Strategy Paper

taas
Progress Through Science

Towards Secure and Sustainable Agriculture

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GOAL

Harnessing the potential of agricultural sciences for the welfare of the people.

MISSION

Promoting growth and advancement of agriculture through scientific partnerships, policy advocacy and public awareness.

OBJECTIVES

- To act as a 'Think Tank' to deliberate on key issues relating to agricultural research and innovation for development (ARI4D) and influence policy decisions
- To organize workshops, conferences, brainstorming sessions, seminars, policy dialogues and special lectures on emerging issues and new developments in agricultural sciences
- To disseminate knowledge among stakeholders through publication of proceedings and policy papers
- To confer awards to the scientists of Indian and foreign origin for their outstanding contributions to Indian agriculture
- To facilitate the scientific interactions and partnership building of non-resident Indian agricultural scientists with Indian scientists

Towards Secure and Sustainable Agriculture

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1. Preamble

The world population is likely to reach 9 billion by 2050 requiring an estimated 70 per cent more food considering the present dietary pattern. The current population of India is 1.40 billion which is likely to reach 1.51 billion overtaking China by 2030. On the contrary, India with only 2.41 per cent area supports around 18 per cent of the world's population. The main challenges are: to alleviate poverty and hunger, reduce the impact of agriculture on the environment and global warming, sustain water and land resources, ensure profitability, and social and economic equity. Therefore, the future thrust shall be around producing more from static arable land and declining water resources. Fortunately, beginning with Green Revolution (GR) in mid-sixties, India's food production has increased more than six-fold (316.06 mt) in 2021-22 (estimated 328 mt in 2022-23; 3.7 per cent higher to previous year). In order to meet the increasing demand of food for additional 15-16 million people each year, despite availability of more diversified food such as fruits, vegetables, milk, meat, poultry, fish, etc. India would still need to produce around 39-40 mt of additional foodgrains by 2030, i.e., around 5.0 mt per annum. Considering the existing stress on natural resources, this is likely to be a formidable task.

Besides existing second generation problems of Green Revolution, such as: decline in total factor productivity, rising cost of cultivation, depleting natural resources (land, water,

agrobiodiversity), inefficient use of costly inputs, higher incidence of diseases and pests, the current concerns are: household nutrition security, quality and safety of food, change in consumer preference towards healthy foods, adverse impact of climate change, inadequate mechanization, labor shortage, wastage due to inadequate post-harvest processing and storage facilities, lack of youth participation, labor migration to non-farm jobs, and linking farmers to markets. Hence, these challenges shall have to be addressed on priority by taking care of the concerns such as: i) production, ii) profitability, and iii) permanency (sustainability). Issues like water and air pollution, ozone depletion and climate change, droughts, floods, disease epidemics and loss of biodiversity are also eroding the natural resources upon which our socioeconomic stability depends. We must, therefore, aim for more sustainable production systems in agriculture.

Currently, around 900 million people in the world live below poverty - about 150 million got added during COVID-19 pandemic. No poverty and zero hunger are the two major sustainable development goals (SDGs) that we need to address successfully by 2030. By nurturing the land and adopting regenerative agriculture, we expect to feed our ever-growing population. Moreover, SDG 2 seeks to end hunger in all forms of malnutrition. Eliminating chronic hunger and malnutrition, therefore, deserves high priority. Unfortunately, India is relatively slow on this front as compared to other countries despite sustained economic growth and likely income enhancement of smallholder farmers (IFPRI, 2020). In view of above constraints, farmers need better economic security while making agriculture more sustainable through natural resource management and resilience in agriculture. Hence, both secured and sustainable agriculture is what India needs at present.

2. Farmer at the Centre Stage

The smallholders and marginal farmers (with < 2 ha), accounting for nearly 86.2 per cent of 146 million farm families, tilling

around 47.4 per cent of total cultivable land and accounting for > 50 per cent of the total agricultural production, are vital not only for India's agrarian economy (10th Agriculture Census 2015-16), but also for alleviating current major challenges of hunger and poverty before the country. Over 50 per cent of the smallholders, referred to as sub-marginal farmers, possess less than 0.5 ha land. Despite their efforts to have high per unit productivity, the existence of small and fragmented holdings is economically non-viable, swelling the ranks of hungry and poor. Recognizing the fact that access of smallholders to technology, land, other production resources, credit, and capital is limited, a holistic 'Farmer FIRST (Farm, Innovations, Resources, Science and Technology)' approach and robust policy initiatives are urgently needed (GoI, 2019). Farmer today needs good soil, water, quality inputs, credit, knowledge and remunerative price for their produce. Augmented by new farm reform policies, aggregation of land through contract farming, diversification of cropping systems, more remunerative markets, and scaling of right technologies and new innovations are likely to mitigate the vagaries of climate change, while encouraging entrepreneurship and generating much needed employment for the rural youth. Thus, there is need to keep the 'Farmer' at the centre stage in research, innovation, development and marketing related activities. Initiatives such as change of name of Ministry of Agriculture and Farmers' Welfare (MoA&FW), doubling farmers' income (DFI), direct benefit transfer, issuance of soil health cards, dedicated TV Channel- DD *Kisan*, and establishing farmer producer organizations (FPOs), etc. are indeed laudable. Yet, the farmer is at the receiving end and requires enabling policy reforms around secure and sustainable agriculture to make him/her truly Farmer FIRST.

While the importance of securing our national borders is well recognized, the importance of farmers' contribution to fight against hunger and poverty, the most fundamental element to achieve sustainable development goals (SDGs), cannot be undermined. The slogan of *Jai Jawan*, *Jai Kisan*, *Jai Vigyan*

by the Hon'ble Former Prime Minister, Shri Atal Bihari Bajpai reiterates the need to bolster support for agricultural science and technology if the country has to remain globally competitive while achieving the goal of *Atmanirbhar Bharat*. Farmer welfare (*kisan kalyan*) has to be crafted through the 'Farmer FIRST' approach backed by appropriate policies, incentives, institutions and up-scaling of innovations as highlighted by Dr Paroda Committee report (GoI, 2019) submitted to the Government of India. The multi-dimensionality of doubling farmers' income necessitates transforming agriculture from a 20th century production-centric to a 21st-century holistic agri-food system. The research reorientation now demands greater thrust on innovation to bridge knowledge and technology gaps so critical for a robust 'plough-to-plate' continuum.

Today, the emerging challenges before Indian agriculture are more daunting. We need an inclusive 'Evergreen Revolution'. Not too long after its spread in the north-western plains, recognition had dawned that Green Revolution technologies had been selective in impact. The resource-poor farmers, especially in the rainfed areas and landless laborers were bypassed. Research priorities thus need a reorientation towards greening the grey (rainfed) areas. Today, to double the income of resource-poor farmers, technologies are required that produce more while saving on costly inputs and build resilience in farming. Watershed management, agro-forestry, silvi-pastoral systems, and secondary and specialty agriculture, etc. have gained considerable importance. Greater focus on horticulture, pulses, oilseeds, spices, medicinal plants, fodder crops, dairying, animal husbandry, poultry, piggery, inland aquaculture, bee-keeping, mushroom cultivation, vermi-composting, etc., are likely to reduce the risk in an integrated farming system.

3. New Challenges and Opportunities

Currently, the main challenge is to provide good quality food to address critical issues of hunger, micronutrient deficiency, overweight and obesity. Although, India produces enough

food yet 10-30 per cent of it is lost or wasted. Besides curbing food wastage, there is need to increase production now under shrinking natural resources (land and water) and declining ecosystems, including agrobiodiversity. Climate change is also having adverse impact on crop yields, and animal health and productivity to a great extent. New transformative 2030 Agenda, the Paris Climate Agreement, and the Sendai Framework for Disaster Risk Reduction forces us to make agriculture more sustainable (AASSA. 2018). The Paris Climate Agreement and recent commitments by the Hon'ble Prime Minister of India in CoP 26 held in Glasgow to generate non-fossil energy by 500 gigawatts, to meet 50 per cent requirement through renewable energy, and to reduce 1 billion tons of projected carbon emission - all by 2030 have indeed set ambitious but achievable targets provided conscious efforts are made on war footing. In fact, there seems to be no other alternative but to rely now more on agriculture to reduce greenhouse gas (GHG) emission by scaling conservation agriculture (CA) or no-till agriculture, especially in the rainfed areas and by laying greater thrust on agroforestry for enhanced carbon sequestering (Kassam *et al.*, 2014; TAAS, 2015; WCCA. 2021). Hence, the vision adopted by FAO (1996) around five principles: i) improved efficiency in the use of resources; ii) conservation, protection and enhancement of natural resources; iii) improved rural livelihoods and social well-being; iv) enhance resilience of people, communities and ecosystems to climate change and threats; and v) responsible and effective governance mechanisms, shall have to be promoted on priority. Currently, both at the national and international level, several policy and action platforms are striving to achieve Paris Agreement but these are either not well-aligned or lack much required innovative approach to enhance the carbon sequestration capacity. Therefore, there is an urgency to accelerate the efforts to scale CA and agroforestry in a Mission Mode at the national level for meeting our national commitments by 2030 (Kassam *et al.*, 2014; TAAS, 2017).

We shall also need to give attention on three pillars of sustainability: social, economic and environmental, thus needing a revisit of agricultural research and innovation for development (ARI4D) agenda. However, it is always important to keep in mind that sustainability should be seen as a continuous and evolutionary process. If the key drivers of transition are effectively put in place, they can pave the way to a more sustainable agriculture. Innovative and adequate policies and incentives, such as regulations, taxes, subsidies, pro-poor social protection, incentives for biodiversity conservation, land tenure, and the access to markets can help in increasing both the income and livelihoods of rural poor. In this context, special attention is needed on gender equality and youth employment. Motivating and attracting youth in agriculture (MAYA) will be the key for enhancing growth and development of agriculture in India. Fortunately, we currently have around 200 million youth in rural India, which should be considered as our great strength. They can be gainfully engaged in and around agriculture provided appropriate incentives, programs and policies are in place to engage them in innovative, diversified, secondary and specialty agriculture (Anitha *et al*., 2019; PAU, 2020; TAAS, 2018).

Further, the research agenda requires involvement of stakeholders' participation, integrating social, economic and environmental aspects; from farm to value-chains; and from technologies to new innovations involving public-private partnerships. Therefore, integrated agricultural production/ farming systems should now be a priority for new ARI4D agenda, with a strong emphasis on ecosystem management and conservation of natural resources. Although GoI is taking various measures, still there is need to increase capital investment in agriculture. Though there is gradual shift from public to private sector investment, yet private sector has not been able to contribute much for want of enabling policy environment concerning intellectual propriety protection and much needed public-private partnership.

For countering the challenges of second-generation problems of Green Revolution and those of climate change, a paradigm shift is needed to harness the opportunities to attain sustainable agriculture through conservation agriculture (CA), organic farming, micro-irrigation, nutrient-use efficiency, etc. 'More crop per drop' has become the new *mantra*. Resource-conserving and climate-smart technologies such as zero-till agriculture, micro-irrigation, resistant varieties to drought, flood, heat, cold and insect-pests, are now attracting greater attention. Besides, integrated pest and nutrient management, organic matter recycling, and use of biofertilizers and biopesticides are drawing greater attention now (IFPRI, 2020; Jat *et al.*, 2015). Innovations such as: hybrid technology, biotechnology (GM crops and use of genome editing), protected cultivation, precision farming, bio-energy, crop biofortification, nanotechnology, remote sensing, information and communication technology, etc. shall have to be scaled on priority. Drones, sensors, artificial intelligence and Internet of Things (IoT) also have great potential to improve efficiency in agri-food production, post-production and agro-processing systems (TAAS, 2021a). Concerted efforts are also required to bring about reforms to harness existing opportunities for sustainable growth in agriculture. In fact, Indian agriculture offers enormous 'uncommon opportunities' that can be harnessed to our advantage. Some of these are: i) a vast institutional and human resource base; ii) a threshold of low productivity that can be enhanced quickly; iii) a reservoir of proven technologies that are yet to reach the farmers; iv) an emerging vibrant private sector waiting for enabling policy environment to contribute significantly; v) opening of the world markets through globalization for Indian agri-products; vi) enhancing quickly the present low-input-use efficiency; vii) availability of good arable land and diverse climatic conditions; and viii) the possibilities to bring in corporate culture in public sector research institutions/organizations (Paroda, 2018).

4. Growth and Investments in ARI4D

Agriculture sector is contributing around 20 per cent to the national gross value added (GVA) which is presently around 180 lakh crores. This used to be around 60 per cent in 1950. In fact, it still compares well with that of industry sector which currently contributes around 25 per cent. While the crops, livestock and forestry sectors have shown fluctuating growth rates, the fishery sector has shown enormous growth from 4.9 in 2012-13 to 11.9 per cent in 2017-18 (Fig. 1). Moreover, compared to fluctuating performance of other sectors, agriculture sector at the national level even under the COVID-19 pandemic has reflected steady performance of 2.9 per cent (Table 1).

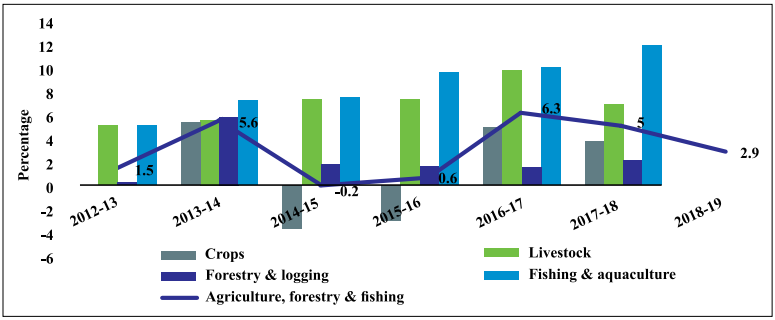

Fig. 1 *Growth rate of GVA in agriculture and allied sectors (2011-12 prices)*

(Source: Economic Survey of India, 2019, GoI 2020)

Table 1. Output growth in agriculture (2011-12 to 2017-18)

Sector	CAGR (%)
Crops	0.8
Livestock	7.3
Fishery	11.9
Forestry & Logging	8.5
Agriculture & Allied Sectors	2.9

(Source: CSO; Base: 2011-12=100)

Agriculture research and innovation for development (ARI4D) in India is largely under public domain. As evident, the total expenditure of the ICAR has remained steady around INR 5,000 crores during the last decade (Table 2) despite evidently higher allocations in some years. This obviously is a matter of concern since most of the expenditure is on establishment with very little left for research (<20%). In nut shell, the investments on agricultural research in India has remained low (0.37%), as compared to other agriculturally important countries such as China (0.62%), Brazil (1.8%) and others, namely, USA, Japan, and Australia spending more than 2-3% on ARI4D (Fig. 2) (GoI, 2019).

Table 2. Funding trend of ICAR in last one decade

(Rs in crore)

Year	Budget Estimate	Revised Estimate	Actual Expenditure
2009-10	3241.40	3261.36	3210.42
2010-11	3818.05	5165.00	5385.83
2011-12	4957.60	5007.60	4729.31
2012-13	5392.00	4620.00	4509.75
2013-14	5729.17	4881.08	4730.76
2014-15	6144.39	4884.00	4840.01
2015-16	6320.00	5586.00	5572.90
2016-17	6620.00	6238.00	5995.20
2017-18	6800.00	6992.00	6989.91
2018-19	7800.00	7953.73	7943.59
2019-20	8078.76*	7846.17*	7174.00**
2020-21	8362.58*	7762.38*	7278.54**
2021-22	8,513.62*	-	-

**DARE/ICAR Annual Reports 2020-21, 2021-22; **ICAR Annual Accounts and Audit Report 2020–21*

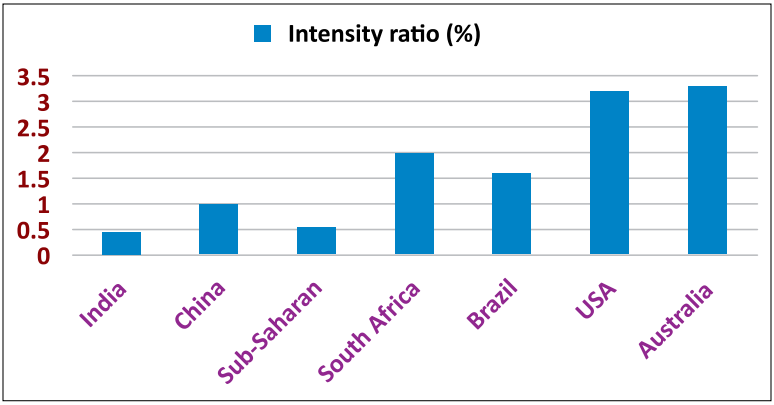

Fig. 2 *Agricultural research expenditure intensity ratios (%) in 2010*

(Source: NIAP, 2011-12)

As already highlighted, despite these admirable achievements, public investment in agriculture research, for more than two decades, has not been commensurate. Successive reviews of the Indian Council of Agriculture Research (ICAR) have highlighted the need to raise research spending considerably. The Gajendragadkar Committee (1972), GVK Rao Committee (1988), RA Mashelkar Committee (2001), MS Swaminathan Committee (NCF, 2006) and T Ramasami Committee (2017), all recommended a minimum of 1.0 per cent of agricultural GDP for agricultural R&D. India falls far short with an allocation of only 0.39 per cent. This is ten times less than in countries such as the USA, Australia, Japan and almost half that in China. On the contrary, returns to public investment in agriculture are 10-15 times higher – much more compared to other sectors, be those on input subsidies, infrastructure development, including roads and education. Hence, we need to triple our investments on ARI4D if we need to be in forefront of other agriculturally major economies at the global level for which we do have enormous potential.

As mentioned earlier, the trajectory of public expenditure on agricultural research has stagnated for decades, hovering

between 0.3 and 0.4 per cent of agriculture GDP. This tepid, business-as-usual approach is unlikely to provide the quantum jump in productivity and efficiency in our production systems. Expected private investment has also not increased due to an obvious lack of enabling policies, including those linked to scaling of innovations, public-private partnership and intellectual property rights (IPR) protection. Moreover, the private sector investments can at best be complementary, but not as substitute for the public investments since outcomes of ARI4D are invariably considered as national public goods.

5. Green Revolution and Beyond

As per Dr Norman E Borlaug, the three cradles of Green Revolution (GR) had been: i) partnership between NARS and global institutions, ii) good institutions and human resource, including hardworking progressive farmers, and iii) political support. With the launch of GR, between 1966 and 2020, wheat production increased by almost 10-fold, from 11 mt to now 111.32 mt, but reduced to 106.41 mt during 2021-22 (4.41% less than last year) due to early onset of summer and rice production increased by 5.6-fold, from 21 mt to 127.93 mt, (2020-21) and 127.93 mt during 2021-22 attaining an all-time high food production of over 316.06 mt in 2021-22 (estimated target of 328 mt in 2022-23). In horticultural sector, India currently produced 333.32 mt of fruits and vegetables (a dip in 0.4% to last year), surpassing even food grains production continuously for the past 7-8 years. In fact, 80 per cent of the production gains were attributed to yield enhancement which transformed the status of 'ship-to-mouth' in 1960s to that of 'self-sufficiency'. The White, Yellow and Blue Revolutions also led to the record production of nearly 208 mt of milk (the highest in the world), 38.4 mt of oilseeds (estimated 45.64 mt during 2022-23) and 15.0 mt (estimated 20 mt during 2022-23) of fish production, which reduced both poverty and hunger to a considerable extent in the country. India also emerged among the top three food producers in the world.

Despite above advances, the average yields of most cereals, pulses and oilseeds have remained low, reflecting a gap between the actual, realizable and potential yields. Moreover, as there is no scope for horizontal expansion, future advancement shall have to be around vertical increase in yields per hectare. Average yields of most crops are still lower than many other countries, which otherwise reflects ample scope for increasing production through higher input- use efficiency and resilience in agriculture. Climate-smart agriculture (CSA), with its triple win by enhanced productivity, resilience and mitigation measures, could result in water smart, energy smart, carbon smart, nitrogen smart, weather smart and knowledge smart agriculture that is more sustainable. As the climate goes on changing, one-time adaptation measure may not be enough (TAAS, 2021).

In fact, genetic restructuring, good agronomic practices (GAP), diversification, integrated cropping and farming systems, efficient use of agrobiodiversity and available natural resources should help meet expected increase by 2050 in food grains production by 70 per cent (Paroda *et al*., 2021). In the present context, the challenge before agricultural scientists and development officials is to quickly scale innovations aiming at: i) conservation agriculture for sustainable intensification (CASI); ii) improving productivity and profitability by adopting resource saving technologies, and iii) promoting climate smart ecosystem services for enhanced carbon sequestration, greater saving of water (more crop per drop), restoring soil health (especially increasing the organic matter content), and conserving available rich agrobiodiversity.

Unless concerted efforts are made in low productivity agricultural regions especially Eastern India to diversify their production systems and connect smallholders to urban food value-chains, India will continue to lag behind in productivity. The more productive zones like Punjab and Haryana would need to diversify their rice-wheat cropping system, and move

towards crops and cultivation practices that save water, energy and costly inputs. Enhancing input-use efficiency in high productive zones, especially for water, fertilizer and fuel, would also lead to significant income gains. Further, major staple crops will be able to adapt to climate change because of development of new varieties that can tolerate unanticipated extreme weather conditions. Concerted efforts would be needed to develop suitable varieties in non-staples, especially pulses and coarse cereals that are better adapted to climate change and harsh agricultural conditions. Fortunately, good technology and management practices exist that can enhance sustainability resource use efficiency. It is argued that current policy environment does not provide needed incentives to farmers to change their agricultural practices to make them more sustainable (Pingali, 2019; 2019a).

For any change in agricultural practices, technology dissemination and access to good knowledge is critical. For this, farmers need a well-trained, re-tooled and dedicated cadre of extension workers. In this context, now we need well trained youth (including women) to provide paid extension services and advisory to the farmers. Also, there is need to enhance production and productivity of small and marginal farmers, halt the miniaturization of farm sizes, and promote off- and non-farm rural employment, land reforms, etc. (Singh, 2019). Sustaining the gains of GR and achieving higher growth in crops like maize, oilseeds and pulses, and sectors like horticulture, livestock, fishery were the major challenges that we had to face boldly with initiatives like creation of over 30 new institutions, modernization of infrastructure and facilities to improve both efficiency and effectiveness, and reorientation of research agenda to address Vision 2030/2050 of all the national institutions/ SAUs. With this, Indian NARS could not only achieve Green, White, Yellow, Blue and Rainbow Revolutions but could also sustain the steady progress over the past 50 years reflecting an all-round growth and development in agriculture.

6. Bridging the Yield Gaps

Understanding yield gap is very crucial as it helps in crop yield predictions. Also, information on determinants of yield gap is important which can be used in policy interventions for enhancing crop production. Advances in breeding and agronomy including improvements in the spatial and temporal arrangement of crops in farming systems are major drivers of enhanced production. In order to obtain a sustained growth rate of 8 per cent, India must accelerate its agricultural growth from the current level ranging between 2 to 4 per cent. Hence, a mission-mode program for faster agricultural growth needs to be initiated on priority. It requires a dynamic approach based on well planned strategies with better coordination and convergence, which include: i) increased capital investment in agriculture, ii) supply of growth-oriented inputs at farmers' doorsteps; iii) improving productivity; iv) increasing wheat and pulse production; v) diversifying some of the rice production areas, especially upland rice; vi) increasing hybrid rice productivity in eastern India where current area coverage (over the last two decades) under hybrid rice is only around 2 mha, though the scope exists for covering at least 10 mha in the next decade; vii) enhancing maize production through single-cross hybrids covering presently around 60 per cent area, whereas scope exists to double the maize production in the next decade if we cover > 90 per cent area under single-cross hybrids. Since there is no scope for horizontal expansion, vertical expansion through increased productivity is the only way forward, needing an agro-ecoregion-wise, state-wise and crop-wise strategy (Chand, 2017; GoI, 2018; Paroda *et al.*, 2021).

There is need to adopt a two-pronged strategy to bridge the yield gaps- vertical gap (GAP 1) between genetic potential, attainable/ experimental stations/frontline demonstration yields and actual/ average yields at the farmers' fields and horizontal gap (GAP 2) between different geographically differentiated regions/districts/ states in different crops. Considerable yield gaps exist between

different regions//states/districts in different crops which need to be bridged to enhance production through the use of better varieties and hybrids and improved agronomic practices, including scaling of conservation agriculture (CA) especially in the rainfed areas. CA has a good potential for increasing crop production while saving on costly inputs, thereby increasing farmers' income. However, its scaling would require a mission approach to make grey (rainfed) areas green, which seemed to have been byepassed earlier by green revolution. Moreover, around 200 mha around the globe have already been covered under conservation agriculture mainly under dryland (rainfed) agriculture. Hence, scaling CA innovation could be our national priority (Kassam *et al.*, 2014; Paroda *et al.*, 2021; TAAS, 2017).

7. Crop Diversification

Crop diversification can be one of the most ecologically feasible, cost-effective, and rational way of reducing uncertainties in agriculture-especially among smallholder farmers (Joshi 2005). Crop diversification also increases resilience, is more agronomically stable, and ensures greater spatial and temporal biodiversity in farms (Holling 1973; Joshi 2005). The resilience is due to factors such as reduced weed and insect pressures, less reliance on nitrogen fertilizers (especially if the crop mix includes leguminous crops), reduced erosion (because of the inclusion of cover crops), and increased soil fertility and yield per unit area (Lin, 2011). Diversification can also enhance climate resilience (GoI, 2020) and conservation of natural resources (soil, water, and biodiversity) by replacing more exploitative approaches and focusing production systems on regenerative agriculture.

Today, we still have the predominance of rice–wheat cropping systems in Punjab, Haryana, and Uttar Pradesh; groundnut in Gujarat; sugarcane in the north (mainly due to the nobilization of sugarcane which led to transfer of genes responsible for drought and disease tolerance from *Saccharum spontaneum*); chickpea in south India (due to the breeding of short duration

varieties); pigeonpea (*Cajanus cajan*) in north-western states such as Haryana, Punjab, Rajasthan, and Gujarat (due to early maturing varieties [<120 days]); soybean in Madhya Pradesh and adjoining states; and winter maize in Bihar with very high productivity (>7.0 tons/ha). Despite these dominant crops, there are still opportunities for shifting areas to short-duration varieties of chickpea (*Cicer arietinum*) in non-traditional areas of Andhra Pradesh, Tamil Nadu, and Karnataka; mixed cropping of urd bean (*Vigna mungo*), mung bean (*Vigna radiata*), and pigeonpea in central and peninsular regions; introduction of short-duration pigeonpea in Gujarat, Rajasthan, Haryana, and Punjab; and lentils (*Lens culinaris*), mustard (*Brassica spp*), and peas (*Pisum sativum*) in rice fallows in Bihar, West Bengal, Odisha, Assam, and some of the north-eastern states (Paroda *et al.*, 2021).

Past experiences have amply demonstrated that expansion of crops in non-traditional areas can lead to rapid progress due to faster adoption of full technological packages without any prejudices for traditional practices. Some good examples of this are puddled rice in north India, use of wide permanent rows for groundnut planting in Gujarat, cultivation of soybean in Madhya Pradesh, *rabi* maize in Bihar, etc. Such an approach is most beneficial when it is based on scientific land-use planning.

Also, there is need for further diversification around local food systems, as has been emphasized by the UN Food Systems Summit held in September 2021 and the second International Agrobiodiversity Congress (IAC) organized in Rome in October 2021 to share and advance scientific research, nature-positive solutions, policies, and practices to transform food systems and deliver on the 2030 Agenda for Sustainable Development through the use and conservation of agrobiodiversity. COVID-19 has also highlighted the importance of crop diversification for greater sustainability of agricultural production systems, as well as for household nutrition security and improved health and immunity. In this regard, the required actions include: i) ensuring

access to safe and nutritious food for all; ii) shifting to sustainable consumption patterns; iii) boosting nature-positive, eco-region-specific production; iv) advancing equitable livelihoods; and v) building resilience against vulnerabilities, shocks, and stress (FAO, 2021; Paroda *et al.*, 2022).

India needs a right mix of policies, moving from subsidy-driven to investment-driven, from price-focused to income-focused, and from exploitative to sustainable agricultural diversification for eliminating hunger as SDG 2 (Paroda, 2017). We also need to incentivize the private sector, especially young entrepreneurs, to build efficient and inclusive value chains for farmers' prosperity.

8. Motivating and Attracting Youth in Agriculture

Globally, there is an increasing concern about the generational gap in agriculture-aged farmers' efficiency is declining, while youth is not interested to take agriculture as a profession. On the contrary, given support and incentives, present youth can face the new challenges more effectively. They are capable of adopting new concepts, ideas, technologies being critical for increasing production. In fact, those nations with motivated youth engaged in diverse, secondary and specialty agriculture, supported by enabling policies, have progressed well. India, with a median age of 29 years with largest population of youth (356 million in 10- and 24-years age group) in the world (United Nations, 2014) has only 5 per cent of the rural youth engaged in agriculture though over 50 per cent of the population still derive their livelihood from farming and allied activities. Hence, a paradigm shift is needed from 'Youth as a Farmer' to 'Youth as Value-Chain Developer and Entrepreneur' (TAAS, 2018). Hence, an increased participation of youth requires greater capacity building and incentives in agricultural production and post-production technologies, and through formation of rural youth associations, agri-clinics, and entrepreneurship programs, including Farmer Producer Organizations (FPOs). The principle of 'Leaving no one behind' would also require

closing the gender gap. In fact, female farmers, representing more than a quarter of the world's population, remain invisible in policy and decision making at every level of agricultural development. They neither have equal rights nor access to assets, information, inputs and services. In addition, women face excessive work burden, much of which remains unrecognized and unpaid (ICAR, 2012; FAO, 2018; Paroda, 2018). The World Bank and FAO had recognized that by empowering and training women, they could boost production by 20-30 per cent. In fact, through MAYA initiatives, rural youth could become 'Job Creators' instead of 'Job Seekers' and help in accelerating growth of agriculture while increasing the farm income (Anitha *et al.*, 2019; PAU, 2020; TAAS, 2018).

To achieve above goal, concerted efforts would be needed to build new skills of youth for innovative agriculture through both formal and informal education right from school level. In addition, the CAUs/SAUs/ICAR institutes must initiate entrepreneurship training through vocational and formal diploma programs. Also, the university curriculum needs to be revisited to address the emerging needs and aspirations of present-day youth and markets. Involvement of youth in 'Plough-to-Plate' initiative can help in doubling farmers' income. For enhancing income of farmers, and for attracting youth in agriculture, emphasis would be needed to promote secondary and specialty agriculture, supported well by value-chain for efficient post-harvest management, use of information communication technology (ICT), creation of agri-clinics, rural based primary processing and effective marketing options (GoI, 2019).

9. Need for Scaling Innovations

Emphasis on innovation both for upscaling and outscaling is critical for accelerating growth and development of agriculture. Those countries that have given high priority to scaling new and rather disruptive innovations have progressed much faster. Hence, greater emphasis needs to be given on harnessing

possible gains through translational research, for which an enabling policy environment has to be in place. The following are some important innovations that need to be scaled on priority to harness possible gains.

For increased crop productivity, greater thrust on hybrid technology is urgently needed. Concerted efforts in a mission-mode to cover more area under hybrids of maize, pearl millet, sorghum, rice and pigeonpea would increase productivity. Increasing the area under single cross and QPM hybrids, suited to different agro-climatic regions, would further double the maize production. In the case of rice and pigeonpea, more intensification of research and extension efforts is needed. Ensuring availability of quality seed at the right time and relatively at low price will greatly help in increasing the seed replacement rates (SRR) (GoI, 2019).

Biotechnology, including molecular breeding and gene-editing (CRISPR/Cas9) also offers great potential for improving productivity of crops. Genetically modified (GM) crops, covering over 200 mha area globally have benefited nations in a big way. India also needs to take advantage of GM crops. Recently, the Govt. of India has approved the use of genome editing technology under SDN1 and SDN2 categories, which is a positive step and hence be capitalized by the plant breeders without any further delay. Use of Bt brinjal, GM mustard and other GM crops such as soybean, corn and canola, if approved for cultivation, could benefit farmers to a greater extent (TAAS, 2021a).

Conservation agriculture for sustainable intensification (CASI) with an area increase from 3.5 to 20 mha can be seen as a new way forward for sustainable production. Benefits of CA are multi-fold. Similarly, the promotion of protected cultivation gives better dividends, brings pride to the profession and can attract youth including women. There is a need to increase the area at least 4 times (up to ~2,00,000 ha) in the next decade. In fact, the protected cultivation increases productivity almost

by 3-5 folds (GoI, 2019). Precision agriculture is also a way forward to achieve environmentally sustainable evergreen revolution using modern tools, techniques and innovations, viz., nanotechnology, artificial intelligence (AI), drones, sensors, robots, etc. Comprehensive and reliable data resources are conducive to augment AI that can bring a paradigm shift by developing smart farming practices using internet of things (IoT) to address the uncertain issues with utmost accuracy enabling farmers to produce more with less, and also provide new business opportunities to youth. AI can also be used for high throughput plant phenotyping, monitoring of natural calamities and environmental degradation, including the crop residue burning. Some examples of scaling innovations on priority in a mission-mode are given in Box 1.

In order to address hunger and malnutrition, being a major SDG, much greater thrust needs to be given to develop and promote high yielding nutri-rich varieties/hybrids of crops that are suited to diverse agro-climatic conditions. In the recent past, ICAR has developed over 70 biofortified varieties of rice, wheat, maize, pearl millet, lentil, mustard, soybean, cauliflower, sweet potato, pomegranate, etc. Promoting cultivation of these biofortified varieties through the needed incentive like higher pricing will help in increasing their production.

10. Reforms Needed in Agriculture

India's agricultural policies must address multiple mandates such as: production imperative (national food security), consumer imperative (keeping food prices low for a large low-income population), and the farmer welfare imperative (raising farmer's income). Realizing the significance of agriculture in India's socioeconomic framework, the government has set an agenda of doubling farmers' income by raising productivity, cutting down on input costs, and promoting diversification towards high value low volume agriculture. For this to happen, the Indian agriculture needs several fundamental reforms (GoI, 2018).

Box 1: Translational Research: Scaling Innovations

- Hybrid Technology (maize, pearl millet, sorghum, rice) – area coverage to be increased substantially under each of these
- Biotechnology – use of gene-editing technology (CRISPR/Cas9) and adoption of GM food crops (soybean, mustard, maize, brinjal)
- Conservation Agriculture – to expand area from current 3,0 mha to at least 20 mha in rainfed region
- Protected Cultivation - expand area from current 0.5 m ha to around 2.0 mha by 2030
- Micro-irrigation - must double the area from current 10 mha to 20 mha
- Bioenergy/Biofuel (use of ethanol permitted up to 20%) – potential sources: sugarcane, maize, rice straw, etc.
- Biofortified Crops (quality protein maize, iron & zinc rich rice, iron rich pearl millet, zinc rich wheat, etc.,) – policy on their increased pricing
- ICT for Knowledge Empowerment – private advisory services involving youth (including women) as private extension

In this context, despite having achieved household food security through the Green, White and Blue revolutions, the problem of poverty, hunger and malnutrition still persists and the real income of farmer seemed to have declined. To reverse these trends, there is an urgency for an introspection of existing technologies, development programs and policy related initiatives and to evolve a new strategy with defined Road Map, to accelerate agricultural growth rate which seemed to have struck around 3 per cent. Also, accelerating agricultural growth is warranted for achieving Sustainable Development Goals (SDGs) by the year 2030 (Paroda, 2017). In fact, India is currently at the centre

stage globally with regard to achieving SDGs, failing which possibly the UN targets would not be met in view of existing concentration of both poverty and hunger, compared to even Sub-Saharan Africa. Hence, there is an urgency to adopt some assertive policies and to scale out new technologies and innovations to ensure increased production linked to input use efficiency, post-production management including value-chain, effective partnership with stakeholders, especially the private sector, and the linkages both at the national and global level. Fortunately, the Government's commitment to meet SDGs and the Paris Agreement for Climate Change do present unique opportunity for the entire agriculture sector to get aligned for a better tomorrow. A recent report on 'Policies and Action Plan for a Secure and Sustainable Agriculture' submitted to the Principal Scientific Advisor, Government of India by Dr RS Paroda Committee (GoI, 2019; Paroda, 2017) has clearly defined a strategy to move forward in this regard. Obviously, the policy makers need to accord high priority to agriculture for continued food, nutrition and environmental security. This would certainly demand doubling of funds for agricultural research and innovation for development (ARI4D), which gives the highest returns (more than 10-15 times) compared to other growth sectors. Also, the enhanced capital investment in eastern and north-eastern region, especially to improve social progress index (SPI), becomes a high priority. Currently, India's position for SDI is relatively low requiring higher investments.

On the contrary, the smallholder farmers are a stressed community whose income is not enough to meet their essential needs. Farmers do need good land, healthy soils, adequate and good quality water, timely supply of key inputs, technologies that can ensure higher and efficient production, good and timely extension services, easy availability of credit at low interest rate, access to national and global markets and finally the respect and dignity which they deserve in the society. Accordingly, reforms are needed around a new strategy to make 'Farmer FIRST' (GoI, 2019; TAAS, 2021).

Now the time is ripe to transform Indian agriculture and the food systems towards a more productive, secure (resilient) and sustainable enterprise for accelerated economic growth, improved livelihood and a true catalyst for creation of jobs downstream around both production and post-production scenario. To achieve this transformation, a right vision and resolute action is needed. It seems that lately we have slipped because India has produced enough. Our agriculture seemed to have prodded along sluggishly giving a reflection of complacency despite pockets of brilliance and available innovations needing scaling. As envisioned by Dr RS Paroda Committee (GoI, 2019), now is the time to bring in change and not to continue the business-as-usual and tinkering at the margin but take bold policy decisions aiming to take Indian agriculture to newer heights.

As stated in the previous sections, there exists opportunities to harness science for new gains by scaling some of the disruptive innovations like: precision agriculture, biotechnology, sensor technology, bioinformatics, climate-smart agriculture, robotics, drones, big data management, artificial intelligence, etc. Hence, key institutional reforms now required are: review of existing agricultural policy and forming a new one on agriculture and farmers' welfare; needed reorientation of on-going missions/ national programs including urgency for initiating some new ones; clearance of important pending Acts/Bills by the Parliament; strengthening national agricultural research and extension system (NARES) by doubling the funding of ICAR; establishment of a new National Agricultural Development and Farmers' Welfare Council (NAD&FWC) under the chairmanship of Hon'ble Prime Minister - on lines similar to GST Council, needed for decision making and to strengthen much needed coordination between Centre and State Governments; establishing Farmers' Welfare Commissions both at the Centre and State level, as an institutional mechanism for providing a platform for regular interaction with farmers to assess their needs; creating an Independent Strategic Planning, Monitoring, and Evaluation Unit to review and assess the impact of all central agriculture related schemes; grassroot knowledge empowerment

through both public and paid extension systems; expanding the mandate of KVKs as 'Knowledge-Skill-Innovation Centres' and to act as Agri-Clinics and ATICs; providing support for creating more Farmer Producer Organizations (FPOs); building trusted partnership with private sector, and finally the empowerment and motivation of women and youth to remain in agriculture and be the true game changers (GoI, 2019; TAAS, 2021).

Also, increased capital investment in agriculture (both public and private), easy access to credit at low interest rate (4%), besides NABARD, Cooperative Banks, creation of more financial institutions like *Kisan* Banks, increasing investments in rural roads, electricity, marketing infrastructure, including pledged warehouses and food processing facilities would be critical in the non-green revolution areas to achieve SDGs. Further, as highlighted by Dr RS Paroda Committee (GoI, 2019), we need to rationalize input subsidies through direct benefit transfer (DBT) mechanism. Also, converting subsidies on fertilizers as incentives for good agronomic practices (GAP) like nutrient application based on need assessment through soil health cards, power and irrigation subsidy as incentives for adoption of conservation agriculture and micro-irrigation, and for bringing more land under trees (e.g.*har med par ped*) by scaling innovations in agroforestry would be win-win for all. Further, to convert subsidies as incentives for both farming efficiency and environmental services, it will be much better to support farmers @ Rs 10,000 per acre per annum up to a maximum of 10 acres (4 ha) per farming family. Dr RS Paroda Committee (GoI, 2019) has also justified this support without any additional burden on the exchequer. It has also re-emphasised that the minimum support price (MSP) be fixed actually at 1.5 times of cost C2 and the procurement in future be extended to all important commodities, with decentralized procurement to be made also by the State Governments.

Hence, bold policy decision and effective monitoring and implementation would make all the difference. In addition, requirement of insurance of horticultural crops, livestock and

fishery be given high priority under *Pradhan Mantri Fasal Bima Yojana* (PMFBY), which requires operational efficiency through accurate weather forecasting, mapping of losses using satellite imagery and timely settlement of claims. For enhancing the income of farmers, and for attracting youth in agriculture, emphasis is clearly needed now on secondary and specialty agriculture, supported well by value-chain for efficient postharvest handling, rural-based primary processing and effective linkage with markets. All these options require policy support, technical backstopping and hand holding. Also, there is need to enhance markets intensity in rural areas and ensure market linkages through e-NAM requiring uniform adoption of Agriculture Produce and Livestock Marketing (APLM) Act and Contract Farming Act by various States. Further, the *mandi* tax must also be rationalized around 5-7 per cent, whereas the charges at some places more than twice the amount.

The Essential Commodities Act (ECA) and Agricultural Produce Marketing Committee (APMC) Act also need to be reviewed with regard to their relevance especially when intention through e-NAM is to create a unified national market to benefit both the producers and consumers. The concerns of seed industry with regard to implementation and harmonization of Biological Diversity Act and Protection of Plant Varieties and Farmers' Rights Act (PPV&FRA), unresolved issues relating to access and benefit sharing (ABS) for use of genetic resources, besides intellectual property (IP) protection on innovation such as genetic modification (GM), genome editing, etc., pricing policy on seeds and long awaited revision of Seed Act need to be addressed on priority (TAAS, 2019). The fertilizer and pesticides industries also have serious concerns relating to regulations and their effective implementation requiring immediate Government intervention to create an enabling environment to ensure accelerated growth of agriculture. It will also be desirable to have corporate social responsibility (CSR) linked to efficient technology dissemination through active involvement of youth (including women) as technology/extension agents, input and/

or service providers and for the establishment of Agri-Clinics involving young entrepreneurs. Considering enormous potential for agricultural exports, it is suggested to revisit our export-import (EXIM) policy and make it long-term foresight oriented to harness the benefits of globalization. For this, Agricultural and Processed Food Products Export Development Authority (APEDA) needs to be strengthened to take-up additional functions of international demand assessment, establishing linkages with potential importing countries and to maintain international food safety and quarantine standards. It should also create a national system of certification of organic foods for both domestic and international markets.

Further, it has been observed that the Seed Bill, Pesticide Management Bill, Biotechnology Regulatory Authority of India (BRAI) Bill, and other important Bills/Acts relating to agriculture and rural development are pending for enactment by the Parliament for long and hence all these be got expedited without further delay (GoI, 2019). A National Policy on Biotechnology, embracing GM and genome editing, National Livestock Breeding Policy (including the enactment of a new Act to protect all indigenous livestock breeds), and the National Land Utilization Policy, which is both owner and tenant-friendly, as proposed in the Model Land Leasing Act, should be considered for quick decision and implementation by all the States concerned. In this context, the fragmentation of land holdings below one ha in irrigated and 2 ha in the rainfed areas, being uneconomical, be legally not permitted. Also, now the digitization of agricultural land ownership records be a major goal of all the States.

India's agriculture policies must address multiple mandates such as: production imperative (national food security), consumer imperative (keeping food prices low for a large low-income population), and the farmer welfare imperative (raising farmer's income). Realizing the significance of agriculture in India's socioeconomic framework, the government has set an agenda of doubling farmers' income by raising productivity,

cutting down on input costs, and promoting diversification towards high value low volume agriculture. For this to happen, the Indian agriculture needs several fundamental reforms.

In this context, despite having achieved household food security through the Green, White and Blue revolutions, the problem of poverty, hunger and malnutrition still persists and the real income of farmer seemed to have declined. To reverse this trend, there is an urgency for an introspection of existing technology, development programs and policy related initiatives and to evolve a new strategy with defined Road Map, to accelerate agricultural growth rate which seemed to have struck around 3 per cent. Also, accelerating agricultural growth is warranted for achieving Sustainable Development Goals (SDGs) by the year 2030 (Paroda, 2017). This obviously calls for some bold policy decisions and efforts for their effective implementation.

India is currently at the centre stage globally with regard to achieving SDGs, failing which possibly the UN targets would not be met in view of higher concentration of both poverty and hunger, compared to Sub-Saharan Africa. Hence, there is an urgency to adopt some effective policies and to scale out new technologies and innovations to ensure increased production linked to input use efficiency, post-production, value-chain, effective partnership with stakeholders, especially the private sector, and the linkages with both national and global markets. Fortunately, the Government's commitment to meet SDGs and the Paris Agreement for climate change do present unique opportunity for the entire agricultural sector to get aligned for a better tomorrow. Dr RS Paroda Committee (GoI, 2019; Paroda, 2017) clearly defined a strategy to move forward in this regard. Thus, policy makers need to accord high priority to agriculture for continued food, nutrition and environmental security. This obviously would demand doubling of funds for agricultural research and innovation for development (ARI4D), which gives the highest returns (more than 10 -15 times) compared to other growth sectors. Also, the enhanced capital investment in eastern and north-eastern region, especially to improve social

progress index (SPI), becomes a priority. Besides SDGs, India's commitment for doubling farmers' income is a major policy initiative, which demands specific focus on increased production with low input cost, sustainable agricultural diversification and efficient post-production management, including value-addition, and better options of linking farmers to market. Obviously, these would demand a paradigm shift in the current national agricultural policies to become more pro-farmer and to accelerate higher agricultural growth for future prosperity.

On the contrary, the smallholder farmers are currently the most stressed community whose income is not enough to meet their daily needs. Farmers need good land, healthy soils, adequate and good quality water, timely supply of key inputs, technologies that can ensure higher and efficient production, good and timely extension services, easy availability of credit at low interest rate, access to national and global markets and finally the respect and dignity which they deserve in the society. Accordingly, reforms are needed around a new strategy and policies aiming at accelerating agricultural growth, achieving SDGs, and doubling farmers' income while perusing a 'Farmer FIRST' approach (GoI, 2019; TAAS, 2021).

Thus, there is need for transforming Indian agriculture and the food systems towards a more productive, secure (resilient) and sustainable enterprise for accelerated economic growth, improved livelihood and a true catalyst for creation of jobs downstream around both production and post-production scenario. To achieve this transformation, a clearcut vision, accompanied by equally bold policies and resolute action is needed. It is apparent that lately we seemed to have slipped because India became food secure. Since then, agriculture has prodded along sluggishly being a reflection of complacency despite pockets of brilliance and available technological innovations needing policy support for scaling. Bringing new innovations to scale and to accelerate agricultural growth above 4 per cent, as envisioned by Dr RS Paroda Committee (GoI, 2019), would require increased investments with priorities and commitments as a pre-requisite

for implementing policy reforms and new programs. It is now time to bring in change and not to continue the business-as-usual and tinkering at the margin but take bold policy decisions aiming to take India to newer heights. The new strategy must address the farmers' diverse needs including: doubling farmers' income through increased production, diversification in farming systems that are eco-regionally most sustainable, input cost reduction by scaling technical innovations (be scientist or farmer-led), availability of credit at low interest rate, value-addition and better income through direct linkages to markets. The strategy should now focus on harnessing scientific, technical and institutional innovations, besides needed policy reforms and stronger national and global partnerships. Insurance of horticultural crops, livestock and fishery needs to be given equal importance under *Pradhan Mantri Fasal Bima Yojana* (PMFBY), linked to operational efficiency for its implementation through accurate weather forecasting, mapping of losses using satellite imagery, and the timely settlement of claims, etc.

For increased income of farmers, and for attracting youth in agriculture, emphasis is clearly needed now on secondary and specialty agriculture, supported well by value-chain for efficient postharvest handling, rural-based primary processing and marketing. All these are badly in need of policy support and technical backstopping. In this context, it is critical that the minimum support price (MSP) is actually fixed at 1.5 times of cost C2 and the procurement in future be extended to all commodities, with decentralized procurements to be made by the States. Also, there is need to enhance markets intensity in rural areas and ensure market linkages through e-NAM requiring uniform adoption of Agriculture Produce and Livestock Marketing (APLM) Act and Contract Farming Act by various States. Further, the *mandi* tax has also to be rationalized around 5-7 per cent, whereas some even charge more than twice the amount. The Essential Commodities Act (ECA) and Agricultural Produce Marketing Committee (APMC) Act also need to be reviewed in regard to their relevance especially when intention

through e-NAM is to create a unified national market to benefit both the producers and consumers. The concerns of seed industry with regard to implementation and harmonization of Biological Diversity Act and Protection of Plant Varieties and Farmers' Rights Act (PPV&FRA), unresolved issues relating to access and benefit sharing (ABS) for use of genetic resources, besides intellectual property (IP) protection on innovation such as genetic modification (GM), genome-editing, etc., pricing policy on seeds and long-awaited revision of Seed Act need to be addressed on priority (TAAS, 2020). The fertilizer and pesticides industries also have serious concerns relating to regulations and their effective implementation requiring immediate Government intervention to create an enabling environment to ensure accelerated growth of agriculture. It will also be desirable to have corporate social responsibility (CSR) linked to efficient technology dissemination through active involvement of youth (including women) as technology/extension agents, input and/or service providers and for the establishment of Agri-Clinics involving young entrepreneurs. Considering enormous potential for agricultural exports, it is suggested to revisit our export-import (EXIM) policy and make it long-term foresight oriented to harness the benefits of globalization. For this, Agricultural and Processed Food Products Export Development Authority (APEDA) needs to be strengthened to take-up additional functions of international demand assessment, establishing linkages with potential importing countries and to maintain international food safety and quarantine standards. It should also create a national system of certification of organic foods for both domestic and international markets.

Further, it has been observed that the Seed Bill, Pesticide Management Bill, Biotechnology Regulatory Authority of India (BRAI) Bill, and other important Bills/Acts relating to agriculture and rural development are pending for enactment by the Parliament for long and hence all these be got expedited without further delay (GoI, 2019). A National Policy on Biotechnology, embracing GM and genome-editing, National Livestock Breeding

Policy (including the enactment of a new Act to protect all indigenous livestock breeds), and the National Land Utilization Policy, which is both owner and tenant friendly, as proposed in the Model Land Leasing Act, should be considered for quick decision and implementation by all the States concerned. In this context, the fragmentation of land holdings below one ha in irrigated and 2 ha in the rainfed areas, being uneconomical, be legally not permitted. Also, the digitization of agricultural land ownership records be now a major goal by all the States.

The Way Forward

In fact, Indian agriculture continues to remain in the forefront of development as it still provides livelihood to half of India's population. At present, increasing productivity and doubling farmers' income are the two major challenges despite decline in average size of land holdings. What is needed now is to increase productivity, decrease the cost of production and increase income of the farmers by linking them to markets. Also, we need to ensure that these gains are sustainable, which otherwise is not an easy task. As such, as already emphasised, bold policy decisions to do business differently are needed to support new science like biotechnology, information technology, nano-technology, bioinformatics, artificial intelligence (AI), etc. and innovations such as: conservation agriculture, micro-irrigation, protected cultivation, genetically modified crops, genome editing, hybrid technology, precision nutrient management, integrated pest management, etc.

Currently, the new opportunities are unfolding in the form of increased demand for agricultural commodities both in domestic and global markets. The growing international demands for rice, wheat and maize besides cotton, soy meal, fruits, vegetables, fish, meat, poultry, etc. have opened up enormous opportunities for boosting agricultural export. In addition, the increasing demand for high-value commodities such as fruits, vegetables, milk, meat, flowers, etc. and agri-processed products in the domestic markets point out the

potential for economic growth in the farm sector. The role of corporate sector in developing and delivering market-driven technologies, besides the government support for contract farming, agro-processing, organized retailing and exports do reflect the needed impetus to Indian agriculture. Some of these encouraging developments are taking place around value chain harnessing the concept of 'farm to fork' and reversing the trend towards 'fork to farm' production systems. Hence, there is need to have in place innovative policies, appropriate institutional arrangements and market-driven initiatives, to harness untapped growth opportunities for our smallholder farmers.

Epilogue

Agriculture must be seen as an important sector of national economy, which has a direct role to contribute towards SDGs, promote inclusive development and welfare of millions of smallholder farmers and accelerate growth of national economy. This would, however, need mobilizing resources for investment, incentives for sustainable farming practices, ease of doing business, progressive market reforms, improved governance to balance centre state relations and strengthened public-private partnership. There is also an urgent need for scientific ago-ecoregional planning and balanced 'agri-food system-based' multi sectoral approach for faster agricultural growth and to contribute at least one trillion (20%) of targeted five trillion economy. Timely implementation of suggested reforms shall surely help achieving this goal and to meet SDGs by 2030.

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Brief Resume

Dr. Raj Paroda, former Director General, Indian Council of Agricultural Research (ICAR) & Secretary, Department of Agricultural Research and Education (DARE), Government of India, holds a unique perspective as an accomplished scientist, able research administrator and development practitioner. He is well known for modernization and strengthening of the Indian national agricultural research system (NARS). Recognizing his enormous contributions in the field of agricultural research, Government of India had bestowed on him the prestigious **Padma Bhusan** Award in 1998. He is recipient of several awards and recognitions, namely Rafi Ahmad Kidwai Prize, ICAR Team Research Award, FICCI Award, Om Prakash Bhasin Award, BP Pal Gold Medal, Norman E. Borlaug Award, Agricultural Today Award, Mahendra Shiromani Award, AB Joshi Award, US Awasthi-IFFCO Award and M.S. Swaminathan Award. He has also served as President, Indian Science Congress (2001) and President, National Academy of Agricultural Sciences (1997-2000). Nineteen universities have awarded him D.Sc. (*Honoris Causa*) degree including Ohio State University and Indian Agricultural Research Institute. He is Fellow of almost all science academies in India, Third World Academy of Sciences, Italy, Russian Academy of Agricultural Sciences, Agriculture Academics of Armenia, Georgia and Tajikistan and Honorary Member of American Society of Crop Science and American Society of Agronomy. Recently, he has been elected as Foreign Fellow of Australian Academy of Technological Sciences and Engineering (ASTE).

Dr. Paroda had been the founder chairman of Global Forum on Agricultural Research (GFAR), from 1997-2002 based at FAO, Rome. He also served for more than two decades (1992-2014) as Executive Secretary of Asia-Pacific Association of Agricultural Research Institutions (APAARI), FAO, Bangkok. Dr. Paroda also served as Chairman, Farmers Commission of Haryana from 2010-2014. He was also a member of Advisory Committee of ACIAR, CABI and WMO, was Chairman of Board of Trustees of ICRISAT, and Member of Finance Committee and SIMEC of CGIAR. Currently, he is serving on the Board of International Fertilizer Development Center (IFDC), Alabama, USA. For the last over two decades, Dr. Paroda is serving as Founder Chairman, Trust for Advancement of Agricultural Sciences (TAAS), based at Indian Agricultural Research Institute, New Delhi.

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