Ecology, Economy and Society–the INSEE Journal 5 (1): 31-62 January 2022

THEMATIC ESSAY

Dismantling Barriers to Upscaling Agro-ecological Farming in India

Mihir Shah*

Abstract: With growing recognition of the increasingly destructive impacts of the Green Revolution (GR) the world over, heightened further by COVID-19, there is an urgent need to scale up alternative approaches embedded within the paradigm of agro-ecology. Even so, actual progress on the ground in this direction has been extremely slow. I argue that this is because the entire policy framework governing agriculture continues to be located within the GR paradigm and acts as a multi-pronged impediment to upscaling agro-ecological farming. The paper proposes key policy reforms that could help dismantle these barriers and facilitate, support, and accelerate movement towards agro-ecological farming in India.

Keywords: Agro-ecological farming; Nature-based solutions; Crop diversification; Ecosystem services; Living soils; Wholesome food.

1. CRISIS OF THE GREEN REVOLUTION

With the wheels coming off the Green Revolution (GR), there is an urgent perceived need all over the globe to design alternatives to chemical-intensive agriculture. The crisis is most powerfully illustrated by the example of India, which was the centrepiece of the GR experiment in the first place.

More than 350,000 farmers have committed suicide since 1990, a phenomenon completely unprecedented in Indian history. There is growing evidence of a steady decline in water tables and water quality. At least 60% of India's districts are either facing the problem of over-exploitation or severe contamination of groundwater (Vijayshankar, Kulkarni, and Krishnan 2011). There is evidence of fluoride, arsenic, mercury, and even

---

* Distinguished Professor, Shiv Nadar University. Chaired the Government of India Committee to draft the new National Water Policy during 2019-20. mihirbhai25@gmail.com

Published by Indian Society for Ecological Economics (INSEE), c/o Institute of Economic Growth, University Enclave, North Campus, Delhi 110007.

ISSN: 2581–6152 (print); 2581–6101 (web)

DOI: https://doi.org/10.37773/ees.v5i1.618

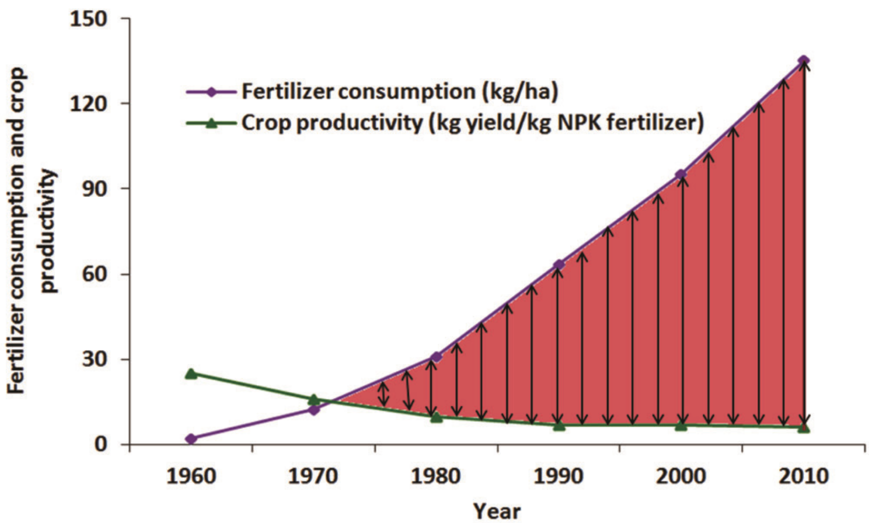
uranium and manganese in groundwater in some areas. The increasing levels of nitrates and pesticide pollutants in groundwater have serious health implications. The major health issues resulting from the intake of nitrates are methemoglobinemia and cancer (WHO 2011). The major health hazards of pesticide intake through food and water include cancers, tumours, skin diseases, cellular and DNA damage, suppression of the immune system, and other intergenerational effects (Margni *et al.* 2002).[1] 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 system, and Corsini *et al.* (2008) show how such immune alteration could lead to several diseases. Agricultural workers spraying pesticides are a particularly vulnerable group, especially in India where they are rarely provided protective gear. A study of farmworkers in Punjab found a significantly higher frequency of chromosomal aberrations in the peripheral blood lymphocytes of workers exposed to pesticides compared to those who are not (Ahluwalia and Kaur 2020). A recent study of 659 pesticides which examined their acute and chronic risks to human health and the environment 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, 2).

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 1). 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.

[1] Even at low concentrations, 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, and application rate, as well as the solubility, mobility, and half-life of individual pesticides.

Figure 1: Relationship Between Fertilizer Consumption and Crop Productivity



Source: Indoria *et al.* (2018, Figure 2)

After the GR, India has had more and more land under one crop at a time and year-on-year production of the same crop on the same land. 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, 3).
>
> 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, 2).

Moreover, despite overflowing granaries, the *Global Hunger Index Report* (2021) ranked India 101 out of 116 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 malnourished people in the world. In 2019, India had 28% (40.3 million) of the world's stunted children (low height-for-age) and 43% (20.1 million) of the world's wasted children (low weight-for-height) under five years of age. Paradoxically, at the same time, the number of diabetics has 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).

2. GLOBAL SEARCH FOR ALTERNATIVES

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) summarizes 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 multifarious instances of how inter-cropping enables farmers to minimize 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.

Most recently, the largest ever attempt in this direction (Tamburini *et al.* 2020) included a review of 98 meta-analyses and a second-order meta-analysis based on 5,160 original studies comprising 41,946 comparisons between diversified and simplified practices. They conclude:

Enhancing biodiversity in cropping systems is suggested to promote ecosystem services, thereby reducing dependency on agronomic inputs while maintaining high crop yields. Overall, diversification enhances biodiversity, pollination, pest control, nutrient cycling, soil fertility, and water regulation without compromising crop yields (Tamburini *et al.* 2020, 1).

A report of the FAO's Commission on Genetic Resources for Food and Agriculture also brings out the key role of biodiversity 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, 6).

Moreover, as a 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, 611).[2]

It is, therefore, no surprise that a recent overview of global food systems rightly points to the "paradox of productivity":

> As the efficiency of production has increased, the efficiency of the food system as a whole – in terms of delivering nutritious food, sustainably and with little waste – has declined. Yield growth and falling food prices have been accompanied by increasing food waste, a growing malnutrition burden and unsustainable environmental degradation (Benton and Bailey 2019, 3).

Benton and Bailey urge policy-makers to move from the traditional preoccupation with total factor productivity (TFP) towards total system productivity (TSP):

> A food system with high TSP would be sufficiently productive (to meet human nutritional needs) whilst imposing few costs on the environment and society (so being sustainable), and highly efficient at all stages of the food chain so as to minimize waste. It would optimize total resource inputs (direct inputs and indirect inputs from natural capital and healthcare) relative to the outputs (food

---

[2] 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, 3).

> utilization). Maximizing TSP would maximize the number of people fed healthily and sustainably per unit input (direct and indirect). In other words, it would increase overall systemic efficiency (Benton and Bailey 2019, 7)

In light of this understanding, attempts are being made all over the world to foster an ecosystem approach that ensured higher sustainability and resilience, lower costs of production, and economic water use along with higher moisture retention by soil. Broadly, these alternatives to the GR 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 (Dawson *et al.* 2019, 17).

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 (Hecht 1995, 4).

A recent overview sums up the key features of this approach:

> Over the past five years, the theory and practice of agroecology have crystalized as an alternative paradigm and vision for food systems. Agroecology is an approach to agriculture and food systems that mimics nature, stresses the importance of local knowledge and participatory processes and prioritizes the agency

> and voice of food producers. As a traditional practice, its history stretches back millennia, whereas a more contemporary agroecology has been developed and articulated in scientific and social movement circles over the last century. Most recently, agroecology—practised by hundreds of millions of farmers around the globe—has become increasingly viewed as viable, necessary and possible as the limitations and destructiveness of 'business as usual' in agriculture have been laid bare (Anderson *et al.* 2021, 2).

In India, many such alternatives to the GR paradigm have emerged over the past two decades. The biggest example is the Community-Based Natural Farming programme of the Government of Andhra Pradesh (GoAP), which started in 2016.[3] Support has also been forthcoming from the Government of India.[4]

We must also recognize that in the context of climate change, nature-positive farming can make a huge contribution to climate adaptation and mitigation strategies, with agriculture accounting for 15% of India's greenhouse gas emissions. According to the World Economic Forum, nature-based solutions have the potential to create $3,565 billion in annual business opportunities and 191 million jobs by 2030.

3. BARRIERS FACING AGRO-ECOLOGICAL FARMING AND POLICY REFORMS TO DISMANTLE THEM

Agro-ecological farming can, therefore, be said to comprise the following key, deeply inter-related defining elements:

a. progressive elimination of chemical inputs at the appropriate pace;
b. regenerating natural cycles for sustained yields and pest management;
c. promoting crop diversification and a decisive movement away from the monocultures of the GR to boost resilience;
d. focus on the productivity of the whole farm system (TSP), moving away from the commodity-centric approach of the GR;

---

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

[4] 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" (NITI Aayog 2020).

e. focus on soil health as a key determinant of the vigour of a farm system;
f. reducing the demand for water for irrigation, which sky-rocketed after the GR and led to a major crisis.

Despite the strong case for agro-ecology and all the government pronouncements and initiatives, we have yet to see these elements of agro-ecology gain significant mileage on-ground in India. While robust data is hard to come by, it can be said with some confidence that farming under the broad rubric of agro-ecology (by default or deliberately) occupies only a minuscule portion of the total cultivated area. There are multiple barriers to the large-scale adoption of agro-ecological farming, and specific policy reforms are required to dismantle them and facilitate, support, and accelerate movement towards agro-ecological farming in India.

There are at least 11 key barriers which, taken together, make it very hard for agro-ecological farming to grow in India. Without dismantling these barriers and putting in place an enabling policy framework with matching investments and action on the ground by state and civil society, the six key features of the agro-ecological approach listed prior will remain a distant dream. These barriers include:

Barrier #1: Incentivizing monoculture
Barrier #2: Uneven regional distribution of investments ("betting on the strong")
Barrier #3: Commodity-centric R&D and investments with a narrow vision
Barrier #4: Pattern of subsidies favouring chemical inputs
Barrier #5: Soil testing rooted in GR philosophy
Barrier #6: Weak legal and regulatory frameworks governing chemical inputs
Barrier #7: Collapse of farm extension and lack of understanding of agro-ecology
Barrier #8: Post-harvest infrastructure challenges which militate against safe and nutritious food
Barrier #9: Outmoded architecture of water governance
Barrier #10: Absence of documentation, monitoring, and research making proof-of-concept harder to establish
Barrier #11: Agriculture education mired in GR paradigm

Table 1: Share of Crops in Public Procurement, 2007–2019 (%)

Year	Rice	Wheat	Rice+Wheat	Nutri-cereals	Pulses	Total
2007–08	70	29	99	1	0	100
2008–09	58	40	98	2	0	100
2009–10	52	41	93	7	0	100
2010–11	53	45	98	2	0	100
2011–12	55	44	99	1	0	100
2012–13	47	52	99	1	0	100
2013–14	55	43	98	2	0	100
2014–15	53	46	99	1	1	100
2015–16	55	45	100	0	0	100
2016–17	61	36	97	0	3	100
2017–18	54	44	98	0	2	100
2018–19	37	58	95	0	5	100

Source: DAC 2020

Dismantling Barrier #1: Incentivizing Monoculture[5]

Ever since the GR, the structure of market incentives has moved farmers towards monocropping with water-intensive crops. Crop diversification, a key element of agro-ecology, has taken a backseat. It is now widely recognized that the GR was simply a wheat–rice revolution.[6] Over the past 50 years, the share of nutri-cereals[7] in cropped areas has gone down dramatically in all parts of India. Even in absolute terms, the acreage under

[5] For the complete datasets of this section, please see Tables 5 and 6 in Shah *et al.* (2021a).
[6] Even globally, around 60% of all plant calories and proteins come from just three grass crops—rice, maize, wheat—even though the FAO claims that at least 30,000 of the 350,000 known plant species on our planet are edible (Miller 2021).
[7] The Government of India took the 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'" (FE Bureau, 2018).

these cereals has been 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 has risen, but that is mainly on account of the rise in acreage under soya. The share of soybean in oilseed acreage rose from less than 1% in the early 1970s to over 40% in 2016–17, even as the share of the other eight oilseeds has stagnated. Other than soybean, the only other crops showing a rise in acreage during the period of the GR are wheat, rice, and sugarcane.

The rise in the 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 soybean, the rise in acreage is due to purchases by sugar mills and soya factories. However, the main story of the GR is that of rice and wheat, which remain the overwhelming majority of crops procured by the government, even after a few states have taken tentative steps towards diversifying their procurement baskets to include nutri-cereals and pulses. Even worse, public procurement still covers only a very low proportion of India's regions and farmers (Khera *et al.* 2020). Apparently, the primary target of procurement is the consumer, not the farmer. Thus, procurement gets limited to what is needed to meet the needs of consumers. An example is the way imports of pulses were ramped up during 2016–18 rather than continuing to expand procurement as per the original plan. Farmers who had shifted to pulses based on that expectation suffered as a result. This quick resort to imports rather than procurement becomes a continual disincentive for crop diversification.

India's cropping pattern before the GR included a much higher share of nutri-cereals, pulses, and oilseeds. These agro-ecologically appropriate crops 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 nutri-cereals, oilseeds, and pulses procured in this manner—in line with *POSHAN Abhiyaan*[8] launched by the Government of India in 2017—would be the supplementary nutrition and meals provided under the Integrated Child Development Services (ICDS) and the *Pradhan Mantri Poshan Shakti Nirman Yojana* (PM POSHAN)[9] and the grains provided through the PDS.[10]

---

[8] *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.

[9] *Pradhan Mantri Poshan Shakti Nirman Yojana* (PM's Nutritional Capacity Building Scheme) is the expanded version and new name of the earlier Mid Day Meal Scheme.

A few state governments are slowly moving forward in this direction. The Odisha Millets Mission (OMM), initiated in 2017–18, works on four verticals—production, processing, marketing, and consumption—through a unique institutional architecture of partnerships with academia and civil society. As of 2020–21, the programme, aimed at encouraging 100,000 farmers to cultivate millets, had spread across 76 blocks in 14 districts (Jena and Mishra 2021). A similar noteworthy example is that of the tribal-dominated Dindori district in Madhya Pradesh, a malnutrition hotspot in recent decades. Here, a state government–civil society partnership has led to a revival in the cultivation of *kodo* (Dutch millet) and *kutki* (little millet), which are renowned for their anti-diabetic and nutritional properties. The Government of Madhya Pradesh's Tejaswini Rural Women's Empowerment programme supports women self-help group (SHG) federations in developing a business plan for establishing a supply-chain for *kodo* bars and *barfis* (fudge), which were included in the ICDS Supplementary Nutrition Programme (Mathur and Ranjan 2021). These are the kinds of reforms and outreach all states need to pursue, with support from the centre.

Thus, the first element of agro-ecology reform becomes very clear: *We need to greatly expand the basket of public procurement to include more crops, more regions, and more farmers aligned with the agro-ecology of each region*. 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 current 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 twin curses 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.[11] 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% more protein than rice. Millets have higher fibre and

---

[10] The recent (October 28, 2021) joint letter from the Secretary, Department of Agriculture and Farmers Welfare, Government of India, and Secretary, Department of School Education & Literacy, Government of India (D.No. 4-612018-MDM-1-1 EE.5), to the Chief Secretaries of all states, requesting them to explore the possibility of introducing millets under PM POSHAN, in the context of the UN General Assembly recently adopting a resolution, sponsored by India and supported by more than 70 countries, declaring 2023 as the "International Year of Millets", is an extremely welcome step.

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

iron content, and a low glycaemic index. Millets also are climate-resilient crops suited for the drylands of India. If children were to eat these nutri-cereals—which provide a higher content of dietary fibre, vitamins, minerals, protein and antioxidants, and a significantly lower glycaemic index—India would be better positioned to solve the problems of malnutrition and obesity.

To clarify, this is not a proposal for open-ended public procurement, or worse, the nationalization of farm trade. That would be neither feasible nor desirable. The argument is for diversification of the procurement basket to include crops suited to local agro-ecologies. Perhaps the best way would be to do what was proposed under the 2018 PM-AASHA scheme,[12] wherein 25% of the actual production of the commodity for that particular year/season (to be expanded up to 40% if the commodity is part of the PDS) would be procured by the government. Without such an initiative, the announcement of MSPs for 23 crops every year is reduced to a token ritual, with little benefit to most farmers.

Dismantling Barrier #2: Uneven Regional Distribution of Investments ("Betting on the Strong")

The overarching strategy of the GR 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). This entailed a focus on already well-endowed regions and farmers to create a large buffer stock of grain that could feed the whole country. After a point, the same GR strategy was applied uncritically through large swathes of the Indian countryside, irrespective of the diverse agro-ecological conditions prevailing in different parts of the country. This policy frame had countless untold consequences for the farms and farmers of India. One of the most deleterious outcomes of this strategy has been the terrible neglect of India's rainfed areas, which currently account for 54% of the sown area and provide 89% of the national millet production, 88% of pulses, 73% of cotton, 69% of oilseeds, and even 40% of the rice production. It has been shown that there is a strong overlap between the incidence of poverty and rainfed regions. Thus, an inadequate emphasis on these regions is responsible for enduring poverty and inequality as well as the crises of water and nutrition security in India.

Ever since the Green Revolution, R&D and investments reflect an aggravated neglect of rainfed regions, including the rich agro-biodiversity of

---

[12] *Pradhan Mantri Annadata Aay SanraksHan Abhiyan* (PM-AASHA) is aimed at ensuring remunerative prices to farmers for their produce.

these areas. Strategies for the water sector also show this bias, with an overwhelming focus on the construction of mega-reservoirs and flood irrigation, to the complete neglect of the specific needs and potential of rainfed regions. The key to improved productivity of rainfed farming is a focus on soil moisture and protective irrigation. Protective irrigation seeks to meet moisture deficits in the root zone, which are a 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 100–150 mm of additional water, rather than large quantities as in conventional irrigation.

Lal (2012) provides a comprehensive list of options for increasing resilience in rainfed areas:

(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 favourable 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 shelterbelts); (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 (Lal 2021, 52).

Despite some advances in the watershed programme over the years and the creation of the National Rainfed Areas Authority in 2006, rainfed areas suffer prolonged neglect as India's policy regime continues to be dominated by a GR paradigm in both water and agriculture. Continued adherence to a one-size-fits-all approach will not allow the expansion of an agro-ecological approach to farming to materialize. Shah *et al.* (1998) and Expert Committee (2019) provide a comprehensive account of the enormous potential of the drylands of India for livelihood generation and water and food security for some of India's poorest people once we adopt a nature-positive paradigm of development. Following these policy prescriptions would correct the historic injustice done to rainfed areas and make a huge contribution to national food and nutritional security, while also enhancing farmers' welfare in a much more inclusive and sustainable manner.

Dismantling Barrier #3: Commodity-centric R&D and Investments with a Narrow Vision

Strongly linked to barriers #1&2, is barrier #3. "Betting on the strong" has meant that agricultural R&D and investments have remained centred on a narrow vision of productivity/acre and only on a few favoured GR crops. Other initiatives driven by more agro-ecological considerations have not received the requisite support. Through careful micro-level trials and experimentation at their field centres, the Indian Agricultural Research Institute (IARI) and state agricultural universities have developed several crop varieties based on local germplasm that are more resilient than conventional GR seeds. For example, the 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). Such varieties are also prescribed by the ICAR–NICRA (Indian Council for Agricultural Research–National Innovations on Climate Resilient Agriculture) project, through their district-level drought adaptation plans (NICRA, 2020) . These efforts need to receive a much greater emphasis in the overall policy scheme. Adoption of these varieties by farmers would require training and facilitation by Krishi Vigyan Kendras (KVKs) so that they are able to learn the new agronomic practices that these varieties involve. Their large-scale adoption could go a long way in reducing the water footprint of even water-intensive crops. Three thousand varieties of rice were being cultivated in eastern India before the GR (Shiva and Prasad 1993). If revived, they could play a big role in promoting nature-positive farming, improving resilience to climate risk, and reducing water demand.

Urgent steps are also needed to break the stranglehold of the commercial seed industry on the supply of seeds. In the case of a crop like cotton, it has been well documented how

> Cultivation of long season hybrid and GMO Bt-hybrid cotton is unique to India. The hybrid technology prevents seed saving, requires annual purchases of high cost seed that leads to sub optimal planting densities. These factors contribute to stagnant low yields and to increases in insecticide use that induce new pests that are increasingly resistant to insecticide and Bt toxins. Subsistence farmers growing rainfed Bt cotton in south and central India have been particularly affected by this hybrid technology (Gutierrez 2018).

Gutierrez argues for "pure line high-density short-season (HD-SS) rainfed cotton varieties, which would greatly increase yields, reduce yield variability, decrease costs of seed and insecticides and increase profits" (Gutierrez 2018, 2206).

It is to be hoped that the Seeds Bill 2021, currently under discussion, would be enacted soon and replace the GR-centred Seeds Act of 1966. A powerful alternative would be a massive upscaling of community seed banks. Community seed banks are unique efforts for collective conservation, production, and distribution of seeds of selected crop varieties. These banks provide seeds to farmers who return a certain quantity of seeds to the bank after harvest. These community seed banks not only help in conserving and reviving traditional crop species and tackling malnutrition at the community level, but they also reduce the dependence of farmers on companies for seeds. Nutrition gardens or backyard kitchen gardens would also help preserve seeds of traditional and nutrition-rich vegetable, fruit, and herb varieties.

At the same time, we need to move away from the commodity-centric GR approach towards diverse biomass production systems comprising trees, shrubs, creepers, and fibre-producing plants with multi-year life cycles and multi-tiered root systems and canopies—which reduce water-use and increase resilience, being less sensitive to variations in rainfall. Far greater investments are required in this direction for agro-ecological farming to take firm root in India.

Dismantling Barrier #4: Pattern of Subsidies favouring Chemical Inputs

The present farm input subsidy regime, which incentivizes production with a high intensity of chemical inputs, must shift to one that supports the production of organic inputs and provides payments for farm ecosystem services such as sustainable agriculture practices, improving soil health, etc. The budgetary and other support for agro-ecology pales in comparison to that provided to chemical inputs. As proponents of agro-ecology argue, if even 50% of the subsidy for chemical inputs was to be provided to support agro-ecological farming, the latter could attain critical mass, which would enable its subsequent growth to be fairly self-sustaining. This support to agro-ecology would, after all, become a way to generate rural livelihoods, especially if the production of organic bio-inputs could be taken up at a large scale by federations of women SHGs and farmer producer organizations (FPOs).

An interesting beginning in this direction has been made by the National Coalition for Natural Farming (NCNF), some of whose partners are setting up Bio-input Resource Centres (BRCs). Even though farmers are aware of the perils of chemical inputs and the benefits of alternative bio-inputs, they often find it easier to buy chemical inputs from the market rather than invest time and energy in preparing bio-inputs. NCNF is facilitating the setting-up of BRCs to overcome the challenge of non-availability of bio-inputs in the required quantities as well as the drudgery involved in making these bio-inputs—the burden of which largely falls on women. There are different models of BRCs run in an entrepreneurial fashion either by collectives of farmers or by individual farmers with the required skills and resources. BRCs undertake bulk production of bio-inputs such as vermicompost, pest repellents, growth boosters, etc., which are made available to farmers within the region.

Governments at both the centre and the state level must promote the development of BRCs at a massive scale, without which the non-availability of bio-inputs will become a serious barrier as nature-positive farming is scaled up in India.[13]

Dismantling Barrier #5: Soil Testing Rooted in GR Philosophy

The GR paradigm focuses exclusively on the 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, 22). It is also mechanistic, in that relationships among parts are seen as fixed, changes as reversible, and systems are presumed to move 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) (Addiscott 2010; Baveye *et al.* 2018; Falconer *et al.* 2012). As Lent (2017, 370) 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. .

[13] It is to be hoped that the NITI Aayog Task Force on Production and Promotion of Organic Fertilizers and Biofertilizers will show the way forward here.

> .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 (Lent 2017, 370).

In the GR vision, 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 fertilizers, 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, 2578).

Thus, the essential questions to be posed to a continued adherence to the GR 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 ecosystem to be cherished and maintained so that it can become a vibrant, circulatory network that nourishes the plants and animals that feed it?
3. Will a toxic, enervated ecosystem with very poor soil quality and structure and gravely fallen water tables be able to continue to support the agricultural production system?

In the words of Rattan Lal:

> 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% or maybe 0.2%. (cited in Sharma 2020).

According to FAO, generating 3 cm of topsoil takes 1,000 years, and if current rates of degradation continue, all of the world's topsoil could be gone within 60 years (Arsenault 2014). Lal favours compensating farmers through payments (around ₹1,200 per acre per year) for soil protection, which he regards as a vital ecosystem service.

It is important to understand the key relationship between soil quality and water productivity and recognize 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 the 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, for gaseous exchange between the soil and the atmosphere, and carbon sequestration. Ecologically, SOM is important in terms of elemental cycling, ecosystem carbon budget, filtering of pollutants, and ecosystem productivity.[14]

This vision of soils implies that 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 beyond the GR preoccupation with NPK. The new vision must be based on the "living soils" concept, where testing is extended to the 3Ms (moisture, organic matter, and microbes). This will also make possible a comparative assessment over time of the GR approach and its alternatives, so that the competing claims of different farming approaches can be validated as being truly "regenerative" and for arriving at the kinds of interventions that may or may not be required in each specific context.

Dismantling Barrier #6: Weak Legal and Regulatory Frameworks Governing Chemical Inputs

Even as it is clearer by the day that agrichemical inputs have disastrous implications for the farm system (as summarized above), the water we drink, the food we eat, and the air we—especially farmworkers—breathe, the legal and regulatory framework governing the use of these inputs remains weak, toothless, and ineffective. Without a greater understanding of the need to strengthen this framework, a move towards agro-ecological farming will remain stymied. It has been persuasively argued that even the data collection process for accidental pesticide poisoning remains undefined and under-focused, even though India is the fourth-largest global producer of pesticides (insecticides, fungicides, weedicides, and plant growth regulators) after the United States, Japan, and China. There is no comprehensive assessment of the public health risks of pesticide use in

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

India. Apart from farm-related risks, we have absolutely no idea about the exposure of children to hazardous pesticides in their homes, play areas, and schools. "Legal and regulatory frameworks are vague in terms of apportioning responsibilities between state and central governments on the one hand and between departments, such as public health, agriculture, police, and pollution control on the other" (Donthi 2021, 3). Without robust databases, we will not get the complete picture of the damage caused by agrochemical poisoning; and without strong regulation, corrective measures will not be taken. Without these being instituted, the need to go beyond the GR paradigm will remain incompletely understood.[15]

Dismantling Barrier #7: Collapse of Farm Extension and Lack of Understanding of Agro-ecology

It is not often adequately recognized that since the GR meant a completely new way of farming, the state-supported agricultural extension system played a critical role in making this happen at scale on the ground. Today, it may be quite difficult to imagine what a colossal task this was, covering hundreds of thousands of farmers across the length and breadth of India. Of course, over the years, this system has fallen into serious decay[16] and is often replaced by commercial suppliers peddling inputs that farmers may not be in need of and, at times, may be way beyond their expiry date. In a fascinating ethnography of field marketing agents for companies like Monsanto in western Maharashtra, Aga (2019, 22) describes what he calls "advertising dressed up as extension," how "agribusinesses create the demand for synthetic chemicals among farmers", and how "marketing as extension lubricates industrial capital's dominance over agricultural production." These kinds of self-serving corporate marketing drives are what tragically pose today as farm extension and "knowledge creation" in many parts of India.

If agro-ecology is to attain scale, we need a completely new vision for farm extension in India, different from both what it was in the heyday of the GR and from what it has unrecognizably degenerated into today. The paradigm of agricultural extension during the GR may be described as top-down, persuasive, and paternalistic technology transfer. If an alternative is to be found, great effort will be needed to re-energize and totally reorient this public extension system. We need to move towards a much more farmer-to-farmer participatory extension system. Special focus must be placed on

[15] Pesticide regulation in India is currently under The Insecticides Act 1968. It is to be hoped that the new Pesticide Management Bill 2020 will be a robust replacement for this outmoded and toothless legislation.

[16] See, for example, this recent ethnography of agriculture extension in Punjab (Chaba 2021).

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. These CRPs need to be empowered to respond to the multiple challenges farmers face in the transition to agro-ecology. They also must work in a truly "rhizomatic" manner, allowing for multiple, non-hierarchical points of knowledge representation, interpretation, and sharing. As Deleuze and Guattari (1987) point out, a "rhizome has no beginning or end; it is always in the middle, between things, interbeing, intermezzo."[17]

Dismantling Barrier #8: Post-harvest Infrastructure Challenges that Militate against Safe and Nutritious Food

A major unaddressed constraint to the expansion of agro-ecological farming in India is the lack of widespread and affordable facilities for testing the maximum residue level of chemicals, toxins, and contaminants (such as lead, copper, arsenic, tin, cadmium, mercury, chromium, nickel, etc.) in farm produce, in line with the regulations of the Food Safety and Standards Authority of India (FSSAI). Without this, there is no guarantee that the produce meets required health and safety standards. Today, the burden of proof of safety is squarely placed on those who claim to be engaged in some way or the other in non-chemical farming. This is an extremely uneven and unfair playing field. Only when widespread testing takes place will consumers be aware of whether or not they are consuming poisons, and, if so, exactly which ones. In the absence of the required testing infrastructure, this is not happening. Consumers have no idea about the kind of food they are eating in most cases. At the same time, studies have shown that the products of seven leading organic food brands in India had traces of heavy metals in them and some had pesticide residues as well (CERC 2017). This generates a crisis of credibility about those professing to practice alternative forms of farming.

The only way out is massive public investments in product testing facilities, where contaminants, toxins, and chemical residues are all tested for. Currently, toxins and contaminants are rarely tested for, and even chemical residue testing remains fragmentary.[18] What is worse, when private

[17] The agriculture programme of Samaj Pragati Sahayog and the farmer-to-farmer video extension programme of its Community Media Unit is a great example of a women-led, technology-based agricultural extension system (see samajpragatisahayog.org for full details).

[18] This is despite the fact that the FSSAI clearly states that organic food shall also comply with relevant provisions, as applicable under the Food Safety and Standards (Contaminants, Toxins and Residues) Regulations, 2011 except for residues of

commercial entities do the testing, they have a great vested interest in providing favourable reports, because, otherwise, they risk losing even the few farmers who come to them for testing. The high cost of testing a food sample for residues of chemical pesticides, heavy metals, and aflatoxins makes it difficult to test a sufficient number of samples to thoroughly screen batches of agricultural produce at different stages in the value chain. As a result, the process of certification becomes extremely cumbersome and expensive, beyond the reach of the vast majority of small and marginal farmers. This high cost is another potential impediment to farmers being able to adopt agro-ecological farming at scale. It is clear that individual farmers will never be able to afford the costs involved in the process. This is another area where FPOs and other collectives of small and marginal farmers become critical. We must also note that while these "demerit" goods are at least under discussion, there is virtually no recognition of the need to identify the positive nutritional value of food. The Nature-Positive Farming and Wholesome Foods Foundation (N+3F), set up in 2021, is pioneering work in this direction by evolving appropriate protocols to ensure food safety and traceability at each stage of the farm-to-plate value chain. It is also supporting farmer collectives in adopting these protocols and moving up the value chain.

The state also needs to intervene so that neither the farmer nor the consumer ends up bearing the entire cost of testing. Of course, state labs need to function at the highest standards of excellence. The recent imbroglio involving the Agricultural and Processed Food Products Export Development Authority (APEDA) is a sobering case in point (Mancombu 2021). In July 2021, the United States Department of Agriculture (USDA) ended its 15-year agreement with the APEDA, which allowed APEDA to accredit agencies certifying organic exports to the US. In November 2021, four European Union (EU) organizations dealing with organic products asked the EU Committee on Organic Production to stop APEDA from accrediting agencies certifying organic products in India. They also asked the EU to delist India from the list of countries recognized for organic product exports to the EU and directly supervise shipments from the subcontinent, just like the US is doing now.[19]

---

insecticides for which the maximum limits shall be 5% of the maximum limits prescribed or Level of Quantification (LoQ) whichever is higher (FSSAI 2017).

[19] The Participatory Guarantee System (PGS) also suffers from numerous operational and efficiency bottlenecks, which prevent it from being a model for scaling agro-ecological farming in a way that enables traceability.

Other areas for public investment are large-scale and separate processing storage (like hermetic technology),[20] transport facilities for the produce of nature-positive farmers so that it does not get contaminated by the produce of conventional chemical farmers, and support for the adoption of non-chemical pest management in post-harvest value chain stages. If we really want to promote crop diversification, we need improved moisture- and temperature-sensitive storage. Dry and cool produce can be stored for longer periods. This demands major investments in new technologies that are now easily available. For nutri-cereals, processing remains an unaddressed challenge; and they also require special storage and transport facilities given their shelf-life issues. Public investment is also needed for user-focused research for developing appropriate solutions to address all of these challenges.

For any transition towards sustainable solutions, we need to address the regime of heavily subsidised fossil fuel–based mainstream agriculture, which will be able to easily out-compete any alternative. If the real economic, as well as the ecological, costs of GR farming were to be factored into the calculation, along with its multiple negative externalities, the agro-ecological paradigm would win hands-down in comparison. Since this is an extremely daunting challenge, much more careful thought needs to be given to outlining the exact roadmap by which India will transition to a safe and nutritious food regime. The FSSAI has based its standards on the best European practices, but we need to carefully study the process through which our farmers can get there. This needs urgent attention and change. It is time now, therefore, for the NITI Aayog to set up a High-level Working Group to examine the entire issue of post-harvest infrastructural support more deeply, including product testing. This is necessary to ensure that the high cost of testing does not lead to a situation where the FPOs of small and marginal farmers get elbowed out by large corporations as the process of testing goes beyond the reach of these FPOs. The Terms of Reference of the NITI Aayog Working Group should include estimating the nature and volume of the public and private investment required while spelling out the roadmap by which India can transition to a consumer- and farmer-friendly regime of safe and nutritious food.

Dismantling Barrier #9: Outmoded Architecture of Water Governance

---

[20] Hermetic technology uses gas-tight and moisture-tight materials to seal or store commodities that are prone to deterioration when exposed to air, moisture, or foreign objects.

For agro-ecology to be established, and for the water crisis to be addressed, there must be a paradigm shift in water away from the construction- and extraction-centric, the command-and-control system of water governance towards a participatory system that incorporates the common pool resource (CPR) nature of water. We also need to bridge the three silos into which we have divided water, viz, those between:

- surface and groundwater;
- drinking water and irrigation;
- water and wastewater.

Moreover, since systems such as water are greater than the sum of their constituent parts, solving water problems requires understanding whole systems and deploying multi-disciplinary teams and a trans-disciplinary approach, as is the case of the best water resource departments across the globe. Since we have written extensively elsewhere on this issue, we will not get into complete detail here, for which Shah *et al.* (2021) would be the best reference.

Without these urgent water reforms being put into place, farming in India will continue to be dominated by unsuitable water-intensive crops, over-exploitation of groundwater, and vanishing rivers—all of which are ultimately combining to make farming an unviable occupation in India today.

Dismantling Barrier #10: Absence of Documentation, Monitoring, and Research Making Proof-of-Concept Harder to Establish

Whenever an argument is made in favour of seeking alternatives to GR farming, questions are always raised about the evidence in favour of these alternatives. Even though such demands are often made by vested interests who benefit from the current high-cost, external input–intensive, and energy-intensity farm systems, all votaries of agro-ecological farming must proactively demand that systems of documentation, monitoring, and research are urgently put in place at the requisite scale.[21] We clearly do not want a new kind of mindless fundamentalism replacing the orthodoxy of the GR. Furthermore, the case for alternatives only gets stronger with such a system in place as robust proof-of-concept becomes demonstrably visible on the ground. It also allows proponents of alternatives to fine-tune their

[21] A very promising attempt at developing such a framework is to be found in Muthuprakash and Damani (2018).

solutions in line with the diverse agro-ecology of India, which is precisely the whole point against the one-size-fits-all fundamentalism of the GR.[22]

Dismantling Barrier #11: Agriculture Education Mired in the GR Paradigm

All the reforms that we have listed above require a total re-orientation of the paradigm within which agricultural education is located in India today. Our agriculture scientists are still being trained in the mid-20th century GR paradigm, taking a narrow commodity-centric view focused on the limited question of raising crop yields per acre. Without a whole systems view of farming, which considers all aspects of the farm as an ecosystem with each and every one of its interconnected parts taken into account combined with an understanding of the soil as a living ecosystem, the new paradigm of agro-ecology cannot be instituted. Thus, both agriculture R&D and farm extension will need to be re-oriented on the basis of a revamped curricula for agricultural science education in India to align it with 21st-century perspectives. The new National Agricultural Education Policy provides a great opportunity for this radical change to be brought into effect, but even this proposed policy would require a complete overhauling of the paradigm within which agricultural education remains mired.

4. CONCLUSION

The unprecedented COVID-19 pandemic is an overdue wake-up call to humanity that business-as-usual is no longer an option. We cannot continue with development paradigms that attempt a command-and-control relationship with nature. COVID-19 has reminded everyone, like never before, how circumscribed the economy necessarily is by the nature of the larger ecosystem governing it. As the imprint of humans on the planet grows larger than ever in the epoch of the Anthropocene, a decisive shift in our relationship with nature becomes imperative.

It is not merely a matter of realizing the constraints within which we operate but of re-envisioning the response: moving from a paradigm of linear mechanics that guided the GR to thinking in terms of complex dynamics that underlie agroecology. We increasingly need to learn to deal with the unforeseen and the inherently unpredictable. The pandemic forces

[22] The setting up of the Indo-German Global Centre for Agro-ecology Research and Learning in Andhra Pradesh in 2021 is a very welcome step in this direction.

everyone to acknowledge that this is now imperative, not just for greater prosperity but for the very survival of human life on Earth.

Agriculture, the most important occupation of people in India, is the sector closest to nature. Sadly, however, even in farming, we have attempted to gain complete control over nature rather than seeking to align with it, even while harnessing its power. The dominance of chemical farming has had very serious, but not fully understood, consequences. 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 (Brown 2020, 7).

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, 2).[23]

This necessitates a paradigm shift in our structures of thought and action to grasp complex adaptive systems (where the complexity of the behaviour of the whole system cannot be completely seen solely through an understanding of its individual parts), of which farming is a very important example (Holland 1998; Gal 2012).

It is clear that India needs to make a strong move forward towards the agro-ecological paradigm of farming. The challenges are many, but the solutions and the impact pathways within which they need to be embedded

---

[23] The pandemic has also thrown sharp light on the perils of the current paradigm of industrial livestock production, something that is beyond the scope of the present paper but merits equal if not even greater attention (Wallace 2016).

are clear and have been amply demonstrated on the ground. India has seen strong farmers' agitations over the past few years. Perhaps the key determinant of whether or not policy will move in the direction advocated in this paper is the adoption and strong advocacy by these farmers' movements of the agenda outlined here. Another crucial factor will be the work of civil society organizations in close partnerships with state governments to create a robust proof-of-concept on the ground at scale so that this evidence attains the critical mass needed to move policy in the right direction.

ACKNOWLDEGEMENT

I gratefully acknowledge the careful reading of the first draft by Sanchita Bakshi, M Karthikeyan, Rohit Parakh, Rangu Rao, and PS Vijayshankar and their very useful suggestions. I would also like to thank the editors and anonymous reviewers of the journal for their extremely insightful inputs that have greatly improved the readability of the essay.

REFERENCES

Addiscott, TM. 2010. "Soil Mineralization: An Emergent Process?" *Geoderma* 160 (1): 31–35. https://doi.org/10.1016/j.geoderma.2010.03.016

Aga, Aniket. 2019. "The Marketing of Corporate Agrichemicals in Western India: Theorizing Graded Informality." *Journal of Peasant Studies* 46 (7): 1458–1476. https://doi.org/10.1080/03066150.2018.1534833

Ahluwalia, Meenakshi and Anupam Kaur. 2020. "Assessment of Chromosomal Aberrations among Agricultural Workers Exposed to Pesticides in Punjab, India." *Journal of Biochemical and Molecular Toxicology* 35 (2): e22646. https://doi.org/10.1002/jbt.22646

Altieri, Miguel A, ed. 1995. *Agroecology: The Science of Sustainable Agriculture*. Boca Raton, United States of America: Taylor and Francis.

Altieri, Miguel A, Clara I Nicholls, Alejandro Henao, and Marcos A Lana. 2015. "Agroecology and the Design of Climate Change–resilient Farming Systems." *Agronomy for Sustainable Development* 35 (May): 869–890. https://doi.org/10.1007/s13593-015-0285-2.

Altieri, Miguel A and Clara I Nicholls. 2020. "Agroecology and the Reconstruction of a Post-COVID-19 Agriculture." *The Journal of Peasant Studies* 47 (5): 881–898. https://doi.org/10.1080/03066150.2020.1782891

Anderson, Colin Ray, Janneke Bruil, M Jahi Chappell, Csilla Kiss, and Michel Patrick Pimbert. 2021. *Agroecology Now! Transformations Towards More Just and*

Sustainable Food Systems. London: Palgrave Macmillan. https://doi.org/10.1007/978-3-030-61315-0

Arsenault, Chris. 2014. "Only Fifty Years of Farming Left if Soil Degradation Continues." *Scientific American*, December 5. https://www.scientificamerican.com/article/only-60-years-of-farming-left-if-soil-degradation-continues/

Baveye, Phillipe C, Wilfred Otten, Alexandra Krachenko, Balseiro-Romero María, Beckers Éléonore, Chalhoub Maha, Darnault Christophe, Eickhorst Thilo, Garnier Patricia, Hapca Simona, *et al.* 2018. "Emergent Properties of Microbial Activity in Heterogeneous Soil Microenvironments." *Frontiers in Microbiology* 9 (August): 1929. https://doi.org/10.3389/fmicb.2018.01929

Kamaljit S Bawa, Nandan Nawn, Ravi Chellam, Jagdish Krishnaswamy, Vinod Mathur, Shannon B Olsson, Nitin Pandit, Prabhakar Rajagopal, Mahesh Sankaran, R Uma Shaanker. 2020. "Envisioning a Biodiversity Science for Sustaining Human Well-being." *Proceedings of the National Academy of Sciences* 117 (42). https://doi.org/10.3389/fmicb.2018.01929

Benton, Tim G and Rob Bailey. 2019. "The Paradox of Productivity: Agricultural Productivity Promotes Food System Inefficiency." *Global Sustainability* 2: e6. https://doi.org/10.1017/sus.2019.3

Bossio, Deborah, Andrew D Noble, David James Molden, and Vinay Nangia. 2008."Land Degradation and Water Productivity in Agricultural Landscapes." In *Conserving Land, Protecting Water. Comprehensive Assessment of Water Management*, edited by D Bossio and K Geheb, pp. 20–32. Wallingford, United Kingdom: Centre for Agriculture and Bioscience International (CABI). https://doi.org/10.1079/9781845933876.0020

Brown, Kate. 2020. "The Pandemic Is Not a Natural Disaster." *The New Yorker,* April 13. https://www.newyorker.com/culture/annals-of-inquiry/the-pandemic-is-not-a-natural-disaster.

CERC. 2018. "Toxic Pesticides and Heavy Metals in Moong Dal." India: Consumer Education and Research Centre.

Chaba, Anju Agnihotri. 2021. "Less Department Staff, Lesser Motivation: How Agriculture Extension Collapsed in Punjab?" *Indian Express*, November 27. https://indianexpress.com/article/cities/chandigarh/less-department-staff-lesser-motivation-how-agriculture-extension-collapsed-in-punjab-7644257/

Chauhan, Bhagirath S, Gulshan Mahajan, Virender Sardana, Jagadish Timsina, Mangi L Jat, 2012. "Productivity and Sustainability of the Rice-Wheat Cropping System in the Indo-Gangetic Plains of the Indian Subcontinent: Problems, Opportunities, and Strategies." *Advances in Agronomy* 117: 315–369. https://doi.org/10.1016/B978-0-12-394278-4.00006-4

Corsini, E, J Liesivuori, T Vergieva, H Van Loveren, and C Colosio. 2008. "Effects of Pesticide Exposure on the Human Immune System." *Human & Experimental Toxicology* 27 (9). https://doi.org/10.1177/0960327108094509

DAC (Directorate of Economics and Statistics, Department of Agriculture, Co-operation and Farmer Welfare). 2020. *Agricultural Statistics at a Glance*. Delhi: Ministry of Agriculture and Farmers Welfare, Government of India. https://eands.dacnet.nic.in/

Dawson, Ian K, Simon Attwood, Sarak Park, and Ramni Jamnadass. 2019. *Contributions of Biodiversity to the Sustainable Intensification of Food Production – Thematic Study for The State of the World's Biodiversity for Food and Agriculture*. Rome: FAO. https://doi.org/10.1016/j.gfs.2019.07.002

Deleuze, Giles and Felix Guattari. 1987. *A Thousand Plateaus: Capitalism and Schizophrenia*. Minneapolis: University of Minnesota Press.

Donthi, Narasimha Reddy. 2021. "Pesticide Poisoning in India Challenges of Data and Management in Public Health." *Economic and Political Weekly* 12 (45–46).

Expert Committee. 2019. *Report on Policies and Action Plan for a Secure and Sustainable Agriculture*. New Delhi: Principal Scientific Advisor, Government of India. https://static.psa.gov.in/psa-prod/publication/Report%20of%20Policies%20and%20Action%20for%20Agriculture.pdf

Falconer Ruth E, Alasdair Houston, Wilfred Otten, and Philippe Baveye, 2012. "Emergent Behavior of Soil Fungal Dynamics: Influence of Soil Architecture and Water Distribution." *Soil Science* 177 (2). https://doi.org/10.1097/SS.0b013e318241133a

FE Bureau. 2018. "Government Renames Millets as Nutri Cereals", *Financial Express*, April 21. https://www.financialexpress.com/market/commodities/government-renames-millets-as-nutri-cereals/1140338/

FSSAI (Food Safety and Standards Authority of India). 2017 (29 December). *Gazette Notification*. New Delhi: Ministry of Health and Family Welfare, Government of India.

Francis, Charles A, ed. 1986. *Multiple Cropping Systems*. London: MacMillan.

Gal, Orit. 2012. "Understanding Global Ruptures: A Complexity Perspective on the Emerging Middle Crisis." In *Complex New World*, edited by Tony Dolphin and David Nash. London: The Institute for Public Policy Research (IPPR).

Ghosh, PK, KK Hazra, MS Venkatesh, and Chaitanya Prasad Nath. 2017. "Increasing Soil Organic Carbon through Crop Diversification in Cereal – Cereal Rotations of Indo-Gangetic Plain." *Proceedings of the National Academy of Sciences, India – Section B: Biological Sciences* 89 (156). https://doi.org/10.1007/s40011-017-0953-x

Global Hunger Index. 2021. "Global Hunger Index – India." https://www.globalhungerindex.org/india.html.

Gutierrez, Andrew Paul. 2018. "Hybrid Bt Cotton: A Stranglehold on Subsistence Farmers in India," *Current Science* 115 (12): 2206–10. https://doi.org/10.18520/cs%2Fv115%2Fi12%2F2206-2210

Gulati, Seema and Anoop Misra. 2014. "Sugar Intake, Obesity, and Diabetes in India." *Nutrients* 6 (12): 5955–74. https://doi.org/10.3390/nu6125955

Hecht, Susanna B. 1995. *The Evolution of Agroecological Thought*. CRC Press.

Holland, John Henry. 1998. *Emergence: From Chaos to Order*. Wilmington, Delaware: Helix Books.

Indoria, Ashok Kumar, KL Sharma, Kotha Sammi Reddy, Srinivasrao CH, Srinivas Karlapudi, M Osman, Pratibha Gudapaty, NS Raju. 2018. "Alternative Sources of Soil Organic Amendments for Sustaining Soil Health and Crop Productivity in India — Impacts, Potential Availability, Constraints and Future Strategies." *Current Science* 115 (11): 2052–62. https://doi.org/10.18520/cs/v115/i11/2052-2062

Jena, Diptimayee and Srijit Mishra. 2021. *Procurement and Public Distribution of Millets in Odisha – Lessons and Challenges*. RRA Policy Brief. Rainfed India.

Jepson, Paul C, Katie Murray, Oliver Bach, Maria Bonilla, and Lars Neumeister. 2020. "Selection of Pesticides to Reduce Human and Environmental Health Risks: A Global Guideline and Minimum Pesticides List." *The Lancet Planetary Health*, 4 (2): e56–e63. https://doi.org/10.1016/S2542-5196(19)30266-9

Khera, Reetika, Narayanan, Sudha, and Prankur Gupta. 2020. "MSP — The Factoids Versus the Facts." *The Hindu*, December 19. https://www.thehindu.com/opinion/lead/msp-the-factoids-versus-the-facts/article33367929.ece

Lal, Rattan. 2012. "Soil Water and Agronomic Production." In *Soil Water and Agronomic Productivity,* edited by Rattan Lal and BA Stewart. Boca Raton, United States of America: CRC Press. https://doi.org/10.1201/b12214

Lent, Jeremy. 2017. *The Patterning Instinct: A Cultural History of Humanity's Search for Meaning*. Amherst, New York: Prometheus.

Mancombu, Subramani Ra. 2021. "End APEDA Supervision of Agencies Certifying Organic Products Export." *The Hindu – Business Line*, November 10.

Mann, Charles C. 2018. *The Wizard and the Prophet: Two Ground Breaking Scientists and their Conflicting Visions of the Future of our Planet.* New York: Penguin.

Margni, Manuele, D Rossier, P Crettaz, and Olivier Jolliet. 2002. "Life Cycle Impact Assessment of Pesticides on Human Health and Ecosystems." *Agriculture, Ecosystems & Environment* 93: 379–392. https://doi.org/10.1016/S0167-8809(01)00336-X

Mathur, Meeta and Sujeet Ranjan. 2021. "Can Magic Millets Provide a Solution for Malnutrition?" *Outlook*, February 21. https://poshan.outlookindia.com/story/poshan-news-can-magic-millets-provide-a-solution-for-malnutrition/374898

Miller, Norman. 2021. "The Forgotten Foods that Could Excite Our Tastebuds." *BBC.* https://www.bbc.com/future/bespoke/follow-the-food/the-forgotten-plants-that-could-excite-our-tastebuds

Muthuprakash, Siva and Om Damani. 2018. "Development & Application of Farm Assessment Index: Towards A Holistic Comparison of Organic and Chemical Farming." *Agroecology and Sustainable Food Systems*.

NICRA. 2020. National Innovations in Climate Resilient Agriculture (NICRA). New Delhi: Indian Council of Agricultural Research. http://www.nicra-icar.in/nicrarevised/index.php/project-details.

Nicolopoulou-Stamati, Polyxeni, Sotirios Maipas, Chyrsanthi Kotampasi, Panagiotis Stamatis, and Luc Hens. 2016. "Chemical Pesticides and Human Health: The Urgent Need for a New Concept in Agriculture." *Frontiers in Public Health* 4: 148. https://doi.org/10.3389/fpubh.2016.00148.

NITI Aayog. 2020. "Agroecology and Natural Farming Could Accelerate Inclusive Economic Growth in India". New Delhi: Press Information Bureau. https://pib.gov.in/PressReleasePage.aspx?PRID=1628285.

Norgaard, Richard B and Thomas O Sikor. 1995. *The Methodology and Practice of Agroecology*. CRC Press.

Pal, Dilip Kumar, Tapas Bhattacharyya, Pankaj Srivastava, P Chandran, and SK Ray. 2009. "Soils of the Indo-Gangetic Plains: Their Historical Perspective and Management." *Current Science* 96 (9).

Repetto, R and SS Baliga. 1996. "Pesticides and Immunosuppression: The Risks to Public Health." *Health Policy and Planning* 12 (2): 97–106. https://doi.org/10.1093/heapol/12.2.97

Shah, Mihir. 2013. "Water: Towards a Paradigm Shift in the Twelfth Plan." *Economic and Political Weekly* 48 (3), January 19.

Shah, Mihir. 2017. "Farmer Protests: Over-reliance on a Single Crop Has Cost Them Dear." *Hindustan Times*, 27 June. https://www.hindustantimes.com/indianews/here-s-why-farm-protests-have-been-loudest-in-punjab-haryana/story-G18qzwYWo7UuvrFmb06xuK.html

Shah, Mihir. 2019. "Water Reform Must Begin at the Farm." *Business Standard*, 7 June. https://www.business-standard.com/article/opinion/water-reform-must-begin-at-the-farm-119060700054_1.html

Shah, M, D Banerji, PS Vijayshankar, and P Ambasta. 1998. *India's Drylands: Tribal Societies and Development through Environmental Regeneration*. New Delhi: Oxford University Press.

Shah, M, PS Vijayshankar, and Francesca Harris. 2021. "Water and Agricultural Transformation in India: A Symbiotic Relationship." *Economic and Political Weekly* 56 (29).

Sharma, Manraj Grewal. 2020. "Rattan Lal: Soil, a Living Being, Can Boost Farm Output, Mitigate Climate Change," *Indian Express*, 23 June. https://indianexpress.com/article/india/world-food-prize-winner-rattan-lal-soil-a-living-being-can-boost-farm-output-mitigate-climate-change-6470075/

Shiva, V and R Prasad. 1993. *Cultivating Diversity: Biodiversity Conservation and Seed Politics*. Dehradun: Natraj Publishers.

Swinburn, Boyd A, Vivica I Kraak, Steven Allender, Vincent J Atkins, Phillip I Baker, Jessica R Bogard, Hannah Brinsden, Alejandro Calvillo, Olivier De Schutter, Raji Devarajan, *et al.* 2019. "The Global Syndemic of Obesity, Undernutrition, and Climate Change." *The Lancet Commissions* 393 (10173): P791–846. https://doi.org/10.1016/S0140-6736(18)32822-8

Tamburini, Giovanni, Riccardo Bommarco, Cherico Wanger, Claire Kremen, Marcel G A Van Der Heijden, Matt Liebman, and Sara Hallin. 2020. "Agricultural Diversification Promotes Multiple Ecosystem Services Without Compromising Yield." *Science Advances* 6 (45).

Thomson Jacob, C, Ajay Parida, and NK Krishna Kumar. 2020. "Conservation of India's Agrobiodiversity Towards Increasing Food, Nutritional and Livelihood Security." *Current Science* 119 (4). https://doi.org/10.18520/cs/v119/i4/607-612

Tomlinson, BR. 2013. *The Economy of Modern India from 1860 to the Twenty-First Century*. Cambridge: Cambridge University Press. https://doi.org/10.1017/CBO9781139108638

Vandermeer, John H. 1989. *The Ecology of Intercropping*. Cambridge: Cambridge University Press. https://doi.org/10.1017/CBO9780511623523

Vijayshankar, PS, Himanshu Kulkarni, and Sunderrajan Krishnan. 2011. "India's Groundwater Challenge and the Way Forward." *Economic and Political Weekly* 46 (2).

Wallace, Robert G. 2016. *Big Farms Make Big Flu: Dispatches on Influenza, Agribusiness and the Nature of Science*. Monthly Review Press.

WHO. 2011. *Nitrate and Nitrite in Drinking Water*. New Delhi: World Health Organization.