single largest source of irrigation (Figure 2). This form of irrigation allows farmers greater control over water – as and when and in the volumes that the crops require it. Over the last four decades, around 84 percent of total addition to the net irrigated area has come from groundwater. At 250 billion cubic metres (BCM), India draws more groundwater every year than any other country in the world. India's annual consumption is more than that of China and the United States of America (the second and third largest groundwater using countries) put together (Vijayshankar, Kulkarni and Krishnan, 2011).

Figure 1: All-India net sown and net irrigated area, 1950-2016



Source: DAC, 2020. https://eands.dacnet.nic.in

Figure 2: All-India percentage of irrigation from different sources, 1950-2016



Source: DAC, 2020. https://eands.dacnet.nic.in

Note: "Other Sources" largely include groundwater sources, such as dug-cum-borewells. Hence, groundwater could well be said to account for nearly 70 percent of irrigation today

iii. **Easier availability of credit:** The access to seeds, fertilizers, pesticides and new irrigation technology was made possible by the easier availability of credit. The nationalisation of 14 banks in 1969 was a landmark step in the direction of improving access to reasonably priced credit in rural India. Recent arguments in favour of re-privatisation overlook the fact that the National Credit Council found that not even 1 percent of India's villages were served by commercial banks in 1969. Furthermore, in 1971, the share of banks in rural credit was no more than 2.4 percent, with most of these loans being made to plantations, not farmers. It is the easier availability of credit that fuelled the investments that drove India's Green Revolution (Shah *et al.*, 2007).[7]

iv. **Role of the agricultural extension system:** Since the Green Revolution meant a completely new way of doing farming, a critical role was played by the state-supported agricultural extension system. Today, it may be quite difficult to imagine what a humongous task this was, covering hundreds of thousands of farmers. Certainly, the paradigm of agricultural extension during the Green Revolution was what may be described as `top-down, persuasive and paternalistic technology transfer', which provided specific recommendations to farmers about the practices they should adopt. If an alternative is to be found to the Green Revolution, great effort will be needed to re-energise and re-orient this extension system, which today finds itself in a state of almost total collapse. It will be necessary to move towards a much more `farmer-to-farmer participatory extension system'.

v. **A stable market:** The setting up of the Food Corporation of India (FCI) in 1965 and the ensuing and expanding procurement operations at minimum support prices (MSPs) ensured a stable market for the farmers.[8] Without this state intervention, left to the vagaries of the free market, the Green Revolution would not have taken off, as the expanded output could have created problems for the farmers, due to a fall in price at times of a bumper harvest.[9]

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[7] There were, undoubtedly, many problems in the manner in which rural credit was handled, which will be dealt with when we describe the paradigm shift required in the architecture of the Green Revolution.

[8] The Foodgrains Prices Committee (1964) recommended the setting up of the Food Corporation of India "to enable the government to undertake trading operations through which it can influence the market prices". Minimum support prices were to be recommended by the Agricultural Prices Commission, also set up in 1965. With this, another objective was added to the food security system: "to guarantee reasonable prices to the farmers and thereby increase production" (Mooij, 1998).

[9] There were many limitations in the nature and scope of the procurement operations, which we will describe in the elaboration of the new paradigm.

III. Wheels come off the Green Revolution

While it is undeniable that the Green Revolution paradigm represents a powerful break from the past that provided India with comfortable food security,[10] it is also true that over the decades that followed, it sowed the seeds of its own destruction, leading to a grave farming crisis in India today. More than 300,000 farmers have committed suicide in the last 30 years, a phenomenon completely unprecedented in Indian history.[11] There is growing evidence of steady decline in water tables and water quality. At least 60 percent of India's districts are either facing a problem of over-exploitation or severe contamination of groundwater (Vijayshankar, Kulkarni and Krishnan, 2011). There is evidence of fluoride, arsenic, mercury and even uranium and manganese in groundwater in some areas. The increasing levels of nitrates and pesticide pollutants in groundwater have serious health implications. The major health issues resulting from the intake of nitrates are methemoglobinemia and cancer (WHO, 2011). The major health hazards of pesticide intake through food and water include cancers, tumours, skin diseases, cellular and DNA damage, suppression of immune system and other intergenerational effects (Margni *et al.*, 2002).[12] Repetto and Baliga (1996) provide experimental and epidemiological evidence that many pesticides widely used around the world are immune-suppressive. Nicolopoulou-Stamati *et al.* (2016) provide evidence of pesticide-induced temporary or permanent alterations in the immune systems and Corsini *et al.* (2008) show how such immune alteration could lead to several diseases. A recent study of 659 pesticides, which examined their acute and chronic risks to human health and environmental risks, concludes that

> "evidence demonstrates the negative health and environmental effects of pesticides, and there is widespread understanding that intensive pesticide application can increase the vulnerability of agricultural systems to pest outbreaks and lock in continued reliance on their use." (Jepson *et al.*, 2020)

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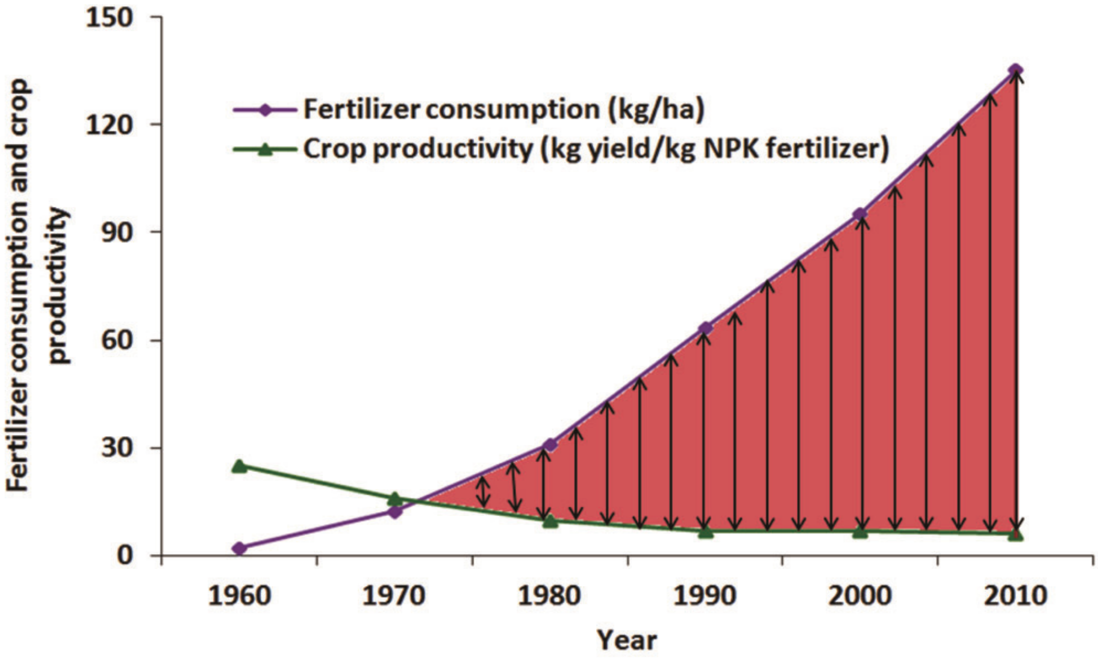
[10] Defined narrowly as having sufficient buffer stocks to ward off any unexpected price surge following shortfalls in production. It needs to be noted that this food security was very different from nutritional security, which does not exist even today, which is also why we are advocating a paradigm shift in agriculture.

[11] This data comes from the National Crime Records Bureau, as committing suicide still remains a crime under Indian law.

[12] Even at low concentration, pesticides exert several adverse effects that may manifest at biochemical, molecular or behavioural levels. The actual transport, presence and impact are, of course, influenced by drainage, rainfall, microbial activity, soil temperature, treatment surface, application rate, as well as the solubility, mobility and half-life of individual pesticides.

It is also clear that the yield response to the application of increasingly more expensive chemical inputs is falling. Indoria *et al.* (2018) show that the average crop response to fertilizer use has fallen from around 25 kg grain/kg of nitrogen, phosphorus and potassium (NPK) fertilizer during the 1960s to a mere 6 kg grain/kg NPK by 2010 (Figure 3). This has meant higher costs of cultivation, without a corresponding rise in output, even as this intensified application of inputs compels farmers to draw more and more water from below the ground.

Figure 3: Relationship between fertilizer consumption and crop productivity



Source: Indoria et al (2018, Figure 2)

Moreover, despite the overflowing granaries, the 2020 *Global Hunger Index Report* by the International Food and Policy Research Institute (IFPRI) ranked India 94th out of 107 countries. FAO *et al.* (2020) estimate that more than 189 million people remained malnourished in India during 2017-19, which is more than a quarter of the total such people in the world. In 2019, India had 28 percent (40.3 million) of the world's stunted children (low height-for-age) under five years of age and 43 percent (20.1 million) of the world's wasted children (low weight-for-height).

Paradoxically, at the same time, diabetics have increased in every Indian state between 1990 and 2016, even among the poor, rising from 26 million in 1990 to 65 million in 2016. This number is projected to double by 2030 (Shah, 2019).[13]

IV. The paradigm shift required in agriculture

It is important to understand precisely why this multi-fold unravelling was inherent in the very architecture of the Green Revolution and what can be done to institute a paradigm shift in farming in India.

IV.1 Not quite a Green Revolution: towards crop diversification reflecting agro-ecology of diverse regions

It is now widely recognised that the Green Revolution was simply a wheat-rice revolution.[14]

Table 5: All-India and region-wise cropped area

('000 ha)

Region	Period	Rice	Wheat	Nutri-Cereal [15]	Pulses	Oilseeds	Sugarcane	Others	Total
North West	1962-65	5 152	6 724	7 795	7 059	4 115	1 539	1 004	33 455
	1980-83	7 376	13 160	6 250	4 193	4 154	1 825	1 941	38 821
	1990-93	7 991	13 459	4 512	3 403	2 409	1 988	4 588	38 236
	2003-06	9 096	14 752	3 797	2 848	1 819	2 215	5 141	39 549
	2012-14	9 680	15 291	3 319	2 410	1 659	2 252	4 741	39 511
East	1962-65	14 623	667	1 719	3 643	770	231	4 105	25 655
	1980-83	15 828	2 018	2 046	3 382	1 563	227	3 410	28 416
	1990-93	15 948	2 121	1 307	2 847	1 830	203	4 648	29 050
	2003-06	14 885	2 193	1 014	1 700	1 234	603	5 757	27 413
	2012-14	16 358	2 596	1 228	1 507	1 396	307	4 466	27 915
Central	1962-65	5 934	5 400	21 421	9 375	6 765	237	10 087	59 338

[13] A new joint study by the Oxford and Lancaster Universities, BITS Pilani and Bocconi University, Italy shows that "there was no evidence that receipt of PDS rice and sugar was associated with improvements in child nutrition" (Bartell *et al*, 2020)

[14] Even globally, the current diet of most people comprises three crops: wheat, rice, and corn, which provide more than 50 percent of the calories consumed (UNCSN, 2020)

[15] The Government of India took a historic decision in 2018 of renaming traditional cereals as `nutri-cereals', dispensing with the long-standing nomenclature, which described them as `coarse cereals', with an implicit inferior status. In a notification, the agriculture ministry said, "the central government hereby declares millets comprising sorghum (jowar), pearl millet (bajra), finger millet (ragi/mandua), minor millets – foxtail millet (kangani/kakun), proso millet (cheena), kodo millet (kodo), barnyard millet (sawa/sanwa/ jhangora), little millet (kutki) and two pseudo millets (black-wheat (kuttu) and ameranthus (chaulai) which have high nutritive value as "Nutri Cereals"." (https://www.financialexpress.com/market/commodities/ government-renames-millets-as-nutri-cereals/1140338)

	1980-83	6 494	6 494	21 975	10 889	7 347	394	11 807	65 596
	1990-93	6 822	6 409	19 571	11 301	12 128	551	12 404	68 911
	2003-06	7 001	7 075	16 434	12 086	15 255	590	15 476	73 697
	2012-14	7 495	9 918	9 767	11 887	17 944	1 211	17 414	75 711
South	1962-65	7 613	319	11 212	2 930	3 727	255	5 733	31 852
	1980-83	7 371	314	8 908	3 388	4 140	502	6 587	31 366
	1990-93	7 169	196	6 580	3 830	6 776	655	7 529	32 736
	2003-06	6 613	250	5 771	4 211	5 740	655	7 798	31 193
	2012-14	7 902	210	5 595	4 755	5 455	1 294	9 790	34 966
All India	1962-65	34 500	13 467	42 368	2 3151	14 829	2 270	21 184	151 315
	1980-83	37 779	21 541	39 602	21 872	17 233	2 983	24 855	165 698
	1990-93	38 828	2 1946	31 400	24 310	22 453	3 376	27 011	168 817
	2003-06	38 913	24 147	26 926	20 846	23 973	3 648	34 744	173 718
	2012-14	39 616	27 965	23 304	20 973	26 530	5 019	35 852	179 260

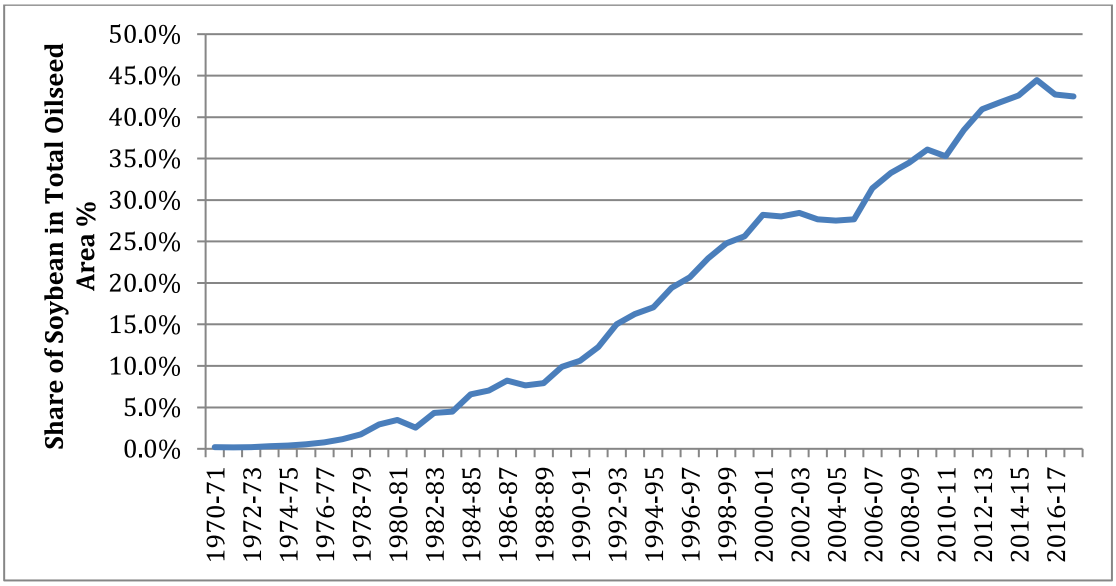
Notes: 1. Tables 5 and 6 are based on calculations that are an update of the pioneering work of Bhalla and Singh (2009) extended till 2012-14 based on Indian Agricultural Statistics
2. As in Bhalla and Singh (2009), in these calculations, all states of the north-east, except Assam, are excluded and only the 44 major crops are included
3. **North-West**: Haryana, Himachal Pradesh, erstwhile Jammu and Kashmir, Uttar Pradesh and Uttarakhand; **East**: Assam, Bihar, Odisha, Jharkhand, West Bengal; **Central**: Chhattisgarh, Gujarat, Madhya Pradesh, Maharashtra, Rajasthan; **South**: Andhra Pradesh, Karnataka, Kerala, Tamil Nadu, Telangana

Table 6: All India and region-wise distribution of cropped area (%)

Region	Period	Rice	Wheat	Nutri-Cereals	Pulses	Oilseeds	Sugarcane	Others	Total
North West	1962-65	15	20	23	21	12	5	3	100
	1980-83	19	34	16	11	11	5	5	100
	1990-93	21	35	12	9	6	5	12	100
	2003-06	23	37	10	7	5	6	13	100
	2012-14	25	39	8	6	4	6	12	100
East	1962-65	57	3	7	14	3	1	16	100
	1980-83	56	7	7	12	6	1	12	100
	1990-93	55	7	5	10	6	1	16	100
	2003-06	54	8	4	6	5	2	21	100
	2012-14	59	9	4	5	5	1	16	100
Central	1962-65	10	9	36	16	11	0	17	100
	1980-83	10	10	34	17	11	1	18	100
	1990-93	10	9	28	16	18	1	18	100
	2003-06	10	10	22	16	21	1	21	100
	2012-14	10	13	13	16	24	2	23	100
South	1962-65	24	1	35	9	12	1	18	100
	1980-83	24	1	28	11	13	2	21	100
	1990-93	22	1	20	12	21	2	23	100
	2003-06	21	1	19	14	18	2	25	100
	2012-14	23	1	16	14	16	4	28	100
All India	1962-65	23	9	28	15	10	2	14	100
	1980-83	23	13	24	13	10	2	15	100

	1990-93	23	13	19	14	13	2	16	100
	2003-06	22	14	16	12	14	2	20	100
	2012-14	22	16	13	12	15	3	20	100

Figure 4: Share of soyabean in total area under oilseeds



Source: DAC, 2018. *Agricultural Statistics at a Glance*

As can be seen from Tables 5 and 6, over the past 50 years, the share of nutri-cereals in cropped area has gone down dramatically in all parts of India. Even in absolute terms the acreage under these cereals has almost halved between 1962-65 and 2012-14. The share of pulses has also drastically come down in the states of Assam, Bihar, Haryana, Himachal Pradesh, erstwhile Jammu and Kashmir, Jharkhand, Odisha, Uttar Pradesh, Uttarakhand and West Bengal. The share of oilseeds appears to have risen, but that is mainly on account of the rise in acreage under soya.[16] Figure 5 shows that the share of soyabean in oilseeds acreage rose from less than 1 percent in the early 1970s to over 40 percent in 2016/17, even as the share of the other eight oilseeds has stagnated. Other than soyabean, the only other crops showing a rise in acreage during the period of the Green Revolution are wheat, rice and sugarcane.

The rise in acreage of wheat and rice is a direct consequence of the procurement and price support offered by the state. In the case of sugarcane and soyabean, the rise in acreage is due to the purchase by sugar mills and soya factories. But the main story of the Green Revolution is the story of rice and wheat, which

[16] See Vijayshankar (2016) for an account of how state support played a crucial role in pushing the "soya-wheat revolution" in Madhya Pradesh

remain the overwhelming majority (97-98 percent) of crops procured by the government even today, even after a few states have taken tentative steps towards diversification of their procurement basket to include nutri-cereals and pulses (Table 7).

Table 7: Share of crops in public procurement, 2007-2019 (%)

Year	Rice	Wheat	Nutri-Cereals	Pulses	Total
2007-08	70	29	1	0	100
2008-09	58	40	2	0	100
2009-10	52	41	7	0	100
2010-11	53	45	2	0	100
2011-12	55	44	1	0	100
2012-13	47	52	1	0	100
2013-14	55	43	2	0	100
2014-15	53	46	1	1	100
2015-16	55	45	0	0	100
2016-17	61	36	0	3	100
2017-18	54	44	0	2	100
2018-19	37	58	0	5	100

Source: DAC, 2018.

A recent study supported by the National Bank for Agriculture and Rural Development (NABARD) and the Indian Council for Research in International Economic Relations (ICRIER) estimated that about 78 percent of India's water is consumed in agriculture (Sharma *et al.*, 2018). FAO's AQUASTAT database puts this figure closer to 90 percent (FAO, 2019). The NABARD-ICRIER study identified three "water guzzler" crops – rice, wheat and sugarcane – which occupy about 41 percent of the gross cropped area and consume more than 80 percent of irrigation water. Shah (2019) suggests that sugarcane, which occupies just 4 percent of cropped area, uses up 65 percent of irrigation water in Maharashtra. In Karnataka, rice and sugarcane, which cover 20 percent of cropped area, consume 70 percent of irrigation water (Karnataka Knowledge Commission, 2019). This has meant grave inequity in the distribution of irrigation (or blue) water across crops and farmers, and also a terrible mismatch between existing water endowments and the water demanded by these water-guzzling crops. The main reason why farmers grow such crops even in areas of patent water shortage is the structure of incentives, as they find that these crops have steady markets. Even a small reduction in the area under these crops, in a region-specific manner and in a way that does not endanger food security, would go a long way in addressing India's water problem.

Thus, the first element of the paradigm shift required in Indian agriculture is to change this distorted structure of incentives. The most important step in this direction is for the government to diversify its crop procurement operations in a very carefully calibrated, location-specific manner, to align with local agro-ecologies. The best way of doing this is to start procurement of crops that match the agro-ecology of each region.

India's cropping pattern before the Green Revolution included a much higher share of millets, pulses and oilseeds. These must urgently find a place in public procurement operations. As this picks up pace, farmers will also gradually diversify their cropping patterns in alignment with this new structure of incentives. The largest outlet for the millets, oilseeds and pulses procured in this manner, in line with the *POSHAN Abhiyaan* [17] launched by the Government of India, would be the supplementary nutrition and meals provided under the Integrated Child Development Services (ICDS) and Mid-day Meal Scheme (MDMS), as also the grains provided through the PDS. A few state governments are also slowly moving forward in this direction. Done at scale, this would enable a steady demand for these nutritious crops and help sustain a shift in cropping patterns, which would provide a corrective to the currently highly skewed distribution of irrigation to only a few crops and farmers. It would also be a significant contribution to improved nutrition, especially for children, and a powerful weapon in the battle against the twinned curse of malnutrition and diabetes.

It is quite evident that a major contributor to this "syndemic" is the displacement of whole foods in the average Indian diet by energy-dense and nutrient-poor, ultra-processed food products.[18] Recent medical research has found that some millets contain significant anti-diabetic properties. According to the Indian Council of Medical Research, foxtail millet has 81 percent more protein than rice. Millets have higher fibre and iron content, and a low glycemic index. Millets also are climate-resilient crops suited for the drylands of India. If children were to eat these nutri-cereals – with much higher protein, iron and fibre and a significantly lower glycemic

[17] *POSHAN* (PM's Overarching Scheme for Holistic Nourishment) *Abhiyaan* is the Government of India's flagship programme to improve nutritional outcomes among children and women

[18] A 2019 report by the Lancet Commission, *The Global Syndemic of Obesity, Undernutrition, and Climate Change*, draws attention to this phenomenon. See also Gulati and Misra (2014)

index – India would be better placed to solve the problems of malnutrition and obesity.

If such a switch in cropping patterns, to reflect the agro-ecological diversity of India, were to be effected, what volume of water would India save by 2030? We have made an attempt to quantify the water that could be saved each year in 11 major agricultural states: Andhra Pradesh, Bihar, Gujarat, Haryana, Karnataka, Madhya Pradesh, Maharashtra, Punjab, Rajasthan, Telangana and Tamil Nadu.[19] These states together accounted for about 66 percent of the total irrigated area of the country in 2015-16.

We quantify the baseline water used in the production of crops using the average (mean) yields and areas for each crop in each state in the most recent ten-year period for which data are available. We compare the baseline water use to two exploratory scenarios of crop replacements:

Scenario 1 (small change): Replacement of high water-demanding crops with low water-using ones to the extent of 10-25 percent of the crop area in the *kharif* season and 25 percent in the *rabi* season; and

Scenario 2 (higher change): Replacement of high water-demanding crops with low water-using ones to the extent of 25-50 percent of the crop area in the *kharif* season and 50 percent in the *rabi* season.

Rice is the major irrigated crop in the southern states of Andhra Pradesh, Karnataka, Telangana and Tamil Nadu, while wheat is the major irrigated crop in Bihar, Gujarat, Madhya Pradesh and Rajasthan. Both rice and wheat are heavily irrigated in Punjab and Haryana. We explore possible crop switches in both *kharif* and *rabi* seasons. In each state, we have taken one high water footprint crop in each season and estimated water saving by switching area under this crop to two lower water footprint crops. Table 8 gives the list of states and seasons analysed.

First, we quantify baseline crop production based on recent yield and area data.[20] Our purpose is to build crop replacement scenarios to demonstrate the potential for crop replacements. For estimating the irrigation water use in these crop replacement scenarios, we have calculated blue water footprints, which represent the volume of water consumed during crop production in m^3 per tonne. Season and state-specific water footprints for cereal crops were drawn from Kayatz *et al.* (2019) and

[19] The basic data on yield, area under cropping and production is derived from the database of Directorate of Agriculture and Co-operation (DAC), Government of India.

[20] We use time-series data for the period 2008-17, the latest ten-year period for which data from the DAC is available for each selected crop in each season (DAC, 2020). Area multiplied by yield gives estimates of crop production.

for other crops from Mekonnen and Hoekstra (2011).[21] In this method, the total evapo-transpiration (ET) requirement of the crops is estimated using FAO's CROPWAT model. National and state specific ET for each of the crops studied is generated, which is modified by the crop factor (k) to get estimated consumptive use of water or total water footprint (TWF) by each crop in each state. The proportion of the green water footprint (GWF) is estimated by modelling effective rainfall during the season. The difference between TWF and GWF is attributed to the irrigation component or the blue water footprint (BWF) of crops.[22] The BWF is multiplied by crop production, to get estimated blue water use by crops in each state in each season.[23]

To estimate the potential for annual water savings, we propose crop switches in both *kharif* and *rabi* crops in different states, through the scenarios in Table 8.[24]

Table 8: Crop replacements scenarios by state and seasons

State	Scenario I (% replacement)		Scenario II (% replacement)	
	Kharif	**Rabi**	**Kharif**	**Rabi**
Andhra Pradesh	10	25	25	50
Bihar	10	25	25	50
Gujarat	25	25	50	50
Haryana	25	25	50	50
Karnataka	25	25	50	50
Madhya Pradesh	10	25	25	50
Maharashtra	25	25	50	50
Punjab	25	25	50	50
Rajasthan	0	25	0	50
Tamil Nadu	10	0	25	0
Telangana	10	25	25	50

In these 11 states, we take the area under three most water-intensive crops, namely rice, wheat and sugarcane, and re-distribute the area to the replacement

[21] Their data is for the period 1996-2005, which is the most recent available estimate for non-cereal crops at the state level. These figures have not been updated as this would require a substantial analysis, beyond the scope of this paper. Nevertheless, our analysis provides a meaningful order of magnitude of the change in water use that can be achieved through this shift in cropping pattern

[22] It is assumed that crops are irrigated only to meet the ET requirement and there is no over-irrigation. To the extent that the farmer has no direct way of measuring ET or predict rainfall, this would lead to an underestimation of the actual water use by farmers.

[23] Not all water footprints are seasonal – only those from cereals are. ET/yield changes and their effect on crop water requirements have not been modelled. Baseline for water savings assumes no change in the adoption of water saving technology

[24] The percentage shift in crop area in *kharif* and *rabi* varies between different states. Here, we have considered the difficulty of replacing a major irrigated crop like rice in the southern Indian states where it also happens to be the main staple crop of the area. We have also considered the possibility that in the water-logged areas of North Bihar, nothing else except rice can grow and hence replacing it would be difficult. In such situations, we have reduced the area shift from 25 percent and 50 percent in Scenarios I and II to 10 percent and 25 percent respectively.

crops.[25] The replacement crops are largely pulses and nutri-cereals. The choice of the replacement crops is governed by an analysis of the cropping pattern of the concerned state in the period before the monoculture of the Green Revolution took firm roots there. Thus, these are crops suited to the agro-ecology of each region and therefore their revival has a solid basis in both agricultural science and farmer experience. The water savings were calculated based on the change in irrigation water required for each state in each season. Irrigation water savings are given as the difference between the water-use at baseline as compared to the crop replacement scenarios. In order to make suitable and realistic proposals for crop replacements, we consider several factors:

i. Seasons: Crop production is strongly determined by seasons, which need to be taken into account while proposing replacements. For example, since most of the nutri-cereals are grown in the kharif season, we cannot propose a replacement of wheat (a predominantly winter crop) with nutri-cereals like jowar. Crop growing seasons for rice in Tamil Nadu are such that the proposals for replacement have to consider if the sowing and harvesting time of the replacement crops match those of rice. Similarly, for replacement of an annual crop like sugarcane in Maharashtra, we have identified a crop sequence covering both the *kharif* and *rabi* seasons, so that the replacement of one crop is with a group of two or more crops.

ii. Source of irrigation and extent of control over water: Crops grown in command areas of large dams are largely irrigated by the field-flooding method. It is, therefore, difficult to replace rice grown in the canal commands and floodplains of rivers like the Godavari and Krishna in Andhra Pradesh with any other crop. However, in the non-command areas of Andhra Pradesh and Telangana, mainly the undulating and upland regions, it is possible to replace rice because the major source of irrigation here is groundwater. The situation in Punjab and Haryana is similar, since groundwater accessed through tubewells is the major source of irrigation.

iii. Soil conditions and agronomy: Once certain crops like rice are continuously grown in an area, the soil conditions change considerably so that any crop replacement may become difficult. This particularly applies to the low-lying regions of West Bengal, Odisha and Chhattisgarh. Similarly, when inter-cropping is practised, there are certain crop combinations involved. So, when we propose replacement of one crop (such as soyabean in Madhya Pradesh), we need to also propose replacement of other crops in the crop mix when the inter-crop does not match with the replacement crop.

Based on these considerations and limiting factors, Table 9 brings together the state-specific and season-specific crop replacements proposed.

[25] We keep the sum of the water-intensive and replacement crops area constant

Table 9: State-specific and season-specific crop replacements

State	Water Intensive Crop		Replacement Crop	
	Kharif	**Rabi**	**Kharif**	**Rabi**
Andhra Pradesh	Rice	Rice	Tur, Groundnut	Gram, Sesame
Telangana	Rice	Rice	Tur, Jowar	Gram, Sesame
Bihar	Rice	Wheat	Tur, Urad	Gram, Lentils
Gujarat	Cotton	Wheat	Tur, Bajra	Gram, Rapeseed
Haryana	Rice	Wheat	Tur, Bajra	Gram, Rapeseed
Karnataka	Rice	Wheat	Tur, Groundnut	Gram, Moong
Madhya Pradesh	Soybean	Wheat	Maize, Jowar	Gram, Rapeseed
Maharashtra*	Sugarcane	Wheat	Jowar, Tur	Gram, Rapeseed
Punjab	Rice	Wheat	Tur, Moong	Gram, Rapeseed
Rajasthan**	Miscellaneous Crops	Wheat	No Change	Gram, Rapeseed
Tamil Nadu***	Rice		Tur, Urad	

Note: *Sugaracane is an annual crop. **We make no change in *kharif* in Rajasthan, as the crops are mostly already low water consuming ones. ***In Tamil Nadu, agricultural seasons do not exactly correspond to the *kharif-rabi* distinction applied in the rest of the country

Table 10 provides a comparison of the total blue water saved (cubic kilometres or billion cubic metres) in 11 states after crop replacements in Scenarios I and II, as compared to the irrigation water required to produce the water-intensive crops in the baseline scenario.

Table 10: Comparison of annual irrigation water under different crop scenarios

State	Blue Water Use (BCM/Year)			Blue Water Saving (%)	
	Baseline	**Scenario I**	**Scenario II**	**Scenario I**	**Scenario II**
Andhra Pradesh	10.06	8.15	6.08	19	40
Telangana	5.46	4.33	3.12	21	43
Bihar	7.80	6.35	4.74	19	39
Gujarat	13.22	10.35	7.48	22	44
Haryana	8.39	7.42	6.38	12	24
Karnataka	1.17	0.97	0.82	17	30
Madhya Pradesh	14.92	12.16	9.40	19	37
Maharashtra	13.93	10.58	7.24	24	48
Punjab	14.26	11.58	8.26	19	42
Rajasthan	15.71	13.97	13.13	11	16
Tamil Nadu	5.45	4.95	4.20	9	23
	110.35	**90.81**	**70.83**	**18**	**36**

Given that water-intensive crops currently occupy over 30 percent of the gross irrigated area in these states, the amount of water saved annually is considerable. This water could be diverted to critical and supplementary irrigation for millions of small and marginal farmers, while also reducing the pressure on rural drinking water sources.

It is possible that these crop replacements will result in a degree of reduction in total output because of differentials in yields across crops.[26] However, it must be borne in mind that the rapidly deteriorating water situation increasingly poses a very serious constraint to maintaining the productivity levels of water-intensive crops, especially in states like Punjab and Haryana. Hence, it would be fallacious to assume that their output levels could be sustained indefinitely. We must also clearly recognise that food stocks over the last decade have greatly exceeded the 'buffer norm', which is around 31 million tonnes for wheat and rice. Indeed, even after all the additional drawals following the COVID-19 pandemic, the Central pool still had 63 million tonnes in stock in October 2020 (Husain, 2020).

Moreover, the nutritional content of the crop mix we are proposing is definitely superior. Increasing consumption of nutri-cereals over rice and wheat could reduce iron-deficiency anaemia, while the increased consumption of pulses could reduce protein-energy malnutrition (DeFries *et al.*, 2018). The impact on farmers' incomes is also likely to be positive both because of lower input requirements and costs of production associated with our crop-mix, as also higher wholesale prices for the replacement crops. The average wholesale price in 2018 for the water-intensive crops was INR 3 171/quintal, compared to INR 3 821/quintal for the replacement crops (see Table 11). Further analysis is required to understand the impact of these changes at the state level, but these data indicate that if steady demand for the replacement crops can be ensured, farmer incomes would not be impacted negatively, even as national nutritional and water security are both advanced through this change. What would help significantly is more emphasis on R&D in replacement crops, stronger farmer extension support for them, as also expanded procurement and higher price support in order to create the right macro-economic environment for crop replacement.[27]

[26] What is encouraging, however, is that in recent times, the productivity of nutri-cereals has been going up because of which despite a sharp reduction in the acreage under nutri-cereals, their production has not declined. This is a positive sign leading us to believe that with greater R&D investments in nutri-cereals, their productivity can be further improved.

[27] It is encouraging to note that recent increases in MSPs have tended to favour our replacement crops and not rice and wheat

Table 11: All-India weighted average wholesale prices, October 2018

	Crops	Weighted average annual wholesale price (INR/quintal)
Water intensive crops	Sugar	3 563
	Rice	2 030
	Wheat	1 889
	Cotton	5 394
	Soyabean	2 979
Replacement crops	Moong	4 774
	Gram	3 862
	Urad	3 740
	Masoor	3 723
	Arhar	3 687
	Ragi	2 256
	Jowar	1 993
	Bajra	1 478
	Maize	1 315
	Sesamum	10 961
	Groundnut	4 249
	Rapeseed	3 817

Source: Ministry of Agriculture and Famers Welfare, published as Answers Data of Session 246, 247 and 248 of Rajya Sabha, Parliament of India, available from data.gov.in

IV.2 Monoculture Impairs Resilience: Return to Polycultural Bio-diversity

Farming faces twin uncertainties, stemming from the market and the weather. For such a risky enterprise to adopt monoculture is patently suicidal.[28] But that is what the Green Revolution has moved Indian farming towards: more and more land under one crop at a time and year-on-year production of the same crop on the same land.

This reduces the resilience of farm systems to weather and market risk, with even more grave consequences in this era of rapid climate change and unpredictable patterns of rainfall. In 2018 and 2019, India had at least one extreme weather event every month. In different regions, these included shortages and excesses of rainfall, higher and lower temperatures etc., many of which exceeded the bounds of normal expectation. A recent report of the Ministry of Earth Sciences (MoES), Government of India (Krishnan *et al.*, 2019) finds that June to September rainfall over India has declined by around 6 percent from 1951 to 2015, with notable decreases over the

[28] In complex organic systems, there is always a trade-off between efficiency and robustness (Csete and Doyle, 2002).

Indo-Gangetic plains and the Western Ghats. During the same period, the frequency of daily precipitation extremes with rainfall intensities exceeding 150 mm per day increased by about 75 percent over central India. Dry spells were 27 percent more frequent during 1981–2011 compared to 1951–1980. Both the frequency and spatial extent of droughts have increased significantly between 1951 and 2016. Climate models project an increase in the frequency, intensity and area under drought conditions in India by the end of the twenty-first century.

The persistence of monoculture makes India even more vulnerable to disruptions from climate change and extreme weather events, for it has by now been conclusively established that

> "crops grown under 'modern monoculture systems' are particularly vulnerable to climate change as well as biotic stresses, a condition that constitutes a major threat to food security . . . what is needed is an agro-ecological transformation of monocultures by favoring field diversity and landscape heterogeneity, to increase the productivity, sustainability, and resilience of agricultural production. . .Observations of agricultural performance after extreme climatic events in the last two decades have revealed that resiliency to climate disasters is closely linked to farms with increased levels of biodiversity" (Altieri *et al.*, 2015).

> "The vast monocultures that dominate 80% of the 1.5 billion hectares of arable land are one of the largest causes of global environmental changes, leading to soil degradation, deforestation, depletion of freshwater resources and chemical contamination." (Altieri and Nicholls, 2020)

It has also been shown that plants grown in genetically homogenous monocultures lack the necessary ecological defence mechanisms to withstand the impact of pest outbreaks. Francis (1986) summarises the vast body of literature documenting lower insect pest incidence and the slowing down of the rate of disease development in diverse cropping systems compared to the corresponding monocultures. In his classic work on inter-cropping, Vandermeer (1989) provides innumerable instances of how inter-cropping enables farmers to minimise risk by raising various crops simultaneously. Natarajan and Willey (1996) show how polycultures (intercrops of sorghum and peanut, millet and peanut, and sorghum and millet) had greater yield stability and showed lower declines in productivity during a drought than monocultures.

Conversely, the recent report of the FAO's Commission on Genetic Resources for Food and Agriculture brings out the key role of bio-diversity in sustaining crop production:

> "The world is becoming less biodiverse and there is good evidence that biodiversity losses at genetic, species and ecosystem levels reduce ecosystem functions that directly or indirectly affect food production, through effects such as the lower cycling of biologically essential resources, reductions in compensatory dynamics and lower niche occupation" (Dawson et al, 2019)

Moreover, as a recent study of agro-biodiversity in India argues, "when we lose agricultural biodiversity, we also lose the option to make our diets healthier and our food systems more resilient and sustainable" (Thomson Jacob *et al.*, 2020).[29] It is thus clear how a move away from monoculture towards more diverse cropping patterns would increase resilience against climate and market risks, while also reducing water consumption.

IV.3 Rejecting the originative flaw (soil as an input-output machine)

The fundamental question that needs to be raised about the Green Revolution is its overall strategy, its conception of the agricultural production system in general, and of soils in particular. The overarching strategy was one of "betting on the strong", which meant focusing investment and support on farmers, regions and crops that were seen as most likely to lead to an increase in output (Tomlinson, 2013). It was a "commodity-centric" vision, where the trick was to deploy such seeds as would maximise output per unit area, given the right doses of fertilisers and pesticides. The amount of chemical nutrients applied would demand correspondingly larger input of water, which would, in turn, make the resultant eco-system extremely favourable to the profusion of pests, which then would threaten output unless pesticides were utilised to kill them.

This is a perspective that exclusively focuses on productivity (output/area) of a given crop by specifically targeting soil nutrients or pest outbreaks (Hecht, 1995). Such a view is atomistic, and assumes that "parts can be understood apart from the systems in which they are embedded and that systems are simply the sum of their parts" (Norgaard and Sikor, 1995). It is also mechanistic, in that relationships among parts are seen as fixed, changes as reversible and systems are presumed to move

[29] This understanding is reflected in the National Biodiversity Mission launched by the Prime Minister's Science, Technology, and Innovation Advisory Council in March 2019, which includes a *Biodiversity and Agriculture Program* that "will aim to reconcile the traditional tension that exists between increasing food production on one hand and preserving biodiversity on the other. By launching a first-ever quantitative inventory of the contribution of biodiversity in forests, rivers, estuaries, and agro-ecosystems to India's food and nutritional security, citizens will be empowered with credible information on the judicious use of bioresources." (Bawa *et al.*, 2020)

smoothly from one equilibrium to another. Such a view ignores the fact that often parts cannot be understood separately from their wholes and that the whole is different (greater or lesser) than the sum of its parts. It also overlooks the possibility that parts could evolve new characteristics or that completely new parts could arise (what is termed as `emergence' in soil science literature).[30] As Lent (2017) argues:

> "Because of the way a living system continually regenerates itself, the parts that constitute it are in fact perpetually being changed. It is the organism's dynamic patterns that maintain its coherence. . .This new understanding of nature as a self-organized, self-regenerating system extends, like a fractal, from a single cell to the global system of life on Earth."

On the other hand, in the Green Revolution vision, the soil was seen essentially as a stockpile of minerals and salts, and crop production was constrained as per Liebig's Law of the Minimum – by the nutrient least present in the soil. The solution was to enrich the soil with chemical fertilisers, where the soil was just a base with the physical attributes necessary to hold roots: "Crops and soil were brute physical matter, collections of molecules to be optimized by chemical recipes, rather than flowing, energy-charged wholes" (Mann, 2018).

Thus, the essential questions to be posed to a continued blind adherence to the Green Revolution approach, in the face of India's growing farm and water crises, are:

1. Is the soil an input-output machine, a passive reservoir of chemical nutrients, to be endlessly flogged to deliver, even as it shows clear signs of fatigue?
2. Or is it a complex, interacting, living eco-system to be cherished and maintained so that it can become a vibrant, circulatory network, which nourishes the plants and animals that feed it?
3. Will a toxic, enervated eco-system with very poor soil quality and structure, as also gravely fallen water tables, be able to continue to support the agricultural production system?

In the words of Rattan Lal, the Indian-American soil scientist who is also the 2020 World Food Prize winner:

> "Soil is a living entity. It is full of life. The weight of living organisms in a healthy soil is about 5 ton per hectare. The activity and species diversity of soil biota are responsible for numerous essential ecosystem services. Soil organic matter content is an indicator of soil health, and should be about 2.5% to 3.0% by weight in the root zone (top 20 cm). But soil in Punjab, Haryana, Rajasthan, Delhi, Central India and Southern parts contains maybe 0.5 percent or maybe 0.2 percent."[31]

[30] Addiscott (2010); Baveye *et al* (2018); Falconer *et al* (2012)
[31] Interviews to Indian Express (22 June 2020) and Mint (12 June 2020)

According to FAO, generating 3 cm of top soil takes 1 000 years, and, if current rates of degradation continue, all of the world's top soil could be gone within 60 years.[32] Lal favours compensation for farmers through payments (around INR.1 200 per acre per year) for soil protection, which he regards as an important eco-system service.

It is important to understand the key relationship between soil quality and water productivity and recognise that every land-use decision is also a water-use decision (Bossio *et al.*, 2008). Rattan Lal (2012) explains how soil organic matter (SOM) affects the physical, chemical, biological and ecological qualities of the soil. In physical terms, higher SOM improves the water infiltration rate and the soil's available water-holding capacity. Chemically, it has a bearing on soil's capacity to buffer against pH, as also its ion-exchange and cation-exchange capacities, nutrient storage and availability and nutrient-use efficiency. Biologically, SOM is a habitat and reservoir for the gene pool, gaseous exchange between the soil and the atmosphere and carbon sequestration. Ecologically, SOM is important in terms of elemental cycling, eco-system carbon budget, filtering of pollutants and eco-system productivity.[33]

In the light of this understanding, attempts are being made all over the world to foster an eco-system approach, with higher sustainability and resilience, lower costs of production, as also economy in water use, along with higher moisture retention by the soil. Broadly, these alternatives to the Green Revolution paradigm, come under the rubric of agro-ecology. In the latest quadrennial review of its Strategic Framework and Preparation of the Organization's Medium-Term Plan, 2018–21, the FAO states:

> "High-input, resource-intensive farming systems, which have caused massive deforestation, water scarcities, soil depletion and high levels of greenhouse gas emissions, cannot deliver sustainable food and agricultural production. Needed are innovative systems that protect and enhance the natural resource base, while increasing productivity. Needed is a transformative process towards 'holistic' approaches, such as agro-ecology and conservation agriculture, which also build upon indigenous and traditional knowledge."

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[32] https://www.scientificamerican.com/article/only-60-years-of-farming-left-if-soil-degradation-continues, 5 December 2014

[33] Several studies have documented the depletion of soil organic matter and organic carbon in the soils of north west India after the adoption of the Green Revolution (Chouhan, *et al.*, 2012; Ghosh *et al.*, 2017; Pal *et al.*, 2009).

Hecht (1995) provides an excellent summary of the philosophy underlying agro-ecology:

> "At the heart of agro-ecology is the idea that a crop field is an ecosystem in which ecological processes found in other vegetation formations such as nutrient cycling, predator/prey interactions, competition, commensalism, and successional changes also occur. Agro-ecology focuses on ecological relations in the field, and its purpose is to illuminate the form, dynamics, and function of these relations (so that) . . . agro-eco-systems can be manipulated to produce better, with fewer negative environmental or social impacts, more sustainably, and with fewer external inputs."

In India, a large number of such alternatives to the Green Revolution paradigm have emerged over the past two decades. These include natural farming, non-pesticide managed agriculture, organic farming, conservation agriculture, low external input sustainable agriculture, etc. but they all share a common base of agro-ecological principles, rooted in the local context. Recently some state governments have given a big push to this movement. The biggest example is that of the Community Based Natural Farming programme of the Government of Andhra Pradesh (GoAP), which started in 2016.[34] Crop-cutting experiments by the State Agriculture Department claim higher average yields, reduced costs and higher net incomes for `natural' farmers compared to `non-natural' farmers, in all districts and for all crops. Encouraged by the results, the GoAP has now resolved to cover the entire cultivable area of 80 lakh hectares in the State by 2027 (Vijay Kumar, 2020). This would then become the largest challenge to the Green Revolution ever undertaken.

Support has also been forthcoming from the Government of India. At an event organised by the NITI Aayog on 29 May 2020, the Union Minister for Agriculture stated:

> "Natural farming is our indigenous system based on cow dung and urine, biomass, mulch and soil aeration [. . .]. In the next five years, we intend to reach 20 lakh hectares in any form of organic farming, including natural farming, of which 12 lakh hectares are under *Bharatiya Prakritik Krishi Paddhati Programme*."[35]

At the same event, the NITI Aayog Vice-Chairman stressed the need to take natural farming to scale:

> "In states like Andhra Pradesh, Telangana, Gujarat, Himachal Pradesh, and Madhya Pradesh this is being practised already quite widely. It has proven its benefit on the ground. Now is the time that we should scale it and make it reach 16 crore farmers from the existing

[34] Initially called Zero Budget Natural Farming, this label, suggestive of a certain kind of fundamentalism and exaggeration, has now been dropped

[35] 'Agroecology and Natural Farming Could Accelerate Inclusive Economic Growth in India' (https://pib.gov.in/PressReleasePage.aspx?PRID=1628285)

30 lakhs. The whole world is trying to move away from chemical farming. Now is the time to make Indian farmers aware of its potential".[36]

IV.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 varieties. 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 (National Innovations on Climate Resilient Agriculture) project, through their district-level drought adaptation plans.[37] Adoption of these varieties by farmers would need training and facilitation by *Krishi Vigyan Kendras*[38] (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.[39]

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 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

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[36] 'COVID-19 has led to more thrust on agroecology, natural farming: NITI Aayog' (thefactnews.in /covid-19-has-led-to-more-thrust-on-agroecology-natural-farming-niti-aayog). Another heartening development is the proposed ban on 27 pesticides by the Union Ministry for Agriculture and Farmers Welfare. The draft notification, 'Banning of Insecticides Order 2020' (14 May 2020), prohibits the import, manufacture, sale, transport, distribution and use of 27 pesticides, some of which are associated with high levels of toxicity leading to even farmers' deaths and have also been declared as extremely hazardous or highly hazardous by the WHO (http: // agricoop.nic.in /sites/ default/ files/Notification.pdf)

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

[38] Agriculture Science Centres

[39] 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.

spreading water homogenously and reduces soil moisture. Therefore, land levelling within farms[40] is a precursor to good agronomic, soil and crop management practices.

Table 12: 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[41]	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*

IV.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

[40] 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)

[41] Conservation agriculture can also minimise risk to climate extremes; https://www.sciencedirect.com/science/article/pii/S0167880916304649?casa_token=-YwaRKXI2BkAAAAA:9QoNi2AD8ONvnBzmYcd7bi4Iz3uJSSchqUfEocCQCyGiBTxJTb7th4778lCbt5J15gu1gf-N5Vw

sown area.[42] The key to improved productivity of rainfed farming is a focus on soil moisture (green water) 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.

Clearly, there is robust scientific support for exploring alternatives to Green Revolution farming, which needs to be an essential part of the response to both the crises of water and agriculture in India. However, there is also a need to make a strong argument against any kind of fundamentalism on both sides. Those who insist on business-as-usual are being fundamentalist and irresponsible because they are turning a blind eye to the distress of India's farmers and the grave water crisis in the country. On the other hand, it is also important that those working for alternatives adopt procedures for transparent verification and evaluation of their efforts. What is more, the efforts will need multiple forms of support from the government, similar to the

[42] 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).

multi-pronged approach adopted at the time of the Green Revolution. We would like to propose a few essential steps here:

1. Building on the intuition of the Hon'ble Prime Minister who initiated the Soil Health Card Scheme, the soil testing capacities of the entire country need to be urgently and comprehensively ramped up. This means not only establishing more soil testing laboratories, but also testing on a much wider range of parameters, based on the `living soils' vision, where testing is extended to the 3Ms (moisture, organic matter and microbes). This will make it possible to assess over time whether the claims of different farming approaches can be validated as being truly `regenerative' and for an assessment to be made about the kind of intervention that may or may not be required in each specific context
2. Widespread and affordable facilities must be made available for testing the maximum residue level of chemicals in farm produce, in line with regulations of the Food Safety and Standards Authority of India (FSSAI), without which there will be no guarantee that the produce meets required health safety standards.
3. This also requires large-scale and separate processing, storage and transport facilities for the produce of `natural farmers' so that it does not get contaminated by the produce of conventional chemical farmers. Millets are crops where processing can be a challenge. Therefore, millet processing infrastructure also needs to become a priority to incentivise farmers to move to water-saving crops and also to move them up the value chain.
4. The present farm input subsidy regime that incentivises production with a high intensity of chemical inputs must shift to one that supports the production of organic inputs and provides payment for farm eco-system services, like sustainable agriculture practices, improving soil health etc. This can, in fact, become a way to generate rural livelihoods, especially if the production of organic inputs could be taken up at a large scale by federations of women self-help groups (SHGs) and farmer producer organisations (FPOs)
5. The SHG-bank linkage would also be crucial in order to ensure that credit actually reaches those who need it the most and whose dependence on usurious rural moneylenders grew after strict profitability norms were applied to public sector banks in 1991 (Shah 2007). Shah *et al.* (2007) explain how SHGs led by women enable these banks to undertake sound lending, rather than the botched-up, target-driven lending of the Integrated Rural Development Programme (IRDP) in the

years following bank nationalisation. The SHG-Bank Linkages Programme has not only benefitted borrowers, but has also improved the profitability of many bank branches in rural and remote areas, thus mitigating the inclusion-profitability dilemma that afflicted public sector banks in the first two decades after nationalisation. As a result, formal rural credit has once again made a comeback during the last decade, after a period of decline in the 1990s and early twenty-first century. Such credit support will be crucial if the paradigm shift in farming proposed in this paper is to be scaled up on the ground.

6. Finally, the entire agricultural extension system needs to be rejuvenated and revamped, to make it align with this new paradigm. Special focus must be placed on building a whole army of Community Resource Persons (CRPs), farmers trained in all aspects of agro-ecology, who would be the best ambassadors of this fresh perspective and understanding, working in a truly `rhizomatic' manner, allowing for multiple, non-hierarchical points of knowledge representation, interpretation and sharing.[43]

Thus, to carry forward the agro-ecological revolution in India, there is a need for an overarching architecture very similar to the one that propelled the Green Revolution in its heyday, even though each of its constitutive elements would be radically different. It is only if the pattern of subsidies is changed and these reforms are put in place by the government that the paradigm shift in farming proposed in this paper will be able to take off in real earnest. Otherwise doubts about its authenticity and power could remain.

V. The paradigm shift required in water[44]

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-

[43] A "rhizome has no beginning or end; it is always in the middle, between things, interbeing, *intermezzo*." (Deleuze and Guattari, 1987)

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

exploitation of aquifers and the inability to manage 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 movement in the case of both large dams and groundwater extraction. Thus, the strategy of constructing large dams across rivers comes 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. This is why the Twelfth Five Year Plan clearly spoke of the need for a fundamental shift from more and more construction of dams and extraction of groundwater, toward sustainable and equitable management of water.

V.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 them 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 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-run of, on an average, 1 382 percent in major projects and 325 percent in medium dams (Planning Commission, 2013), in addition to which there are humongous human and environmental costs.[45]

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. In the Ganga plains, the topography is completely flat and storages

[45] 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)

cannot be located there, as they would cause unacceptable submergence. Further north in the Himalayas – comparatively young mountains with high rates of erosion – the upper catchments have little vegetation to bind the soil. Rivers descending from the Himalayas, therefore, tend to have high sediment loads. There are many cases of power turbines becoming dysfunctional because of the consequent siltation. Climate change is making the predictability of river flows extremely uncertain. Diverting rivers will also create large dry regions, with adverse impact on local livelihoods. The neo-tectonism of the Brahmaputra valley, and its surrounding highlands in the eastern Himalayas, means that modifying topography by excavation or creating water and sediment loads in river impoundments can be dangerous. Recent flooding events in Uttarakhand and Nepal bear tragic testimony to these scientific predictions.

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 in command areas like Dharoi and Hathuka in Gujarat, Waghad in Maharashtra, Satak, Man and Jobat in Madhya Pradesh, Paliganj in Bihar and Shri Ram Sagar in Andhra Pradesh. 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), 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 the overall water-use efficiency in India, 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.

V.2 Participatory groundwater management

In a classic instance of vicious infinite regress,[46] 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, which have limited capacity to store groundwater and have very low rates of natural recharge. Once water is extracted from them, it takes very long for it to regain its original level.

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,

[46] 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)

it is not possible to divide the water, a fugitive resource which 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 the country 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 which 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 come together to jointly manage their precious shared resource. They develop 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* (Atal Groundwater Scheme).[47] While both of these are pioneering initiatives, the likes of which the world has never seen before, they have failed 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.

V.3 Breaking the groundwater-energy nexus and legal reform

It is also necessary to break the groundwater-energy nexus that has only encouraged the mining of groundwater by making both power and water virtually free for the farmers. The solution cannot be marginal cost pricing, which would have an extremely adverse impact on the access to groundwater for millions of small and marginal farmers and endanger their livelihoods. We cannot afford to kill the goose that lays the golden egg (WLE, 2015). A possible way forward could be to emulate the *Jyotigram Yojana* (Village Lighting Scheme) of the Government of Gujarat, through the separation of power feeders. The key here is the rationing of high-quality power to farmers for eight hours. Many states have now followed Gujarat's example, with different hours of rationing: Punjab (five hours), Rajasthan and Karnataka (six hours), Andhra Pradesh (seven hours), Haryana, Madhya Pradesh, Maharashtra and Tamil Nadu (nine hours). While the jury is still out on the effectiveness of this measure in containing groundwater use, a recent study by Ryan and Sudarshan (2020) seems to suggest that it might be working well.

Concomitantly, urgent legal reform is required because groundwater continues to be governed by British common law of the nineteenth century, whose provisions seriously limit access to groundwater for small and marginal farmers. The common-law doctrine of absolute dominion gives landowners the right to take all water below their own land. The legal status of groundwater is effectively that of a chattel to the land. When water is extracted from below the land, the principle of *damnum absque injuria* (damage without injury) legally sanctifies unlimited volumes of abstraction, which can adversely impact water levels in neighbouring wells or tubewells.

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[47] Named after former Prime Minister Atal Bihari Vajpayee, the *Atal Bhujal Yojana* is a scheme for management of ground water

The science of hydrogeology explains that water flowing underneath any parcel of land may or may not be generated as recharge on that specific parcel. Recharge areas for most aquifers are only a part of the land that overlies the entire aquifer. Hence, in many cases, water flowing underneath any parcel of land will have infiltrated the land and recharged the aquifer from another parcel, often lying at a distance. When many users simultaneously pump groundwater, complex interference results between different foci of pumping, which is a common feature in many parts of India, where wells are located quite close to one another. This is typically how water tables have plunged in India and there is no legal protection available against such consequences, thereby endangering the lives and livelihoods of millions of farmers.

The Government of India has drafted a Model Groundwater (Sustainable Management) Bill, 2017 (Cullet, 2019). It should be formally approved, so that state governments can use this model to adopt groundwater legislation giving priority to protection measures at aquifer level and an access framework centred on ensuring the realisation of equitable and sustainable groundwater management and governance.

V.4 Protecting 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.

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 India's 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 bound to be 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. The Mahatma Gandhi National Rural Employment Guarantee Act (MGNREGA) scheme must be recast on a watershed basis and its enormous resources used for watershed and river rejuvenation, as also for the restoration of traditional water harvesting systems that still exist in so many parts of India, even if in a state of decay and disrepair.

This regenerative work must be integrated with groundwater-related demand management initiatives, for it is groundwater base-flows that keep rivers flowing after the monsoon. River catchments and aquifers must be always managed together within a river basin protection programme. Fundamentally, what all of this demands, is bottom-up participatory management in every river basin in India.

V.5 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 management that this paper proposes. Apart from civil and irrigation engineering and hydrogeology, 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.

V.6 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.

V.7 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.[48]

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 take into account all available information and expertise while

[48] 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

making decisions, and their voice has a definite bearing and influence on processes and outcomes.[49]

VI. 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."[50]

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).

[49] 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

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

This necessitates a paradigm shift in our structures of thought, to be able to grasp complex adaptive systems[51] (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-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 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.

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

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