

Article

A New Paradigm for Transforming Indian Agriculture

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Abstract

India's policymakers and farmers have a huge responsibility to make India a developed nation by the 100th anniversary of freedom and achieving the UN sustainable development goals of zero hunger, nutrition security and overcoming poverty. Ensuring food security for a growing population (estimated at 1.66 billion in 2050), in the context of growing water scarcity, land degradation, impacts of climate change and large yield gaps is a mammoth task. The farmers, agricultural scientists, extension staff, and policy makers have so far done a great job of ensuring food security for the 1.4 billion population. However, given the rising challenges there is an urgent need to use new scientific tools such as ICT, AI, cloud computing, drones, remote sensing for providing integrated and holistic solutions. Using the 4-ISEC model and creating value-chains by strengthening the science of delivery to reach 147 million farmers and promoting collective efforts through Farmer Producer Organisations (FPOs), and enhancing resource use efficiency are necessary steps to achieve India's farming and food security goals.

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Prime Minister Narendra Modi on the occasion of the 75th anniversary of India's Independence called on the Indian people to ensure that by the 100th anniversary of Independence in 2047, India becomes a developed nation. With an estimated 64.61 percent of the Indian population living in the rural areas¹ where livelihood is agriculture-based, a huge responsibility rests on the shoulders of policy makers and farmers not only to ensure food and nutrition security for the population but also to contribute proactively to making India a developed nation. Indian farmers, agricultural scientists, extension staff, policymakers, and administrators did a great job of transforming the country from a net importer of food in the 1960s to becoming a self-sufficient and food-secure Bharat (India). India is now surplus in food production which touched 316.06 million tonnes which is higher by 4.82 million tonnes than in 2020-2021.²

But the next 25 years will pose very different challenges for sustaining food production. The World Population Prospects (WPP) estimates that India's population will rise from the present 1.4 billion to 1.66 billion by 2050. Such rapid strides in population in India have serious implications, particularly for food production and water availability, as 80 percent of water withdrawals in India are for agriculture. Thus, rising population and rising incomes would place new demands on food. Climate change brings with it uncertainties in monsoon rainfall, weather conditions, as well as heat waves, forest fires, floods and droughts, and wide price fluctuations in farm produce. India, therefore, needs transformative changes in its agricultural policies and practices if it is to have sustainable agriculture, food sufficiency and variety.

The New Agrarian Phase and Growing Challenges

India faces three major supply challenges which must be overcome if the agricultural sector is to meet the rising food demands of the people and ensure that incomes of the farming families also increase steadily. These are: water scarcity, degradation of land, and climate change.

Water Scarcity

India entered the league of water-deficient nations (below 1700 cubic meters per person) per year during the 2011 census and joined the league of the most water-stressed countries. Per capita, water availability in 1951 was 5177 m³ per year which has fallen to 977 cubic meters in 2010 and was expected to reach 802 cubic meters in

2022 and 677 in 2050 due to population growth. India shares 17 percent of the world's population and only 4 percent of water globally. Meeting food demand for the growing population in tropical India with limited arable land and water resources is a challenge during the 21st century. Growing competition over finite water resources, compounded by climate change impacts and also the growing incomes of the people is likely to have serious implications for India's food security, the livelihoods of farmers and India's development trajectory. As per the World Economic Forum estimate, 51 percent of the population comprising some 350 million people will be in the upper middle, high income and high consuming category by 2030 as compared to 24 percent in 2020.³ With increasing urbanisation, shrinking farm size, developments in education, migration from villages to cities in search of better livelihoods, and increasing incomes, more people are taking to animal-based food, and the number of vegetarians are shrinking (Table 1).

Table 1. Increasing Population, Water Footprint and Freshwater Demand

Parameters	2010	2022	2050
Population in India (Million)	1150	1400	1600
Vegetarian Percentage Population	60 %	50 %	40 %
Vegetarian Population (Million)	690	700	664
Non-Vegetarian Population (Million)	460	700	996
Daily water footprint for Vegetarian diet, Litre/day	4500		
Daily water footprint for Non-Vegetarian diet, Litre/day	15000		
Annual water requirement for Vegetarian diet (BCM)	1133	1149	1090
Annual water requirement for Non-Vegetarian diet (BCM)	2519	3832	5453
Total water requirement (BCM)	3652	4981	6543

Source : Derived from Water Demand in India in 2010-2050 by Sector-Statista 2021.

*Population used for 2022 is the actual population and for 2050, it is estimated by the UN.

With an annual average rainfall of 1180 mm, India does not face a water crisis, but its management of water resources demands urgent attention, particularly so in agriculture. In most rain-fed areas, water availability is not a problem, but rainfall

distribution and poor management create water scarcity for crops, resulting in low rainwater use efficiency and low crop production.⁴ India receives half of its annual rainfall in just 15 days making floods and drought a fact of life in the country.

Normally, when people talk about water scarcity, they refer to it as a blue water issue. Farmers and policymakers always see the provision of irrigation (blue water) as the first and easy option, overlooking the large opportunities possible in the management of green water (ground water) resources in the landscape as per the Comprehensive Assessment of green and blue water.⁵ Compared to the 6.5 billion global population facing blue water stress by 2050, only 0.27 billion will have water scarcity if both green and blue water are considered together. Fields in Punjab and Haryana, Uttarakhand, and western Uttar Pradesh, where irrigation canals are in abundance, experience lavish use of water from the rivers of the Himalayas. This has reduced the flow of water downstream and increased water scarcity in the plains. Similar is the situation in the *Cauvery* and *Godavari* basins. As a result, *Bundelkhand*, *Marathawada*, and the *Deccan* region are areas of acute water distress. The lengthy court litigation and the political war of words between Tamil Nadu and Karnataka would not have erupted over *Cauvery* water sharing had water been efficiently used for agriculture.

Land Degradation

Land degradation is a serious problem worldwide and has been in existence in the past as well. However, the pace of natural resource degradation has greatly increased in recent times due to the burgeoning population and the increased exploitation of natural resources. Global food systems are responsible for 80 percent of the world's deforestation, 70 percent of freshwater use and 40 percent of the planet's degraded land, according to the latest report by the United Nations Convention to Combat Desertification (UNCCD). The cost to restore one billion degraded hectares (2.47 billion acres) of land by 2030 is estimated to be \$300 billion annually. Investing in restoration creates benefits that exceed the costs, says the report, as every dollar invested in restoration activities provides a \$7-30 return in economic benefits.⁶ The global experiences relating to land degradation highlights the significance of the processes (loss of soil organic matter, soil physical degradation, nutrient depletion, chemical degradation, soil erosion and sedimentation, and degradation of landscape functions) that are closely linked to water use and management.⁷

Some 97.85 million hectares — nearly 30 percent of India’s land — had degraded by 2018-19, according to the *Desertification and Land Degradation Atlas of India*, released by the Space Applications Centre of the Indian Space Research Organisation. Land degradation has increased with the availability of irrigation, leading to erosion, rising salinity, overuse of irrigation as well as run-off, nutrient loss and lower productivity. Inappropriate use of chemical fertilisers, overuse of nitrogen, use of di-ammonium phosphate in place of single super phosphate have caused sulphur deficiency in many farms such as those in the soybean growing areas in Madhya Pradesh, and led to nutrient depletion and land degradation.

Nearly 30 percent of India’s land had degraded by 2018-19.

The emergence of secondary and micro-nutrients deficiency in rain-fed areas has caused and continues to cause land degradation in India. Soil health is severely affected due to land degradation and is in need of urgent attention. Often, soil fertility is the limiting factor to increased yields in rain-fed agriculture.⁸ Soil degradation, through nutrient depletion and loss of organic matter, causes serious yield decline. It also affects water availability for crops as a result of poor rainfall infiltration and plant water uptake due to weak roots. Nutrient mining is a serious problem in smallholder rain-fed agriculture. On-farm diagnostic work of the International Crops Research Institute for the Semi-Arid Tropics (ICRISAT) in different community watersheds in different states of India, as well as in Southern China, North Vietnam, and Northeast Thailand, showed severe mining of soils for essential plant nutrients, including secondary micronutrients, and macronutrients.⁹ Land degradation reduces water use efficiency (WUE) at field and landscape scales and affects water availability, quality, and storage. Because of this strong link between land and water productivity, improving water management in agriculture requires land degradation to be mitigated or prevented.

Climate Change

Climate change is already at our doorstep, its implications are going to be borne by the poor and the small and marginal farm-holders. Climate change will have a large effect on water globally which will vary regionally due to spatially variable changes in precipitation, increased rate of glacier melt and retreat affecting river water flows, greater evaporation due to an increase in temperature, and higher water demand. These changes are likely to affect all aspects of agricultural water management, including irrigation availability, soil moisture, evapotranspiration, and run-off as well as rainwater

harvesting.¹⁰ Rain-fed agricultural economies are largely based on weather-sensitive agricultural production systems.¹¹ The semi-arid areas have increased by 8.45 million hectares (m ha) in Madhya Pradesh, Bihar, Uttar Pradesh, Karnataka, and Punjab, resulting in an overall 3.45 m ha addition to semi-arid tropics (SAT) (Figure 1) is a concern as the areas affected are granaries of India.¹² Dryness and wetness are increasing in different parts of the country in the place of moderate climates existing earlier in these regions. Finally, ecosystems, whether freshwater, coastal, marine, or terrestrial, require water to sustain the provision of services, which are indispensable for human well-being. Water-related climate risks cascade through food, energy, urban, transportation, and environmental systems with mutual and conflicting influences. Therefore, a cross-sectoral approach is needed to address not only the potential impacts of climate change within a sector, but also the interactions between the sectors.

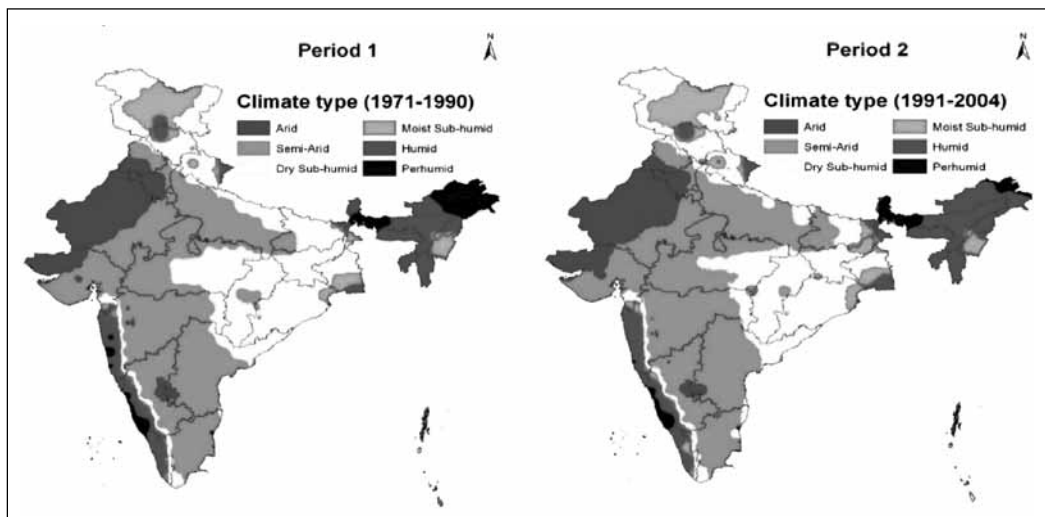


Figure 1. Changes in agro-climatic regions in India due to climate change during 1971-1990 and 1991-2004

At present, farmers' crop yields are low in India, with large yield gaps (0.5 to 5 t ha⁻¹) based on the agro-eco region and the technologies used by the farmers.¹³ Large yield gaps for rice (5.47 q ha⁻¹), maize (12.77 q ha⁻¹), oil seeds, and field peas have been reported.¹⁴ The yield gaps for several crops and overall yields can be substantially increased by improving the science of delivery, using new technologies, as a large number of farmers (51%) in India do not get any extension support.¹⁵ Considering the vast canvas of agriculture for production, a large local market, enabling policies, and significant

scope for value addition and export through infrastructure development, the huge potential of Indian agriculture can be harnessed for making her a powerhouse for food production -- not only for India but for the world.

New Paradigm in Indian Agriculture

Considering the importance of agriculture and its role in meeting the Sustainable Development Goals (zero hunger, nutrition security, income security, gender equality, clean water and sanitation, climate action, etc.), as well as India’s growth trajectory, there is an urgent need to transform the agriculture sector in the country by adopting a new paradigm in agriculture for sustainable development. The complexities and challenges can be overcome using new technologies and innovative, enabling, and implementable policies with proper implementation, monitoring and evaluation. As it is said “*What gets measured gets delivered*”, effective monitoring is the key for harnessing the potential through a new paradigm.

Challenges can be overcome using new technologies and innovative, enabling, and implementable policies.

Four ISECs Model: Co-operation for Innovation and Impact

Indian agriculture needs to be transformed to become climate resilient and sustainable, adopting an integrated and holistic approach through building partnerships by discarding the compartmental approach through the consortium and adopting the 4-ISECs (Innovate, Sustainable, Economic Gain, Consortium) strategy. A compartmental approach has deprived the farmers of knowledge about new technologies, markets, and impacts of climate change as the current extension system is not reaching 51 percent of farmers in India. The consortium approach involves a number of stakeholders/ partners and is a multidisciplinary and multisector approach providing end-to-end

4-ISECs

Innovate	Sustainable	Economic Gain	Consortium
Inclusive	Socially Acceptable	Equity	Collective
Intensive	Scalable	Efficiency	Capacity Building
Integrated	Synergistic	Environment Protection	Convergence

solutions to the farmers. Participatory integrated watershed management based on a consortium approach is one of the tested, sustainable, scalable, and eco-friendly options.¹⁶ The innovative approach is briefly described as 4-ICES¹⁷ (later revised to 4-ISECs).¹⁸

Crossing the “Death Valley of Impacts”

In spite of the availability of game-changing technologies with the researchers for increasing agricultural productivity, large yield gaps for all crops are observed in India due to the existence of the *Death Valley of impacts*.¹⁹ Science needs to change its focus for crossing the *Death Valley* of impacts to achieve real impact.²⁰ Scientists, as well as research managers, extension staff, policymakers, donor agencies, publishers of research journals, and farmers, must change their mindset. Community participation which is driven by tangible benefits for society through demand-based solutions rather than supply-driven solutions can change the mindset of people and culture. The belief that staying in rural areas is a no choice option needs to be changed through the development of rural areas with the Provision of Urban Amenities to Rural Areas (PURA) like government initiatives. Change of mindsets and the participation of people are challenges that have to be overcome actively. For crossing the Death Valley of impacts the strategy of building relevant partnerships is a must for providing integrated and holistic solutions to the farmers. Given the climate change impacts and climate variability, there is an urgent need to transform Indian agriculture using science and new technologies and scaling up their adoption to benefit millions of farmers. As discussed earlier, as a country we know “what to do but don’t know how to do it.” Our emphasis should be more on strengthening science of delivery along with science of discovery. The main advantages of the consortium approach include synergy and creativeness in tackling natural resource challenges for which solutions are rarely found with a single discipline expertise.²¹ The capital of partnership/collaboration is far larger than the financial capital and consortium.

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New Technologies for Higher Productivity and Incomes

The main bottleneck for scaling-up new technologies/products with small farm-holders is the absence of reliable information at the right time and right price. To keep pace with the current challenges and aspirations of the farmers’, new technologies

such as Information and Communication Technology (ICT), Remote Sensing (RS), Internet of Things (IoT), Artificial Intelligence (AI), Machine Learning (ML), cloud computing, drones, robots, and nano-technologies, need to be deployed to expand the reach for small farm-holders. Farmers need information not only on best practices and technologies for crop production but also information about post-harvest tasks including processing, marketing, storage, and handling, as well as on allied sectors supporting farmers' livelihoods.²² Fortunately, India has needed talent, technologies, and resources to undertake such a challenge.

The Micro, Small and Medium Enterprises (MSMEs) need to be promoted in rural areas through Farmer Producer Organisations (FPOs) to overcome the problem of fragmented agriculture and to reach a large number of small and marginal farmers. It is necessary to improve their livelihoods through a value-chain approach that would, simultaneously, boost employment. Lack of extension support (technical advice, input, and ideas) for the small farm-holders was identified by the Ceres 2030 researchers (globally based on a meta-analysis of >1000 research papers and reports) as the main constraint for the adoption of new approaches/technologies/products. The small farm-holders are more likely to adopt new approaches -- such as planting climate-resilient crops -- when they are supported by technical advice, input, and ideas. For efficient knowledge delivery at their doorsteps and for providing integrated solutions, Farmers' Clubs, Self-help groups (SHGs), Producer Groups, Farmers' Cooperatives, Common Interest Groups (CIGs), etc., will play an important role in extension services in the near future. Some channels, like input dealers, and private companies try to deliver recommendations with the purpose of commercial benefit. However, if they are not backed by proper promotional and regulatory mechanisms, government should take the initiative to promote them through institutional mechanisms. At the same time, this will help safeguard farmers from any misguided information.

For transforming the service sector as well as farming in India, the government has implemented a spate of quality innovative systems like Aadhar as well as Jan Dhan bank accounts, Direct Benefit Transfer (DBT), Goods and service tax (GST) with e-challans, e-NAM (electronic national agricultural market), etc. This has been done in the shortest possible time for a country of 1.3 billion people. For rural transformation, the will and grit of the government is the need of the hour. The country's data wealth is locked in the lockers of concerned data holders and is not easily available to users

even in other government departments in a timely manner. In the era of information technology, big data, Machine Learning (ML), Artificial Intelligence (AI), etc., can be applied successfully and meaningfully if quality data is available.

The silos which are created with watertight boundaries need to be broken up by reforms that would enable the country to harness the power of the IT revolution. The Ministry of Statistics and Project Implementation has to be strengthened and tasked to work along with the IT Ministry to collect, sanitise, organise, and develop protocols for data security, sharing, and use. Through appropriate mechanisms (policies, incentives, etc.), further fragmentation of land must be checked as smaller and smaller farms are less efficient in total and particularly so in using new technologies such as drones and robots. Government reforms are in this direction, for example, the Ministry of Agriculture has been named Department of Agriculture, Cooperation and Farmers Welfare (DAC&FW), and the new Ministry of Jal Shakti brings together water-related activities of different ministries.

India is moving in the right direction for transforming agriculture in the country as evident from the number of initiatives and concept papers like Indian Digital Ecosystem for Agriculture (IDEA) initiated by the government departments for transforming agriculture through the new Farm Laws. There is an urgent need to promote Public-Private-People Centric Partnerships (4Ps) for the implementation of a holistic and integrated platform. For transforming rural areas, there is an urgent need to build partnerships with public-private corporates for people-centric business initiatives. Co-creation of innovations is promoted by such initiatives as the capital of partnership/collaboration is potentially very large, and a consortium based approach promotes innovation and integration.

The use of drones in agriculture will go a long way in enhancing efficiency and the Government has on January 26, 2022 released a certification scheme for agricultural drones, which can carry a payload that includes chemicals or other liquids used in spraying. The government on January 23, 2022 offered a 100 percent subsidy, up to March 2023, to Farm Machinery Training and Testing Institutes, ICAR Institutes, Krishi Vigyan Kendras (Agriculture Science Centres), and State Agriculture Universities to promote the use of drones for agricultural work and reduce the labour burden of farmers. A contingency fund of Rs. 6,000 per hectare is being created for hiring drones from Custom Hiring Centres (CHCs). The subsidy and contingency funds will assist

farmers in gaining access to and adopting this vital technology at a low cost. In a revolutionary step, the government has already started issuing permissions to scientific institutions to use drones for research and development. Drones are poised to play a significant role in agriculture, particularly in precision agriculture, crop yield improvement, locust control, and reducing costs through increased efficiency of operations. Government approval for the use of drones in pesticide and nutrient applications, coupled with increasing industry participation, is expected to positively influence India's agricultural drone market in the coming years. Drone technology with Artificial Intelligence (AI), Machine Learning (ML), and remote sensing capabilities is becoming popular due to the large benefits. With its online Digital Sky Platform, the central government has acknowledged the importance of unmanned aerial vehicles (UAVs), ML and AI, which is anticipated to rapidly augment drone adoption in the country's agriculture sector.

Enhancing Water Use Efficiency

In place of the current Minimum Support Price (MSP) approach adopted by the government for farmers cultivating crops, there must be an agro-eco region (AER) and market-based farming approach, i.e., "fork to farm" instead of a "farm to fork" approach for achieving the Sustainable Development Goals (SDGs) through enhanced use of water as well as other resources. Emphasis on green water (soil moisture) conservation and its efficient use by reducing run-off and associated soil loss, and avoiding unproductive losses due to evaporation need to be emphasised. Great opportunity exists for improving green water productivity by shifting non-productive evaporation to productive transpiration, with no downstream water trade-off. The current focus on water resource planning at the river basin scale is not appropriate for water management in rain-fed agriculture, which overwhelmingly occurs on farms of <5 ha at the scale of small catchments that are below the river basin scale. Integrated Water Resource Management (IWRM) adoption is a challenging task as it calls for the convergence of several departments related to agriculture, irrigation, drinking water, sanitation, rural development, etc. The Central government has initiated the convergence through the Jal Shakti Ministry, which must be taken forward vigorously. The government of India's emphasis on integrated watershed development is commendable and it needs further strengthening. Along with conservation and efficient use, recycling and safe reuse of wastewater and other ecosystem services must be widely adopted.²³

Enhancing Nutrient Use Efficiencies (NUE)

After the introduction of fertilizer-responsive and high-yielding crop varieties, fertilisers are playing a prominent role in improving food production and enabling the “Green Revolution.” The applied fertilisers are also subjected to various types of losses such as leaching, volatilization, denitrification, fixation, etc., which reduce their efficiency (nitrogen 30-40 percent in rice and 50-60 percent in other cereals, phosphorus, potassium, and sulfur are 15-20 percent, 60-80 percent, and 8-12 percent respectively for most of the crops).²⁴ With regard to micronutrients, the efficiency of most of them is observed to be below 5 percent. Therefore, there is an urgent necessity to adapt sustainable alternative strategies to enhance crop production through higher nutrient use and water use efficiency. Subsidized fertilisers, particularly nitrogenous, results in the overuse of nitrogen-based fertilisers and the ultimate distortion of nutrient (nitrogen-phosphorus-potassium) ratios, all of which result in a low NUE.

There is an urgent necessity to adapt sustainable alternative strategies to enhance crop production through higher nutrient use and water use efficiency.

Since 2016, the government has required all agricultural urea to be coated compulsorily with an extract from neem cakes produced from neem trees (*Azadirachta indica*) compulsorily to stop its divergence for industrial use.²⁵ According to industry estimates, there could be savings of about Rs. 10,000 crores on account of lower use. This policy intervention overcame the shortages for agricultural use as well as reduced the subsidy burden caused by the diversion of urea for industrial use. The neem extract-coated urea inhibits denitrification and enhances the NUE by 5 to 7%.²⁶ Soil-test-based nutrient management increases N use efficiency. Moreover, the government’s efforts on soil health card, coating of urea with neem seed cake extract, and reducing the size of a urea bag by 5 kgs have gone a long way in enhancing NUE —reducing chemical use and increasing profits for the farmers. The use of nanotechnologies for the controlled release of fertilisers can go a long way in doubling NUE. In India, already, Nanomaterials are being tested on a field scale for minimising losses as well as for enhancing NUE. Nano-fertiliser uptake is more as they are loaded on nano-particles which enter the plant cells and work at the cellular level. Nano fertilisers can be applied either by spraying or soil application and are cheaper and require lesser amount compared to chemical fertilisers.²⁷ India, which is the largest importer of urea and Diammonium

phosphate (DAP), is eyeing self-sufficiency in urea through the production of locally developed versions of nano-urea. Six new plants would be operational by 2024-25, reducing import of urea by 20 million tons and saving Rs. 400,000 million annually.²⁸ The plants would be using technology developed by Indian Farmers and Fertilisers Cooperative (IFFCO).

Empowerment of Farmers through Skill Development

Small farm-holders need to be empowered through skill development and the extension services have to be taken to their doorsteps. As indicated above, through an improved knowledge delivery system using new technologies such as IT, cloud computing, AI, ML, RS, and modelling, farmers have to be empowered. India needs to adopt a sustainable business model instead of a dependency model through freebies. The populist culture of freebies must be stopped and the Supreme Court has recommended forming a committee of All India Taxpayers and also a Committee to examine the issues of freebies. However, it's a daunting task as most politicians see this as an easy way to swing the voters.

India needs to adopt a sustainable business model instead of a dependency model through freebies.

Developing Sustainable Agriculture

Worldwide, policy-makers face common challenges: improving coherence between various sectoral policies, balancing economic growth with social, environmental, and climate action, and using resources more efficiently and effectively. A common ground for compromise needs to be found to effectively address trade-offs between development and environmental protection and also between the diverging interests of different economic sectors. At the same time, applying a nexus approach can bring mutual benefits to energy use, agriculture, ecosystems, and water efficiency.²⁹ For the success of any initiative/programme, enabling policies at both macro and micro-level, as well as enabling institutions and proper implementation, monitoring, and learning, are very much needed. The best example of watershed management in India has demonstrated that the watersheds, which started as a drought-prone area programme (DPAP) of the Central government in close cooperation with State governments, evolved through common guidelines issued by the Central government. By evolving watershed guidelines, this programme was transformed from soil conservation and rainwater harvesting to water

harvesting, efficient water use, soil conservation and livelihood improvement, through several revisions in the guidelines.³⁰

Similar was the case for many successful scaling-up programmes such as Bhoochetana and Bhoo Samrudhi in Karnataka, Rythu Kosam in Andhra Pradesh and Corporate Social Responsibility (CSR) projects. The government of India is actively pursuing the transformation of agriculture through a basket of new reforms to promote value-chain development as well as marketing at the national and international levels. A series of new reforms such as -- the creation of Gramin Agricultural Markets (GrAMs) as aggregation platforms; opening up of markets through new initiatives such as the Agricultural Produce Market Committees (APMCs); promotion of intra and interstate direct trade under the Farmers Produce' Trade and Commerce (Promotion and Facilitation) Ordinance 2020; the Agricultural Export Promotion Policy 2018 that focuses on volumes, standards and quality, and cluster approach to production; liberalisation of controls in place under the outdated Essential Commodities Act 1955; contracts in respect of farming and services through Farmers (Empowerment and Protection) Agreement on Price Assurance; have all been introduced. Also, with the introduction of special Kisan rail and air flights to carry farm produce to country-wide markets under the Farm Services Ordinance 2020, and Promotion of 10,000 Farm Producers' Organisations (FPOs) under the Atmanirbhar (self-reliant) Bharat initiative, and large investments in the farm sector, Agri logistics will get a boost across all sectors.

For rural transformation, proper implementation is very critical and a must. Awareness building as a people's movement, government fund transfers to rural households through Direct Benefit Transfers (DBT), implementation of programmes through an online process, and removing intermediaries who generate corruption, are other initiatives being implemented. However, as indicated earlier, there are no policies as yet for promoting sustainable water use in agriculture, agro-ecological sub-regions (AESR) and market-based agriculture (fork to farm) instead of MSP-based agriculture (farm to fork), and shifting agriculture to a business model rather than subsistence agriculture in India. Such enabling policies and associated institutions would help the scaling-up of integrated holistic solutions for the farmers and transform the rural sector through a new paradigm.

Way Forward

Considering the growing population, decreasing land and water availability, increased fragmentation of farms, increasing degradation of soil and water, climate change and its impacts, the need to meet the SDGs, and existing large yield gaps between what farmers harvest at present and the achievable potential yield of all the crops, the challenges to achieve food, nutrition and income security for the country is a daunting task. Further, climate variability and climate change impacts complicate the situation.

- There is an urgent need to transform agriculture in India keeping in view that most farms are small and marginal (147 million), 54 percent area is rain-fed, and varying climates and soils can be found across the country. It is necessary to adopt an integrated holistic business model (fork to farm) for agriculture through a new paradigm. An urgent need is to overcome the fragmentation of land as a result of increasing number of cultivators and inefficient management of farms. The empowered FPOs need to be closely monitored for their performance in each district so that they reach all the small farm-holders. An efficient and innovative monitoring and evaluation system has to be in place.
- The government needs to adopt an innovative, sustainable, efficient, consortium approach by building partnerships with all the actors, including the private corporates. The model of 4 ISECs has shown the potential to develop an integrated and sustainable approach to farming to achieve food and nutrition security for the growing population.
- Urgent steps are needed to harness new technologies such as Information and Communication Technology (ICT), AI, ML, cloud computing, RS, GIS, weather forecasting, and simulation modelling, for the benefit of farmers. Farmers need integrated knowledge through interdisciplinary research for development rather than compartmentalised disciplinary research. There is a need to adopt a continuum of the science of discovery to the science of delivery as suggested by ICRISAT.
- The government of India's new policies on linking countrywide markets for agricultural produce and enabling the farmers to scale up their produce anywhere and with anybody, along with contract farming, mechanisation, strengthening FPOs

for cooperative action and enabling value addition in rural areas, will definitely help to overcome the woes of the farmers and support them to produce sufficient and nutritious food for the people.

- Sustainable management of water resources is an important challenge that needs urgent attention. As indicated earlier, water management must be the business of all stakeholders, and the carrot and stick approach (punitive as well as rewarding measures) is urgently needed. The populist culture of freebies must be reformed. The Supreme Court has recommended forming an official committee and an All India Taxpayers Association to examine the issues of freebies. However, it's a daunting task as most politicians see this as an easy way to swing the voters.
- For sustainable use of water in agriculture policies must be put in place as 80 percent of consumptive use of water is in agriculture. The IWRM approach needs to be promoted and adopted and emphasis must be on integrated watershed management emphasising efficient use of green water (soil moisture), rainwater harvesting, and its use through drip and, sprinklers, and provision of information using IT-based solutions/Apps on when and how much water needs to be utilised.
- Wastewater needs attention as it is perennially available and untreated wastewater use is a health risk. Decentralised construction of wetlands in rural areas through watershed SHGs and Committees need to be implemented. Similarly, groundwater use for irrigation needs to be regulated as many districts are overexploited. However, the policies alone don't help as observed by the Water-Land and Tree Act (WALTA) passed in 2002 in Andhra Pradesh and Telangana, as well as Crop Planning in Telangana.
- The knowledge delivery system (extension system) must be strengthened through MSMEs promoted by the FPOs. The FPOs need to be strengthened through government policies and support for financing, technical personnel, the convergence of government schemes, and linking Researchers. Extension staff must adopt a demand-driven approach rather than a supply-driven driven approach to provide integrated solutions to the complex issues faced by farmers, and build public-private partnerships among the needed institutions/organisation. Efficient and innovative monitoring of the FPOs is strongly recommended.

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