Souvenir

7th M S Swaminathan Award 2018-19

ENVIRONMENT AND AGRICULTURE

RETIRED ICAR EMPLOYEES' ASSOCIATION (RICAREA)
HYDERABAD TELANGANA INDIA

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M S Swaminathan Award - An Overview

The Retired Indian Council of Agricultural Research Employees' Association (RICAREA) was formed in1997 to promote and further the ideals and objectives of the Indian Council of Agricultural Research (ICAR) by providingservices to Governmental Agencies, NGOs, Public & Private enterprises, and farming community. The association is also serving as a pool of resource persons for scientific and extension bodies, besides bringing awareness of developments in science and technology among the farming community and general public. At present the Association has a membership of 325.

As part of the activities, RICAREA in association with Nuziveedu Seeds Ltd., Hyderabad, Andhra Pradesh has instituted a prestigious National award in the name of the living legend Prof. MS Swaminathan. This award carries a Cash prize of Rs. 2.0 lakhs, a Medal and a Citation. This is an important recognition to the agricultural scientists for their lifetime achievements and contributions to Indian agriculture.

The first MS Swaminathan award for the biennium 2004-2005 was presented to the leading Poultry Scientist Dr Genda Lal Jain on 27th October 2005. The second M.S. Swaminathan award for the biennium 2006-2007 was presented to Dr B S Prakash, NDRI Scientist on 3rd November 2007. The third MS Swaminathan award for the biennium 2008-2009 was presented to Dr S Nagarajan, wheat pathologist and Former Director, Indian Agricultural Research Institute, New Delhi (ICAR-IARI) on 14th November 2009. The fourth MS Swaminathan award for the biennium 2010-2011 was presented to Dr S R Sai Kumar, Ex Project Director, Maize, New Delhi and Dr N Shobha Rani former Principal Scientist and Head Crop Improvement ICAR-IIRR (Formerly known as DRR) Hyderabad on 19th May 2012. The fifth M.S. Swaminathan award for the biennium 2012-2013 was presented to Dr. Surender Lal Goswami former Director, ICAR-NAARM, Hyderabad. The sixth M.S. Swaminathan award for the biennium 2015-2016 to Prof. RR Hanchinal, Chairperson of Protection of Plant Varieties & Farmers' Rights Authority, GOI, New Delhi. In all the six occasions Souvenirs with articles from leading scientists of different crops, disciplines were released.

Thirteen nominations were received from eminent scientists from all over the country covering Agricultural sciences and Animal sciences for the 7th MS Swaminathan award for the biennium **2018-2019.**

The Selection Committee under the Chairmanship of Dr R. S. Paroda unanimously selected Dr. V. Praveen Rao, Vice-Chancellor, Professor Jayashankar Telangana State Agricultural University, Hyderabad for the 7th award. This Souvenir, seventh in the series is brought out to mark the occasion of the Seventh MS Swaminathan award presentation function. This Souvenir is a collection of invited articles including the article by the awardee Dr. V. Praveen Rao.

The Office Bearers and the Executive Committee members sincerely thank Sri M Prabhakara Rao, MD Nuziveedu Seeds and all the RICAREA members who have extended their unstinted support and encouragement.

Editors

About Retired ICAR Employees' Association (RICAREA)

Retired Indian Council of Agricultural Research Employees' Association (RICAREA) was formed on 13th September, 1997 with 22 members including 5 office bearers with Dr. E A Siddiq as its President. The Association was registered in Hyderabad under the Andhra Pradesh (Telangana areas) Public Registration Act 1350 Fasli (Act I of 1350 F November 22, 1997). Currently the Association has a membership of 325.

The Objectives of the Association are :

- To serve as a pool of resource persons for scientific and extension bodies.
- To bring about awareness of developments in science and technology among the farming community and general public.
- To recognize and felicitate outstanding scientists for their lifetime achievements.
- To safeguard the general welfare and to provide a forum for sustaining professional interest of the members.

Website and Publications

Keeping in tune with the changing times a website (www.ricarea.org) was launched to disseminate information about all activities of RICAREA to members as well as other interested organizations.

A Newsletter containing information about current topics on Indian Agriculture, health and nutrition, Administrative matters and members' views is published and circulated to RICAREA members, ICAR Institutes, input agencies and NGO's.

A Directory of RICAREA members with addresses and phone numbers along with other useful information about medical facilities, ICAR and its institutes *etc.* has also been published.

MS Swaminathan National Award

As part of the activities the Retired ICAR Employees' Association (RICAREA) has instituted a prestigious National award in the name of the Doyen of Indian Agriculture Prof. MS Swaminathan in 2004-2005. So far six awards for the years 2004-05, 2006-07, 2008-09, 2010-11, 2012-13 and 2015-16 were presented to leading Scientists in Agricultural and Animal Sciences.

National Seminars

Realizing the urgent need to revamp the rural agricultural scenario to turn the farming into a productive activity, RICAREA have organized a two days' National Seminar on Integrated Farming Systems for Sustainable Agriculture and Enhancement of Rural Livelihoods on the 13th and 14th December 2015 in collaboration with the ICAR and National Academy for Agricultural Research Management (NAARM) at Rajendranagar in Hyderabad. Several organizations including ICAR, ITC, Nuziveedu Seeds Pvt. Ltd, ANGRAU, PJTSAU, NABARD, Satya Seeds, Bayer (India) Ltd., NAL and the ICAR Institutes located in Hyderabad came forward and extended their support for the Seminar. An Exhibition relevant to the theme of the Seminar was organized on the occasion in which the local ICAR Institutes and some voluntary organizations participated. Mrs.V Usha Rani, IAS, Director-General MANAGE inaugurated the Exhibition and chaired the proceedings of the Seminar. Dr. S Ayyappan, Director-General ICAR and Secretary to the Govt. of India (DARE) delivered the Keynote Address. Around 25

Expert Invitees who have worked in the area of Integrated Farming Systems, five successful progressive farmers, several scientists and research workers engaged in the area of Integrated Farming Systems and members of RICAREA participated in the Seminar. The Book of Abstracts of all the contributions was distributed to the participants and other interested agencies. Proceedings of the National Seminar has recently been published.

In view of the declining economy of small holder families, the Retired ICAR Employees Association (RICAREA) conducted a Seminar on "Sustainability of Small Farmer in Changing Agricultural Scenario" in collaboration with Prof. Jayashankar Telangana State Agricultural University (PJTSAU) on December 22,2018 in order to come up with strategies to augment the current sustainability of small holder families. Dr R.S. Paroda former Secretary to the Govt. of India (DARE) & Director-General of ICAR was the Chief Guest of the Seminar, who inaugurated the Seminar and delivered Keynote Address on augmenting the income levels of farmers in general and small farmers in particular. The inaugural session was chaired by Dr. V. Praveen Rao, Vicechancellor,Professor Jayasankar Telengana State Agricultural University and Dr. V. Damodar Naidu,Vice Chancellor, Acharya N.G. Ranga Agricultural University was the guest of honour. fifteen experts presented their overview in different sub-sectors of agriculture and about 18 young scientists presented their research results through posters. A couple of farmers shared their field experiences and a number of participants contributed to the discussions in the three technical sessions. The collective wisdom of the seminar participants was distilled into a set of recommendations, with implications to research, extension and policy sectors and they were shared with many that matter. The Proceedings of the National Seminar under the title "Sustainability of Small Farmer in Changing Agricultural Scenario" has recently been published.

Annual Day

RICAREA Annual Day is being organized since 1998 in which members with their families participate. A custom was started from 2001 also onwards to invariably invite an eminent personality as Chief Guest for the function. The list of luminaries who graced the annual day function was Dr D. Bala Subramaniam (2001), Justice. G Raghuram (2002), Gen. KV Krishna Rao (2003), Dr. Kakarla Subba Rao (2004), Dr. YL Nene (2005), Dr. A Appa Rao (2006), Dr. A Panduranga Rao (2007), Dr. AV Gurava Reddy (2008), Dr Palle Rama Rao (2009), Dr. PK Joshi (2010), Dr P Krishnaiah (2011), Dr S L Goswami (2012), Dr. A Padma Raju (2013), Prof. V Rajani Kantha Rao (2014), Dr. D Rama Rao (2015), Dr. WR Reddy, IAS (2016), Dr. V. Praveen Rao (2017), Prof. Podile Appa Rao (2018) and Prof. & Dr. B. Balasubramanian (2019).

Felicitations to Members

Members who have completed 75 years are being felicitated on the Annual day function. So far around 140 members have been felicitated with a Citation, a Shawl and a Memento.

Many members have contributed to the growth of this association. We place on record our fond memories of those departed and left an indelible mark on the growth and development of our Association. Among them are : Drs. B Venkateswarlu, PV.Ramana Murthy, Dr R. Vidyabhushanam, Dr S.V. S. Sastry, KVP Rao, MJ Balakrishna Rao, TP Sriharan, NS Rao, K Vidyasagara Rao, APK Reddy, R Mallikarjuna Rao, Dr. MVS Sastry, Dr. MV Rao, NGP Rao, SS Narayanan and Prof. K Madhusudhana Rao.

The members who are actively associated and still contributing to the overall growth of the Association are : Dr. MVR Prasad, Dr. V Jaya Mohan Rao, Dr. GGSN Rao, Dr. EA Siddiq, Dr. Y Muralidharudu, Dr. S Indira, Dr. G Nagaraj, Dr. AGK Murthy, Dr. KPC Rao, Dr. K Muralidharan, Dr. PR Vanamayya, Dr. D. Rama Rao, Dr. Y. Rama Krishna, Sri. T Damodaram, and Sri D. Gandhi. Dr. K Krishnaiah, Dr. NP Sarma, Dr. U Prasada Rao, Dr. Mahbir Singh, Dr. PSVV Vidysagar, Dr.VVS Murthy, Sri. VV Ramana Rao, Sri G Narayanappa, Dr. J Rama Krishna Rao, The current Executive Body of the Association is able to function effectively due to the whole hearted support and help received from all the RICAREA members especially the past and present office bearers and executive members.

Executive Committee of RICAREA


Dr. M.V.R. Prasad
President


Dr. GGSN Rao
Vice-President


Dr. V. Jaya Mohan Rao
Vice-President


Dr. Y. Muralidharudu
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Dr. M. Nageswara Rao
Regional Secretary
Rajahmundry Centre


Dr. G. Narayanappa
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Dr. U. Prasada Rao


Dr. P.R. Vanamaiah


Dr. Mahabir Singh


Dr. S.V. Rao

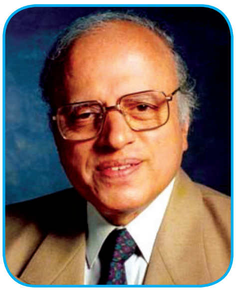

Mr. T. Damodaram


Mr. D. Gandhi


Mr. B. Kishtaiah


Mr. K. Satyananda Rao

Patrons



Prof. M. S. Swaminathan
Chief Patron

Dr. Genda Lal Jain

Dr. B.S.Prakash

Justice G. Raghuram

Sri A.Pandu Ranga Rao

Dr. A.V. Gurava Reddy

Dr. Palle Rama Rao

Dr. R.B. Singh

Dr. B.S. Dhillon

Dr. Surender Lal Goswami

Micro Irrigation – A Sustainable Technology for Crop Intensification, Improved Crop Productivity and Water Use

V. Praveen Rao
Vice Chancellor, Professor Jayashankar Telangana State Agricultural University

1. Water Scarcity and Agriculture

Intensified but sustainable crop production will be a key factor in addressing one of the greatest challenges of the 21st century: feeding 9.7 billion people globally including 1.6 billion in India by the year 2050. Inherent in this challenge are the limitations of arable land as well as a shortage of fresh water sources. Ecologically, crop intensification can protect marginal lands for further development, limit soil degradation and conserve water resources. Intensification on a smaller land area also has potential to reduce inputs applied for crop production and protection. Irrigated agriculture in little less than 20% of the cultivated area produces about 40 to 45% of the world's food highlighting the importance of irrigation in global food security. Similarly, in India 48% of irrigated land contributes 60% of country's food needs. Although there was a great expansion of irrigated lands in the past seven decades, from a meagre 22.6 million ha to 98 million ha in the country, most water experts agree that such additional great expansion in the 21st century will not be possible. The problem could be exacerbated by the largely known effects of climate change on quantity and quality of water available for irrigation and the concurrent increases in water demand to meet municipal, industry, energy production and other needs.

More than 1.2 billion people, or almost one-fifth of the world's population, live in areas of physical scarcity, and 500 million people are approaching this situation. Another 1.6 billion people, or almost one quarter of the world's population, face economic water shortage in countries which lack the necessary infrastructure to take water from rivers and aquifers). According to the United Nations World Water Development Report 2018, an estimated 3.6 billion people (47% of the global population) live in areas that are potentially water-scarce for least a month in a year, and this population could increase to some 4.8–5.7 billion by 2050. Similarly, as per NITI Aayog Report "Composite Water Management Index 2018", India is suffering from its "worst water crisis" ever with about 600 million people grappling with acute shortage.

The challenge is great to the agricultural sector since it utilizes 70% of the global water resources (84.6% in India) for irrigation of crops. In India with 18% of the global population, the per capita water availability declined from 5178 m3 /year in 1951 to 1441 m3 /year in 2015, which is lower than the water-stressed norm of 1700 m3/year (Fig. 1). According to 2030 Water Resources Group (WRG), in base case scenario the water demand for agriculture in India is projected to grow to almost 1195 billion (B) m3 driven by domestic demand for rice (361 Bm3), wheat (335 Bm3), sugarcane (152 Bm3) and other crops (347 Bm3) for a growing population, a large proportion of which is moving toward a middle-class diet. The agricultural community must therefore make a sustained and diligent effort not only to increase the food supply, but it must also conserve water and protect water quality. Additionally, it must do this at multiple scales from the largest, most technologically advanced largescale producers to small holder units with minimal technology input. Irrigation technologies will definitely play a large role in meeting these challenges and micro irrigation is a specific method of irrigation that has inherent advantages in addressing some of these challenges.

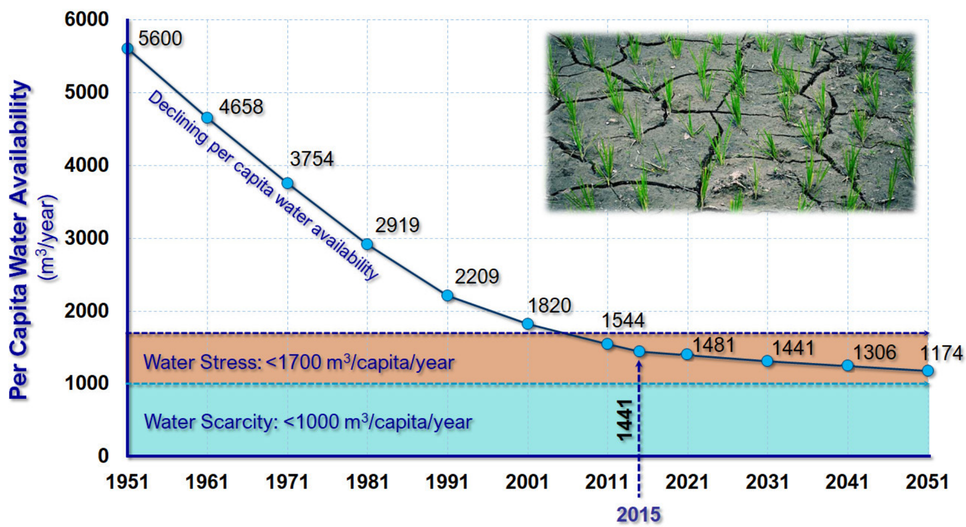


Fig. 1. India – Decreasing per capita water availability with growing population

2. Micro irrigation – Efficient Water Use

In India, food grain production and food security has largely been possible through high input, high yielding intensive irrigated agriculture. But over 50% of cultivated lands that produces nutri-cereals, pulses, oilseeds, fruits and vegetables are still monsoon dependent. The efficiency of existing dominant surface irrigation system in the country is very low, (<35%). On the other hand, with usage of micro irrigation systems, conveyance losses are minimal. Surface soil evaporation, runoff and deep percolation are also markedly reduced by using micro irrigation (surface and subsurface drip irrigation) methods (Fig. 2). Another water saving advantage is that water sources with limited flow rates can be used successfully. Efficient water use leads to additional benefits such as increased irrigated area besides adaptation of marginal and degraded lands for cultivation of crops. It also aids in soil heath management and prevents water logging. A recent survey consisting of 5,892 beneficiaries across 13-states implementing National Mission on

Micro irrigation (NMMI) indicated ~8.5% increase in the area under irrigation and conversion of 519 ha to cultivation out of 845 ha of unused waste or degraded lands. The benefits of micro irrigation particularly drip irrigation in diverse crops has been widely evaluated in water scarce regions of the world. A review of evidences from several field studies on drip irrigation strongly suggests significant financial, economic and social benefits. However, the adoption, diffusion and spread of these technologies are far below potential and expectations.

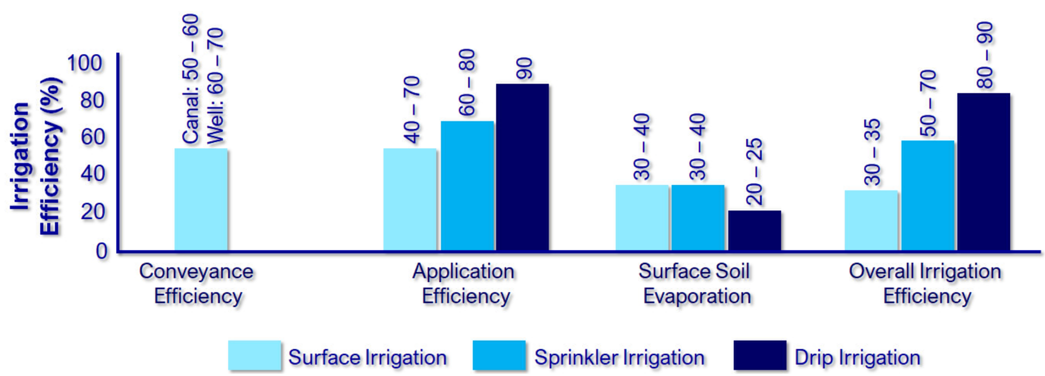


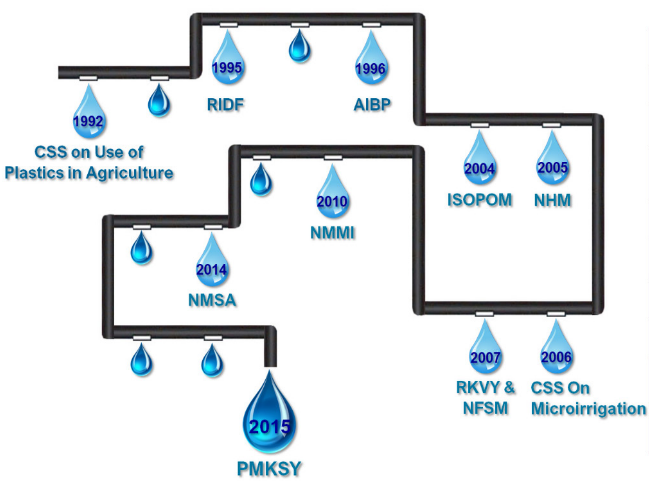
Fig. 2. Irrigation efficiency under surface, sprinkler and drip irrigation systems

3. Micro irrigation: Genesis, Potential and Penetration

Micro irrigation (initially in 1960s referred to as drip) concepts date back to as early as 1860 where subsurface clay pipes were used in combination with irrigation and drainage pipes (Davis, 1974). Originally experimented in United Kingdom, Germany, France, Netherlands and USA for irrigating greenhouse crops, drip irrigation became a commercially viable technology only after the advent of inexpensive, weather-resistant polyethylene plastics post World War II in Israel (Blass, 1964). In 1959, Simcha Blass and Kibbutz Hatzerim developed and patented the first practical surface drip irrigation emitter.

Drip irrigation is one of the most promising options for increasing the efficiency of irrigation. The hardware delivers steady, low quantities of water directly to the root area of a crop in a precise and parsimonious manner that increases efficiency, allowing the irrigation of crops in areas where water costs or ecology might otherwise prohibit this, boosting and stabilizing crop production, and thereby increasing the amount and stability of the food supply. Though advanced drip irrigation systems offer the greatest efficiency gains, systems have also been redesigned for simpler and smaller-scale irrigation with little reduction in observed benefits. Wide-scale adoption of current modern-day drip irrigation commenced in 1970s in countries as diverse as Australia, Israel, Mexico, New Zealand, South Africa, and USA to irrigate vegetables, orchards and its coverage was reported as 56,000 ha (Kulkarni et.al., 2006). The Working Group on Micro irrigation of the International Commission on Irrigation and Drainage (ICID) has conducted surveys on the extent of micro irrigation periodically since 1981. These surveys, summarized by Reinders (2000), indicate that area under micro irrigation grew slowly but steadily; from 0.41 million ha (M ha) in 1981 to 1.1 M ha in 1986, 1.77 M ha in 1991, 3.2 M ha in 2000 and to 6.2 M ha in 2006 (Reinders, 2000 and Kulkarni et.al.,2006) and 9.95 M ha in 2010. Of the roughly 1524 million ha of arable land in the world today, 324 million ha of area is irrigated, and only a little over ~15 million ha is drip irrigated. Much of this lies in 7 countries: India, the USA, Spain, China, Korea, Brazil and South Africa. Together, these countries represent nearly 74.6% of the world's drip irrigated area. These countries, especially USA, also have significant sprinkler irrigated areas and are among the top five countries with respect to the adoption of planned efficient irrigation technologies.

Drip irrigation was introduced in India during 1970s from Israel and the USA, where the technology was practiced widely by large commercial farmers. Preliminary experimental field trials showed that other than water saving, the crop yields using drip irrigation were substantially higher than crops irrigated by surface methods of irrigation viz., furrow, basin and border irrigation. The Government of India realizing the potential of drip and sprinkler irrigation as water conservation technologies sought to support farmers either through focussed Centrally Sponsored Schemes(CSS) such as Use of Plastics in Agriculture, National Mission on Micro irrigation (NMMI), CSS on Micro irrigation or other schemes with micro irrigation as a component viz., Rural Infrastructure Development Fund (RIDF), Accelerated Irrigation Benefit Programme (AIBP), Integrated Scheme of Oilseeds, Pulses, Oil Palm and Maize (ISOPOM), National Horticulture Mission (NHM), Rashtriya Krishi Vikas Yojana (RKVY), National Food Security Mission (NFSM) and National Mission on Sustainable Agriculture (NMSA) (Fig. 3). To address end to end solutions for water management in agriculture, Government of India has launched a comprehensive flagship programme called, "Pradhan Mantri Krishi Sinchai Yojana" in 2015 (Fig. 3).



CSS	Centrally Sponsored Scheme
RIFD	Rural Infrastructure Development Fund
AIBP	Accelerated Irrigation Benefit Programme
ISOPOM	Integrated Scheme of Oilseeds, Pulses, Oil-Palm and Maize
NHM	National Horticulture Mission
RKVY	Rastriya Krishi Vikas Yojana
NFSM	National Food Security Mission
NMMI	National Mission on Microirrigation
NMSA	National Mission on Sustainable Agriculture
PMKSY	Pradhan Mantri Krishi Sinchayee Yojana

Fig. 3. Government of India schemes timeline with micro irrigation as a component or focused micro irrigation schemes

More specifically, the "*Per Drop More Crop*" component of the scheme focuses on micro irrigation systems that promote precision farming by making water available in a targeted manner to the root zone of crops. To supplement the programme, the Government has also approved an initial corpus of Rs. 5000 crores for setting up a dedicated "Micro irrigation Fund" with National Bank of Agricultural and Rural Development (NABARD) in 2019 and later enhanced it to 10,000 crores in 2021. NABARD aims to extend loans to state governments to undertake special and innovative projects in micro irrigation. These CSSs provided a broad framework for promotion of micro irrigation technologies all over the country. However, each state is following a different institutional framework for promotion of micro irrigation depending on the agro-ecological conditions and local priorities. The expansion of area under drip irrigation has expanded rather sluggishly since its introduction in 1970s, starting from 1500 ha in 1985 to a little over 70,000 ha in 1991-92 and to 225,000 ha in 1998, which was still very low compared to an estimated potential of 69 million ha. Traditionally Maharashtra state has been the front runner in terms of area coverage under micro-irrigation. However, over the past two decades, Gujarat, Andhra Pradesh and Telangana states have initiated projects in special purpose vehicle (SPV) mode *viz.*, Gujarat Green Revolution Company (GGRC), Andhra Pradesh Micro Irrigation Project (APMIP) and Telangana State Micro irrigation Project (TSMIP), respectively, for large scale promotion of micro irrigation in smallholder fields. As a result of innovative institutional mechanisms adopted in these SPVs the area under micro irrigation in these states expanded rapidly. Estimates made in March 2021 suggest that drip irrigated area in India has further expanded to over 6.112 million ha (M ha) with Maharashtra (1.314 M ha), Andhra Pradesh (1.388 M ha), Gujarat (0.852 M ha), Karnataka (0.752 M ha), Tamil Nadu (0.735 M ha) and Telangana (0.591 M ha) accounting for 92.1% of the area. Similarly, the sprinkler irrigated area in March 2021 was calculated at 6.796 M ha.

4. Impact of Micro Irrigation – Input savings, Yield and Economic gains

A survey of literature on the impacts of micro irrigation technologies indicates that they are usually promoted primarily for one or more of the following objectives: (i) As means to save water in irrigated agriculture and avert the water scarcity crises, (ii) To overcome labour shortages and higher labour costs, (iii) As a strategy to use marginal quality waters *viz.*, saline and wastewater, (iv) To enable cultivation on waste or degraded lands, undulated terrain and hilly areas, (v) For irrigating crops under protected conditions, mulched crops, and landscapes (vi) Aerated irrigation (AI) to mitigate hypoxic conditions in problematic soils, (vii) As means to apply fertilizers via fertigation to enhance nutrient use efficiency, reduce leaching and pollution of water, (xiii) As a strategy to increase crop yields and income, and reduce poverty among the rural poor, and (ix) To enhance the food and nutritional security of rural households.

In a survey done for the Government of India by NMMI across 13 states indicated that micro irrigation of crops improved all facets of the field, fruit and vegetable crops production process, from reduction in input consumption *viz.*, water, energy and fertilizer, to increased productivity of the crop. It has even given farmers the flexibility to introduce diverse crops on their lands.

Accurate and localized application, frequently at predetermined amounts sufficient to satisfy crop evaporative demand maintains high matric and osmotic potentials (lower soil water suction) in the root zone with no problems of soil aeration and elimination of the wide fluctuations in soil water in the course of growing season, which typically result from traditional flood and sprinkler irrigation methods. This leads to optimal crop growth and increased productivity of the crops. Across various studies, it has been found that the adoption of drip irrigation systems helped boost the yield in the range of 23.1 to 94.6% in fruit orchards, 32.9 to 112.2% in field crops, 15.6 to 67.8% in vegetable crops, 17.2 to 98.3% in root, bulb & tuber crops, 21 to 70% in plantation crops, 86 to 100% in spice crops and 140.2 in flowers. Whereas an average increase of 42.3% in the productivity of fruit crops and 52.8% increase in the productivity of vegetable crops was registered in 13 states. This in turn helped to increase farmers' income from 20.1 to 68%.

Irrigation of small portion of the soil volume, decreased surface evaporation, reduced irrigation runoff from the field. The dry soil between rows could reduce water uptake by weeds and also store more precipitation. It also controlled deep percolation losses below the crop root zone and favoured increased beneficial use of water by crops leading to significant savings in water and increase in water productivity. Numerous field studies indicated that adoption of drip irrigation helped to reduce irrigation requirement in the range of 18.7 to 47.7% in fruit-orchards, 2.1 to 42.9% in field crops, 11.9 to 38% in vegetable crops, 14.3 to 51.3% in root, bulb & tuber crops, 12 to 56% in plantation crops, 36.7 to 46.7% in spice crops and 41.4 in flowers. Whereas, water productivity gains were in the range of 36.7 to 313.7% for different crops.

With usage of micro irrigation systems, wastage of water is eliminated as compared to other irrigation methods resulting in higher on-farm irrigation water application efficiency. Improved efficiency reduces seasonal irrigation water requirement, hence fewer pumping hours means reduced energy consumption and electricity bills. Drip irrigation also has a potential for reducing pumping energy costs since system operating are considerably lower compared to overhead sprinkler pressurized systems. As a result of the improved on-farm water application efficiency through judicious use in drip irrigation systems, the overall energy consumption and irrigation costs have been shown to come down by 30.5% and 31.9%, respectively.

Application of water-soluble fertilizers frequently via irrigation system, directly in the wetting zone, matching the crop demand at various growth stages, improves distribution and availability of nutrients with minimum leaching beyond the root zone or runoff and increases the efficiency of applied fertilizer usage, resulting in an average reduction in consumption by 28.5%. Besides fertilizer, other agrochemicals such as herbicides, insecticides, fungicides, microbial solutions, and CO_2 can be supplied to improve crop production.

Farmers also favoured crop diversification on the farms as a direct result of adoption of micro irrigation systems. On an average, 30.4% farmers introduced new crops. Flexibility in cultural operations, reduced operational labour, adaptation to marginal soils, limited weed growth, enhanced water availability, reduced salinity hazard *etc.*, besides enhanced crop yields and improved farm profits help boost farmers' confidence to try diverse crops as per the market orientation.

While increasing the water savings and productivity of crops, drip irrigation also delivered many other potential economic and social benefits to the society – increased farm profits (20.1 to 68%) and provided a higher benefit cost ratio varying from 1.83 to 2.74 in vegetables and 1.75 to 2.78 in fruits (Fig. 4); it also reduced poverty among the rural poor; food and nutritional security of rural households; and effectively addressed environmental concerns. Micro irrigation technology was shown to maximize the synergistic interactions of improved seeds, water and fertilizer ensuring the congruence of sustainability, productivity, profitability and equity.

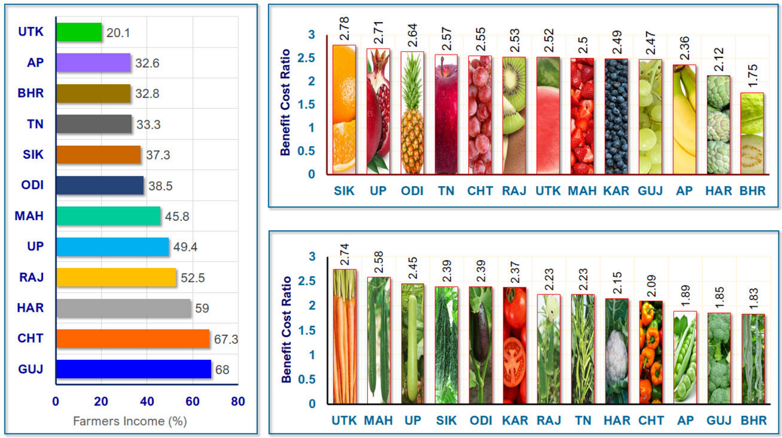


Fig. 4. Drip irrigation - Enhanced farmers income and benefit cost ratio in various fruit and vegetable crops across Indian states

5. Policy Implications

Over the years, government (state and central) as well as various non-government agencies have been promoting drip and sprinkler irrigation as a "concept of precision agriculture" through a "Package Solution" with the following salient features of micro irrigation technologies mentioned earlier. The farmers, on the other hand, have different priorities and concerns. They demand solutions and technologies that would provide them with: (i) Assured higher returns, (ii) Lower production costs, (iii) Simple and no risk technology, (vi) Generic applicability, and (v) Higher and better yields with fewer pumping hours. Hence, there are obvious gaps between what the market demands and what the micro irrigation industry has to offer. This gap can be bridged by:

Stable Policy Environment

A major issue seen with micro irrigation schemes in the country is frequent changes year over year in the implementation guidelines. These are often very complex and time consuming. For example, NHM (2005) to CSS on micro irrigation (2006) to RKVY & NFSM (2007) to NMMI (2010) to OFWM under NMSA (2014) to PMKSY in 2015(see Fig. 3) create problems for states in implementation as per the envisaged milestones. Ensuring stable policy and enabling environment for a longer time frame holds key for accelerated adoption of micro irrigation.

Region and Crop Specific Solutions

Making drip mandatory for water guzzling crops like sugarcane. The water requirement of sugarcane is estimated at 1800 to 2400 mm/year, which is more than 2 to 3 times the requirement of cotton, maize, vegetables *etc.* Following the example set by Maharashtra and Karnataka, there is a need to make drip mandatory which not only cuts down water use in sugarcane but also actually increases its cane and sugar yields. Taking a crop-specific focus would yield quicker results with large areas brought under micro irrigation in shorter periods of time. Next crop focus could be on direct seeded drilled rice, maize, cotton, fruits and vegetables which are other major water guzzling crops. Oilseeds and pulses can be other focus crops. With the increasing demand for oilseeds and pulses, the nation needs quick measures to increase productivity of these crops while saving precious natural resources. Micro irrigation suppliers should devise region and crop-specific packages. For example, a supplier could provide a "sugarcane drip package in Maharashtra" or "cotton drip package in Punjab, Gujarat and Telangana" where the company would prescribe the equipment and guidelines for effective use of these for the specific region and crop in question.

Paradigm Shift – Water Saving to Income Enhancing Technology

As a long-term objective, water conservation using drip irrigation promises a social good that will benefit not only the farmers but also the domestic water consumers, industry as well as future generations. However, several field studies have demonstrated that adoption of surface and subsurface drip technologies is accompanied by expansion of irrigated area, enhanced yields, diversification to high value water intensive crops and greater cropping intensities (Rao *et.al.,* 2014). This means that while, crop yields and water use efficiency increases, overall water use by crops may also increase (Birkenholtz, 2017). This counter-intuitive thesis is also referred to as Jevons' Paradox, named after British economist William Stanley Jevons. Ward and Pulido-Velazquez (2008) reported that in the Upper Rio Grande Basin of North America drip irrigation registered higher water use than flood irrigation on a basin scale, while also producing higher crop yields. Likewise, Birkenholtz (2017) from a field study in Rajasthan, India observed the operation of the Jevons paradox with respect to drip irrigation systems, where farmers acquire drip irrigation to intensify production rather than conserve water, which rather than reducing the demand for groundwater is exacerbating groundwater over-extraction. Ward and Pulido-Velazquez (2008) also indicated that where return flows are an important source of downstream water supply, reduced deliveries from the adoption of more efficient irrigation measures will redistribute the basin's water supply, which could impair existing water right holders who depend on that return flow. These findings support the conclusions of Schierling *et.al.*, (2006), and others(Huffaker and Whittlesey, 2003; Ahmad *et.al.*, 2007;Molden, 2007;Pfeiffer and Lin, 2013; Gomez and Gutierrez, 2011). So far, there is no indication that the results would be any different in India. It is therefore proposed for a paradigm shift in the positioning of micro irrigation technologies in the minds of farmers: from 'water saving' technologies to 'income enhancing' technologies to save input (reduced production costs on labour, fertilizers, electricity *etc*) or enhance output (enhanced crop yields with premium quality). We believe that farmers are more likely to respond positively to technologies that promise them tangibly higher income rather than an offer of theoretical and diffused water saving. Additionally, there is a need for more research focused on understanding what drives the Jevons paradox and what institutional levers may be employed to close the gap between water-use efficiency and intensification dynamics (Birkenholtz, 2017).

Micro Irrigation Penetration

Despite academic and practitioner recognition of the benefits of drip irrigation technology, expanding private irrigation equipment industry, convincing financial and economic viability and promoting extensively over the past 2 – 3 decades through subsidies and schemes, the appeal of the technology has remained confined to "gentlemen farmers" and in a few states of Maharashtra, Andhra Pradesh, Karnataka, Tamil Nadu and Telangana. Current penetration of micro irrigation varies in different states of India is variant. The average penetration in the country is estimated at 5.5% which is much lesser compared to countries like Israel (90%), Russia (78%), Spain (75%), the USA(55%), and Brazil (52%) (Fig. 5). According to the International Commission on Irrigation and Drainage (ICID), drip irrigation accounts for 73.6% of all irrigated land in Israel (mechanized sprinklers account for a remaining 16.4%). The Israeli drip irrigation experience represents a case of early and still unparalleled national scale adoption. As a comparison, India, China and the USA are three other countries that can be considered to represent successful drip irrigation adoption, though at substantially smaller scales relative to the overall size of the agricultural sector and available arable land. India now has close to 12.9 M ha under micro irrigation with 6.11 M ha under drip and 6.79 M ha under sprinkler irrigation. This is attributed to the large cultivable area (143 M ha) and area under irrigation (~69 M ha) in the country – the second largest area under irrigation in the world. Yet, with more than one-half of the cultivable land in the country in rainfed areas, there is mammoth potential for promoting drip and sprinkler irrigation in the country. A recent estimate by Chand (2020) projects the potential area, which could be brought under micro irrigation systems (drip and sprinkler) at 72.17 M ha to 77.58 M ha under different scenarios considering canal, tank and groundwater (bore, tube and open wells) irrigation.

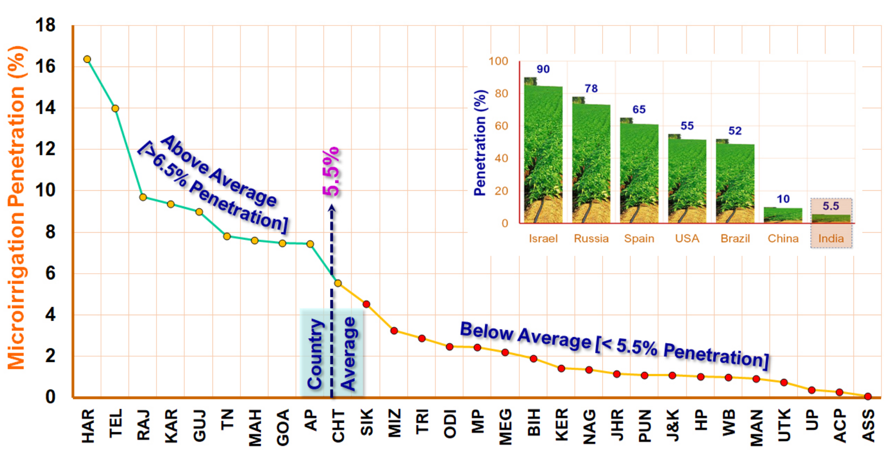


Fig. 5. Penetration of micro irrigation in different states of India and world

Moderating the subsidy level by capping it at 50 percent in states (e.g., Maharashtra, Andhra Pradesh, Tamil Nadu, Gujarat, Karnataka, Rajasthan etc) where penetration is already above the national average and re-distributing the funds in other states, where a higher subsidy is necessary to promote further penetration can help in more inclusive and uniform growth of area under micro irrigation in the country. This can be a reform driven approach (which shall be a part of the scheme guidelines).When states, who do not comply with capping policy, they may be declared ineligible and the entire subsidy funding must be met from state budgets to implement their own programmes.

Regulation of Prices

In contrast to 'fixed' unit prices, farmers and suppliers may be allowed to negotiate, subject to price ceilings. The SPV (APMIP, TSMIP or GGRC) or implementing agency in the state may set up price ceilings to ensure that farmers (and the state exchequer) get a fair deal but allow suppliers to compete with each other in negotiating the best price directly with the beneficiary farmers. In order to do this, the SPV or implementing agency will have to ensure that prospective micro irrigation adopters are well aware about the quality of products and services offered by different micro irrigation system manufacturers. This can be done by conducting regular surveys of beneficiary farmers about their experience with specific brands and using the results of the survey to rank or grade the performance of different manufacturers. The results of such an exercise should be widely publicized and should be made available to prospective adopters so that they can make informed choices. Such a system would be the hallmark of a truly 'demand-driven' micro irrigation promotion regime.

Energy – Water Nexus

The prominence of groundwater irrigation in India's agricultural economy and the need for energy to extract groundwater means that the fate of the water, agriculture and power sectors are inevitably intertwined. India uses 84.6% of its water (Bm3) for irrigation and 65% of irrigation supply is provided by groundwater. As a result, since the early 1970s, there has been a steady decline in groundwater table particularly in North-West (N-W) India (0.2 to 1.0 m/year). Such large-scale withdrawals are mainly due to 196-fold increase in the irrigation wells from 0.15 million in 1960 to nearly 29.5 million in 2015 (GEC, 2015). Further, modelling groundwater levels of N-W India revealed that, if the present level of abstraction continues at the same rate until 2028, groundwater levels will decline at rates of up to 2.8 m/year in critically overexploited areas. This has also led to increased energy demand for pumping and increased costs for installing deep submersible pumps. Free or subsidized electricity has frequently been cited as one of the main factors causing groundwater depletion in many regions of India (Gulati et.al., 2019). A study in more than 370 districts in India indicated that a 10% reduction in electric subsidy could decrease the groundwater demand by 6.8% (Sishodia et.al., 2016).One of the reasons attributed for farmers' tendency to over-irrigate is the unpredictability of power supply. When farm power supply is erratic, farmers tend to pump groundwater whenever power is available irrespective of the water requirement of the crop. Considering the seriousness of speedily depleting groundwater resources, the provincial Governments in Punjab and Haryana as well as Government of India have initiated new policy program (Water is Life, Direct Benefit Transfer of Electricity etc.) for saving water in agriculture. Effective rationing of power supply to agriculture, rigorous check on power theft and strict adherence to a pre-announced power supply schedule for farmers will incentivize farmers to adopt micro irrigation technologies. Another promising development in the country is smart new solar pump policy for farmers. By creating an opportunity to earn cost for the solar power produced, grid-connected solar irrigation pumps will make it profitable for farmers to shift cropping patterns to high-value, micro irrigation friendly crops as well as adopt practices and technologies that minimize water and energy use (Shah and Verma 2014).

Micro Irrigation in Canal Command Areas

Irrigation in canal command areas is predominantly by gravity-flow; water is released and flows through the hierarchy of canals into farmers' fields by gravity. Further, since the canal systems are managed and operated by a government department, farmers have little or no control over water releases. This discourages farmers from adopting micro irrigation technologies. However, several states including Karnataka, Rajasthan, Gujarat and Maharashtra are making efforts to reconfigure canal command areas and integrate Pressurized Drip Irrigation Network Systems to facilitate and promote adoption of micro irrigation in canal command areas. A notable example of such innovative community based integrated micro irrigation is the project was commissioned by the Krishna Bhagya Jal Nigam Ltd. (KBJNL) in Karnataka in 2017 to combat water scarcity in 24,000 ha in Hungundtauk of Bagalkot district under the 'Ramthal (Marol) II Stage Drip Irrigation Project' (Fig. 6).

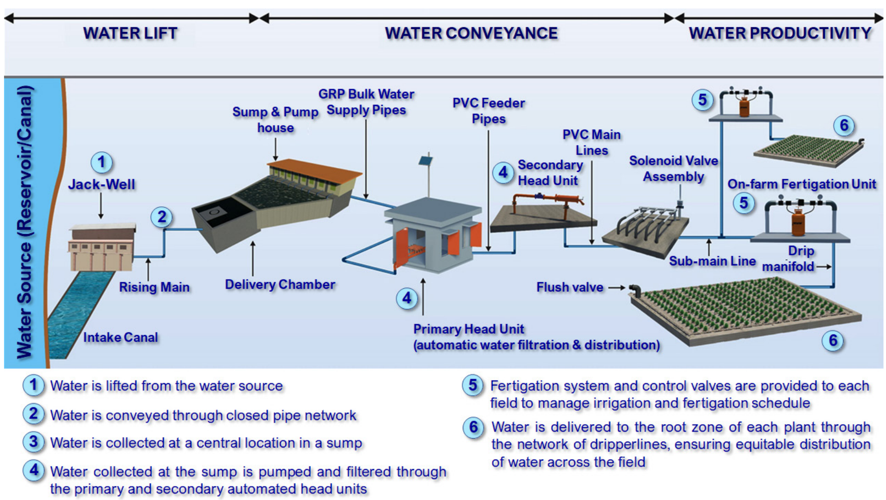


Fig. 6. Ramthal Drip Irrigation Project - Framework for implementation of drip in canal command areas

In this project KBJNL worked with Netafim and Jain Irrigation – two leading micro irrigation manufacturers in the country – on a build-operate-maintain-transfer basis model at a cost of Rs. 766.83 crores. The water from Krishna River is lifted from Narayanpur reservoir and floated to Ramthal sump and then it is distributed through pipe network instead of open canal up to individual farms and on-farm drip irrigation system using modern automation system to individual farms using 2150 Km HDPE / PVC pipe network, electromechanically programmed control devices such as pumps, control valves etc. It ensures that water is drawn from source equivalent to needs of the crop by farmers, thus cutting down the wastage, and saving water; with less manual intervention, it ensures timely and precise irrigation and fertigation to crops. The farmers can regulate irrigation in their farm using technology through mobile phones enabling data logging and monitoring. Recent experiments with on-farm water storage to mitigate inadequate and variable water supply in canal commands in the Indira Gandhi Nahar Pariyojana project in Rajastahan combined with micro irrigation was also shown to be highly successful in water control and timing of inputs, increase in gross irrigated area, crop yields, higher average net value of output per ha of 56%, improved benefit cost ratio of 2.2 and internal rate of return of 35% (Amarasinghe et.al., 2012). Such a policy framework for the development of command area can potentially be a game changer for the spread of micro irrigation in the country. In this policy framework detailed guidelines concerning drip and sprinkler design modules, system components, automation, unit costs inclusive of water conveyance and distribution infrastructure, separate budget provision etc., are to be incorporated for promotion of drip and sprinkler irrigation in canal and lift irrigation command areas of the country.

Leveraging Value Chain and Developmental Programmes

Opportunities for market-led micro irrigation promotion also exist in the value chains of high-value cash crops such as cotton, vegetables, fruits, sugarcane etc. In the Maikaal region of Madhya Pradesh, Central India, an organic company called bioRe has been promoting drip irrigation among cotton farmers (Eyhorn et.al., 2005) since early 1990s for improving livelihoods of smallholders. Likewise in Gujarat, the Aga Khan Rural Support Programme, India (AKRSP-I) has been promoting the Drip Pool project in Sayla and Chotila blocks of Surendranagar and Jasdan block of Rajkot district since 2011 to improve productivity of cotton by reducing water footprint and livelihoods among cotton farmers. Where farmers are linked directly with niche markets (as in the case of organic cotton farmers in MP) or where companies put a high premium on product quality and standardization (as with Gherkin or Rose farmers in peri-urban Bangalore), drip irrigation can be promoted with support from the value chain. Just as sugar mills and cooperatives help farmers with skills and inputs to produce high quality cane, they can also be used as intermediaries to promote the adoption of drip irrigation technologies.

Drip Candidature Crops

Presently the technology is in vogue only in a few agri-horticultural and cash crops. A field study by Namaraet.al. (2007) indicated that the higher the share of cereals and pulses in the cropping pattern, the lower the probability of adopting micro irrigation technologies as these farmers cultivating staple food crops are currently excluded from the benefits of innovations in micro irrigation technologies. There is a need to expand to many other fruits, vegetables, flowers, medicinal & aromatic crops, field crops such as maize, rice, redgram, soybean etc., silviculture plantations, protected agriculture, high-density orchards, saline water & wastewater use, problem soils etc. A recent field study by Jat et.al., (2019) suggested that bundling precision agronomic innovations like conservation agriculture (CA), inclusion of short duration legumes in rice and maize based cropping systems coupled with subsurface drip irrigation (SDI) and fertigation provides science backed evidence to address multiple challenges of food, nutrition, water, energy, soil health and climate change in intensive cereal-based systems of north-western Indo-Gangetic plains of South Asia. These results are of immense value to farmers, policy planners and civil society for addressing the current and future challenges of farming in India and need to be verified in groundwater irrigated commands of various states under diverse agro-ecological conditions.

Drip for Climate Resilience in Rainfed Drylands

Appropriate policy modulation to enable inclusion of micro irrigation technologies such as drip and sprinkler irrigation systems as an integral component of the watershed programmes and improve water productivity of harvested precious water to benefit the resource poor rainfed dryland farmers. Interactions with farmers and implementers of the drip programme in several states reveal that switch to drip irrigation and other similar technologies is not enough to address the problem of water scarcity. Where there is little or no water, the benefits of drip technology is limited. This triggers the need for an increased focus on promoting water availability along with effective water management. An integrated approach promoting water harvesting and conservation techniques together with the adoption of drip irrigation technology is needed. A portion of the funds (if additional funds are not available) may be allowed to be diverted for these activities and to conserve water collected during the rainy season. This would ensure availability of more water throughout the year and also help increase cropping intensity in intervention areas.

Agronomic Field Service

Besides the financial intervention and subsidy support agronomic field service is the key for improving farmers' incomes and environmental sustainability. For example, precise delivery of water through drip leads to better seed germination, field emergence of seedlings and reduced mortality. This means less re-sowing and gap filling, leading to a uniform and robust crop. Another important agronomic input to farmers is field irrigation and fertigation scheduling (when and how much to apply) for better crop performance and higher water and nutrient use efficiency. Similarly, crop health management following integrated pest and disease management is also important to cut down production costs. At present this component is not to the level of satisfaction.

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Crop Diversification for Sustainable Agriculture

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Traditionally, in the past, agriculture had been quite diversified and rather more sustainable around crops, livestock and silvi-pastoral systems. In fact, crop diversification had since long been a potential option for resilient and highly sustainable farming systems which for generations enabled improved livelihood, good health and household food and nutrition security. The scientific advancements and options for improved varieties and new crops, mainly during mid-sixties and seventies when seeds of Green Revolution were sown, led to gradual shift towards a few crops having potential to yield more and provide higher income. Such an approach eventually narrowed down dependence on a few crops like wheat, rice, maize, sugarcane, *etc*.

In fact, crop diversification depends on several interactive factors, *viz*., environmental, technological, institutional, market and income related factors. All these had led to gradual shift in India's cropping systems. The dynamic aspect of diversification had been accommodation of new crops or cropping systems that are best suited to prevailing eco-regional conditions, while ensuring higher production and income. Crop diversification also helped in much desired shift from regional dominance of a particular crop to a number of crops that meet varied demands for food such as: coarse cereals, pulses, vegetables, fruits, oilseeds, sugarcane, *etc*. Diversification largely depends on technological innovations aimed at sustainable intensification, as well as increased productivity while reducing cost on inputs so as to raise farmers' income. In fact, by growing a variety of crops, farmers face low risk and can get access to national and international markets. Crop diversification, besides food security, also helps in achieving household nutrition security, otherwise so critical to achieve ZeroHunger being the most important sustainable development goal (SDG2).

As a matter of fact, the main challenges for agricultural diversification are: land degradation; decline in soil health; ground water depletion; environmental pollution; and total factor productivity decline. These constraints must, therefore, be addressed on priority in case existing cropping systems are to be made both sustainable and remunerative to the farmers. In case of Indira Gandhi Canal Command area in Rajasthan, especially in Ganganagar, Bikaner and Jaisalmer districts, faulty adoption of crops like rice, wheat and cotton had led to problems of salinity, water logging and factor productivity decline. Instead, it would have been more sustainable if the emphasis was laid on silvi-pastoral and agro-forestry approach centred around animal-based farming system.

In fact, for crop diversification the future strategy must aim at: i) horizontal approach adopting crop intensification and crop substitution that are most suited to specific eco-regions, ii) vertical approach for enhancing productivity using genome editing and good agronomic practices (GAP) aimed at judicious use and increased efficiency of costly inputs such as water, energy, fertilizers, pesticides, *etc.* iii) post-harvest processing, value addition, branding, packaging, *etc.* to enhance income, iv) water use efficiency through micro-irrigation especially in dry lands, v) varietal diversification (introducing both high yielding varieties and hybrids for higher productivity), vi) incorporation of legumes, vii) adoption on large scale of integrated pest management, and viii) the risk management through inter-cropping, mixed cropping, a shift towards low volume high value crops and mixed farming.

In the Green Revolution era, major focus had been on cereals(mainly rice and wheat).Over the years, fortunately our food basket has diversified, thanks to focus on crop diversification. Also, the pattern of cropping has shifted mainly in favour of more profitable crops like pulses, oilseeds, cotton, sugarcane, vegetables, fruits and spices. At the state level, Andhra Pradesh, Maharashtra and Gujarat seemed to have the highest crop diversification followed by West Bengal, Bihar, and Karnataka. Most of other states, especially Odisha, Madhya Pradesh and north-eastern states are yet confined to a few traditional crops only.

Today, we have predominance of rice-wheat cropping system in the north (Punjab, Haryana and Uttar Pradesh),groundnut in Gujarat, sugarcane in the north mainly due to nobilization of cane, gram in the southern India and arhar in the north-western states like Haryana, Punjab, Rajasthan and Gujarat due to early maturing varieties (120days), soybean in Madhya Pradesh and adjoining states, winter maize in Bihar with very high productivity (>7.0 tons/ha), *etc.* This change from traditionally grown less remunerative to more productive crops being ideally suited to geo-climatic, socio-economic and technological options had invariably been gradual. It, however, got accelerated mainly after independence when cradles of success including policy support, good institutions, human resource, infrastructure, *etc.* were created. Despite these, still there are opportunities for area expansion through short-duration varieties of chickpea in non-traditional areas of Andhra Pradesh, Bihar, Tamil Nadu and Karnataka; inter or mixed cropping of black gram, green gram, and pigeon pea in central and peninsular region; introduction of short-duration pigeon pea in Gujarat, Rajasthan, Haryana and Panjab; and lentils, mustard and peas in rice fallows in Bihar, West Bengal, Odisha, Assam and some of the north-eastern states. To achieve additional production of pulses, there is need to breed and promote short duration (less than 120days) pigeon pea hybrids for the north-western region; improved varieties of soybean and *Kabuli* gram for the north western region; popularization of improved short-duration, disease-resistant varieties of mungbean to fit in rice-wheat-cropping system in the north and promotion of urad bean in rice fallows in the coastal region of Andhra Pradesh, Odisha and West Bengal. The decline in production of sorghum and pearl millet is largely due to change in dietary habits, low yields, and shifting of areas towards more remunerative crops like cotton, soybean, wheat, oilseeds, pulses, *etc*. Though farmers have been cultivating sorghum (both in *kharif* and *rabi*) and pearl millet in rainfed areas, their production has been highly volatile largely due to low and erratic rainfall. The challenge mainly is to breed early hybrids to replace HHB67 in the very dry region(A1zone) in Rajasthan and varieties/hybrids of *rabi* sorghum to replace predominantly an old Maldandi variety in Maharashtra. Quality protein maize(QPM) hybrids suited to different agro-climatic zones, and greater coverage of area under single-cross maize hybrids will further enhance maize production for which role of private sector is critical. There are also a number of under utilized crops, namely, pseudocereals (grain amaranth, buckwheat, quinoa), legumes (rice bean, faba bean, adzuki bean, mothbean), and small millets (finger millet, foxtail millet, proso millet, little millet, barnyard millet, kodo millet) that have high nutritional value and niche for drought and heat tolerant conditions. Soybean, popular in Madhya Pradesh and Maharashtra, may have good potential for replacing rice to some extent in north India. Utmost care needs to be taken to promote the cultivation of specific crops in their niche areas for harnessing their maximum genetic potential. Past experiences have amply demonstrated that new area approach can lead to faster progress on account of quick adoption of full technological packages without any prejudice on account of traditional practices ,for example, puddled rice in north India, wide permanent row for groundnut planting in Gujarat, soybean in Madhya Pradesh, *rabi* maize in Bihar, etc. Such an approach is more beneficial provided based on scientific land use. Other examples are: hybrid rice in eastern India, soybean in eastern and north-eastern region, sunflower in north India. After Brazil, India is the second largest sugarcane growing country in the world. It has best R&D infrastructure and known globally for nobilization of cane resulting in short duration, drought and disease tolerant varieties that enabled its spread to central, northern and western India. Earlier, productivity in Uttar Pradesh, Haryana, Punjab and Maharashtra was even less than the national average, despite availability of good varieties and production technologies. With area coverage under a new variety "CO0238", the scenario for productivity and sugar recovery has changed significantly. Yield potential of maize can be enhanced significantly by bringing more coverage under single cross hybrids that are currently available. Its extension to eastern Uttar Pradesh, Bihar, Jharkhand, West Bengal is already taking place.

Crop diversification has also helped world over in attaining sustainable agriculture. For example, most sustainable cropping system accounts for 38 and 35 percent of global maize and soybean production in USA., producing around 320 and 84mt, respectively. Over 85 percent is produced in the north-central region known as 'Corn Belt', where 2-year maize–soybean rotation is the dominant cropping system. Israel, one time the world's leading fresh citrus producer and exporter now grows more than 40 types of fruits which apart from citrus include , avocado, bananas, olives, apples, cherries, figs, plums, grapes, dates, straw berries, prickly pear, persimmon, loquat and pomegranate. These crops have replaced there wheat and cotton. Similarly, several varieties of dates were tried in Coachella valley, but 'Deglet Noor',an Algerian variety, became most popular covering approximately 90% area today. In fact, date cultivation has made California desert green over the last century. Likewise, Rajasthan farmers prefer to grow crops like guar-a traditional crop requiring less water and now considered an important industrial crop with considerable export potential.

Considering the importance of crop diversification, farmers need to be continuously motivated and encouraged to go for crop diversification for better sustainability and both income and employment opportunities. An accelerated pace of diversification to create positive impact on income, higher employment and conservation and efficient use of natural resources emphasizes the need for increased investment on R&D, scaling of innovations linked to sustainable farming systems that are best suited to varying agro-ecologies. However, as emphasised earlier ,adoption of crop diversification must ensure that it does not adversely affect the existing environmental balance concerning available natural resources.

The current argument is for a shift away from cereal-centric Green Revolution related cropping system to a more diversified farming system, which is climate resilient and sustainable in long run (Economic Survey, 2019).This will help in conserving natural resources (soil, water and biodiversity) by discouraging exploitative approach and having a paradigm shift towards production systems around regenerative agriculture. Such an approach would require scaling of innovations to improve resource use efficiency through appropriate policies and programmes. In this context, there is need to confess that scientific land use planning so far had been a weak link. Fortunately, unlimited opportunities in unexplored frontiers of science exist to make new gains from application of science, technology and innovation(STI) for sustainable agricultural growth and development. In conclusion, crop diversification has helped us in the past to achieve food security, but now we need to reorient existing cropping systems to be more sustainable and to continue addressing our household food, nutrition and environmental security.

Translating PM's Elusive Goal "Doubling Farmers' Incomes" into Ground Reality: Scenario, Challenges, Opportunities and the Way Forward

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The Current Agrarian Crisis on the Domestic Farm Front and the Worsening Plight of the Farmer

Despite drastic fall in its share of gross domestic product (GDP), agriculture still holds a pre-eminent place in the country's economy (% share of GDP= 2016-17 = 17.32%; 1950-51 = 49.41%); it forms principal source of livelihood to 58% of its population (and rural India # 68.3%) and provides employment to 2/3 the workforce in the country side (census 2011). The domestic farm scenario has undergone incredible transformation since 50s thanks for the maze of technological advances unleashed over last 40 years and the resilience of Indian farmer to take advantage of emerging opportunities and switch over to newer soil-water-crop-livestock - marine and inland fish culture management systems; the result of all these efforts - quantum jumps in production of food crops (1950-51 = 50.82 m.t; 2016-2017 = 275.7 m.t); oilseeds (1950-51 = 6.2 m.t ; 2016-17 = 31.3 m.t); cotton (1950-51 = 3.04 m. bales; 2016-17 = 32.6 mb), pulses (1950-51=8.4 m.t; 2016-17 = 23.0 m.t.); Sugarcane (1950-51 = 54.8 m.t; 2016-17 = 303.6 m.t); milk (1950-51 = 17 m.t.; 2016-17 = 163.7 m.t.) eggs (1950-51 – 1.8 billion; 2016-17 = 88.1 billion) and various other farm commodities. Simultaneously, productivity levels of all farm commodities, be it agri-horti or animal, fish, sheep, goat witnessed spectacular growth. Quite paradoxically, the country's backbone of its economy, the farmer who holds today the grandiose encomium 'Annadata' presents a dismal picture amidst his yeoman contribution to the stupendous achievements in the form of green, yellow, blue and white revolutions coupled with food and livelihood security. Over the last two decades, there has been a widening farm - non- farm as well as rural - urban or Bharat - India income inequality. As per report of 70th round of NSSO survey 2002-03 to 2012-13, farmers seldom make on an average Rs 6426 income per month which is lower than legally laid out minimum wages for unskilled workers in agri-sector and not even 20-25% of either the country's average *per capita* income or what a lower strata Govt., employee earns today (Dalwai,2018 and NSSO,2014). What is worse still, 61 out of 90 million farm house-holds with one or lower than one hectare are reported to have a net negative monthly budget (income = Rs. 4718; consumption expenditure = Rs 5701; net balance – Rs. 983). Added to their extremely low disposable incomes and poverty are the chronic problems of high indebtedness, recurrent crop failures, uncertain and erratic returns to his produce at the marketplace, supply of sub-standard and spurious inputs and the associated crop losses. What is more shocking, the incidence of suicides among farmers registered rapid rise in the recent past (# average number of suicides/ year over the last 3 years = 12000) (National

Crime Records Bureau of India). Little surprise, today there is widespread dis-enchantment among farmers as well as rural youth with farming resulting in growing rural to urban migration, widespread exit syndrome, progressively shrinking gross cropped area and incidence of rampant absentee farming. The yester years popular adage "farming supreme, business good and service worst" has undergone a reversal *i.e.*, "service supreme", business "good" and farming "the worst".

What Ails the Country's Much Talked of 'Annadata'

Contrary to the popular saying of late Pandit Nehru 'everything can wait but not agriculture' in reality it is 'nothing can wait but the farmer'. Currently, all government's developmental efforts are focused more towards production and productivity improvement, food security rather than farmer welfare and income security. Today's widespread agrarian distress is a product of cumulative neglect of farmer and his abandonment to the mercy of weather god, exploitative market forces and marketers of spurious inputs. As a result, the country's farm sector and its key stakeholder *i.e.*, the farmer is plagued by a plethora of chronic maladies such as weak institutional support systems (credit, service, marketing, input), ineffective risk mitigation mechanisms against weather induced hazards and market driven volatility in prices, flawed land tenure and tenancy, poor infrastructure (irrigation, transport, communication, storage, post-harvest storage, processing , logistics infrastructure), far from farmer friendly public policies (marketing, farm trade, farmer subsidies, rural infrastructure, *etc.*), preponderance of extremely small holdings (one hectare or less accounting to 67.1%; 1-2 ha = 17.9%) and the associated dis-economies of scale (NSSO, 2014), coupled with widespread rural indebtedness. Needless to over emphasize all these maladies warrant urgent remedy on a war footing.

Mission 2022 of PM and the Ambiguity Surrounding 'Farmer Income'

Dr M.S. Swaminathan, Chairman, National Farmers' Commission in his report recommended for fixation of farm prices at 50 per cent above farmers' weighted cost of production; the report is however, silent on which cost whether Comprehensive or C2 costs *i.e.*, paid out costs plus interest on fixed capital assets, rent on owned land, or A2 *i.e.*, all paid out costs plus Imputed family labour (FL). As part of Government's larger strategy for removal of agrarian distress, Mr. Narendra Modi, PM of India while addressing a Kisan rally in Bareily on 28 February 2015, gave a clarion call to the nation for doubling the incomes of farmers by the year 2022 on a mission mode. Based on past income growth rates of farmers, Ramesh (2016 and 2017) and the Committee on Doubling Farmers' Income (DFI) headed by Dalwai (2018) suggested an annual growth rate of 10.4% for attainment of DFI (real) well on targeted time *i.e.*, year 2022. Ashok Gulati (2018) and Ashok Gulati and Saini (2016, 2018 and 2018a) were however, highly skeptical of achieving such ambitious growth rates in view of country's dismal track record of not only agri- growth for the last 4 years (2014-15 to 2017-18 = 1.9%) but, low levels of growth in real farmer incomes (2012-13 to 2016-17 = 2.5%; 2002-03 to 2012-13 = 3.6% CAGR). Even more pessimistic of Dalwai' (2017 and 2018), and Ramesh (2017) and Nabard (2016) are Thomas and Kaundinya (2018) who projected 25 years for DFI at current 3% agri growth. Given all these and the dependence of net farmers' incomes on a host of factors, both direct and indirect *viz.*, weather, input-output price parity, technology and input levels applied, pricing, transaction costs in marketing, etc. DFI by 2022 in real terms on a sustainable basis may indeed be daunting, if not impossible.

The Finance minister in his 2018 budget speech stated that MSP's in most crops are already fixed at 50 per cent over costs and announced his Government's commitment to extend the latter across the board. A perusal of MSPs for 14 *kharif* crops for 2017-2018 marketing season *vis-a-vis* CACP's A2 (actual paid out costs) plus imputed family labour, (A2 + FL), C2 (i.e A2 + FL + imputed rent on value of owned land + interest on value of owned fixed capital assets excluding land) on the contrary, reveals an entirely different picture (CACP, 2017); the Govt.'s declared MSP's are 50% above A2 plus family labour in only 3 out of 14 crops namely bajra, arhar, urad while they are close to production costs in Jowar, Niger and17.8 to 43.8 percent higher in 8 others (CACP, 2017). What is surprising, none of the above crops registered the promised 50 per cent higher returns over C2 costs (Table 1). Even those which received higher MSP levels than C2 costs, the extra income fell far short of 50%. Contrary to widespread farmers' expectations and other recommendations of Swaminathan's Commission, even the latest MSPs announced by Government of India for *kharif* marketing season, 2018-19 are nowhere near the promised 50% returns over C2 costs (CACP 2018). Quite obviously, what the finance minister actually meant when he assured cost plus 50% net returns to farmers over MSPs is cost plus 50% more over A 2 + FL costs rather than C2 costs (Ashok Gulati and Saini, 2018b). Such a practice is in fact, at total variance with what business enterprises adopt; they take not only paid out costs but a whole lot of indirect costs such as interest on value of owned fixed capital assets, rent on value of owned land (in case of farm sector), management input as a pre-determined percentage of total C2 costs. The adoption of such a discriminatory approach for 'determining what should be the cost plus income' to the farmer in the farm sector which is as much a business enterprise as any other, be it manufacturing or service is not only surprising but grossly unjustified and in contravention of demand of farmer organizations as well as the recommendations of Swaminathan's Committee. Farmers are rightly entitled as any other businesses for inclusion of not only all direct but indirect costs in their total costs while fixing MSPs from the point of assured income over his real production costs.

Farmers' Income Today, Prime Minister's Dream, Challenges and the Way Forward

The accomplishment of mission 2022 of Mr. Modi calls for multi-pronged integrated solutions covering a whole spectrum of activities related to not only '*production phase*' but also '*post-production*' as well right up to the consumer. The ultimate income from any business enterprise is a function of its unit price of the output (production)* minus the total cost of production. One could maximise income from an enterprise by either stepping up productivity levels or by realizing higher unit prices of output or both coupled with/without concurrent reduction in production costs. The farm sector in fact, offers a plethora of options for realising this goal as discussed below.

1. Raising productivity levels from farming: Despite spectacular gains brought about in the general productivity levels of various farm products, be it agri-horti crops, livestock, fish, agro forestry over last 70 years, there nevertheless, exists even at current levels of state of art technology, wide yield gaps (= ranging from = 40 to 70%) in different farm commodities. Needless to over emphasize, all such gaps between what is exploitable with the available technologies and prevailing yields at field level need to be bridged expeditiously through massive extension and developmental efforts backed up with matching and timely input service support system.

2. Lowering unit costs of production: Equally wide ranging are the avenues (viz., technological, social, institutional, infrastructural, policy interventions) for cutting down unit production costs in the farm sector and through that step up farmers' net realizations. As for instance, the agri sector alone consumes more than 90% of country's ground water resources (and 83% of total water resources); India in fact, uses twice the amount of water to grow crops compared to a country like Israel with extremely scarce water resources. A multitude of proven and cost effective technological interventions are today readily available across geographies in the farm sector to bring down unit costs substantially in conjunction with maximization of resource use efficiency of plant-soil-water and nutrients. These inter alia involve exploitation of state of art region/situation tailored, implementable and cost effective technologies such as micro-irrigation, conservation farming, crop diversification, stepping up cropping intensity through relay/sequence cropping in all assured moisture areas, choice of region/situation tailored farming systems coupled with adoption of recommended agro production-protection practices in tune with appropriate soil water conservation measures viz., optimum planting time, seeding rates, method and spacing, soil test based balanced nutrient application as per suggested time and placement, integrated pest, disease, weed and water management, adoption of practices such as direct seeding/ Sri/aerobic cultivation in rice, precision and timeliness of critical operations namely interculture, irrigation, stage and time of harvest, micro irrigation etc. The successful tapping of all such avenues in synergy with other equally important initiatives discussed elsewhere undoubtedly offers unlimited scope to prune down production costs without affecting ultimate output

3. Safeguarding farmers against weather risks, natural hazards: Excessive dependence of farming on weather and the impending climate changes pose gravest threat to the livelihood and income security of farmers, bulk of whom are small and marginal. Even after 70 years of planned development, farming in our country continues to be a gamble with the wayward monsoon and its erratic behaviour in space and time (droughts, excessive wet weather, floods, hailstorms, cyclones etc). Despite a host of national crop insurance schemes since 80s (NAIS of 1985 and modified NAIS of 1999-2000), risk protection through insurance remains a pipe dream even today; together they account for a negligible share of either total gross cropped area or number of farmers in the country (Banerjee and Bhattacharya, 2011; Raju and Chand, 2008, Nabard, 2016). Notwithstanding its greater acceptability over traditional yield loss assessment or indemnity based crop insurance, the weather based crop insurance scheme is yet to gain foothold because of very weak infrastructure backup in terms of automatic weather stations, low earth orbit (LEOs), rainfall data loggers, Drones etc. The situation is no better with the much publicised Pradhan Mantri Fasal Bima Yojana (PMFBY) (Targeted coverage by 2018-19 = 50%; actual in a majority of states = 20-25%). This is in contrast to the exceptionally high coverage reported from countries like USA (coverage = 90%) and China (coverage=70%) (Ashok Gulati and Hussain, 2018 and Ashok Gulati 2018 a). Protection of incomes against natural calamities should therefore, form an integral part of doubling income on a sustained basis. This no doubt, calls not only for massive investments in infrastructure, premium subsidies as well as harnessing of latest technologies (satellite imagery, GPS data analytics, drones) but re-

tailoring of on-going insurance schemes to suit to ground level priorities and situations together with massive educational efforts for their popularization.

4. Protection against market volatility in prices and loss of farmer incomes: Farmers suffer not only on account of adverse weather aberrations but violent fluctuations in prices as well, more particularly after the advent of globalisation and the emergence of global market place. Unlike developed countries of west, which totally insulate their farmers against volatile price falls or revenue shortfalls through payments in one form or the other (direct, market linked, deficiency), India offers no such luxury to its farmers bulk of whom are small and marginal. Even the MSPs which GOI offers to 23 crops hardly touch the lives of bulk of the country's 140 million and odd farm holdings for want of a guaranteed procurement mechanism in most crops other than rice and wheat. Commodity agricultural futures which the national commodity exchanges (NCDEX and MCX) claim to serve as a powerful safety valve to farmers avert income losses on account of price fall are yet to gain momentum and receive widespread acceptance (% coverage ≤ 2%).This is not unexpected since the domestic farm sector is dominated by holdings of two ha or less and their disposable surpluses very low. Although farmer producer organisations (FPOs) not only offer viable and sustainable solution for tackling the vexed problem of dis-economy of scale of millions of small farms, but act as aggregators and harness futures as an effective tool/instrument for the benefit of its member farmers, they are yet to gain popularity. The success stories of large number of FPOs in the country (Kolhapur Sugar Co-operative of Maharashtra, Mulakanur Cooperative of Telangana, Maha grapes and Hivre Bazar of Western Maharashtra), only underlines the urgent need to dissuade farmers from current political or/casteist grouping and organise them into need based FPOs of one form or the other (cooperatives, cooperative companies, self help groups, etc) and through it help the latter help themselves improve their collective bargaining power as well as voice and solve their problems (NABARD, 2016); otherwise freeing farmers from current agrarian crisis and the associated maladies such as widespread poverty, rural indebtedness, livelihood insecurity, and damocle's sword of suicides hanging over their heads would be an eternal mirage.

5. Minimising loss of output and incomes on account of poor post-harvest processing and storage infrastructure: Apart from weather induced risks and market volatility, not only public and private sectors but farmers suffer considerable quantitative and qualitative erosion of various agri-commodities on account of inefficient harvest, post-harvest handling, processing, storage, transport in the on farm - off-farm value chain. As per studies of all India coordinated project on post-harvest technology(ICAR), PAU, Ludhiana, the extent of total post-harvest losses vary from 4.65%-6% in cereals,6.4%-8.14% in pulses,3.1%-10% in oilseeds,6.7%-15% in fruits,4.6%-12.4% in vegetables, 1.2%-7.9% in plantation crops to 1% -7.2% in livestock produce (Jha et al., 2015). Even today, the country's post-harvest infrastructure remains abysmally weak. Unlike other countries such as Brazil (= 70%), Malaysia(= 83%) only a miniscule of domestic horticultural produce is processed (vegetables = 2%; fruits = 4%) leading to huge post-harvest losses (Rs. 92651 crores at production levels of 2012_13 & wholesale prices of 2014) (Jha, S.N et al., 2015). Undoubtedly, the food logistics chain in India warrants huge investments for bridging the gaps in scientific post-harvest infrastructure.

6. Creation of conducive and matching farm policy support systems: The pro-consumer and anti-farmer agri policies of successive governments have indeed played havoc with farmers' economy. The latest studies of Organization of Economic Cooperation and Development-Indian Council of Research on International Economic Research (OECD-ICRIER, 2018) strongly corroborate such a distortion; according to their report, domestic farmers on an average' received, over the last two decades, 14% less payments/year than what they otherwise get in the global market place while consumers on the other hand, enjoyed 25% price advantage/year on all commodities. As is obvious from what is highlighted below, the prevailing policy environment is far from farmer supportive in helping farmers achieve either high resource use efficiencies per unit of area/input/effort/ time and/or quantum jumps in agri-horti-livestock-poultry-fish by harnessing already available exploitable technologies in the field:

- Our current fertilizer subsidy policies (nutrient based subsidies, freeing of P and K prices *etc*) encourage highly imbalanced use of plant nutrients (current N:P:K being 10:4:1; while optimum is 4:2:1) in place of soil test based situation and crop specific nutrient application to the detriment of soils, their nutritional status (micro & secondary nutrient deficiencies) as well as against farmers' own interests.
- Similarly, absence of any rigid water regulatory policies as in countries like Israel with meagre water resources result in gross abuse of our precious and scarce water resources (as per National Commission for integrated Water Resources Development; water requirement by 2050=1180BCM; present availability = 6,95BCM) through flooding as well as excessive and liberal applications instead of using more efficient, well established micro irrigation systems (coverage today as per MOAC and FW 2016 = 8.63 m.ha i.e., 6.2% of total sown area of 140 m.ha.) and promotion of water guzzlers like rice, sugarcane at the cost of more efficient water users like oilseeds, millets like sorghum, bajra), maize, pulses, horticultural crops. A case in point is Maharashtra which uses 65% of its otherwise scarce irrigation water resources (total irrigated area = 19%; national = 47%) to sugarcane, a very low WUE crop with just 4% of gross cropped area in the state leaving other more efficient crops virtually water starved. The Cauvery basin of Tamil Nadu and Karnataka presents more or less a similar story.
- An yet other area related to critical farm inputs is our growing unabated proliferation of fake and spurious substandard seeds, fertilizers, pesticides, biological and their associated risks *i.e.,* crop losses, inefficient resource use, cost escalation, indebtedness, farmer suicides in the face of continued prevalence of obsolete seed laws of 1968 (and indefinite shelving of more stringent new seed act of 2003), insecticides act (1968) and total absence of any regulations to check rampant supply of substandard and spurious biologicals. Equally unfavourable to the domestic producers are a number of other farmer support systems/policies which impact ultimate farmers' costs as well as their margins and operational efficiencies and they include:
- The government's MSPs which are otherwise considered as a sovereign guarantee to farmers for protection of their investments in the event of price fall below the declared benchmark and ensure reasonable margins over their costs have become no more than a "paper tiger" in as many as 21/23 crops for want of either

an assured procurement system or alternate mechanism for reimbursement of price deficiency over MSP as in case of Madhya Pradesh Government's more successful *Bhavantar Bhugtan Yojna* (BBY). Ashok Gulati, Tirtha Chatterjee *et al.*, (2018) & Ashok Gulati, Marco Feroni *et al*. (2018) are however, highly critical of not only current agri price support system/ MSPs but also price deficiency payment schemes, be it BBY of Govt of MP or its pan India version " *Pradhan Mantri Aay Sanrakshan Abhiyan* (PM_ Aasha) as such interventions ignore demand side and distort agri-market system. They advocate instead adoption of least distortionary, crop neutral intervention policies in the form of direct investment support on the lines of Govt of Telangana's "*Rythu Bandhu*" scheme of payment of Rs 4000/acre to every land owning farmer (both in *kharif* & *rabi* seasons) in other words conversion of subsidies into direct income transfer

- The land market which in fact, is the key driver for stepping up "productivity", "efficiency" and " "investment" of millions of small and marginal farms in the country side is seriously constrained on account of inaccurate &/or incomplete land records (titles, ownership/tenancy, size, boundaries *etc*.) and the associated high transaction costs including civil litigations. Equally to blame for today's 'unsustainable' farm holdings 'growing exit' syndrome or withdrawal from cultivation is the reluctance of land owners lease in their land assets for fear of threat from tenants under the draconian tenancy act which is skewed in favour of the latter and the absence of proper land leasing policies so essential for overcoming dis-economies of scale and improve efficiencies of small and marginal farm holdings, besides promoting their diversification (NABARD, 2016). As per reports of Shreya Deb (2018), un-official leasing figures (= 25%or more) far exceed those of official tenancy estimates of 13% (NSSO 2014). This only underlines the urgent need for streamlining our system of land administration using state of the art technologies /tools (geospatial drones, digital) together with transparent and liberalized land lease policies through adoption of model land leasing act of MOAC and FW across the country.

- The introduction of Mahatma Gandhi National Rural Employment Guarantee Act (MGNAREGA) has adversely impacted not only labour availability in rural heartland but pushed up labour costs in times of crucial agricultural operations. This warrants a re-appraisal of MGNAREGA *vis-a-vis* the concerns of farm sector to make it a win win proposition. The MGNAREGA scheme may be employed to meet the demands of agricultural operations in a collective farming mode.

- Equally to blame are our faulty and knee jerk import-export policies *viz*., liberal imports through very low import tariffs in domestically high sensitive commodities like edible oils despite availability of very high bound rates(= 300%), or restrictive *ad hoc* export policies (stock controls for private players, controls on future trading, export bans, minimum export prices) in times of bumper domestic production to the disadvantage of domestic producers (Ashok Gulati and Terway,2017)

- "Competitive state loan waivers" by states have become of late a norm rather than an exception to keep vote base intact and capitalise on farmers distress. Such moves not only fail to address the real malady *i.e.*, "agrarian crisis" but lead to more such demands. What the farmers need is not such *ad hoc* temporary remedies but creation of income generating avenues in the off farm domain akin to what services did in the urban sector through transformation of rural area into manufacturing hubs of post-harvest value chain from farm to fork.

- Our key investment policies in the country's most crucial sector *i.e.*, farm sector continue to be overwhelmingly biased towards food and input subsidies neglecting the crucial agri infrastructure; In fact, public investments in agriculture as a percentage of agri GDP has declined from 3.9% in 1980-81 to 2.2% in 2014-15 while input subsidies increased from 2.8% to 8% over the same time span (Ashok Gulati, Marco Feroni *et al.*, 2018); this is too glaring from a cursory look at expenditure bill of 2018-19 for agriculture and food (total bill = Rs. 3.66 lakh crores; input and food subsidies = 88%; agri-investment =12%). No surprise, if our *per capita* water storage capacities are very low (=213CM) compared to other countries (China = 1111 CM; Australia = 4733 CM; USA = 1964 CM) even after building large number of large and small dams (Niti Aayog, 2018). Not only irrigation, our post-harvest infrastructure is abysmally poor. Unlike other countries such as Brazil (70%), Malaysia (83%), Philippines (78%) only a miniscule of domestic horticultural produce is processed (vegetables = 2%; fruits = 4%) leading to huge post-harvest losses (=Rs92651crores). Unless this imbalance in our agri investments is rectified and farm infrastructure gets a major boost, raising productivity and economies of millions of small and marginal farms would continue to elude us.

- The model APMC (Development and Regulation) act which was introduced way back in 2003 by GOI as part of its larger national objective to establish more efficient, transparent and integrated marketing system is yet to be translated into field reality in most states. The existing agricultural marketing under APMC act in states and their poor infrastructure, monopolistic and uncompetitive policies have only perpetuated fragmentation and inefficiencies with huge number of intermediaries. Contract farming which is permitted under the modified state APMC acts of 2003 though offers unlimited avenues to farmers minimise their risks on account of market volatility and leverage on improved access to technology as well as inputs has not yet become very popular because of one or the other inherent limitations. The recently launched "Agriculture produce and livestock contract farming and services (promotion and facilitation) act, 2018 which is outside the ambit of APMC acts of states is expected to receive patronage from all stakeholders i.e., farmers, agro industry, retail chains as it removes all current hurdles. Though e-Nam is expected to free farmers from the monopoly of APMCs and provide them access to unified national marketing platform with attendant advantages (dis-intermediation, transparency, wastage control), it's penetration and reach to date is too low (585/7500 regulated markets under APMC) to create any visible impact in the immediate future for want of one or the other reasons (delays in amendment of APMC acts by many a states for facilitation of introduction of e-Nam, lack of internet connectivity, poor infrastructure & equipment).

- Farmer producer organisations which hold ultimate key for removal of structural handicaps of country's millions of small and marginal holdings (which constitute 85% of total operational holdings) as well as their transformation into viable and sustainable businesses through successful exploitation of the benefits of economy of scale, the latter offers (*viz.*, enhanced bargaining power through forward and back ward linkages and their associated advantages *i.e.*, mobilisation of input supplies, aggregation of outputs, their marketing, custom services at lower cost & the resultant reduced transaction costs in marketing, direct marketing *etc*) remain till to date grossly under exploited on account of inherently weak support system (institutional finances, post-harvest infrastructure, integration with value chain, access to technology, inputs).

What is therefore urgently needed, if PM's dream of DFI on a sustained basis is to be made a reality in tune with improved livelihoods of millions of farm households and other workforce the latter support, is the speedy rectification of all these and various other loopholes in our farm policies together with creation of mutually reinforcing and synergistic policy environment and supportive infrastructure in the form of post-harvest processing facilities including storage, transport, market linkages with value chains.

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Prelude to *Pongamia*

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Pongamia glabra Vent. or *Millettia pinnata* or *Pongamia pinnata (karanj*) (2n=22) is a species of oil seed bearing tree of the legume or pea family, Fabaceae, native to eastern and tropical Asia including India, Australia and Pacific islands. The nomenclature *Pongamia pinnata (karanj*) is commonly used in India.

The history of Pongamia in India is linked to a wide variety of related plant/tree systems native to the Indian subcontinent. Its history overlaps or coincides with the development of agriculture in the Indian subcontinent since the Iron Age, with some of its traditions tracing back to prehistoric eras such as those of the Bronze Age Indus Valley Civilization. It has thus been called one of the oldest trees in the world.

Pongamia is a tree with more or less tending towards dense globose canopy, bark smooth and greyish brown. Compound leaves with large leaflets. Fruit is a woody pod with single seed. It is Evergreen tree, to 18m high, bark 10-12 mm thick, surface grey, smooth, speckled with brown; blaze-yellow; branchlets lenticellate. Leaves imparipinnate, alternate; stipules lateral, small, oblong, cauducous; rachis 10-15 cm long, slender, pulvinate, pubescent; leaflets 5-7, opposite, estipellate; petiole 6-10 mm; slender, pubescent; leaflet 4.5-12 x 2-7 cm, elliptic-acuminate, elliptic-lanceolate, ovate or ovate-oblong, apex acuminate, margin entire, glabrous, chartaceous; lateral nerves 5-8 pairs, pinnate, ascending, slender, faint; intercostae reticulate, obscure. Flowers bisexual, purplish-white, 15-18 mm long, in lax axillary racemes, axis pubescent; bracts small, cauducous; calyx tube campanulate; minutely 5 toothed, apex truncate; corolla exserted; petals 5, clawed; standard suborbicular with curved folds above the claw; wings obliquely oblong, slightly adnate above the claws to the obtuse keel petals which are joined near the tip; stamens 10, monodelphous, the vexillary stamen free below and above; anthers uniform; ovary sub-sessile, inferior, 1-celled, ovules 2; style in curved, beardless; stigma capitate. Flowering generally starts after 3–4 years with small clusters of white, purple, and pink flowers blossoming throughout the year. The raceme-like inflorescences bear two to four flowers that are strongly fragrant and grow to be 15–18 mm (0.59–0.71 in) long. The calyx of the flowers is bell-shaped and truncated, while the corolla is a rounded ovate shape with basal auricles and often with a central blotch of green colour. *Pongamia* is cross pollinated mediated by honey bees.

Fruit a pod, 4-5 x 2-2.5 cm, obliquely oblong, flat, thick, pointed at both ends, indehiscent, slightly falcate; seed one, reniform *Pongamia* has numerous common names in countries throughout southern and southeast Asia (e.g., in India it has the colloquial names Pongam, *Honge, Kanuga* and *Karanj*). *Pongamia* tree is cross pollinated mediated by bees.

In recent years *Pongamia pinnata* has been identified as one of the most trusted feed stocks for the production of biodiesel (Bodade and Khyade,2012; Biswas *et al.*, 2013; Dwivedi and Sharma, 2014; Prasad, 2021) The oil content varies in the natural tree populations from 25 to 40%. *Pongamia* oil contains several components of nutraceutical and pharmaceutical value of which 'karanjin' is very important that offers wide ranging applications in medicine, agriculture and industry (Vismaya *et al*., 2010; Prasad 2021). Additionally, *Pongamia* has established its efficacy in ameliorating problem soils (Prasad 2007; Warr, 2018).

Applications in rural India: Although *Pongamia* is yet to establish itself as a regular tree plantation crop in India, there is a long history in the country of using various components of the tree for fuel, green manure, insecticides, and traditional medicines in India. The oil extracted from seeds was extensively used as fuel for lighting lamps and as mosquito repellent. The leaves and bark were made into paste and applied over skin ailments such as scabies, psoriasis, wounds, itches, piles and inflammations. The leaf, root and bark extracts and decoctions were used to cure abdominal enlargement, ascites, biliousness, diseases of the eye and skin, vaginitis, piles, tumours, ulcers, and wounds. There was a traditional practice for the flowers of *Pongamia* being used against biliousness (nausea) and diabetes. The paste and extracts of green pods and seeds were used to control for keratitis, piles, urinary discharges, and diseases of the brain, eye, head, and skin. The oil was popularly used against biliousness, eye ailments, itch, psoriasis. leucoderma, leprosy, rheumatism, skin diseases, worms, and wounds. The raw stem twigs and young branches were used as tooth brush and to check tartar and gingivitis of teeth. Additionally, the leaves and young branches including twigs of the tree are universally used as organic manures particularly in rice fields. Some farmers (including my own grandfather) used to drink juice extracted out of leaves to strengthen immunity levels and to control various stomach and respiratory ailments and other diseases.

***Pongamia* and drought:** Drought is major abiotic stress limiting agricultural production in all the arid and semiarid areas of world. Adverse impact of drought on agricultural crops varies depending upon its intensity and duration. When the drought extends for more than two three weeks, the growth rhythm of annual crops gets adversely affected. Depending upon the physiological and developmental stages of the crop subjected to drought, the fall in productivity varies.

Since most of the annual crops despite their adaptation to dryland agricultural conditions are prone to the adverse effect of moisture stress due to drought, it is logical and appropriate to look for drought resistant perennials which can yield despite intensity and duration of drought. Among such drought resistant perennials adapted to drought conditions, the tree species *Pongamia pinnata* known as *karanj* in India has been found to be the most productive even under chronic drought conditions of higher intensity (Prasad *et al*.,1994; Prasad, 2021).

Some of the worst conditions of drought occurred in India during the years 1972, 1974 and 1979 throughout the country resulting in total crop failures. Under such conditions, it was found that around 520 villages in different parts of the country escaped the adverse effects of drought largely due to the vast *Pongamia* tree populations in those villages. Those trees yielded well leading to the recovery of good quantities of pods and kernels which gave the farmers of those villages some income levels to manage their livelihoods satisfactorily despite the bad drought in the above indicated years. *Pongamia* tree has the deepest root system exceeding the depth of more than 10 meters and spread of more or less of equal dimensions.

Additionally, the tree has established a productive symbiotic relationship with soil microflora *viz.,* rhizobia and vascular mycorrhizae, which add to the drought resistance of the tree. How the root hairs or hairy-roots of *karanj* tree penetrate even rocky substrate in soil aided by vascular mycorrhizae is amply illustrated (Prasad 2021).

Ethno-pharmacology: Various plant parts of *Pongamia pinnata* tree are valued for a number of pharmacological applications. The roots of *Pongamia pinnata* are good for cleaning foul ulcers, cleaning teeth, strengthening gums and gonorrhoea. The root paste is used for local application in scrofulous enlargement. The fresh bark of *Pongamia pinnata* is sweet and mucilaginous to taste initially, which becomes bitter and acrid. It is anti-helmintic and useful in *beriberi*, ophthalmology, dermatopathy, vaginopathy, and ulcers. Leaves of *Pongamia pinnata* are digestive, laxative, antihelmintic and are good for diarrhoea, leprosy, dyspepsia and cough. Flowers are useful to quench *dipsia* in diabetes and for alleviating *vata* and *kapha*. The seeds are anti-helmintic, bitter, acrid, haematinic and carminative. They are useful in inflammation, chronic fevers, anaemia and haemorrhoids. The oil is anti-helmintic, styptic and recommended for opthalmia, leprosy, ulcers, herpes and lumbago (Yadav *et al.*, 2011).

Extract of roots combined with coconut milk and lime water has been used for treatment of gonorrhoea: a sexually transmitted infection. Tender twigs and stems are used for cleaning gums, teeth and cure ulcers in mouth. Roots are bitter in taste; but anti-helminthic and as such used for curing vaginal and skin diseases. Juice of the root is used for cleansing foul ulcers and closing fistulous sores. Aqueous extracts of stem bark exhibit significant curative properties and recommended for enhancing the functioning of Central Nervous System (CNS). Also the product is known to possess sedative and antipyretic activity(Anonymous 2021). According to Orwa *et al.*, (2009), the leaves are known to have antiseptic properties and the press-cake leftover from oil extraction is used as a liniment. The roots are used to treat abscesses and as fish poison. The wood is not durable but is used for cabinet and tool making. It is also an important source of firewood in arid areas (Orwa *et al.* 2009). More recently, karanj has been cultivated as a garden ornamental and for shade.

Leaves and cake for animal feed: Though not particularly palatable, leaves are being used as fodder in arid areas, particularly when other sources of fodder / forage are scarce due to drought. The press-cake can be used as feed but should not be fed to animals alone since it contains a number of anti-nutritional factors including karanjin. It has been conclusively demonstrated by CFTRI that protein of *Pongamia* cake is comparable to that of soybean in terms of quality following removal of the above mentioned irritants through simple acid hydrolysis (Vinay and Sindhukanya, 2007; Soren *et al.*, 2009). Such conversion of *Pongamia* seed cake into animal feed with good nutritional qualities may be more useful (Panda *et al*., 2006). It is worth attempting converting *Pongamia* seed cake into animal feed in view of its promising nutritional qualities.

The leaves and flowers are high in nitrogen and can be used to enrich soil (Morton 1990). In India, karanj is used in land reclamation and as a soil stabiliser. It is being trialled for 'phytocapping' landfill waste in Rockhampton (Venkatraman and Ashwath 2009).

Distribution, population density and production of *Pongamia* in India: Within India, *Pongamia* occurs in the states *viz.,* Andhra Pradesh, Arunachal Pradesh, Assam, Bihar, Dadra and N. Haveli, Delhi, Goa, Gujarat, Haryana, Himachal Pradesh, Jammu and Kashmir, Karnataka, Kerala, Madhya Pradesh, Maharashtra, Manipur, Meghalaya, Mizoram, Nagaland, Orissa, Pondicherry, Punjab, Rajasthan, Sikkim, Tamil Nadu, Telangana, Tripura, Uttar Pradesh and West Bengal. It is also found in the Andaman and Nicobar Islands of Indian Union. Published reports on the acreage and production of *Pongamia pinnta* in India are too scanty to mention. It is estimated that the annual production of *Pongamia* kernels in India is of the order of 130,000 tons (Rabab *et al*., 1997).

An effort was made to gather the area under *Pongamia* in India through discussions with various organizations pertaining to Forestry, Agro-forestry and Dryland Agriculture. The discussions have revealed that the area under *Pongamia* in India is of the order of 500,000 ha in the form of unorganized tree stands, with an estimated domesticated tree population of 37.5 million (Prasad, 2021) all along the country's rural belt. Assuming an average minimum yield of 10 kg of pods or 4 kg of kernels per tree, the total estimated pod production should be of the order of 370,000 tons resulting in an approximate total kernel / seed production of 148,000 to 150,000 tons per annum. It may be noted that the trees are not growing under any system of tree management; but are totally neglected without any care. (Prasad 2021)

Carbon credits from *karanj* trees to enhance rural economy.: According to Prasad (2021) a study carried out in 2006 estimated that over the course of a 25-year period, one *Pongamia* tree has the potential to sequester 767 kg of carbon. The carbon sequestration ability of *karanj* was calculated for 3,600 trees planted in the Powerguda village in Adilabad district of Telangana State in India. The certified carbon emission reduction was sold to '500ppm GmbH', which is an environmental group of Germany. The reduction came from replacing diesel fuel with natural oil from *Pongamia* seeds (Dsilva, 2015). The purchase was effected for ten years' supply of emission reduction from 140,000 kg of *Pongamia* oil, worth $4,164.

Income support from *karanj*: In the absence of organised productive plantations of *Pongamia*, the availability of significant and perceptible data on this subject is very nebulous. Nevertheless,the material presented under the subtitle "Pongamia and Drought" is itself a testimony of the income support accrued to farmers from *karanj* trees.

Calculation of estimated profit from an organised and well managed *Pongamia* plantation has since been reported by Prasad (2019). From a ten years' old organised and well managed plantation of elite genotypes of *karanj* over an area of one acre with 200 trees, the profits that would accrue from different components are as follows.

(i) Profit in terms of kernel sale (@ IRs.30/-per kg) shall be around IRs. 26,000/- average per year per acre

(ii) Profit in terms of oil yield (price of oil @Rs.60/- per kg) will be around IRs. 200,000/-per acre per year.

(iii) The profit that would accrue from seed cake and briquettes (from pod shells) would be extra gains to the item (ii).

The above income levels far exceed that of normal dryland crops, which often get adversely affected due to abiotic and biotic stresses.

A dryland farmer by name Shri Chikkanna, aged 64 years of Bidaluru Village in Tumkur district of Karnataka has a single high yielding tree of *karanj* on his land holding of one-acre dryland adjoining his residence. According to him the tree yields regularly 80-90 kg of seed kernels every year. According to the farmer, he made a minimum sum of IRs. 4,000 to 4,500 every year from the sale of the kernels alone (2012-2015) with no inputs to the tree, apart from the green manure value of the foliage and tender twigs. According to the farmer the income from the single tree of *karanj* was more stable and sustaining than what he got out of his land of one acre by growing annual grain crops.

Absence of organised plantations of *Pongamia* in India: Despite its attributes such as healing power, yield of useful oil, effective insecticidal properties, manurial value etc., it is ironical that there are no organized plantations of *Pongamia* in India. The reasons for this anomaly are as follows.

- Pongamia tree has the tendency to produce root suckers from its base, which ensures its rapid propagation.
- The tree is highly resistant to abiotic and biotic stresses and can remain productive up to 60 to 70 years of age.
- A tree in the backyard and few scattered trees here and there around a village were adequate to meet the needs of rural folks. Accessing karanj tree was very easy to the populations.
- The tree stands proliferated in an unorganised manner, which didn't need any specific management due to the above mentioned qualities, with some levels of pod and seed yields.
- The commercial exploitation of Pongamia was not developed.

The way forward: Till recently *Pongamia* has been employed extensively by the Forest Department for afforestation. The differences between *Pongamia* planted for afforestation and proposed elite *Pongamia* plantations have to be understood and appreciated. In the case of *Pongamia* used for afforestation, the tree becomes a small component of the complex tree populations used for this activity. *Pongamia* trees planted in the above kind of programmes cannot be managed towards achieving sustainable economic yield levels.

The concept of growing *Pongamia* in an organized plantation has not taken roots in India. However, with the availability of elite genetic materials and technologies of vegetative propagation the road is laid for commercial exploitation of *karanj* tree through organized productive plantations. In the case of elite *Pongamia* plantation high quality genetically elite grafts of only one species *viz., Pongamia pinnata* form the planting materials and the plantation is raised in a definite plantation geometry and population density and managed scientifically to achieve the economically sustainable levels of productivity.

Currently 3% of the world's forests are plantations, consisting of 60 million hectares in developed nations and 55 million hectares in developing nations (WRI,1998; FAO, 1999).

In some regions, plantations comprise a major proportion of forest area, including

44% in Japan, 20% in New Zealand, and over 90% in Britain (Donald *et al.*, 1997; FAO, 1999). Though tropical forest cover is declining throughout the world, tropical plantation area has increased dramatically, from about 10 million hectares in 1980 to about 44 million hectares in 1990's (Lugo, 1997). Plantations can realize much more production of the economic produce on a much smaller land base (Karen *et al*., 2010, JudyLoo *et al.,* 2014).

Indeed, some calculations indicate that plantations could meet the demand of most industrial products demands on <10% of the world's forest land area (Sedjo and Botkin, 1997).

Establishment of an elite *Pongamia* based bio-energy plantation is a long term investment and deserves a very critical planning. The selection of proper location and site, planting system and planting distance, choosing the planting materials have to be considered carefully to ensure maximum production.

Certain plantation management strategies specific to *Pongamia* are as follows:

- Maintain diversity of genotypes: Grow clones from diverse elite trees rather than those from one or two mother trees, if there is no consideration of a specific product from plantation
- Eco-friendly management: Avoid use of chemical pesticides and other strong chemicals that would harm the symbiotic biological systems including insect pollinators.
- Ensure soil conservation avoiding erosion and carry out water harvesting by collecting run-off in farm ponds exploiting the natural slope.
- Nutritional management must be effected through mostly organic sources.

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Unlocking the Potential of Indian Agriculture – Role of Seed Industry

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Indian Agriculture is today at the cusp of unravelling its true and dormant potential and the Indian Seed Industry is playing a crucial role in this process.

Indian seed industry is the most vibrant among the agri-input sector given the significant potential in terms of fostering innovation for improvement of productivity and profitability to farmers. The industry is driven by research and development in plant breeding and biotechnology for development of new varieties of plants and customizing innovative agronomic practices tailored around new plant varieties and the diverse agro-climatic conditions and requirements of crop management systems. Typically a seed company is structured around different functions such as R&D, Production, Processing, Marketing and Sales.

The seed industry landscape of India comprises several larger companies and institutions both in private and public sector with expertise in all the industry functions mentioned above. At the same time the industry has evolved into a competitive landscape with many small and medium players with core competencies in one or more functions such as R&D, seed production or processing or marketing. The co-existence of all the players, including large Indian and MNCs with end to end functions and small and medium players which specialize in one or more functions defines the essence of a globally competitive Indian seed industry.

The Indian Seed industry has evolved over the past 5 decades starting from 1960s and 1970s when Government initiated seed legislation and public institutional structures for development of the industry. Upon the strong public sector foundation laid out between 1960s and 1980s within the background of green revolution, Government of India promoted the industry with its policy reforms in the subsequent decades, which further gave fillip to the private sector participation in Indian seed industry. Notable among them are the New Seed Policy, 1988 and the National seed policy in 2002, which helped in strengthening the Indian seed industry in the areas of R&D, product development, supply chain management, quality assuranceand also enabled significant private sector investments in the Indian seed sector.

Owing to this, India has emerged among the large seed markets across the world by the beginning of millennium. Also in parallel the public sector institutions in the form of State Seed corporations and National seed corporations, in coordination with the National Agricultural Research System of State Agricultural Universities (SAU) and Indian Council for Agricultural Research (ICAR) have also played a vital role in laying a strong foundation of the industry. In this milieu, Government policies and enabling Legislative frameworks for developing a modern seed industry were also developed in the form the Protection of Plant varieties and farmers rights act,2001, Bio-diversity act, 2002 and amendments to Indian patent act in the interests of larger public good and to give a clear direction to the future of Indian seed industry.

Today the Indian seed industry is among the top 5 globally valued at USD 4 Billion. The industry has consistently grown at a CAGR of 5% to 7% in the past one decade and is poised to further grow in the coming decades on key drivers such as increase in Seed replacement rate for Open Pollinated Variety (OPVs) crops, improvement in hybridization, new innovations in plant breeding and biotechnology leading to development of new high value traits and Plant varieties aligned to dynamic consumer and market requirements and convergence of farm mechanization, R&D , supply chain management with new age technologies such as block chain, artificial intelligence, digital technologies, integrated supply chains,nano-technologies, biological inoculants, etc.The key challenges which underlie Indian agriculture and strongly linked to Indian seed sectoralong with opportunities and growth drivers of Indian seed industry are explained in detail in the below paragraphs.

1) Low productivity and profitability: India is a land of agro-climatic diversity with only 40% of the arable area under irrigated conditions. Agriculture in the majority of dryland and rainfed area in India is dependent of life-saving irrigations from available sources and from erratic monsoons. In atleast 25% of the dryland semi-arid and arid regions, agriculture is totally monsoon dependent. This dependency also determines cropping patterns in various regions of the country. Further the average farm land size in India is less than 1 ha, which is further fragmented due to inheritance of land. The fragmentation of land as a resource and small size of farms leads to predominance of smallholder farmers. Realization of economies of scale and scope in such small land area is difficult and implementation of automation and mechanization is a challenge for improving crop productivity. These conditions lead to sub-optimal performance of Indian agriculture and also to overdependence of a large population on agricultural activities. The value and average productivity in India in several crops is lower than the global averages, although India has the largest arable area on the planet. The above factor is intricately linked to growth of seed industry and industrialization of agriculture which has been achieved in certain countries like USA,China,Australia, Brazil, where high aggregate productivity levels have been achieved.

   Achieving higher productivity for such arable area in India, which is a key challenge and also presents tremendous opportunity in which Seed sector can play an important role, as seed is the primary input and driver for Indian agriculture. It is to be understood that as such the core essence of seed sector is to develop new varieties of plants, whose seeds are produced, processed and marketed by seed industry. Therefore, overall growth of Agriculture is hinged on the growth of seed sector, as seed being the primary input of agriculture, encapsulates the genetic potential of the plant variety and all other inputs and crop management are applied to the Plant variety which emerges out of the seed.

2) Diversity in Agro Climatic Conditions: The agro-climatic diversity of India presents both tropical, sub-tropical and temperate climates and also immense soil diversity, which enables

growth of wide variety of crops. While agro-climatic diversity, availability of assured irrigation or rainfall and soil types in terms of varied conditions enabling suitability for crop cultivation and management pose a challenge in breaking aggregate productivity barriers, the conditions again present an opportunity to specialize in select crops specific to the regional requirements. This enables India to focus on development of crop-wise clusters in different regions and become the agriculture hub of the world. Accordingly, the Government is also promoting specific agricultural and horticultural crops in arid and semi-arid regions and also encouraging agri-industrial clusters to develop demand driven production.Given the diverse agro-climatic and edaphic conditions, India can not only be an innovation driven R&D seed industry for its domestic market in specific crops, but also a seed production base for similar agro-climatic zones in especially in Asian and African continents. Further the diverse climatic conditions within India also necessitate development of a comprehensive varietal evaluation system for commercialization of new plant varieties.

3) Increasing rate of Hybridization: Harnessing heterosis or hybrid vigour in crop plants for improving overall productivity is a key genetic strategy in seed industry. Hybrid Plant varieties in many crops have not only lead to high input responsiveness and delivered high yields, but also led to improvement in tolerance to biotic and abiotic stresses leading to prevention of yield losses. Since 1970s hybrid crops in millets and Maize have increased in area and more so from 1990s due to the active role of private sector who specialized in hybrid seeds as a strategy to deliver higher value to farmers. Today the hybrids have increased to a great extent in many crops.

In Cotton 99% of the area is covered under hybrids,in pearl millet 90% of area is under hybrids, similarly in many vegetable crops like Cauliflower, Watermelon, etc., hybridization has reached more than 90%. However still there is huge scope for hybrids in certain crops like Maize (70%-80%), Mustard (40%), vegetable crops, etc. In Rice hybrids are growin in 6% -7% of the total area, however due to lack of required grain parameters and cooking quality reasons Rice hybrids are still not adopted widely in India. In crops like Wheat, Pulses and oilseeds hybrids with significant advantage over varieties need to be developed for large scale adoption. Therefore, not only the increase in hybridization in different crops, but also value addition through Biotechnology approaches such as transgenic crops, Gene-edited crops, etc., can be realized coupled with both hybrids and open pollinated varieties.

4) Need for Quality seed and increase in Seed Replacement Rate (SRR): Many of the food crops being Open Pollinated Varieties (OPVs), farmers save the seed from their grain produced by them and utilize the same as seed. This is called Farm Saved Seed (FSS), which is extensively used in crops like Rice, Wheat, Soybean, pulses, oilseeds, etc. However, repeated used of FSS leads to loss of genetic purity and lowers the crop yields. The seed replacement rate (SRR) in many of the crops in food grains ranges from 20% to 40% and is continuously improving as farmers all over India are recognizing the need to use quality OPV seed with high genetic purity, which is produced fresh only for seed purpose. The doubling of SRR

can tremendously increase the value of Indian seed industry.

5) Moving from Supply driven to Demand driven agriculture: Largely Indian agriculture has been supply driven, which is gradually beginning to move toward demand driven agriculture. This will create supply chain which gets activated by actual demand in the market and enable a profitable crop planning by farmers. Traditionally the cropping patterns in India are dictated by agro-climate and soil conditions, farmer's expertise in particular crops and market demand. However, if the predictability of demand improves across the supply chain with integration of global demand chains and market linkages, high value, demand driven seed sector can be developed in India with focus on exports. Even though India is 5th largest seed sector in the world with USD 4 bn market size, our exports are abysmally low as Indian seed industry largely operates in line with the supply driven nature of Indian agriculture. This shift to demand driven agriculture presents an excellent opportunity for being a key growth driver of Indian seed industry. Information and communication technologies (ICTs) can play a key role in the same.

6) Low investments in R&D: The fact that India has low crop productivity and thereby low profitability in agriculture throws up scientific challenge to the Indian seed industry for an opportunity for innovation and R&D for development of climate resilient plant varieties suitable for smallholder farmers, which can increase productivity in arid and semi-arid tropical regions. Further development of plant varieties to biotic and abiotic stresses and the dynamic consumer and market requirements, also provide an excellent opportunity for the seed industry to develop new crop varieties on a regular basis which can create sustainable growth for Indian seed industry. However this needs investment in R&D both by Indian companies and also in public sector research institutions. Currently the R&D investment is 3% to 5% in Indian seed organizations, whereas the required R&D investment is from 9% to 12%. The huge untapped potential of Indians seed sector can be unlocked by right investments in both applied and basic R&D in plant breeding, agronomy, seed technology and biotechnologies for moving from sub-optimal equilibrium to an optimal equilibrium of productivity.

7) Skilled manpower: Human resource is the key strength of India and availability of educated and skilled workforce in India in various functions of seed industry, viz. R&D, seed production, agronomy, seed quality, sales and marketing, ICT, etc., gives India the capability and a strong base to develop a seed sector with sustainable growth. Further with expertisein all the key disciplines of seed industry, India can also become a hub for global seed sector and agribusiness by leveraging its human resource strengths and diverse agro-climatic conditions suitable for seed industry. As mentioned above the tailoring of curricula by SAUs and other educational institutions shall further help in tapping the opportunity.

8) Seed Exports & Imports: Export of seeds doesn't involve import of any inputs. This results in only inward flow of valuable foreign funds. Paradoxically, Foreign Trade Policy 2015 -2020 (extended till 31st March, 2021) has totally ignored this potential of seed industry for export earnings, For instance, export of grain sorghum has 5% entitlement of credit scrip, however, ironically export of Sorghum

Seeds which has more value addition and employment generation capacity, does not have any such entitlement at all, The present scheme has also discontinued the benefits available in the earlier scheme under Visesh Krishi& Gram Udyog Yojna (VKGUY).

Since MEIS for agriculture products can continue as the agri products which are not bound by the "Agreement on Subsidies & Countervailing Measures", the Department of Commerce (DOC) / DGFT need to provide adequate incentive for export of seeds. Such an incentive would enable the Industry to effectively compete with China which has emerged as large exporter of seeds in the world trade. DOC/DGFT may provide the same MEIS benefits to seeds that are being provided to the produce of such seeds.

Key Interventions to be undertaken by Government for enabling transformation in Indian Seed industry: India is moving towards a new regime of seed laws with the introduction of the new Seed Bill 2019. Further the Government of India is also planning to implement new processes and systems for seed traceability across the country. However certain basic reforms are due which need to implemented at the earliest.

1. Increase in R&D investment and developing an enabling environment with public private partnerships to foster convergence of multi-disciplinary approaches to improve innovation and profitability of Indian seed sector. Government should promote centres of excellence in project mode with clear outcomes and deliverables for improvement of R&D in both public and private sector. Special emphasis should be given for capacity building of domestic seed companies, FPOs involved seed sector and seed producers for improvement of their enabling infrastructure and capabilities for developing a globally competitive Indian seed industry. Government of India should develop a mission mode projects for seed sector to trigger a massive push for transformation of the sector which will further enable transformation of Indian agriculture.
2. For seed companies which have comprehensive organizational functions such as R&D, production, processing and marketing with operations in multiple states, a single centralized integrated license should be provided for ease of operations.
3. Implementation of uniform procedures for issue of seed license and inclusion of new variety in seed license is an essential requirement to be implemented on a pan-India basis.
4. Keeping in view the national interests 100%FDI in seed sector should not be allowed. Indian citizen/entity should have controlling stake in any seed company with foreign investment. Such policy restrictions exist in China and many SE Asian countries for protecting domestic sector and enabling a competitive market.
5. Development of standards driven accreditation system for recognition of third party seed quality testing laboratories (STLs) shall improve quality assurance in seed sector. Small and medium enterprises (SMEs) in Seed sector should be encouraged for quality seed production by providing free access to such accredited STLs.
6. R&D investment by SME companies with 100% shareholding by Indian citizens shall be reimbursed to the extent of 50%.This encourages local companies to further focus on R&D and spur innovation to deliver improved Plant

varieties as per market and consumer requirements.

7. Public Private Partnerships between Indian companies with 100% shareholding by Indian citizens and the National Agricultural Research system (NARS) should be encouraged with respect to private sector capacity building and commercialization of R&D.

8. The arrangement of adequate low interest working capital loans and soft loans for investments in R&D and infrastructure and Capital subsidy to the extent of 25% is an essential requirement for strengthening seed sector. Further all loans to seed companies need to be classified as Agriculture loans under priority sector lending.

9. With varied agro-climatic zones, India can be an excellent low cost standards driven production hub for various countries of North and South. Special economic zones for different crops identified for specifically export oriented seed production will not only add value but also generate gainful employment.

10. Varietal testing fees in ICAR AICRIP trials should be reduced and rationalized especially for domestic seed companies with 100% local ownership, so that a large number of seed companies can test their varieties at maximum locations and successfully meet requirements of regional and local markets.

11. Policy & procedures for Custom seed production of foreign varieties exclusively for export purpose should be made and training/capacity building of Indian companies for standards driven custom production process need to be enabled.

12. ICAR and SAUs in constant interaction with industry should plan to tailor their syllabus and courses to align with human resource needs of seed industry.

13. Government of India has been promoting FPOs and Agribusiness parks for the past one decade. Policy intervention for involvement of FPOs in seed sector and integration with Agribusiness parks for creating demand driven supply chain will be an important step for aligning Government policy and industry needs.

14. With respect to Dispute resolution regarding Income Tax, the proposed resolution by NSAI which is also issued by DACFW, is pending with CBDT. This may be resolved by bringing a rule like in case of Coffee, Tea or Rubber, so as to tax about 20% income as seed production which involves agriculture operations in addition to processing, packing and labeling as per Seeds Act.

15. The only IPR protection available for seeds and Plant Varieties including transgenic plant varieties is under PPVFRA. All trait licensing including GM traits shall be as per section 26 of PPVFRA. Section 3(j) of Indian Patent Act (which excludes seeds and plant varieties) shall be enforced in letter and spirit in India so as to stop monopoly in seed industry which is detrimental to farmers and national agriculture as well.

16. Creation of Indian Seed Export Promotion Council by the DACFW and promotion of Indian seed in all the countries in all the regions will offer a great opportunity for India to enhance Indian seed farmers income, creation of rural employment and at the same time India playing a strategically important role in global agriculture.

For promoting self-reliant India and increasing India's share of global seed production, incentives such as dry port facilities closer to seed production centres are proposed to be set up. The ports will have warehouse available for seed storage, globally recognized seed quality testing (third party private laboratories), seed export documentation and phytosanitary certification agencies and plant quarantine facilities. Policy & procedures for Custom seed production of foreign varieties exclusively for export purpose should be made. Special economic zones may be identified for seed production and export to encourage seed production for export in States which have excellent agro climatic conditions to take up quality seed production.

Conclusion

Indian seed industry has made rapid strides in last four decades. However still we have to achieve many more milestones in terms of solving key scientific challenges for enhancing the productivity and profitability of Indian farmers given the constraints faced by Indian agriculture. Further, the industry is yet to realize its full potential in meeting the huge demand for quality seeds of improved plant varieties in particular in area of seed exports.

The proactive nature of Government as an enabler by bringing the new Seed law regimes, improvements in enforcement of PPVFR act and Biodiversity act, enforcing legislative reforms for contract farming, implementing systems of seed traceability, fostering convergence of Plant breeding and biotechnology and seed industry operations with new emerging technologies blockchain, artificial intelligence, robotics, digital platforms and data science and promoting self-reliant India or AtmaNirbhar Bharat, by giving importance to capacity enhancement of domestic companies shall further lay a strong foundation for a globally competitive Indian seed industry.

Climate Smart Agriculture: Can it Help Indian Agriculture Cope with Global Warming ?

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The Prime Minister of India has called for doubling of farmers income by 2022. As per the discussion paper of NITI Ayog, this requires all round improvements in Indian agriculture including productivity growth, investments on irrigation, post harvest processing and value addition, market reforms, insurance and research and development. The paper also acknowledges the challenge posed by climate change in achieving the goal. Evidence over the past few decades has established that significant changes in climate are taking place worldwide as a result of enhanced anthropogenic activities. Despite the spectacular success of the green revolution and achieving self-sufficiency in food production, there are increasing concerns on sustaining the pace of agricultural growth. Lack of yield break throughs, deteriorating soil health, ground water depletion, declining size of operational holdings and labour shortage are cited as some reasons for slow agricultural growth. Added to these factors are the climate change and climate variability which are now emerging as major concerns. Climate change impacts on agriculture are being witnessed all over the world, but countries like India are more vulnerable in view of the high population depending on agriculture, excessive pressure on natural resources and poor coping capabilities. The negative effects of year to year climate variability are already evident. Despite significantly increasing area under irrigation-reaching up to 45%, the country still is vulnerable to monsoon variability .Though increasing production from *rabi* season has largely stabilized our overall food production, significant declines in production are witnessed in coarse cereals, pulses and oilseeds when the monsoon rainfall becomes deficit during *kharif* as observed in the last decade. This leads to huge imports of pulses and edible oils. Extreme rain events and floods are also causing extensive damage to standing crops across the country year after year. Therefore climate has become central to agricultural planning and decision making in the country. Besides droughts and floods, cyclones, heat wave, cold wave, frost and hail storms are already taking heavy toll on crop yields and farmer's income every year in some parts of the country or the other. The impact of future climate change on agriculture is more worrisome if we do not take strong adaptation and mitigation measures.

Production Losses

Modeling studies by ICAR under the Network Project on Climate Change (NPCC) indicate that in the medium term (2010-2039), impacts on food production are in the range of 4.5 to 9%, while in the long term (2070-2099) the production could decrease by as much as 25%. Since agriculture makes up roughly 15% of India's GDP, a 4.5 to 9%

negative impact on production implies a cost of climate change to be roughly up to 1.5% of GDP per year. For every one degree increase in temperature throughout the growing season, the production of wheat in the country may reduce by 4-5 million tones. Rise in minimum temperature is happening during *kharif* season @ 0.19^0C 10 yr^{-1} in most part of the country which has a negative impact on paddy yields over 50% of cultivated area. (Bapujirao *et al.*, 2014). With decreasing summer rainfall trends in Chattisgarh, Jarkhand and eastern MP, paddy yields are also likely to decrease in parts of eastern India where the crop is grown as rainfed. Most climate models predict a marginal increase in total rainfall in the country but the number of rainy days are projected to decrease, causing heavy intense rainfall in few days followed by long dry spells. This is likely to cause flash floods, inundation of crop fields and soil erosion affecting *kharif* crops across the country. Warming during winter season has implications for production of *rabi* crops like wheat, mustard and chickpea in the indo-Gangetic plains. Rabi season is now contributing nearly 50% of the food grains and this contribution is likely to further increase in future. Therefore insulating *rabi* crops also from the impacts of climate change through adaptation and mitigation is key for ensuring food security.

Impact on Sunrise Sectors

Based on the recent growth rates in production and contribution to agricultural GDP, horticulture, dairy, meat and poultry are considered sunrise sectors. These sectors are also equally vulnerable to global warming. Horticulture crops are particularly sensitive to temperature, unseasonal rainfall, hailstorms and pest and diseases caused by climate variability. The yields of Apple in Himachal Pradesh are declining in the traditional areas because of rise in temperature and inadequate chilling requirement (NPCC, 2007). Farmers are shifting the crop to higher elevations on the hills in order to realise acceptable yields. Mango is another typical example of a premier crop in India suffering production losses due to climatic variability. In addition to the indiscriminate use of placrobutazol, unseasonal rains and temperature fluctuations are mainly attributed to the flowering, fruit drop and quality problems in alphonso mangoes. grapes, oranges and pomegranate in Maharashtra and kinno in Panjab and Himachal Pradesh repeatedly suffer heavy losses due to hail storms. Climate change impacts pollination and yields, as high temperature affects the pollinators.

Global warming also affects the livestock sector. Rise in THI in many parts of the country causes the dairy animals spend more energy for maintenance with negative implications on milk production. Modelling estimates by NDRI indicate that milk production might decline by 15 million tons by 2050. High producing crossbred cows and buffaloes will be affected more. The annual loss in milk production at all-India level due to heat stress was estimated at Rs.2662 crores. (Upadhyay *et al.*, 2009). While the commercial poultry is highly vulnerable to heat wave and we saw huge mortality of poultry birds during summer heat waves till a decade ago, the industry has responded quickly by improving the designs of the poultry farms and installation of foggers *etc*. They are also bringing new innovations in feed incorporating supplements that enhance the coping ability of birds to heat stress.

Besides direct effects on crops, climate change is likely to impact natural resources like soil and water. Increased rainfall intensity in some regions would cause more soil erosion leading to land degradation. Increased temperatures will also increase crop water requirement. A study by

ICAR-CRIDA, Hyderabad on major crop growing districts in the country for four crops, *viz.,* groundnut, mustard, wheat and maize indicated a 3% increase in crop water requirement by 2020 and 7% by 2050 across all the crops/locations. Irrigation requirement in arid and semi-arid regions is estimated to increase by 10% by every 1^oC rise in temperature. The frequency of extreme weather events like hail storms is also increasing in recent period. Hail storms usually cause localized damage and generally occur in Panjab and Himachal Pradesh regularly. However during 2014 and 2015 *rabi* seasons (February – March), widespread hail storms occurred in most parts of the country, *i.e.* Gujarat, Maharashtra, Karnataka and Telangana causing heavy damage to field crops and horticulture.

Vulnerable Regions

Climate change (CC) does not impact every one equally. For example rainfed agriculture is more vulnerable because of the dependence on monsoon. A vulnerability mapping of Indian agriculture to climate change by ICAR-CRIDA (C. A. Ramarao *et al.,* (2013) indicated that many districts in the western Indian states like Rajasthan, Gujarat and Karnataka are highly vulnerable to droughts, while parts of eastern UP and Bihar are sensitive to flood damage. Small and marginal farmers are more vulnerable due to their poor coping abilities. Extreme events like hail storms, severely impact horticulture crops like grapes, oranges, mango, banana causing flower and fruit drop and sometimes farmers loose the entire crop for the season. Agricultural labourers loose wage income when crops fail but no systematic study has been made on the impact of climate change on landless.

In view of the economic impact of climate change on agriculture sector and its implications on food security and farmers welfare, adaptation and mitigation measures are urgently required at different levels. Individual farmers have to be provided with innovative technologies and products that enable him to reduce farm level production declines and minimize his risks, while States and Nations have to put in place the required policies that sustain aggregate level production. This is to check price volatility and avoid huge relief payments on compensation of losses. Adaptation, particularly has a prominent role in developing countries like India. Since global warming is an issue that cuts across international borders, co-operation among developed and developing countries in technology exchange and financial assistance are of paramount importance. This is particularly critical in mitigation. The recently concluded Paris Agreement has mandated partner countries to reduce GHG emissions by certain percentage so that the temperature rise can be contained below 2^0C. The establishment of Green Climate Fund is an important step in this direction.

CSA Frame Work

Sustaining agricultural production in the face of climate change requires a series of scientific inputs and practices which is broadly known as Climate Smart Agriculture (CSA). As defined by FAO, CSA is an integrated approach that addresses the interlinked challenges of climate change and food security with the objectives of i) Sustainably increasing productivity to support equitable increases in farm incomes, ii) Adapting and building resilience of food production systems to climate change at multiple levels and iii) Reducing greenhouse gas emission from agriculture (including crops, livestock and fisheries). CSA is not a technology but an approach which relies on use of modified production technologies, new policies and investments on managing risks.

Regional and National Initiatives

CGIAR has initiated a major research programme on the application of CSA approach to reduce the vulnerability of farming in developing countries (https://ccafs.cgiar.org/), while the Indian Council of Agricultural Research has launched a mega project on Climate Resilient Agriculture in India i.e. National Initiative on Climate Resilient Agriculture (NICRA) (http://www.nicra-icar.in/). Considered as one of the few major projects in developing countries, NICRA has the twin objectives of generation of appropriate climate resilient technologies in crops, horticulture, livestock, fisheries and poultry and its demonstration on farmers fields through more than 130 Krishi Vigyan Kendras to provide the farm level resilience.

Experience of the NICRA clearly indicated that by adoption of already available technologies and practices with a whole village approach, we can bring much needed resilience to agriculture against climate change. By adopting scientific water conservation methods, ground water recharge, use of drought tolerant varieties, adjusting the planting dates, modifying the fertilizer and irrigation schedules and adopting zero tillage, farmers are able to realize satisfactory yields even in deficit rainfall and warmer years. These interventions have also lead to positive carbon balance in the villages quantified by using FAO, EX-ACT model (Srinivasarao *et al.,* 2016).

Internationally, extensive research is under way on evolving climate resilient technologies and practices. Varieties are being developed in different crops with multiple abiotic stress tolerance. The first such example is the identification of *sub*-1 gene in paddy by IRRI Philippines which confers sub mergence tolerance. The introduction of *sub*-1 in mega variety like "*Swarna*" has resulted in "*Swarna sub*-1" which is now grown successfully in large parts of eastern India and north east were paddy crops gets inundated during *kharif* season. In wheat, ICAR-NBPGR has screened more than 300 germplasm lines of wheat and identified several promising heat tolerant lines. Biodiversity conservation is important in fighting climate change. Several local germplasm lines may be low yielding but may contain very useful traits like heat and drought tolerance.

Other Climate Smart Practices relate to water and nutrient management. Direct seeded rice for example emits less methane compared to puddled rice. Neem coated urea and application of nitrogen fertilizers in wheat, maize and paddy based on leaf colour charts reduces the total N requirement and indirectly cuts down the N_2O emission. Crop residue burning releases tons of carbon dioxide in to the atmosphere in states like Panjab where paddy straw is burnt every year in order to vacate the field for wheat planting. Conservation agriculture practice under which wheat is planted with zero tillage offers an alternative to burning which is now being promoted. Innovations in water management including extensive use of micro irrigation is by far the most important input for CSA.

The country needs to provide robust agro advisories to farmers based on real time basis. This requires a huge effort of weather data collection, assessment of crop condition, soil moisture, pest and diseases under field conditions on real time basis and translating this entire data in to a simple advisory which the farmer can follow. Lot of investments are made on installation of automatic weather stations in different states but no serious efforts are made to actually utilize the weather data for climate resilient agriculture. With the use of dynamic models like CLIMEX and DYMEX, we can assess the spatial distribution and abundance of important pests and study how future climate change may cause emergence of new pests and biotypes.

While the impacts of climate change and variability are to be assessed on regional basis, the adoption of climate smart practices can best be done at village level with a goal of creating Climate Smart Villages across the country. These villages will basically adopt weather smart, water smart, energy smart, carbon smart and nitrogen smart practices. Besides technologies, policy inputs on prudent use of water, nutrients, carbon and energy are essential to promote CSA. (Venkateswarlu and Shankar, 2009). To sum up, investments on generation of new production and conservation technologies, policies that support rational use of resources, sharing of global best bet practices and capacity building of farmers will go a long way towards making agriculture climate smart. While these are national initiatives, global efforts on mitigation of green house gas emissions are equally important to tackle global warming on long term basis . The ongoing COP26 at Glasgow hopefully will come out with strong commitments and positive action on climate change mitigation

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ICTs in Agriculture for Industry 4.0

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1. Overview of Changing Agriculture Scenario

Agriculture (including crops, horticulture, livestock, fishery, forestry and agri-engineering) remains the largest sector of Indian economy. The small and marginal farmers (having less than two hectare) constitute about 85% in terms of number of operational holdings in the country (http://agricoop.gov.in/doubling-farmers). Doubling real income of farmers by 2022 over the base year 2015-16, requires annual growth of 10.4% in farmers' income (Chand, Ramesh 2017).

World wide, Information Communication Technologies (ICTs) are gaining prominence in all professions and play a crucial role in poverty alleviation, marketing, agricultural technology transfer and sustainable development. ICTs promise play a pivotal role in food security and empowering the citizens to better manage their livelihoods to attain improved socio-economic status and prosperity (Sonam Jakhar, 2015). As agriculture is key determinant to industrial development in India, the practical challenges encountered and solutions adopted in the fields of Industry would lay foundation for agribusiness as a key contributor to Industry 4.0 (often referred to as Fourth Industrial Revolution or IR4.0).

Farmers make complex decisions on how to use their land, what crops to grow and how, what inputs and when to use them, how to finance, where to buy their inputs and sell their produce. Such information needs are important. But this paper is not about mere information needs of farmers, but more about innovative enterprises that makes it happen as part of their inherent business process. Towards this, the paper explores the catalytic role of ICTs in transforming agribusiness enterprises in the seven broad sub-sectors of agriculture that fuels growth leading to Industry 4.0. In other words, the paper draws attention to high growth entities in agriculture sub-sectors on one hand, list of evolving promising ICTs in agriculture domain on the other and their confluence leading to new and ever growing business opportunities. Besides listing the two, the paper also envisages scenarios highlighting the potential for such confluences and options to realise the envisaged growth thereof.

2. Opportunities in Agriculture

2.1 Opportunities in Agribusiness

Multiple means of using ICTs to improve competitiveness and efficiency of agriculture and there by farmers' income are:

- Technology support (for productivity enhancement, increasing cropping intensity, reduction of input cost, value addition, waste management, quality, diversity etc.)
- Scientific management of natural resources

- Transparent and modern market systems
- Finance and insurance
- Risk management
- Automation in harvest and post-harvest processes
- Systems for timely advice at affordable cost
- Proactive policy & regulatory system
- Governance of developmental schemes (planning, monitoring & evaluation)

2.2 ICT-based Technologies in Agriculture

The major ICT-based technologies that are revolutionizing agriculture world over are(COST. 2009):

- High performance computing including intelligent software
- Automation (farm, factory and lab)
- E-commerce
- Digital learning
- Supply chain management
- Satellite imaging (GIS and Remote sensing)
- Sensors for low cost detection
- Smart packaging
- RFID
- Bio-informatics & Systems biology

The Internet of Things (IoTs) is a huge opportunity for farmers to monitor their crops and increase productivity. Satellites, drones, wireless sensor networks, analytical farming devices systems, farm management systems, big data applied to the farm and food management chain are all examples of IoT and Smart Farming (https://e-agriculture.org).

3. ICTs Use in Agriculture

3.1 Current Status of ICTs Use in Agriculture

For India, the information technology sector revenue valued at USD 194 billion in 2021, is estimated to reach about USD 300 billion by 2025. Its estimated contribution to Gross Domestic Product is about 9.5 per cent (Nawawy EL, Morshedy, 2017). According to the Mckinsey Global Research Institute's Report "12 Technologies to empower India" (2014), the estimated collective impact of technology interventions (mainly Information technology) in agriculture is about "45 to 80 billion dollars" by 2025.

The next green revolution would be driven by the next generation agriculture technologies, *i.e.*, GRIN Technologies (Genetics, Robotics, Informatics & Nano-Technology). Promising ICTs that unleash agricultural productivity (Joseph Byrum, 2016, Michell Zappa, 2014 and FAO, 2017) are described in brief in the following sections.

3.2 ICTs in Service to Farmers

Currently, ICT applications related to agriculture and its reach to farmers are found both at a macro- and micro-level. Most of the initiatives are providing information about agriculture, weather, insurance, pest-management, waste management, risk, markets, storage, inputs, *etc* and connect companies, distributors, retailers and farmers along the agri-chains. Interestingly, micro-scale projects create value added information for the benefit of farmers. Such micro-scale projects funded by public or private agencies or developed as business models are key to Agri-Industry 4.0.

3.3 ICTs in Governance of Developmental Schemes

Development projects like Soil health card, Crop insurance, Farm mechanization, Land records, Modern agri-marketing, Food security mission, Horticulture mission, *etc* are being implemented through respective Government schemes using ICTs for inline management. They provide a great business opportunity to competent data science professionals.

3.4 ICTs in Biotechnology and Synthetic Biology

Biotechnology can be used to isolate specific desired traits in crops. This information is then coupled to large-scale trials for determining the most viable candidates. Synthetic biology is the broad redefinition and expansion of biotechnology, with the ultimate goals of being able to design, build and remediate engineered biological systems that process information, manipulate chemicals, fabricate materials and structures, produce energy, provide food, and maintain and enhance human health and our environment. These process generate many terabytes of data that must be sifted through, correlated, and used in a decision-making process to cull less effective options. Information technology is a crucial enabler for turning these data into useful product-development decisions(https://www.nae.edu/Publications/Bridge/52548/52555.aspx).

3.5 ICTs in Farm Mechanization & Automation

The ICT-integrated systems started on machines (tractors, combines, *etc*) but are rapidly spreading to the entire agricultural production chain. The future farm-site will be automated and information rich with agricultural mechanization systems. This level of information would influence the production value chain - at pre- and post-harvest stages. In Livestock systems, animals with GPS, RFID and biometrics can automatically allow real-time monitoring of the location and health of farm animals.

Precision farming is a farm management system based on observing and responding to intra-field variations using various information and other technological tools. Precision farming involves integrated use of three technologies, namely, satellite imagery, sensors and integrated communication system.

Robots are used automating tedious tasks to monitor conditions and harvest crops. Automation in conjunction with sensors and data analytics ensure that planting, harvesting, irrigating and the application of other inputs are performed with high precision.

Using precision farming, farmers can manage their crop and field conditions like fertigation, moisture, pest control, *etc.* At macro level, satellite imagery, Internet of Things, Cloud Computing with data analytics is revolutionizing the way countries can assess, monitor and plan the use of their natural resources, including monitoring deforestation and desertification.

Utilizing ICT-based innovations, various startups are trying to provide agribusiness solutions. The key to Agri-Industry 4.0 is to create a still more proactive eco-system to nurture such innovations.

3.6 ICTs in Knowledge Management & Skilling

Indigenous knowledge: Knowledge is one of the main drivers of prosperity and well-being. Providing a channel for intangible knowledge with farmers is a major challenge and opportunity. Employing IT to make explicit use of farmers knowledge, practices evolved over time is an example of technology enhancement of transaction information fueling the knowledge spiral. This means knowledge creation and use could be a breakthrough of monumental proportions.

Skilling: Out of about 230 million people engaged in agriculture, about 173 million are to be skilled by 2022. GoI envisages providing variety of skill development avenues through formal and informal education and training to develop rural youth so as to move the skilled : unskilled mix from 65: 35 (in 2013) to 80 : 20 by 2022 (www.skilldevelopment.gov.in). Skilling rural youth and agri-professionals is yet one more untapped market and potential entry for new enterprises.

Social media: Young farmers began using ICT and social media on a personal basis to tell their farm's story, give updates during the harvest season, promote upcoming farmers markets, answering consumer questions and many more.

Data analytics: The vast amount of farm data collected through various farm implements, sensors, on crops and their environment can be analysed using advanced mathematics. It includes use of simulation models to make informed choices based on past and current conditions on items such as best time to plant crops, to identify crop varieties with higher yields and other desirable traits and efficient use of natural resources.

Thus, building up human capacity is critical investment for Agri-Industry 4.0.

3.7 ICT-based Innovative Startups in Agri-Value Chain Business

The major breakthrough in linking small farmers to the new initiatives is made possible by wireless systems like smart mobiles, tabs and personal digital assistants (PDAs). A high level of computer literacy is not essential for using such devices.

On supply side, digital platforms of large agri-business companies are providing a wealth of information to farmers and intermediaries on farm technologies. On the demand side, e-commerce platforms directly link the farmer to the food processing and retail stages of the value chain.

With about 792 million broadband subscribers (as per TRAI data as on June 30, 2021 www.trai.gov.in) and with rural tele-density of 60 per cent making them ready to receive the benefits of ICTs. Thus, it is big challenge to Agri-Industry 4.0 for making an inclusive development of ICTs use in agriculture.

4. Characteristics of ICTs relevant to Industry 4.0

India has a variety of ICT models, whose design and business model has been changing with advances in information technology. With rapid changes in information technology and penetration of mobiles and wireless access provided way for many innovative enterprises in agribusiness space. Broadly, the evolving models rely on their business from value creation in primary production or processing or retailing and in some cases they may cover a mix of these three.

4.1 Value Creation in Primary Production

Business enterprises operating of value creation in primary production focus ICT use on forward and backward linkages. Illustrative business enterprises operating on this model are Safal, Venky's, Amul, Grapenet, Mangonet, *etc*. Such models business scope covers:

- Genetic development
- Inputs (fertilizers, seed, hatcheries, feed)
- Processing facilities
- Branding and marketing

4.2 Value Creation in Processing

Business enterprises operating of value creation in processing focus on ICT use on backward linkages. Illustrative business enterprises operating on this model are Cereal flakes (Kellog), Ketchup (Pepsi). Such models business scope covers:

- Providing crop production practices
- Test for varietal integrity
- Storage and handling
- Transport to process plants
- Retailing

4.3 Value Creation in Retail Chain

Business enterprises operating of value creation in retail chain use ICTs to track the in-market process. Illustrative business enterprises operating on this model are Retailers like Spencers, Reliance, More, Suguna, Dabur, *etc*. Such models business scope focus on upstearm segments that covers:

- Farm level quality
- Traceability
- Input supply
- Transport
- Testing quality
- Information flow

5. Issues of ICTs Use in Agribusiness

Developments in ICTs are dynamic as there are continuous changes in the technology, products and services. For non-ICT organisations like agriculture, this dynamism poses many issues and challenges. A number of significant issues and barriers in use of ICTs include:

Information quality and reliability*:* There are concerns about the quality and reliability of information that can be accessed online such as databases, advisories, content, and the like. In absence of reliable information, farmers may be exploited with incorrect information and cockeyed ideas.

Access: The issue of access has two dimensions. The first, and most basic is physical access to systems and internet. The second dimension is analytical skills, *i.e.* ability to find and evaluate information and then use it effectively to influence decisions and behaviors.

Training: The changes in ICTs are at fast pace. As agri-organizations can not have the full benefit of ICTs expertise, periodic trainings in this area is one alternative. Every institution and programme must have a comprehensive training and development plan, with focus on ICTs.

6. End note

ICTs facilitates the acquisition and absorption of knowledge, and infusion of emerging technologies in to small scale agriculture through value added applications, e-services and learning. Universities and research institutions need to adapt to the emerging changes in ICTs to become relevant so as to develop relevant human resources for providing efficient and effective services.

Government can support digital economy and reinforce the transformational role of ICTs in agriculture and rural development policies and programmes. Quality data with adequate protection will enable all stakeholders, Governments, the private sector, the civil society and international organizations to identify problems, plan, monitor on collection, storage and use of digital data to make effective use for sustainable development and poverty alleviation. Pro-active policies on agri-startups through public-private partnership will be key to Industry 4.0 in agribusiness.

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Strategies to Enhance Farm Income through Improved Weather Based Agro-advisory Services

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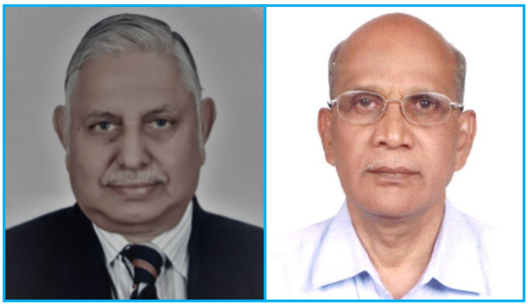

During the past few decades there are strong evidences to indicate that significant changes in climate are occurring across various regions of the globe in the form of increased frequency of extreme weather events such as severe droughts, floods, storms, heat waves, cold waves, high wind regimes *etc.* The significant cause to this sustained increase in climate variability, known as climate change has been a resultant of increased level of greenhouse gases (GHGs) in the atmosphere and the associated warming of global environment. The reason for this increase is mainly ascribed to enhanced human activities such as industrialization, uncontrolled burning of fossil fuels, increased use of refrigerants and changed land use patterns and practices. As a result, there has been a considerable rise in global mean temperatures, more so in the recent two decades and more. The increase in mean air temperatures of the globe was 0.76^{0}C during the past 100 years. This rate of increase has been higher during the past two decades and the recent period recorded the warmest years in sequence. The latest provisional WMO 'State of the Global Climate 2021' report, based on data up to the first nine months of the year 2021 indicating that the past seven years are the seven warmest ever, on record, with July 2021 being the hottest July month on record (NOAA,2021)

These climatic conditions are increasing the production risks and threatening the food security of nations. Agriculture is one of the main sectors that is likely to be impacted by climate change (John Hay,2007) which is expected to reduce agricultural production by two per cent every decade until 2050. According to the Intergovernmental Panel on Climate Change, the impacts of climate change hold significant influence on the timings of seasons and the distribution and quantum of receipt of rainfall, which is of great concern for farmers.

In a country like India, the consequences of climate change can be harsh with projections of decline in yields of major food crops due to warmer temperatures and increased drought risk in the coming decades. Thus, risk characterization and risk management are critical issues in agricultural productivity management. These risks are higher in rainfed areas which are mainly dependent on the quantum and distribution of rainfall during the monsoon season of June to September over major part of the country. As against the national average of 48.8% of the total cropped area being irrigated, 51.2% of the total cropped area is still rainfed and is strongly dependent on uncertainties of monsoon. This shows that the dependency of Indian agriculture on climate is very large and as such the Indian agriculture is often called a gamble in monsoon.

Research studies have brought out that though the annual rainfall remained about the same or decreased slightly in some regions, an increase in high rainfall events and increase in dry spell durations during the cropping season have been visible in many parts across India. Further, the last few years, especially 2015 witnessed El Nino impact with large part of the country experiencing drought conditions, more so in Maharashtra, peninsular states and in parts of AP and Telangana. As many as 15 states were affected and 33% of the cropped areas were damaged. The losses to farmers were in excess of Rs 20,000 crore. During the current cropping season of 2021, the country had witnessed 24% deficit rainfall in August and 35% excess rainfall, from normal in September with prolonged active monsoon conditions till 24th October and with weather activities still continuing in states like Tamil Nadu and parts of Kerala. Under these increasing occurrence of varying weather conditions, the year to year cropping seasons are also influenced to a large extent. Therefore, there is an urgent need for taking up systematic adaptation measures to increase the resilience and adaptive capacity of the farming communities to varying weather situations, through various modern technological tools such as reliable short range weather forecast, economically viable weather based agro advisories *etc.*

From agricultural point of view, weather plays a major role in influencing the decisions of the farmer, starting from land preparation, sowing to harvesting, post harvest management including storage and transport. For the rainfed farmer, all his farm operations begin with the onset of rains and his choice of crop and cropping system depends on the long-range forecast of weather expected during the coming monsoon season. Once he decides on his crop, the next step would be the land preparation, which depends on the quantum of the pre-monsoon showers. In case these showers are poor to wet the top soil layers, he has to wait till the monsoon onset to carry out both the land preparation, followed by sowing after sufficient moisture accumulates in the top soil layers that can enable germination of the crop and support seedling growth till the next rains are expected. Thus, from sowing onwards he depends on the medium and short-range weather forecasts to manage his crop and to decide on the various farm operations he had to adopt for better plant growth and in managing any moisture stress that is caused by the inter spell duration of rain events. The timely availability of weather information thus becomes crucial to the farmer for efficient management of the rainwater for crop growth and better crop productivity. Good weather code thus becomes his motto, where he attempts to take best advantage of good weather situations and can manage to reduce the impacts of bad weather conditions on his crop growth and performance. Besides the rainfall regime, his interest extends to other important weather variables like the temperature and humidity regimes which mainly control the evaporative demand of the crop and also influences the micro-climate and pest and disease incidence in his crop. Timely information of coming weather situations enables the farmer to be prepared adequately with control measures to mitigate the adverse impacts of weather on his crop to the extent possible.

Weather information across the country is being recorded mainly by IMD and also being supported by various other agencies and institutions. With the initiatives taken up various state government agencies, good net work of rain gauges and also many networks of Automatic weather stations (AWS) have come up across the country. Also, remote sensing agencies have been collecting data from various satellites on vegetation status, incidence of pest and disease and monitoring drought and flood situations. Thus, a large source of weather and related parametric data is being generated regularly. Thus, data analytics of this various sources of information can help in analyzing long term weather patterns of a region and also in field level monitoring of state, region, district, block and even up to village level weather and agricultural conditions on a regular basis.

Agro-Advisory Services

Looking to the importance of weather information needs of farmers, IMD and ICAR have initiated Agro advisory services to farmers in 1945 and have been improving upon the quality of the information disseminated to the farming community. From a regional level forecasts IMD now is providing short and medium range weather forecasts up to a block level and based on these weather forecasts both ICAR and IMD are providing district and block level forecasts (*Gramin Krishi Mausam Seva*) on weather conditions and crop management strategies to farming communities.

Thus, weather forecasts and agro advisories form an integral part of improved crop management and farmers, especially the small and marginal, who need sustained support through improved knowledge management for empowering them to meet the vagaries of the weather and take up adaptative measures to meet the challenges of increased climatic variability as a result of climate change. Access to improved knowledge can help them minimize the climate change risks and enable them in the efficient use of existing infrastructure and natural resources. It is here that the information and Communication Technology (ICT) has come to the aid of the farming community in a great way. With the fast improvement in mobile technologies and accessibility of mobiles even in remote regions, it has now become possible to transfer knowledge to larger number of farming community on efficient crop management approaches and in adopting Climate Smart Agriculture (CSA). In addition, the crop insurance agencies are interested to generate information on crop status during different phases of growth and impacts of extreme weather events like high temperatures, high intensity rains, floods, drought, high wind regime, pest damage *etc.* causing crop losses, so as to settle weather related insurance claims quickly and with confidence. Further many of the state governments are interested to generate accurate information on crop booking and area sown under each crop in space and time, with geo-references.

However, the current approach to providing agro advisories is not fully satisfactory to the farming community. Analysis by extension agencies indicate that farmers are not keenly following up the agro advisories as they feel that they are general in nature and does not specifically deal to their situation or meet their individual need. For example, even though the same crop is grown in a region, some farmers might have sown early, some during the normal growing season and some sow it late. Thus their crops are at different pheno-phases when a weather event occurs (rain or critical temperature) and so their crop's response would be different. This has to be taken into account in the advisories and also, they would expect a personal approach to their problem and not a 'general approach to all', with the same advice. Thus, agro advisories have reaped success mainly in those regions where the extension officials have adopted those farmers and are in regular contact with them or visit their fields. Thus, one of the main lacunae in the current approach is 'addressing the last mile' - that is including the farmer as a major player (provider and consumer) in the information exchange and in suggesting him the suitable alternate strategies.

Need for Smart Agro Advisories

Any approach adopted to provide such 'smart' and improved agro advisories has to take many measures to synthesize and integrate all the relevant information to enable to provide more accurate advisory to the farmer. For this they have to bring on to one platform, the data from satellites, weather stations (regular and AWS) and integrate this data with simulation models and with ground information on crop status collected from village level officials and progressive (and other concerned) farmers on crop, phenophase, crop health through photo based information (in the form of pictures taken on crop condition and uploaded to the cloud) for analysis, integration and interpretation using machine language (to handle the large data base).

States like Andhra Pradesh have taken steps to monitor the individual farmers activities across the state, by mapping their survey numbers with latitude and longitude coordinates. Further they have appointed 5000 MPEOs (multi-purpose extension officers) who are to visit two villages a day and interact with 20 farmers each in their farms. This innovative approach provides many opportunities for monitoring individual farmers fields and provide them agro advisories individually. With a unique field ID tagged to each field and the farmers provided with a picture-based App, the farmer takes a picture of his field when he sows his crop and fills a small proforma providing information on the crop, variety, date sown and inputs provided. The App saves this information and uploads it to the cloud when net is available, providing information on from which field it is taken and the mobile number of the farmer. Such information uploaded from individual farmers fields, enables the tagging of the information to the field pixel, enabling easy identification of not only the crop but also whether it was sown early, normal or late. Any further images taken at later periods by the farmer and also the MPEO's during their field visits, can be tagged together to monitor the progress of growth and health of the crop, specific to the corresponding farmer.

Through this process the agriculture department will get accurate crop booking information, enabling the mapping of the area sown under each crop in time and space in that region through geo references and the unique ID, tagged to each field visited by the MPEO's. This Information can be extrapolated using satellite data to come up with aggregated statistics on area sown under different crops and at different periods. This will help in assessing the current individual crop condition in the geo- tagged farmers' fields and also to estimate the area covered by a specific crop, cropping pattern in the region. Further visits by these officials, as well as the concerned farmer and also by any individual (like the progressive farmer of the village, or a school boy given the task of photographing fields at regular interval) taking photographs at that field (and other fields) will keep on getting uploaded by the App (along with Lat and Long) and tagged to the concerned farmers database. Thus, during the crop growing period, crop health assessments and other relevant crop information from individual fields, along with corresponding satellite information on a weekly basis can be compiled and provided to the farmer and officials regarding the crop condition, pest/disease/ moisture deficit (drought) or moisture surplus (flood) status. This will also lead to continuous and efficient performance of the MPEOs in data collection and information dissemination to government and the advisory agency in 'near real time'. Such farmer specific crop information, will be processed using crop models, cloud computing and machine learning tools, which will enable in providing improved/ smart crop specific Agro advisories to individual farmers on a regular basis during the crop growing period. These advisories would be for three crop conditions *viz.*, early, normal and late sown crop. Individual farmers will receive location specific crop relevant agro weather advisories on their mobiles.

The currently available District /Mandal level weather forecasts provided by IMD (using 9x9km grid WRF model) have to be down scaled (3x3 km) and using additional data available from local sources, and data from AWS network, satellite information and weather radar data, pooled together, to improve the accuracy of advisories at the micro level. The weather advisory will be improved, to be applicable to the respective location, crop type, crop stage, soil properties, current soil moisture and will be used to provide location and crop specific Agro advisories, using a 'cluster approach' (discussed below), to be of better use to the individual farmer at his farm. Such improved agriculture services, available at the door step of the farmer will not only boost his confidence to adopt innovative methods in agriculture management but also enhance the quality and productivity of his crop leading to improved livelihoods.

Any specific query on the agro advisory in respect to crop condition, any pest/ disease issue will, however, be provided to the farmers in a ' cluster approach' (one advisory to all those farmers having similar crop conditions/ phenophase) but will be received by the concerned farmer and also by other farmers on individual basis as per his crop status. In case of any adverse weather condition damaging the crop fully or partially, the farmer can take a photograph and upload it. This information can be cross checked by the insurance company through weather data and satellite data. Once confirmed of a likely damage, it can form a committee of MPEO, local Panchayati member and any other member to represent them and these members along with the concerned farmer, visit the field, assess the damage and come up with an agreement on the per cent damage with the farmer. This information on per cent damage would be submitted in a proforma along with photo (providing the Lat/Long of the field from where the photo is taken) of the damaged crop area, are uploaded from the farmer's field. Such a procedure can enable the insurance companies to judge the authenticity of the damage and clear the insurance payment rapidly, in 48 hours. Such seamless insurance payments by the concerned agency during extreme weather event damages, will enhance the confidence of the farmers enabling to come forward in large numbers to avail crop insurance proposals.

In addition, improving access of the farmers to vital market information, supporting them to adopt group dynamics to get good quality seeds and inputs will lead to better Finance-Production-Market linkages (through bankers, mobile trading, tendering, bartering platforms) can help reduce transaction costs and middle men interference thereby providing higher profits, boosting farmers income. The rural youth can also play a big role in this Endeavour, because of their agility and marketing abilities. This will also help in providing self created job opportunities to the village youth and will also enable them to return back from the cities to the villages. The Farmer Producer Companies supported by the Government can also play a lead role in assessing the total productivity in their domain and can place in advance the opportunities for early marketing of their produce economically, thereby enhancing the farmers income sustainably.

The major players in this smart/ improved agro advisory system would be the Ministry of Science and Technology, Earth sciences and Ministry of Agriculture and Farmers welfare, from the central Government, while at the state level the concerned Ministry of Agriculture, Department of Agriculture , the concerned Agricultural universities, ICAR institutes and other institutes in the state providing technical backstop on strategies for crop production and contingency planning at district level, besides many corporate agencies coming forward to support agricultural endeavors. For technology transfer to the farmers, at the state level the main player would be the department of agriculture, while at the district level the concerned JDA/DDA/ ATMA/KVK's / DATTC and other Mandated agencies. At Mandal level the ADA/AEO's/ MPEO's will lead, while at the Village/ cluster of villages level, the VDO's/NGO's/ Farmer societies/ Panchayati will play the major roles.

This approach can be tried on an experimental basis in few districts and once proved successful to enthuse larger number of farmers, can be up scaled to other districts. Such an approach can not only make these improved Agro advisory services more valuable to individual farmers providing them more confidence in managing their agriculture and achieve enhanced quality productivity believe in government's committed support for their welfare. It can also help farmers in future to come forward to pay for the advisory services in future, leading to a business model for a P-P-P. Also, the experiences gained during such an experimental phase will enable the field level officials to carry forward the technological adoptions by farmers in future, in a seamless manner.

In turn organizations like ATMA can take these strategies forward at ground level with the help of MPEOs, other field staff. KVKs can also help in the successful demonstration of the technologies and up-scaling them at village and block level. Ultimately the department of Agriculture can converge the efforts of public, private and NGO organizations to avoid duplications and to follow a clear strategy for a planned multi-stakeholder involvement. This will lead to improved benefits to farming community and increased productivity and profitability. Providing access to such adaptative technologies can help farmers in following resilient cropping strategies and achieving sustained agricultural productivity and overcoming the impacts of climate change, a win-win situation.

Since this would need a lot of computer time, cloud computing, remote sensing data analysis, modelling, monitoring crop data, extreme weather events, assisting in rapid settlement of insurance claims and providing smart agro-advisories to individual farmer's mobiles and attending to their queries. This would mean that the state department would need support of expertise from private agencies to take the lead and join forces with agriculture related central and state agencies and agriculture universities, in a P-P-P mode to take up such an integrated Farmer specific approach, to collate and analyze such large data and reach such a voluminous group of farmers with diverse cropping systems. It is a welcome step that Government of India is planning in a large way to share national agricultural data base for development of a integrated package to plan sustainable regional crop production technologies and simultaneously to provide technological and financial support to farmers and FPC's to develop appropriate linkages for enhancing farmer's income and also national productivity in a sustainable manner, meeting the future challenges of Climate change through Climate smart agriculture.

Concluding Remarks

Weather based Agro- advisories that are being currently implemented in the country can be further strengthened by incorporating reliable short and medium range weather forecasts along with use of improved AI technologies and ground monitoring of crop condition, to provide appropriate advisories specific to particular micro regions and reaching to meet the needs of individual farmers. The advisories should able to cater to the requirements of all types of farmers *viz.,* Urban, Peri -urban, coastal, high rainfall, plains, hilly regions and desert region spread across the country under varying Agro-climatic conditions. With the improvements in Information technology and mobile technologies, development of user friendly and add free apps with exchange of relevant crop and weather specific information should be encouraged and made available to meet the needs of individual farmers, at their doorstep. Market information, current price and future price trends along with demand for the next season should be made available to farmers and FPC's to enable them to plan their cropping sequences. As many apps are developed across different states, an integration of some of these apps to provide reliable market information to concerned farmers on a national level should be attempted so that farmers can decide where and when to sell his crop. Private agencies like NCML (National Collateral Management Services Limited) who provide storage facilities to farmers to hold his produce till a favourable market is available to him, should be encouraged. In addition to regular advisories, farmers should be provided with timely weather alerts about thunderstorms, lighting, landslides, flood alerts, snow avalanches etc., besides occurrence of rains and flooding during harvesting and crop drying conditions, to enable them to adopt to the extent possible, methods to save their harvested crop. As many agencies including local Government and private entrepreneurs have entered in to this field of weather forecasting and farm advisories, there is every possibility that the beneficiaries may get confused about what/ whom to follow to save his crop. Therefore, there is a need to establish a regulatory authority to monitor the functioning of the agro advisory system for better agricultural crop production and integration of weather advisory information at State/National level.

Organic Farming – Challenges and Scope for Sustainable Agriculture Development

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Introduction

"Agriculture can be sustainable and self-reliant only if farmers use locally available resources as inputs eg. Farm wastes, cow dung and other biomass for preserving the soil as a living material". Organic farming can be defined as a production system which largely excludes or avoids the use of fertilizers, pesticides, growth regulators, *etc.* and relies mainly on organic sources to maintain soil health, supply plant nutrients and minimize insects, weeds and other pests. In other terms, It is a system approach of crop production, observing the rules of the nature, targeted to produce nutritive, healthy and pollution free food, protecting the entire system of the nature, maximizing the use of on-farm resources, minimizing the use of off-farm inputs and avoiding the use of chemical fertilizers and pesticides (NPOF).

There are several potential applications are associated with organic farming to climate change mitigation. In particular greenhouse gases (GHG) emissions are reduced by avoidance of mineral fertilizers, lower N_2O emissions due to low N input and careful management, Less CO_2 emissions due to better soil structure and more plant cover, Highest mitigation potential of organic acids lies in carbon sequestration. The emission reduction potential by avoiding mineral fertilizers is about 20%, compensation potential by C sequestration is about 40-70% of world's current annual GHG emissions (Tuomisto *et al.*, 2012; Muller *et al* ., 2017).The worldwide organic farming covers the total Area of 37.2 m. ha. By 1.8 million organic producers and practiced in 162 countries. the major organic cultivating land from Australia (12.02 m. ha.), Argentina (4.4 m ha) and India (1.10 m. ha) 0.6% of the total agricultural area with 5,47,591 organic farmers. The global Market for organic food: 62.9 billion US $, organic food exports increased from 100 m US $ (2008-09) to 157.22 m US $ (2010-11) (World Scenario-2012 survey; Muller *et al* ., 2017). It is commonly assumed that by 2050, agricultural output will have to further increase by 50% to feed the projected global population of over 9 billion (Alexandratos, N. and Bruinsma, 2012).This challenge is further exacerbated by changing dietary patterns. It is, therefore, crucial to curb the negative environmental impacts of agriculture, while ensuring that the same quantity of food can be delivered. There are many proposals for achieving this goal, such as further increasing efficiency in production and resource use, or adopting holistic approaches such as agro-ecology and organic production, or reducing consumption of animal products and food wastage (Muller *et al.,* 2017). Organic agriculture is one concrete, but controversial, suggestion for improving the sustainability of food systems. It refrains from using synthetic fertilizers and pesticides, promotes croprotations and focuses on soil fertility and closed nutrientcycles (IAASTD-2009; Foley, 2011).The growing health consciousness among the consumer and increasing awareness about organic food has led numerous opportunities for organic producers. Along with opportunities, there also arise various challenges like marketing of organic produce, soil health testing facilitates, availability of biopesticides and biofertilizers are faced by the organic farmers in India.

Organic Farming in India

The concept of organic agriculture is not alien to India. In fact, the first scientific approach to organic farming dates back to the *Vedas* of the later Vedic period, the essence of which is to live in harmony with, rather than exploit, Mother Nature. There is brief a mention of several organic inputs in our ancient literatures like *Rigveda, Ramayana, Mahabharata, Kautilya Artha Sashthra etc*. In fact, organic agriculture has its roots in traditional agricultural practices that evolved in countless village's and farming communities over the millennium (Singh *et al.,* 2019).Therefore, traditionally Indian farmers are practicing organic farming and gradually changed to chemical-based cultivation since 1950's. Chemicals increasingly applied with green revolution and liberal use of chemicals led to health hazards and also Air, water and soil pollution noticed everywhere simultaneously soil fertility declined in many places. It is definitely true that India had witnessed a tremendous growth in agricultural production in the era of Green revolution. Food grain production, which stood at a mere 50 million tons at the time of independence, had increased almost five and half times to 273.38 million tons by the end of 2016-17 (Press Information Bureau, GOI, 2017) from 159.59 million hectares of cultivated area in country (Agriculture Census, 2010–11). The technologies involved during the inception of green revolution supported by policies and further propelled by agrochemicals, machinery and irrigation were the main driving forces for the enhanced agricultural production and productivity (Roychowdhury *et al.,* 2013). Despite the fact that the food security of India was definitely addressed by these technologies (Charyulu and Biswas, 2010), an important setback was that the farmers using these technologies were still had to depend upon the purchased inputs. With manufacturing of fertilizers and pesticides as the two major inputs of Green Revolution (GR) technologies, an important point of consideration was the need for fossil fuels and/or expensive energy which are associated with serious environmental and health problems.

In last 50 years we are using heavy amount of fertilizers and pesticides and we already reach on plateau and diminishing low of return start to work (Venkateswarlu *et al.,* 2008), so we need to apply more input (fertilizer and pesticides) to get small raise in production which cause second generation problem and few of such epitome examples are some regions of Punjab (cancer belt of country) and endosulfan story of cashew plantations area in Kerala (proving finding of Rachel Carson's Silent Spring was published in 1962). Insecticides and herbicides in ideal condition lethal for target group only, for non-target group and human it is safe but this principle is not followed strictly and indiscriminate use of these chemicals put human life and ecosystem health on verge (Aktar *et al.,* 2009). All these thing and unsustainability issue associated with modern agriculture force us to look back (Balachandran, 2004) in history to know either we are not doing any mistake by depending on off-farm inputs because crop production is a recycle system of nature by putting too much off farm input we are making it fragile day by day. One of such natural, recyclable and sustainable approach of farming is Organic farming. It is the effective and cost-efficient way to achieve sustainable development in the agriculture sector (IFOAM, 2010). Organic source of nutrient also helps to combat with the problem of multi nutrient deficiency and low organic content in our soil which is affecting productivity of major food crops at farmer field (Singh *et al.,* 2017).

Organic crops cannot be grown with synthetic fertilizers, synthetic pesticides or sewage sludge. They cannot be genetically engineered or irradiated. Organic animals must eat only organically grown feed and cannot be treated with synthetic hormones or antibiotics.The increasing awareness of the fitness and health benefits of organic foods are fueling the demand for these products across the world. Most developed countries, including the European Union, United States, Canada, Japan, China, Russia, and Australia, require country of origin labeling in order to market food as organic within their borders. Organic food is the fastest growing sector of the American food industry (Alexander *et al.,* 2015).The government of India is offering strong support and promoting organic farming as it will increase the economic contribution, positive impact on biodiversity, and effective soil management. Organic foods are getting popular in India due to the availability of organic manures in rural areas, the depleted soil and product quality, as well as increased commercialization and competitiveness of the Indian agro-market. Farmers are ready to adapt organic farming based on profitability and concern developed for safe food production and environment protection. National Programme for Organic Production (NPOP) - Launched by Ministry of Commerce, Govt. of India in 2000 for the continuous support and services to the Indian organic farmer. There are several agencies are accredited under NPOP like APEDA, spices board, coffee board tea board, coconut development board and directorate of cashew and cocoa development are in working in support of farmers.

Constrains on Organic Farming in India

The organic foods have labor intensive demand and farmers do not use pesticides, chemical fertilizers, or drugs. Thus, organic foods normally cost 20%–100% more than conventional foods. Moreover, after all the rigorous procedures involved in obtaining labels for organic foods, there is no means for distinguishing between organic and conventional foods unless they are taken into the lab for testing. Organic foods tend to spoil faster than non-organics because they are produced without artificial preservatives or irradiation.Therefore, consumers will not be able to ascertain if the food was produced according to the promised characteristics such as safety and trust worthiness or not. A lot of skepticism are shown by consumers regarding the certification process of organic and non-GMO labels. Besides all these the major issues faced by organic farmers are soil health management, pest and disease control and organic produce marketing.

1. Soil health management: Soil health is a term which is widely used within discussions on sustainable agriculture to describe the general condition or quality of the soil resource. Soil management is fundamental to all agricultural systems, yet there is evidence for widespread degradation of agricultural soils in the form of erosion, loss of organic matter, contamination, compaction, increased salinity and other harms (European Commission, 2002). This degradation sometimes occurs rapidly and obviously, for example when poor soil management leads to gully erosion. Often degradation is slower and more subtle, and may only impact on agricultural production and the wider environment over years. For this reason, research has been directed to devising measures of the health of soil, which could be used to monitor itscondition and inform its management so that degradation is avoided(Kibblewhite *et al.,* 2008).

Agro-ecological systems such as organic farming and other forms of soil-conserving sustainable agriculture can compete with conventional agriculture and have the potential to maintain food productivity while improving health and diet as well as sustaining soils, waters and ecosystems (Halberg *et al.* 2015; IPES-Food 2016). Agro-ecological systems are two to four times more energy efficient than conventional agriculture (IPES-Food 2016).They are thus important for the future because of the irreduced reliance on fossil fuels for cheap energy and fertilizers and on the navel idea that technology can continue to solve our problems (Weis, 2010). Agro-ecology, with such emphases on efficient input use and environmental benefits, is also compatible with ideas of sustainable intensification (Lampkin *et al.,* 2015). Organic farming provides the sustainable soil quality, crop yield and ecosystem services, perhaps as a result of soil-aware management(Taylor *et al.*, 2006).

Assessment of soil health across agricultural systems, soil types and climatic zones presents major scientific and policy challenges. Clearly, no single indicator will encompass all aspects of soil health, nor would it be feasible (or necessary) to measure all possible indicators (Kibblewhite *et al.,* 2008). Soils provide multiple ecosystem services, and as such, soil health management in support of sustainability must consider three points: that enhancing many soil ecosystem services requires multi-functional management; that managing soil to improve one service can have positive (synergistic) or negative effects (tradeoffs) on another service; and that soil health management should sustain soil services over the long term(Lehmann *et al.,* 2020).

Management of agricultural practices using new technologies such as testing of soil nutrient is found to be economical and environment friendly in organic farming. In agriculture, encourage alternate means of soil fertilization relies on organic inputs to improve nutrient supply and conserve the field management. Several organic sources are associated to improve the soil fertility under organic farming like farm yard manure, compost, vermicompost, coir pith compost, poultry manure, crop residues, green manures, and agro wastes. Bio fertilizers, known as microbial inoculants, contain actively living cells of micro-organisms. Efficient nitrogen fixers or perform other functions which beneficially affect plant growth and yield. N and P are the main nutrients that can be supplemented by bio fertilizers. *Rhizobium, Azotobacter, Azospirillum*, blue green algae and Azolla for N, *Mycorrhiza* and phosphate solubilising micro-organisms for P are important to many crops. All these natural sources enhance the soil nutrient concentrations; moisture content and their contribution to plant uptake and also crop nutrient requirement are to be considered to estimate the quantity of organic sources.

Farmers and stakeholders need to be made aware of the importance of management for long-term sustainability of soil and food production, and we believe this could be facilitated by improving their connection with the soil. Also human society as a whole needs to become more aware of its connection to the soil and realise the dependence on soil for food, biomass and the functions it provides to maintain the biosphere (FAO and ITPS 2015). It is also very important to increasing awareness and understanding of soil security and soil health management in the general public and in agricultural (Morgan *et al.,* 2015).

2. Pest and disease control: One way to increase food availability is to improve the management of pests. There are estimated to bearound 67000 different crop pest species including plant pathogens, weeds, invertebrates and some vertebrate species and together they cause about a 40% reduction in the world's crop yield (Oerke *et al.,* 1994). Croplosses caused by pests undermine food security alongside other constraints, such as inclement weather, poor soils and farmers' limited access to technical knowledge. In contrary to synthetics, biopesticides have emerged as a green tool in the era of sustainable agriculture. These are the most likely alternatives to some of the most problematic chemical pesticides currently in use. Biopesticides offer solutions to concerns such as pest resistance, public health issues and detrimental effects on the surrounding environment. Despite the benefits associated, the overriding challenge for the biopesticide industry is to live up to the promises and expectations of the end-users or the market and public as a whole. It is a well-known fact that as far as environmental perspective is concerned, biopesticides are far better than synthetics, but at the same time, we can't deny that this greener approach is struggling for its place in established conventional chemical pesticide market (Mishra *et al.,* 2020).

In India, the concept of biocontrol of plant diseases has been in practice for a very long time (Schmutterer, 1985). The neem tree (*Azadirachta indica* A. juss) and its derivatives, *i.e.* leaf extract, oil, and seed cake have been used as fertilizers and also for minimizing the risk of post-harvest loss instored cereals (Isman, 1997; Brahmachari, 2004). There are evidences where some insects and birds were used in pest eradication (Subramaniam, 1952). During the 1960s, the concept of integrated pest management (IPM) had also emerged with a target of judicious use of pesticides in agriculture (Smith and van den Bosch, 1967). Later, the US National Academy of Sciences' also exemplifed the term IPM in a broader way, and along with multiple complementary methods to suppress pests, biocontrol was also added (Peshin *et al.,* 2009).

However, in India, a major technological breakthrough in the field of biocontrol happened when chemical insecticides failed to control *Helicoverp aarmigera*, *Spodoptera litura*, and other pests of cotton (Kranthi *et al.,* 2002).It was realized that biocontrol is the only means that can beutilized as a safe, cost-effective, and eco-friendly method to control the widespread resistance of chemical insecticides towards pest insects. Later, biopesticides became a part of IPM which was previously completely based on the use of chemical pesticides. To control pest and diseases in the organic farming the farmers need to practice sustainable preventive and controlling methods like selection and cultivation of tolerant crops and crop varieties, cultural control, mechanical control, biological control, use of pheromone traps and biopesticides.

Biological control comprises the use of plants or botanicals, microbial pesticides, biocontrol by insects, biorationals. Botanicals means use of various plant products have been in use for many centuries in India to minimise losses in crops and grain storage. A large database of plant species that possess pest-controlling insecticidal, anti-feedant, repellant, attractant and growth inhibiting properties exists in every village. Plants widely used for botanical pesticides are Anona sp, *Azadirachta indica*, Chrysanthemum sp., Cymbopogan sp., Nicotiana sp, Pongamia sp, Vitex sp., *etc*. Seeds, leaves, extracts, fruits, kernels, oil and decoctions from botanicals are used to control the pests. Biopesticides are living organisms – or their derived parts – which are used as biocontrol agents to protect crops against insect pests. Seed treatment, seedling root dip, soil application or foliar spray will effectively control fungal diseases and bacterial diseases.

Commercially important microbial bio-pesticides and biorationals used in India

Category	Products	Target pest	Major crops
Bacteria	*Bacillus thuringiensis* *Bacillus sphaericus* *Bacillus subtilis* *Pseudomonas fluorescens*	Lepidoptera Mosquitoes, flies Fungal pathogens Fungal pathogens	Cotton, maize, vegetables, soybean, groundnut, wheat, peas, oilseeds, rice
Viruses	Nuclear Polyhedrosis Virus (NPV) of Helicoverpa armigera, Spodoptera sp. and *Chilo infescatellus*	American Boll worm, tobacco caterpillar and shoot borer	Cotton, sunflower, Tobacco and sugarcane
Fungi	Trichoderma viride Trichoderma harzianum Trichoderma hamatum	Fungal pathogens	Wheat, rice, pulses, vegetables, plantations, spices and sugarcane
	Beauveria bassiana Verticillium lecanii Metarhiziumanisopliae Paecilomyceslilacinus Nomuraearileyi	Insect pests such asbollworms, white flies,root grubs, tea mosquito bugs	Cotton, pulses, oilseeds, plantation crops, spices and vegetables
Biorationals	Pheromone traps Pheromone lures, sticky traps and mating disruptants	Bactocera sp. Chilo sp. Dacus sp. *Eariasvittella* *Helicoverpaarmigera* *Leucinodesorbonalis* *Pectinophora* *gossypiella* *Plutella xylostella*	Cotton, sugarcane, vegetables, fruit crops

There are many constraints that are responsible for their lower adaptability amongst farmers. However, technological challenges and long-term sustainability are the major issues that require immediate consideration.

3. Marketing of organic produces: Marketing and distribution are not efficient because organic food is produced in smaller amounts from the need of world's population that needs to survive. This could lead to starvation in countries that produce enough food today. Along with great opportunities with organic farming, there also arise marketing challenges faced by the organic and conventional farmers in India. The major marketing challenges faced by the farmers, namely, lack of warehousing facility, lack of price information, inadequate demand for crop, costly transportation, market price variations, and lack of government support. There are significant differences in the marketing challenges faced by the conventional and organic farmers across the nation.

Marketing of organic produceis mainly the buying and selling. Rapid transformation in terms of increasing concentration in processing, trading, marketing and retailing is being observed in the agri-food system all over the world. Traditionally the farmers were unaware in advance when, to whom and at what price they are going to sell their produce. This scenario has changed with the greater coordination between farmers, processers, retailers and other players in the supply chain. Now the farmers are producing to the requirements of the market rather than relying on the markets to absorb whatever they produce.The real challenge lies in organising the small and marginal farmers for marketing and linking them to high value agriculture. Thus, group approach is needed for getting benefits from marketing. Small farmers can also benefit from the emerging super markets and value chains if linked effectively. According to the ways in which the farmers link to the buyers, market linkages can be classified into the following categories: 1.Farmer to domestic trader, 2.Farmer to retailer, 3.Linkages through cooperatives, 4.Farmer to agro-processor, 5.Farmer to exporter, 6.Contract farming.

Type of linkage	Collective activity	Advantages for farmers	Disadvantages for farmers
Direct between farmers and traders	Farmers usually act on individual basis with traders. May work together informally to bulk-up produce to reduce costs and attract larger traders	Trust ensure long term sustainability Formal farmer organisations not usually needed	May need to accept short-term deferred payments Limited access to better markets
Direct between farmers and retailers Linkages through cooperatives	May require formal group Structure Farmers may link directly with the cooperatives or through groups	Reliable market at agreed price Inputs, technical assistance etc. may be supplied on credit Crop marketing, packaging, grading and storage and sometimes processing organised by cooperatives Potential for farmers to sell large volumes	Must meet variety, quality and safety specifications Must be able to supply agreed quantities at all times. Cooperatives often depend on subsidies and external managerial assistance. Commercial activities can collapse when subsidies and assistance run out

Direct between farmers and agro-processors	Farmer groups can bulk-up produce for collection by processor Groups can facilitate supply of inputs and provision of technical assistance	May provide secure market at agreed price Inputs, technical assistance, etc. may be supplied on credit Processor often provides transport Potential for farmers to sell larger volumes	There may be an inadequate market for the processed products, thus jeopardizing sustainability Must meet variety, quality and safety specifications Open market price may be higher than that agreed with processor
Farmer to exporter	Often involves grouping of Farmers External technical assistance may be required	Potential high returns if quality can be achieved Inputs, technical assistance, *etc* may be supplied on credit Exporter often provides transport and packaging	Export markets are inherently risky Compliance with standards can be problematic even with technical assistance
Formal large-scale contract farming	Company may prefer to group farmers, formally or informally, for inputs and output marketing and extension	Inputs, technical assistance, *etc.* may be supplied on credit Crop marketing organized by company	Companies often require external agency (bank) to finance credit provision Frequent mistrust between farmers and companies and their employees Contracted price lower than market price may lead to sales outside of the contract

Marketing Institutions	**Features**
Rythu Bazaar in Andhra Pradesh	First started in Andhra Pradesh in the direction of empowering the farmers to participate effectively in the open market to get a remunerative price for their produce. To avoid the exploitation of both the farmers and the consumers by the middlemen by creating a positive atmosphere of direct interface between them
Apni Mandi	First started in Punjab in the direction of ensuring direct contact of the producer farmers and consumers and thereby enhancing the distributional efficiency of the marketing system. This system does away with the middlemen. The price spread is considerably low. Working satisfactorily in the case of fruitsand vegetables

Farmers markets	Farmers markets initiated in various states to eliminate middlemen and traders fromthe marketing of vegetables in the farmers markets, and to establish direct contacts between farmers and consumers.
Hardaspar Vegetable Market	Hardaspar vegetable market is a model market for direct marketing of vegetables in Pune city, This is one of the ideal markets in the country for marketing of vegetables. The market has modern weighing machines. Linking farmers to vegetable markets
Shetkari Bazar	Shetkari bazaars were established in the Maharashtra state for marketing of fruits and vegetables
	It will eliminate middlemen, links producers and consumers directly, reduce price spread, and enhance producer share's in consumer rupee. Thus these markets increase the farm income, wellbeing of the farmers
Krushak Bazars	Established in the state of Orissa in 2000-01
	The purpose is to empower farmer-producer to compete effectively in the open market to get a remunerative price and ensure products at affordable prices to the consumer
Cooperative Marketing Society	The need for cooperative marketing arose due to defects in the private and open marketing system. A cooperative marketing society can eliminate some or all of the intermediaries. Few successful cooperative marketing societies for fruits and vegetables. eg. Maha-grape-cooperative federation marketing, Maharashtra, Cooperative marketing. pomegranate, Co- operatives marketing banana in Jalgaon district, Vegetables co-operatives in Thane District, Milk co-operatives in Maharashtra, HOPCOMS, Bangalore and Gujarat and Co-operative cotton marketing society.
Contract Farming / Contract Marketing	Essentially is an agreement between farmer-producers and the agri-business firms to produce certain pre-agreed quantity and quality of the produce a particular price and time. This is an important initiative for reducing transaction costs by establishing farmer-processer linkages. Successful contract farming includes Organic dyes-Marigold farmers and extraction units in Coimbatore, Pepsi Company and farmers of Punjab and Rajasthan for tomato growing
Safal Market	NDDB started a fruits and vegetable unit of SAFAL at Delhi was one of the first fruit and vegetable retail chain. NDDB has set up an alternate system of whole sale markets in Bangalore as a pilot project. This market is a move to introduce a transparent and efficient platform for sale and purchase fruits and vegetables by connecting growers through Grower's associations.
Forward and Future Markets	Forward and Futures markets have been identified as important tools of price stabilization and risk management. Extension of forward and futures markets to all major agro commodities has, therefore, assumed great importance. Commodity futures markets in the country are regulated through Forward Contracts (Regulation) Act, 1952

Commodity Exchanges	Commodity exchanges for futures trading narrows the marketing, storage and processing margins, there by benefiting both growers and consumers. NAFED started National Multi-Commodity Exchange of India Ltd. on 26th November, 2002, for cash crops, food grains, plantations, spices, oilseeds, metals and bullion among others. National Commodity and Derivate Exchange of India Ltd. was established in Dec, 2003 atMumbai with a similar purpose.
Food retail super mar-kets	Food retail markets in India during 1990s and early 2000 opened up the availability of food products dramatically. They key functions are • Higher standards • Lower prices
Organic Mandi	Being initiated in Haldwani in Uttarakhand by Mandi Samiti

In the marketing of the final produce, the price that they receive at the farm gate is considerably lower than the retail price. The new institutional innovations in the marketing have been initiated in India in the last decade and some of the cases show that they are far friendlier to the farmers when compared to the traditional marketing forms. The evolving innovative marketing concepts like direct marketing, co-operative marketing, contract farming etc are however not free of hitches. Proper planning and action of the farmers and the private players capable of engaging in such innovative channels.

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India Needs an Alternative Agri-food System to the Current Chemical Agriculture

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The need for change of agri-food system in India is under serious consideration by the NITI Ayog Government of India (GOI), and the policy influential bodies such as Trust for Advancement of Agriculture Sciences (TAAS), Council on Energy, Environment and Water (CEEW), Asia Agr-Age-History Foundation (AAHF) and *Rythu Sasdhikara Samstha* (RySS). GOI initiated several schemes on promoting traditional agricultural systems considering even separate budget lines for organic and natural farming systems; TAAS conducted a brainstorming webinar on the need to promote Regerative Agriculture, AAHF reviewed the strengths and weaknesses of traditional farming systems including Organic Agriculture and the Andhra Pradesh Community Natural Farming promoted by RySS reached about 5 lakh farmers on ground level practice at different levels. The author has personal interactive experience with all the above institutions and based on these reports and publications, this article is developed. Article summarizes the key Indian Think Tank ideas on agricultural transformation. Need for the agri-food system transformation, analysis on options and the conclusions as perceived by the author are presented in this article.

The 10 elements listed by the Food and Agricultural Organisation (FAO) in agroecology are Diversity, Co-creation and sharing of knowledge, Synergies, Efficiency, Recycling, Resilience, Human and social value, Culture and food traditions, Responsible governance and, Circular and solidarity economy. India has over 10,000 years of agricultural experience embedded into communities and ecosystems. Intensive high input yield oriented chemical agriculture has been practiced for the past six decades only that significantly contributed to food security. India has become not only self-sufficient in food grain production and has become an exporting country with annual export of rice alone worth over 30,000 crore rupees. However, an imbalance emerged in production of pulses and oilseeds. Annual cost to Indian foreign currency for edible is next only to petroleum products to the tune of over 70,000 crores annually. Consumption of fruits and vegetables is also at a lower level than recommended. Investment on expanding irrigation and development of technologies for increased production of food grains particularly rice and wheat is responsible for the imbalances in food production and over exploitation of natural resources. Contribution of agriculture products to GDP in India declined from about 52% in 1950's to about 14%. India being a predominantly agrarian country about 50% of the population still depend on agriculture with per capita land available as low as 0.12 hectares. Organic farming promotion being followed in countries like Australia with large farm holdings or western world is not relevant to India. Hence it is necessary that India should develop its own system of agricultural transformation as large number of farming families livelihoods are associated.

Why Alternative Agri-food System?

Enhanced food production along with unsustainable exploitation of natural resources led to land degradation,ill health of soil, poor productivity, salinization of soils, degradation of biodiversity, loss of organic matter and microbial biomass. In terms of food grain production globally enough calories are produced to feed 9 billion people. However the current production process degrades soils, harms the environment putting our health and further food production at risk. The three main Sustainable Development Goals (SDG) are to achieve i) Zero Hunger (food and nutritional security) ii) Zero Poverty and iii) Good health and Well-being by 2030. India including most of the countries in Asia Pacific region and Africa are nowhere near to achieving these SDGs by 2030. A different strategy is required to accelerate the achievement of SDG goals. Hunger and food access or inequality issues which can be addressed partly by supporting small scale sustainable agriculture. In Spite of the positive contribution of chemical agriculture to food security, still a large cultivated area (more than 40%) is under low input and rainfed agriculture in India which contributes over 50% of the current food grain production substantially in millets, oilseeds ad pules. In spite of food security achieved in India, chemical agriculture contributed to nutritional insecurity affecting over 800 million people, several millions of hectares of land degraded, soil erosion of serious consequences happened to the extent that the agriculture has become unprofitable and unsustainable. It's in this context various options of sustainable farming system and practices are reviewed below.

What are the Options?

Dr. YL Nene, globally renowned agricultural scientist, critically reviewed various methods of farming system options available to support sustainable agriculture in his article in 2017. A brief analysis on various traditional options is provided below.

The methods of "Do Nothing" and "Biodynamic" are not practical to achieve food security. *Rishi-Krishi, Agnihotra-homa* farming, and *Krisha-Suktis* and *Vrikshayurveda* can be practiced only in small individual farms and not applicable to large-scale agricultural transformation. Vermiculture, Natueco culture, *Panchagavya*, Compost Tea and Bokashi Tea are potential methods of cultivation that can contribute to food security. However practicing these methods may have certain limitations and scientific evidence needs to be developed in order to integrate these methods into sustainable agriculture. Zero Budget Natural Farming (ZBNF) proposed by Mr Subhash Palekar also known as Subhash Palekar Natural Farming (SPNF) with dynamic changes from the grassroots level is now known as APCNF. APCNF is one of the most tested on ground agri-food system practiced in large area with huge farm families participation, which has potential to transform agri-food system of India with back up of science based evidence.

Recently CEEW reviewed different farming systems that contribute to sustainable agriculture. A brief assessment of various farming systems/methods is provided below. The farming systems options are Agroforestry, Conservation Agriculture, Precision Farming, Biodynamic Farming, Contour Farming, Integrated Farming, Permaculture, Floating Farming, Organic Farming and Natural Farming. The methods that support sustainable agriculture are SRI, Crop rotation and Intercropping, Cover crops and Mulching, IPM, Vermicomposting, and Rainwater Harvesting and Artificial recharge of groundwater. A brief review on different agri-food systems and sustainable methods is provided below.

Agroforestry

Area covered under agroforestry is 25 million hectares with an estimation of less than 5 million farmers. FAO's agrro-ecological principles relevant to this system are synergies, efficiency, recycling, resilience, human and social values, diversity, co-creation and sharing of knowledge, culture and food traditions. Areas with the highest organic farming are Jharkhand - 21%; AP,&Telangana- 19%; TN- 13%; Odisha - 13%; Chattisgarh - 13%; and Bihar-14%. Challenges and recommendations are creating incentives in the form of carbon credits to scale up. This will help in carbon sequestration and lack of capital for initial investment which is especially a constraint for small and marginal farmers. Key stakeholders of Government are Institute of Forest Management, Bhopal; Research Institutes are 37 All India Coordinated Research Projects, Indian Council of Forestry, Research and Education, Forest Research Institute, Dehradun, BAIF Development Research Foundation, and CSOs/NGOs are CARITAS, PRADHAN, Canter for Agriculture and Rural Development, NIRMAN, CORD, *Bundelkhand SewaSthan*.

Conservation Agriculture (CA)

Area covered under conservation agriculture is 2 million hectares with 1 million farmers are estimated to practice CA. Large farmers predominant (Rice wheat, Sugar cane and maize based), FAO's agri principles relevant are Synergies, efficiency, recycling, resilience, human and social values, diversity, co-creation and sharing of knowledge. Areas with highest organic farming are Punjab, Haryana, UP, Delhi, Bihar and West Bengal . Challenges and recommendations are only partial CA is prevalent in India, literature Is limited to cereals growing, cropping systems.; support CA impact studies in other, agro-climatic conditions and zones; lower yields in the first 2-3 years, difficult to estimate impact, no specific policy support, limited access to agricultural implements for crop residue management . Key stakeholders of Government are : Department of Agriculture, Cooperation & Farmers Welfare (DAC&FW); ICAR - Indian Institute of Rice Research; ICAR - Directorate of Wheat Research, Karnal; ICAR - Central Research Institute for Dryland Agriculture; ICAR-Indian Institute of Soil Science. Research Institutions are International Maize and Wheat Improvement Centre (CIMMYT); Borlaug Institute for South Asia (BISA); International Rice Research Institute - India; International Food Policy Research Institute (IFPRI); International Crops Research Institute for the Semi-arid Tropics (ICRISAT); Punjab Agricultural University (PAU). NGOs/CSOs are Centre for World Solidarity (CWS); Gram Disha Trust; Foundation for Ecological Security; SRIJAN; Nature Institute for Welfare of Society; ELA Agri Solutions; Kalpavriksh; Rural Technology and Development Centre (RTDC); Gram Vikas; Nuhaar Foundation.

Precision Farming (PF)

Area covered under precision farming is 9.2 million hectares with an estimate of 3 million farmers. Medium and large progressive farmers(High value commercial and horticultural crops). FAO's agri principles relevant are efficiency, resilience, human and social values , co-creation and sharing of knowledge. Areas with highest organic farming are Andhra Pradesh - 22%, Haryana - 17%, and Gujarat - 11%. Challenges and recommendations are policy level support is needed for technical assistance and to develop pilots and models which can then be scaled up. Support needs to be provided for women to run CHCs and skill women to run LLLs.Adaption of PF is slower in rainfed areas to improve adaptation. Support for Custom Hiring Centres and awareness generation in rainfed areas is needed. Research efforts needs to be enhanced in order to drive cost effective PF technologies . Key stakeholders of Government iare: CIAE, NABARD, NCPAH; Research Institutions are Precision farming developmental centres, ICAR, NIT, ISRO, MS Swaminathan research Foundation, Dryland agriculture project, University of Agriculture UAS and NGOs and CSOs are Precision Agriculture for Development (PAD); Smallholder Adaptive Farming and Biodiversity Network (SAFBIN); Kalpavriksh, Environment Action Group; Indo-Global Social Service Society; ANANDI; Utthan; Grama Bharathi; AFARM Pune; Sai.

Contour Farming

Area covered under contour farming is nearly 2 million hectares with an estimate of less than 3 million farmers. FAO's agri principles relevant are efficiency, resilience, human and social values, diversity, co-creation and sharing of knowledge, culture and food traditions. Areas with highest organic farming are Rajasthan, J&K, Himachal Pradesh, Uttarakhand, AP, TN, Karnataka, Kerala, Maharashtra, Odisha, WB, Tripura, Manipur, Mizoram, Nagaland, Sikkim, Arunachal Pradesh, Assam. Challenges and recommendations arelimited research on economic and social impacts of contour farming with more studies that cover various agro-ecological zones;vital to know contouring on scientific lines, so that contour bunding etc can be done and that nutrients are not washed away; and handholding, knowledge and skilling also needs to be an area of focus. Key stakeholders of the Government are: Department of Agriculture, Cooperation and Farmers' Welfare (DAC&FW); Department of Agriculture,Himachal Pradesh; Agriculture Department, Government of Sikkim. Research Institutions are ICAR-Research Complex for North Eastern Hill Region; Dryland Agriculture Project, University of Agricultural Sciences, Bangalore; International Crops Research Institute for the Semi-arid Tropics (ICRISAT); College of Agricultural Engineering and Technology, Odisha (CAET). NGOs/CSOs are People's Endeavor for Social Change (PESCH).

Integrated Farming System (IFS)

Area covered under integrated farming is less than 0.1 million hectares with an estimate of less than 0.1 million farmers with mostly small and marginal farmers. FAO's agri principles relevant are synergies, efficiency, recycling, resilience, human and social values, and diversity. Challenges and recommendations lie in leveraging IFS systems to contain migration and improve farming incomes. A policy that looks into IFS and nutrition after research is needed and explores options for financial support for scaling up after research. Key stakeholders of the Government are Central Research Institute for Dryland Agriculture (CRIDA); Indian Council of Agricultural Research (ICAR) – IIFSR Modipuram Meerut; ICAR-Mahatma Gandhi Integrated Farming Research Institute (MGIFRI); Agriculture Technology Application Research Institutes (ATARI); Research Institutions are Faculty Centre for Integrated Rural Development and Management - An Off-campus Faculty-Centre of Ramakrishna Mission Vivekananda Educational and Research Institute (RKMVERI); Tamil Nadu Agricultural University (TNAU); Rani Laxmibai Central Agricultural University, Jhansi. NGOs/CSOs are Welthungerhilfe; Foundation for Ecological Security; Abhivyakti Foundation; Society for Promotion of Wastelands Development (SPWD); and Development Research Communication and Services Centre.

Biodynamic farming

Area covered under biodynamic farming is 19,131 hectares of certified Biodynamic farms in India. Sixty thousand hectares of uncertified area under Biodynamic farms with Close to 1,00,000 Farmers practicing bio-dynamism. FAO's agri principles relevant are synergies, efficiency, recycling, resilience, human and social values, diversity, co-creation and sharing of knowledge. Areas with highest organic farming are TN, AP, Kerala, Karnataka, Telangana, MP, Gujarat, UP, WB, Assam, Punjab, Uttarakhand. Challenges and recommendations:no definitive conclusion on agronomic, economic, performance- so longitudinal survey is needed; .no explicit support under current policies. There is slight evidence on how biodynamically grown food has better nutrition. More research in this is needed. Key stakeholders of the Government is ICAR – Central Institute for Subtropical Horticulture. the Biodynamic Association of India conducts research. NGOs/CSOs are SARG Vikas Samiti; Bhaikaka Krishi Kendra; Lipok Social Foundation.

Floating Farms

Areas covered under floating farms is negligible with 145 poor landless families in Odisha (Short rooted leafy vegetables). FAO's agri principles relevant are synergies, efficiency, recycling, resilience, human and social values, diversity, co-creation and sharing of knowledge. Areas with highest organic farming are Dal Lake, In Kerala - Kottayam, Alapurzha,Pathanamthitta, Puri- Odisha, Majuli- Assam. Challenges and recommendations are hand-holding, training and research for small farmers are needed for sustenance; research on making mass adoption which has potential to generate surplus vegetables for marketing and lack of policy support and financial constraints. Key stakeholders of NGOs/CSOs are Regional Centre for Development Cooperation (RCDC); Society for Women Action Development (SWAD); United National Development Programme (UNDP); South Asian Forum for Environment (SAFE); Welthungerhilfe; AusAID India.

Permaculture

Area covered under permaculture is less than 0.5 Million hectares with an estimate of less than 0.01 million hectares with mostly small farmers (horticulture, floriculture, perennial and arable crops, poultry, dairy). FAO's agri principles relevant are synergies, efficiency, recycling, resilience, human and social values, diversity, co-creation and sharing of knowledge. Areas with highest organic farming are HP, Uttarakhand, Rajasthan, MP, Maharashtra,Odisha, WB, Bihar, Telangana and Andhra Pradesh. Challenges and recommendations are no peer reviewed research on permaculture and no support for policy research. Key stakeholders of the Government are the National Centre of Organic Farming; Regional Centres of Organic Farming. NGOs/CSOs are Aranya Agricultural Alternatives; Deccan Development Society; The India Permaculture Network; Aananda Permaculture Farms; Bhoomi College.

Organic Farming

Area covered under organic farming is 2.8 million hectares under certified organic farming (Participatory Guarantee Scheme, 3rd party certification) with Certified organic area is 1.9 million hectares. FAO's agri principles relevant are synergies, efficiency, recycling, resilience, human and social values, diversity, co-creation and sharing of knowledge. Areas with highest organic farming are Ladakh- 21.4%, Uttarakhand – 18.2%, Sikkim – 100%, and Goa-18.3%. Challenges is cumbersome certification processes. Policy support to tackle them is needed to scale up. Support long term assessments (health, value chains). Organic farming is being promoted most by CSOs - use their leverage to scale up. Low yields in the first 2-3 years until soil health is rejuvenated. So impact on this with policy measures and action needed. Affordable and good technology needed for women. Careful involvement and mobilization of farmers is necessary (CSE) Key stakeholders of the Government are National Centre for organic farming, Regional Centres for organic farming and Gujarat Organic Agricultural University- Govt institutes. Research Institutes are Centre for Indian Knowledge systems, ICAR, IIASD, Institutes and universities under all India Network Programming on Agriculture. A total of 63 CSO's are working on organic farming.

Natural Farming (NF)

Area covered under natural farming is 6,52,000 hectares in AP, around 2000 Hectares have been identified for pilot/experimental basis for ZBNF in each agro-climatic zone (Economic survey of Karnataka), Himachal Pradesh - 6377 hectares with 6,00,000 farmers enrolled in AP as of Nov 2020, 1,67,000 are practicing NF in Himachal Pradesh under *Prakrithik Khethi Kushal Kisan*; Karnataka -80,000 with small and marginal farmers. FAO's agri principles relevant are synergies, efficiency, recycling, resilience, human and social values, diversity, co-creation and sharing of knowledge, culture and food traditions. Areas with highest organic farming are Andhra Pradesh, Himachal Pradesh and Karnataka. Challenges and recommendations are:short term studies often inconclusive. need to study long term effects and impacts; insignificant monetary allocation by state and centre;and ready made inputs and market support required for scale up. Enable capacity building by harnessing women's knowledge and enabling them to disseminate knowledge and skills. PMBS - support investment costs in this domain. Key stakeholders of the Government are RYSS, *Prathik Kethi Kushal Yogana*, Govt of Himachal Pradesh and NITI Ayog. Research Institutes are World Agroforestry Centre, UNEP, FAO, CEEW, CSE, S-STEP, CEES. CSOs, NGOs are CSA, NCNF, SPS, Pradhan, SAFBIN, FES, Rural development society etc.

SRI

Area covered under SRI is 3 million hectares with greater than 3 million farmers along with small and medium landholders. FAO's agri principles relevant are synergies, efficiency, recycling, resilience, co-creation and sharing of knowledge. Areas with highest organic farming are Tamil Nadu, Andhra Pradesh, Odisha, Karnataka, West Bengal, Madhya Pradesh, and Uttarakhand. Challenges and recommendations are: additional wage days in MNREGA , which can generate more income and facilitate transition of farmers to SRI;knowledge driven challenges and therefore application of skilled labour in this field is a constraint; and effective mechanization for weeding which also promotes reduced burden on women for de-weeding . Key stakeholders of Government are Indian Institute of Rice Research, NABARD, ICAR, Joint Action initiative on SRI- AP. Research Institutions are SRI, an ICRISAT-WWF initiative; ICRISAT, Tamil Nadu Agricultural University; M.S. Swaminathan Research Foundation NGOs/CSOs are Watershed Support Services and Activities Network (WASSAN); AME Foundation; Voice Trust; PRADAN; EKOVENTURE; Timbuktu Collective; Living farms; People's Science Institute; People First Foundation; SRIJAN; PRADAN; Nirmal social development trust; Unnati.

Cover Crops and Mulching

Area covered under Cover crops and Mulching is 1.9 million hectares and nearly 20 million hectares under mulching. FAO's agri principles relevant are synergies, efficiency, recycling, resilience, human and social values, diversity, co-creation and sharing of knowledge. Areas with highest organic farming are Tamil Nadu,AP , Telangana, Karnataka, Maharashtra, Gujarat, Madhya Pradesh, Rajasthan are the rainfed states where mulching is adopted. Challenges and recommendations are that the use of plastic sheets as covers for mulch is increasing; set up of recycling plants; and no specific policy on cover crops. Key stakeholders of the Government are ICAR, CRRI , DAC&FW, CAZRI, CRIDA. CSOS and/or: PRADAN; Living farms; BAIF Development Research Foundation; Centre For Dignity; PRADAN; Samaj Pragati Sahayog (SPS); Jamnalal Kaniram Bajaj Trust; Self-Reliant Initiatives Through Joint Action (SRIJAN); Samuhik Vikas Sansthan; Nature Institute for Welfare of Society; Center for Sustainability Policy and Technology Management; Jeevit Mati Kisan Samiti, Kedia.

Crop Rotation and Intercropping

Area covered under Crop Rotation and Intercropping is 30 million hectares with 15 million - crop rotation and 0.8 million- intercropping. FAO's agri principles relevant are synergies, efficiency, recycling, resilience, human and social values, diversity, co-creation and sharing of knowledge, culture and food traditions. Areas with highest organic farming are Tamil Nadu, Goa, Karnataka, Telangana, Madhya Pradesh and Gujarat. Challenges and recommendations are: intercropping is labour intensive; innovation in agri instruments, so that weeding is not hard.; research on intercropping methods for ecosystem services and not just productivity; studying the legume effect and scaling up. Key stakeholders of Government are Department of Agriculture, Cooperation & Farmers Welfare (DAC&FW); ICAR,National Rice Research Institute (NRRI),Central Research Institute for Dryland Agriculture (CRIDA); ICAR - Indian Institute of Farming Systems Research (IIFSR), ICAR-Central Arid Zone Research Institute (CAZRI). Research Institutions: Punjab Agricultural University, Ludhiana; University of Agricultural Sciences, Bangalore. NGOs/CSOs: PRADAN; bioRe Association India; Natural Capital; Centre for Dignity; CARITAS INDIA; Living Farms; Manjari Foundation; BAIF Development Research Foundation; People's Science Institute; Lipok Social Foundation; FES, Vaagdhara; CORD; Organic Foods Pvt Ltd; Ekta Nature Farming Producer Company Limited; Shunya; Indo-Global Social Service society *etc.*

Integrated Pest Management (IPM)

Area covered under IPM is 5 million hectares with 5 million farmers along with Small and medium landholders. FAO's agri principles are Synergies, efficiency, resilience, human and social values, diversity, co-creation and sharing of knowledge. Areas with highest organic farming Consumption of biopesticides is highest in Maharashtra with Kerala coming second. Challenges and recommendations are further evidence on use of bio-pesticides and IPM in health and other domains in terms of impact; cost effective and straightforward certification systems are needed; and location specific IPM modules. Key stakeholders of the Government are the Directorate of Plant Protection Quarantine & Storage (DPPQ&S); National Institute of Plant Health Management NIPHM); Indian Institute of Chemical Technology, Hyderabad. Research Institutions: 35 Central Integrated Pest Management Centres (CIPMCs) established in 28 states and 2 UTs, BAIF developmental foundation, Anand Agricultural University NGOs/CSOs: PRADAN; *Samaj Pragati Sahayog*; Jamnalal Kaniram Bajaj Trust; Centre for World Solidarity (CWS), CARITAS India; Gram DishaTrust; People's Science Institute; Farm2Food Foundation; Ekta Nature Farming Producer Company Limited; Indo-Global Social Service Society; Equality empowerment foundation; BAIF Development Research Foundation.

Vermicomposting

Area covered under Vermicomposting is 3.5 million hectares with 1.5 million farmers along with Small and marginal land holding farmers. FAO's agri principles relevant are synergies, efficiency, recycling, resilience, human and social values, diversity, co-creation and sharing of knowledge. Areas with highest organic farming are Assam, Madhya Pradesh, Maharashtra, Karnataka and Himachal Pradesh . Challenges and recommendations are: vermicomposting has the potential to create additional entrepreneurship activities among the youth; rural skilling and vocational training needs to be given in this domain;labour intensive process- thereby establishment of vermi-composting demonstration centres and facilitating knowledge platforms to scale up and States should incentivise vermicomposting through various schemes. Key stakeholders of Government are Govt: National Centre of Organic Farming (NCOF); Regional Centres of Organic Farming; ICAR- Central Research Institute for Dryland Agriculture (CRIDA); ICAR-Mountain Livestock Research Institute, Manasbal; National Bank for Agriculture and Rural Development (NABARD).Research Institutions: International Crops Research Institute for the Semi-Arid Tropics (ICRISAT); Tamil Nadu Agricultural University (TNAU); Andhra Pradesh Horticultural University; Kerala Agricultural University; JNAVV Agriculture College, Indore; T.M. Bhagalpur University (Bihar); NGOs/CSOs: Apna Kheti; M.S. Swaminathan Foundation; PRADAN; CARITAS INDIA; Centre for World Solidarity (CWS); Association for Promotion of Organic Farming (APOF, Bangalore); Bhawalkar Ecological Research Institute (BERI); Manipur Small Farmers Agri Business Consortium (Imphal); BAIF Development Research Foundation; PRADAN; Foundation for Ecological Security; Udyogini; Access Livelihoods Group.

Rainwater Harvesting and Artificial Recharge of Groundwater(RWH)

Area covered under Rainwater Harvesting and Artificial recharge of groundwater is less than 20 million hectares with Less than 5 million farmers practice RWH along with medium and large landholders. FAO's agri principles relevant are synergies, efficiency, recycling, resilience, human and social values, diversity, co-creation and sharing of knowledge. Areas with highest organic farming are good success in initial years in TN. Now being practiced by other states like Odisha for disaster management. Challenges are: no accurate data on best performing state or number of agricultural RWH structures as per report; less adoption among smallholders due to loss of land for RWH structures; communication gaps need to be bridged; RWH needs to be scaled up more;and documented evidence on benefits of the same though incentives. Key stakeholders of Government are: Central Ground Water Board, Ministry of Water Resources; ICAR-Indian Institute of Water Management; ICAR- Central Research Institute for Dryland Agriculture (CRIDA). Research Institutions: International Water Management Institute (IWMI); Indian Institute of Management (IIM), Ahmedabad; Institute of Rural Management, Anand (IRMA); Physical Research Laboratory (PRL). NGOs/CSOs: Centre for Science and Environment (CSE); Watershed Organisation Trust (WOTR); Advanced Center for Water,Resources Development and Management (ACWADAM); Arghyam; Samerth Charitable Trust; PRADAN; Kalpavriksh, Environment Action Group; Indo-Global Social Service Society; Gram Vikas; Equality empowerment foundation.

Conclusions

- A national level long term strategy to be developed for implementing large scale agricultural transformation initiating from low input to high input farming systems, without compromising food security and addressing current challenges of nutritional insecurity, soil, water and air pollution and building resilience to the changing climate.

- Establishment of Agroecology Departments in leading research institutions and agricultural universities of NARS to develop critical mass of human resource.
- Needto enhance investment on research of NF practices to build science based validation.
- Support and build farmer innovation (bottom up approach) and farmer to farmer extension system with emphasis on women SHGs.
- Document ground level success stories of NF based Agri-food innovation systems in diverse ecosystems.
- Encourage research on building social capital and learning modules on agro-ecological farming.
- Enhance capacities of scientific community on validating and refining the agro-ecological practice.

Genome Editing in Crops: Novel Opportunities

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Plant molecular biology has revolutionized agriculture by facilitating introduction of foreign genes in crop species and expressing novel traits such as pest resistance, disease resistance, quality improvement *etc.* Transgenic plants are usually developed relying upon the genetic transformation techniques mediated by *Agrobacterium tumefaciens*, particle bombardment, protoplast uptake of DNA *etc.* The transgene integration mediated by these techniques takes place at random sites in the plant genome. The position of the integration in the genome and the complexity of the integrated DNA influence the quality of transgene expression. Development of techniques that mediate transfer and integration of foreign genes at specific pre-determined locations obviates many problems associated with existing methods of gene transfer. Introduction of foreign genes via gene targeting based on the technique of homologous recombination offers many advantages such as precision gene integration, single copy transgene insertion and high expression of the transgenes. It would allow the construction of "safer" transgenic crops, which would not suffer from unknown "position" effects due to random integration. The earliest attempts to carry out genome editing in plants exploited the phenomenon of homologous recombination and non-homologous end-joining. This requires nucleases that can create specific double-stranded break (DSB) at desired location in the genome. Initially, Zinc finger nucleases (ZFN) and Transcription activator-like effector nucleases (TALENs) served this purpose. However, discovery of Clustered regularly interspaced short palindromic repeat (CRISPR) sequences took the biological sciences by storm and promised uncommon opportunities in human health and medicine as well as agriculture.CRISPRs were first identified in *E. coli* in 1987 by a Japanese scientist, YoshizumiIshino and his team, who accidentally cloned an unusual series of repeated sequences interspersed with spacer sequences while analyzing a gene responsible for the conversion of alkaline phosphatise. The knowledge was later exploited by several scientists, especially Emmanuelle Charpentier (Max Planck Institute for the Science of Pathogens, Berlin) and Jennifer Doudna (University of California, Berkeley) to put CRISPRs to work. They were honoured by the Nobel Committee in 2020 with the award of Nobel Prize in Chemistry.

CRISPRs and CRISPR-associated systems (Cas) impart adaptive immunity against foreign DNA like plasmids, bacteriophages and viruses through RNA interference like mechanism in bacteria. There are three type of CRISPR systems discovered so far and Type-II system is most studied and simplest and the one adopted for genome editing. Since 2011 many groups demonstrated the wide applications of CRISPRs for genome editing.Its use for genome editing in human cells, zebra fish, and mouse was demonstrated by 2013. The application of CRISPR for genome editing in plants was also established around same time by different groups in Arabidopsis, rice, and tobacco.

The use of genome editing technologies has opened new avenues for crop improvement. The ability to modify DNA sequences *inplanta* helps in direct determination of the role of sequence motifs in gene expression and function. Applications of these technologies for crop improvement are manifold. Conventional breeding relies on the availability of allelic differences existing in the nature and is limited by the availability of the same. The relative ease with which the genome editing technologies are used for creating mutations in the DNA of interest can be used for accelerated breeding for novel traits. One of the earliest examples of genome editing in crops was altering the phytic acid content and increasing the nutritional quality in barley (2013) followed by imparting disease resistance against powdery mildew in wheat (2014). The first genome edited commercial crop is a non-browning mushroom in US and Canada (2018) that has the browning enzyme knocked out thereby improving its shelf life. Gene edited soybean was made available by Calyxtof USA in 2019. The soybean oil contains reduced saturated fatty acids and zero trans fatty acids. Recently, Sanatech of Japan commercialized gene edited tomato that contains high levels of gamma-aminobutyric acid (GABA), an amino acid believed to aid relaxation and help lower blood pressure. The gene edited tomato contains four to five times more GABA than a regular tomato. The opportunities are mind boggling. For instance, insect pest resistance can be achieved against highly specific monophagous pests (E.g., Brinjal shoot and fruit borer and Rice yellow stem borer) by silencing key genes involved in the biosynthesis of aromatic secondary metabolites that attract the pest.

Although, the potential applications of genome editing technologies are immense so are the associated challenges. The major technical challenge is decreasing the off-target modifications in the DNA. Apart from this, efficient delivery methods, the optimal expression of nucleases in plants are also are needed for increasing the efficiency and their wide adaptation.

Several countries have exempted genome edited plants from regulation. India is still in the process of taking a decision although a draft of the guidelines for regulation have been prepared more than two years back.

Date Palm Cultivation In India – An Overview

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Introduction

Although the origin of date palm, *Phoenix dactylifera* L is very ancient, the cultivation was recorded around 4000 B.C. in Southern Iraq – Mesopotamia. Predecessor to date palm is believed to be *Phoenix reclinate* Jacq from tropical Africa or *Phoenix sylvestris* (L). Roxb. from India or perhaps a hybrid between these two species. The religious significance of date fruits is well known in various communities across the world. The palms are mostly grown in arid and semi-arid zones and provide essential nourishment to impoverished and famine-prone populations in poorer countries. For the health-conscious populations date fruits are a source of energy and considered a superfood. In recent years more and more progressive farmers are taking up the cultivation of date palm in several Indian states to get assured and better income. In this article challenges in date palm cultivation in India are briefly summarised with suggestions for increasing the area and productivity.

Suitable regions globally: Date palm grows both in Northern hemisphere as well as Southern hemisphere with cultivated palms distributed between 10^{0}N (Somalia) and 39^{0}N (Elche/Spain or Turkmenistan). Among the countries with large land parcels of date palm plantations are Morocco, Algeria, Tunisia, Libya, Israel, Egypt, Iraq, Iran, Saudi Arabia *etc.* that are located between 24^{0}N and 34^{0}N. In Southern hemisphere date palms are also grown in Namibia, Australia, South Africa *etc.*

The hardy plants are grown in a wide variety of soil right from sandy to sandy loam soils besides poor and problematic ones. They can be grown both alkaline and acid soils but the performance depends on the availability of water sources and condition.

Popular varieties: There are more than 4000 varieties of date palms grown in different parts of the world. Out of so many varieties about 250 or so are very popular and grown widely. The quality, size, texture, colour, yield, *etc* are highly variable and determine the popularity and demand in the market. Most popular varieties are 'Ajwa', 'Madjool', 'Deglet Nour', 'Sukkari', 'Kimia', 'Khudre', 'Khunaizi', 'Zahidi', 'Khlas', 'Barhee', 'Halawi', *etc*. In India also several farmers have procured the popular varieties from the Middle East as tissue culture plants and grown them in their farms. So we too grow the same popular international cultivars that are grown elsewhere. Because of climatic conditions and weather in some locations there was success. The native cultivars grown in Gujarat are categorized on the basis of colour into yellow variety and red variety. However, other characteristics like earliness, size, taste, texture, yield, *etc* are equally important especially astringency free fruits is critical for consumption. A few elite palms germplasm has been selected and is being propagated vegetatively and Tissue Culture methods to produce good planting materials. The characterization (DUS characters) of local elite cultivars that includes 46 red fruit and 22 yellow fruit and

7 mixed category is in the pipeline and soon the researchers (Date Palm Research Station, Mundra, Gujarat) and development agencies in the public and private sector are expected to launch them with specific nomenclature for better management of cultivars.

We receive the S-W monsoon from June and lasts till end of August resulting in the exposure of the date fruit bunches to water which causes diseases, rotting making fruits unfit for picking. Hence, for India there is always a demand for varieties that mature early and escape the monsoons.

Area and production*:* According to Food and Agriculture Organisation (FAO) the major dates producing countries are Egypt, Saudi Arabia, Iran, Morocco, Algeria, Tunisia, UAE *etc.* (Table 1). These countries in the MENA region (Middle East and North Africa) produce nearly 90% of the processed dates. India does not figure in the list of FAO since the fruits produced in India are consumed as fresh and no processing is involved. Traditionally the Rann of Kutchch area of Gujarat and some parts of Rajasthan and Punjab are suitable for date palm cultivation. Although, date palm cultivation is showing progress in introduction to new areas in the states of Tamil Nadu, Andhra Pradesh, Maharashtra, the major chunk of fruits are produced and marketed by Bhuj area of Gujarat. In recent years Rajasthan government has taken several initiates to promote date palm cultivation in some parts of Rajasthan and reached an area of 906 ha (10 year old) with production of about 2500-2800 tonnes and with production rising every year due to young and growing palms.

Nutritional value of dates: Dates are considered very high in nutritional value and provide healthy calories. The richness of nutritional value of dates is excellent when compared with other fruits and cereal foods, apricot -520 calories/kg; banana-970 calories/kg; orange-480 calories/kg; wheat bread-2,295 calories/kg; cooked rice-1800 calories/kg; and dates provide 3000 calories/kg. It is a highly nourishing fruit with more than 70% carbohydrates with water content varying between 15 and 30% based on the stage of the fruit and variety.The sugar ranges from 65% to 80% on dry weight basis mostly of inverted form (glucose and fructose). Fresh fruits have higher content of inverted sugars, the semi dried varieties contain equal amount of inverted and sucrose, whereas dried varieties contain higher sucrose. Water content varies from 7% in dried to 79% in fresh depending on variety.

Some date varieties have been shown to possess anti-inflammatory and anti-oxidant properties to an extent and give health benefits to the consumers. The highly valuable variety from the Medina region of Saudi Arabia called 'Ajwa' has these special nutritional characteristics and is the most expensive one. Such varieties grown exclusively in a reputed location are granted GI and it is understood efforts are being made to get the tag by the respective government.

Propagation: The palms are propagated through various methods *viz.,* seeds, offshoots, and tissue culture plants. Raising seedling from elite palms was a old method and it was discontinued in many regions because of obvious reasons like the diecious nature of the plant and variations in characters. Most commonly followed method is through selection of offshoots (suckers) mostly from the rootzone of mother palm and planting them in the soil.

Now a days several companies are available for the tissue culture plants of good varieties of date palm either indigenously or through imports. Due to somaclonal variation some farmers were reluctant to plant the tissue cultured plants in their fields. Hence, the laboratories involved in the propagation of date palm tissue culture plants should test the clonal fidelity through molecular markers and sampling techniques.

The most ideal period of the season is when the temperatures are moderate with no seasonal rains. This season is generally from March to April and October to November in the Middle East. Perhaps the same seasons works well for Indian situation also.

Agronomic practices: The planting is done at a spacing of 8x8m or 8x10m depending upon the size of the farm. Fruit thinning is done to get better fruit size, quality, and texture so that market prices are good. It is also a standard practice to reduce the number of bunches per palm and the number of strands per bunch, and number of fruits per strand. Though this is labor intensive, many farmers have to resort to this to get better yield, quality and market price.

During the growth of the fruit bunches to reduce the pressure on the talks, a Bunch support is provided by tying to the leaf bases. To protect fruits from winds, rains, birds, etc., each bunch is covered with a fine net, or craft bags, or other materials. Leaf pruning is a standard procedure in the initial years of growth of the palms. Regular dethorning of leaves is done to prevent injury during various operations conducted on the palms at regular intervals.

Irrigation: Irrigation is a critical component for growing date palms and one has to factor various conditions like soil salinity, temperature, humidity, winds, cloud cover, *etc.* There are many methods available to overcome any adverse effects associated with these conditions. At present in many countries the emphasis is on shifting to drip irrigation from the old practice of flood irrigation where large quantities of water are wasted. Even today in countries like Saudi Arabia the drip irrigation has been adapted in only about 50% date farms and they are making efforts to reach the 100% target. In India also many state governments are giving subsidies for installing drip irrigation system in the farmers' fields. Though irrigation is essential, excess water logging and poor drainage leads to death of palms in heavy rainfall areas. Care must be taken to provide good drainage along with timely irrigation schedules to get the best yields.

Fertilizers: The fertilizers should be applied based on the recommendations made by the local Horticulture department. Young palm needed to be given regular fertilizers NPK in split doses twice depending on the soil type, rainfed or irrigated, weather, and age of trees. Each Adult palms is generally given 30-40 Kg FYM and 200 g each of N, P, and K under rainfed conditions 50-60 kg FYM and 200 g each of N,P,K under irrigated areas per year. Many farmers are practicing organic farming because of additional price and suitability for export markets.

Pollination: The date palm is dioecious with female and male plants separately producing unisexual flowers. Male palms are required for pollen production and for pollinating the female flowers. For a good fruit setting in females, there should be adequate supply of viable pollen at the receptive stage in female inflorescence or opening of the spikelets. Each female palm produces about 15-25 spathes each of which contains 150-200 spikelets.

In nature pollination may occur through wind, honey bees and insects but there is a wide gap between artificially pollinated and natural one with the former giving excellent results. Progeny raised from seedlings usually have nearly 50% males and support natural pollination in a few countries. However, in countries where intensive cultivation is practiced, artificial pollination is a must.

When natural pollination fails and female flowers are not fertilized there is development of carpels that leads to parthenocarpic fruits with no commercial value.

For good production of quality fruits, the farm should be planted with male palms at the rate of 10-11 per 100 female palms. In some areas only 2% or 1 male every 50 female palms is suggested but it is not scientifically good.

One of the criteria for male palms is that they produce pollen in good quantities when the female flowers are ready for pollination. Usually, female flowers remain receptive for about 7-10 days and during this period pollination has to be done. One interesting factor is that the 15-25 inflorescences that are produced in female palm would have to be pollinated in 3-4 phases.

Generally Fresh male strands of males are tied to the spikelets for pollination. Sometimes Pollen suspension with some artificial additives are sprayed for the same purpose. Many farmers use dried pollen collected in the current or previous season and stored properly in a cool dry area for pollination. For application on the female spikelets, cotton pieces, puffers and mechanical devices are also used. To dilute and increase volume of the pollen, dry flour or inert talc is added. About 60-80% pollination is considered as good for adequate fruit setting.

Pests and diseases: Date palm are attacked by a few pests and most dangerous one is Red Palm Weevil, *Rhynchophorus ferrugineus.* In India the RPW is not a major pest of date palm but is infested by Scale insects, leaf caterpillars, black palm beetle, and birds damage fruits. Among diseases False smut/Ghaphiola, Leaf spot and other fungal disease affect the date palm.

Harvesting: The growth stages of fruit determine the harvesting in any regions. Basically, there are four stages namely i) Kimri, ii)Khalal iii) Rutab and iv) Tamar. In the first stages the fruit is pea sized and green and growing. In the Khalal stage the fruit is fully grown and changing colour from green to red or yellow depending on the variety. The third stage called Rutab is when the fruit attains softness and very much edible as fresh fruit. The last stage is called Tamar at fully maturity and fairly dry and ready for safe storage without any rotting. The fruits in the Tamar stage are the ones that are suitable export or import.

Yield: The yield of date palm depends on several variables like variety, size, stage, age of tree, irrigation, agronomic and cultural practices, etc. From the 4th year onwards the tree start yielding but stabilize around 10-12 years but continue to increase till 15th year. If a tree is harvested at Tamar stage the yield may be around 50-60 Kg in 10th year. It may reach up to 200kg in a 15-year-old palm. In India due to rains and other climatic conditions, mostly the Khalal stage fruits are harvested. At this stage the fruits contain nearly 70-80% water content and have to consumed unless stored in cold storage. For improving the quality and storage of Khalal stage fruits several techniques are available and farmers should adapt them to get price benefit.

Markets and price: In India the local produce is very small and good cultivars without astringency and good taste fetch very good price. Some farmers groups have formed cooperative societies to avoid exploitationby middlemen and worked out marketing strategy. Now a days in India farmers are getting Rs.100/- per Kg of fresh fruit. Met some farmers who are exporting Barhee to European countries and getting excellent revenue while progressive farmers are branding their elite cultivars and selling in Metros at almost Rs300/- per Kg of fruit.

Establishing new date palm farm: The initial cost of planting material for date palm compared to other fruit crops is a little higher. Moreover, the availability of quality planting material is a hurdle for many farmers. To get one tissue culture plant the farmer has to pay between Rs.2500-3500 /- and for one acre with 150-160 plants around Rs. 4,00,000-5,00,000/- per Ha is required for plants alone. However, many state governments aregiving incentives of 75% subsidy for planting material besides subsidies for drip irrigation systems. These incentives will go a long way in encouraging the farmers to take up alternate crops like date palm cultivation and reduce the imports.

Date fruit Imports:

India is one of the largest importers of date fruits and it imported 441.95, 385.17 and 282.58 thousand metric tons during 2017,2018 and 2019 respectively. The date fruits are mainly imported form Pakistan, Iraq and United Arab Emirates.

Suggestions/Recommendations

1. Identification of Indian elite varieties with complete characterization.
2. Identification of early cultivar suitable for different climatic conditions prevailing in different parts of India
3. Popularisation of date palm cultivation in non-traditional regions, to increase farmers income.
4. Establishing cold storage facilities in the vicinity of date farms by government or/and cooperatives.
5. Planting material is still a huge constraint and efforts should be made to establish nurseries with elite palms, tissue culture plants, to serve as mother palm repositories.
6. Use GIS mapping to identify suitable date palm cultivation areas in different states.
7. Arrangement of training in date palm cultivation to new farmers and other departmental staff.
8. A central research and development institute for date palm promotion and coordination is needed to increase the area and productivity of date palm in India to enable more than doubling of famers' income.
9. India is importing huge quantities of date fruits from MENA countries and it is necessary to produce them locally to make India "Atmanirbhar" in dates production.

Table 1. The date palm cultivation area and production in major countries in 2019 (as per FAO statistics)

S. No.	Country	Area (Ha)	Production (Tons)
1	Algeria	170082	1136025
2	Egypt	48031	1603762
3	Iran	160117	1307908
4	Iraq	438191	639315
5	Israel	4799	43412
6	Mauritania	9192	21926
7	Morocco	59613	101537
8	Namibia	139	354
9	Oman	25382	372572
10	Pakistan	104836	483071
11	Palestine	676	7729
12	Saudi Arabia	117881	1539756
13	Tunisia	63224	288700
14	United Arab Emirates	34119	323478
15	United States of America	6230	55700
16	India	19814*	184252*#

(https://doh.gujarat.gov.in/Images/directorofhorticulture/pdf/statistics/Area-Production-2019-20.pdf)

#Fresh fruit is consumed and no processing is involved and hence not listed in the statistical data of FAO.

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Current Perspectives on Animal Parasites and Parasitic Diseases: The Diagnostic and Vaccine Design and Future of Genome-enabled Technologies

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The present paper provides a broad overview of the rapidly evolving area of the practices or techniques of the livestock parasite diagnosis and the essential scientific elements involved in vaccine development and design. Also, an attempt is made to deal about the applications of genome-enabled technologies that have immense potential to make the existing disease control methods more effective and sustainable to find the long-term solutions to the parasitic disease problems.

Parasites and parasitic diseases have no-journalistic value like many bacterial and viral diseases but they are equally important because of their ubiquitous nature and the unremitting losses they cause to the livestock production systems. Parasites co-evolved with the host for millions of years to establish and perpetuate from their ecological niches in various organs of the host. However, specificity to host and organ for establishment is usually fixed for most parasites. The hot and humid climate of the tropical and subtropical countries favours the growth and propagation of parasites and their vectors, leading to widespread morbidity, mortality and associated production losses due to impaired growth, productivity and delayed reproductive maturity.

Climate-change is no longer debated, only the mechanisms responsible for this phenomenon are a matter of controversy. With the impending climate-change scenario, international tourism, globalization, intensification of animal raising systems, *etc.*, there are new encounters with changes in phenological events, parasite life-cycle dynamics, its epidemiology, all warranting improved and versatile tests suited for epidemiological inquiries or disease outbreak investigations. Consequently, the R&D on diagnostic parasitology, epidemiology and vaccine development are undergoing dramatic changes. In recent years, there has been tremendous effort to focus research on the development of newer diagnostic methods focusing on serological, molecular, and proteomic approaches. New tools and technologies are needed to protect the animal and public health sectors against existing, emerging, trans boundary and zoonotic diseases. Systems are needed for rapid screening and detection of response to, and recovery from animal disease events to ensure livestock welfare. The identified needs include development of sensitive and specific diagnostics, pen-side tests, veterinary interventions, and in-process monitoring devices.

The purpose of any viable parasitic control strategy is to keep the parasitic challenge at a minimum rate to avoid clinical symptoms and the associated production losses. Total eradication from a geographical region is unlikely for most parasitic diseases due to their ubiquitous nature and the high persistence of the infective stages in the environment. Parasitic strains mutate and evolve rapidly. Therefore, there is a need for a more rapid and cost-effective identification of parasites. Before choosing and starting any control programme, it is necessary to have a detailed knowledge about the parasitic infections in their natural host population, their prevalence rates and transmission patterns. These characteristics may differ between geographical regions, local management traditions, *etc.* If this knowledge is missing or, is only scarce, an investigation of the parasitic occurrence and epidemiology should be initiated prior to starting any control programme.

In classical parasitology, morphology is the primary criterion for the identification and classification of parasites, at the same time comparative data derived from interdisciplinary studies or what is termed as 'integrated taxonomic approach' complimenting taxonomic identification systems are increasingly used to strengthen the morphological/ taxonomical system. For parasite taxonomists, morphology continues to be the mainstay for identification, speciation, understanding the adaptation of organisms to various ecological situations and construction of phylogenies. Optical microscopy is universally reckoned as the gold standard, while the modern parasitological laboratory uses both wet lab and dry lab skills today in sensitive and specific identification of parasites. The wet lab skills while use both routine parasitological techniques well combined with the standard biotechnology tools; the dry lab skills use bioinformatics tools essentially comprising of molecular data-mining software for analyses.

The new generation immunodiagnostics have to address some of the current limitations and challenges of the present lot of serology-based assays such as failure to differentiate between past, latent, acute, and reactivated infections, the lag between the onset of infection and antibody development, establishing utility for following immune response to therapy or for prognosis, *etc.*, which has been a subject of major research interest to parasitologists. Cross-reactions with unrelated parasitic conditions are the rule rather than the exception particularly in metazoan infections. With the advent of modern biochemical, immunochemical and molecular biology-based techniques, there are good prospects of producing specific antigens from a variety of parasitic organisms.

The field of immunology has been brought to limelight since the late 1960s and the last five decades have brought about rapid advances, both conceptual and technical in parasitic immunology. Because of the exquisite specificity of the immune response, the interaction between antigen and antibody *in vitro* is widely used for diagnostic purposes for the detection and identification of either the antigen or antibody. The commonly used tests in parasitic disease diagnosis are the complement fixation test, immunodiffusion, indirect haemagglutination, indirect immunofluorescent antibody test, enzyme-linked immunosorbent assay (ELISA) and radioimmunoassay. For serological diagnosis of parasitic diseases and for mass screening of parasitic diseases, ELISAs combine the specificity of antibodies with the sensitivity of simple enzyme assays, by using antibodies or antigens coupled to an easily-assayed enzyme. ELISAs can provide a useful measurement of antigen or antibody concentration. It is a rapid, simple and sensitive assay which can be carried out using both native, purified and synthetic antigens. The recombinant proteins produced as molecularly cloned fusion proteins from parasites are a valuable source of reagents for numerous applications. Development of diagnostic tools, candidate antigens or immunogens for vaccination and their use in structure-function analysis of parasite proteins, screening and profiling of candidate drugs, etc. are some of the applications of these cloned proteins.

There is an increasing number of ELISA formats *viz*., Dot-ELISA, SELISA, competitive ELISAs, dip-stick ELISA, RAST-ELISA, FAST-ELISA, k-ELISA, DIGELISA, TSP-ELISA, lateral flow assays, *etc.* There are several commercially available test kits available for companion animals and commercial dairy herds. These recombinant antigens based ELISAs have the capacity to differentiate between immune responses generated by vaccination from those due to infection. This has made it possible to overcome some of the major drawbacks of antibody detection tests: the fact that, because antibodies can persist in animals for long periods, their presence may not indicate current infection. DIVA means differentiating infected from vaccinated animals. These specialized vaccines, developed against some viral diseases (AI, CSF, FMD, IBR, pseudo rabies, *etc.*) also termed as marker vaccines, induce an immune response which is different from that induced by natural infection. These marker vaccines are based on deletions mutants of wild-type pathogens or subunit vaccines and inactivated whole virus vaccines. The DIVA immune response can then be detected/captured by DIVA companion diagnostic tests such as enzyme-linked immunosorbent assays (ELISA). Currently, there are no DIVA based vaccines receiving any R&D attention against any parasitic diseases.

Using hybridoma technology, it is now possible to immortalize antibody-producing cells by cell fusion techniques to experimentally produce monoclonal antibodies of a given class, specificity and affinity with quantum leap in the resolution and discriminating power. This Nobel prize winning technology in 1970 has revolutionized the outlook of medical and veterinary sciences and provided versatile tools with vast applications ranging from specific diagnostic tests to magic bullets in immunotherapy. The Mab based ELISA protocols or tests can detect current infections and further facilitate differentiation between the other closely related species/subspecies. This has important implications for disease control, especially because of the association of different parasite species with different epidemiological and disease circumstances. For the demonstration of parasite antigens, monoclonal antibodies are generally used in a "solid phase sandwich assay". In this procedure the monoclonal antibody, adsorbed to a solid support, is reacted with the suspected host serum and the relevant antigen sequestered from it. The sandwich is completed by reacting this bound antigen with the same or a different monoclonal antibody that is labelled with a radionuclide or other tracers and that will also bind to the antigen.

Another unique approach of parasitic impact assessment and performance in large dairy herds as a part of the management strategy, is using bulk-tank milk ELISAs. It is a rapid and inexpensive method of assessing herd exposure to parasites. The future may see an extension of such test formats to include relevant other health biomarkers such as liver proteins, regulatory hormones or acute phase proteins, *etc.* Advantages of such biomarker detection tools are many for routine herd health monitoring in ruminants, considering that non-invasive sample matrices like saliva can be used besides multiple parameters can be assessed for multiple pathogen detection from a single sample. The most useful future diagnostic tools will not only assess the parasite infection intensity levels but also their impacts on key production parameters. There is going to be a paradigm shift for translation of new diagnostic technologies to manage parasitic disease on farms from laboratory-based tests that focus on population-level species diagnosis to on-farm tests, which can be used as real-time decision tools.

In the current trend of globalization, animal health measures have increasing importance to facilitate safe international trade of animals and animal products while avoiding unnecessary impediments to trade. There is an implicit obligation in terms of international standards to ensure that the diagnostic tests (both prescribed and alternative tests) approved by *Office International des Epizooties*, the WTO reference organization for standards relating to animal health and zoonoses meet a minimum standard of diagnostic performance.

Meeting New Challenges in Parasite Disease Diagnosis and Epidemiology

Today, there is an international obligation and agreement to have disease surveillance and monitoring systems and approaches consistent with the sustainable global systems for exchange of comparable information with the world health and standard setting organizations like OIE and Codex Alimentarius. Given the new dispensation, there is an implicit need for improved diagnostic ability and quality-assured diagnostics and then competence building to meet the future requirements of disease surveillance and monitoring programmes. This is primarily needed to:

1. To identify parasite species, stocks or strains involved in a disease.
2. Determination of distribution of parasite species, and assessment of the risk of a disease on a herd, regional, or national basis.
3. Certification of infection status of animals for trade requirements and for disease eradication.
4. Identification or confirmation of the cause (s) of disease or death (outbreaks).
5. Identification of specific arthropods as vectors and of transmitting vector stages.

Consequently, the R&D on diagnostic parasitology, epidemiology and vaccine development are undergoing dramatic changes. In recent years, this area has received increasing attention to focus research on the development of newer diagnostic methods using serological, molecular, and proteomic approaches. The impressive advances in recent years in materials sciences and in nanotechnology, as well as in nucleic-acid synthesis and engineering, led to many prototype tests for nucleic-acid testing towards point-of-care diagnosis of genetic and infectious diseases.

Molecular Diagnostics -Nucleic Acid-based Platforms

Generally speaking, molecular diagnostics today are a major aid to guide patient management, from diagnosis to treatment, in other words from diagnostics to the theragnostic, a combination of diagnosis and therapeutics. At the core of it, they are more sensitive methods allowing detection of low-threshold levels of infectious agents, with no exception to parasites, including their vectors and intermediate hosts with an ability to detect infections earlier than was previously possible. Molecular methodologies offer numerous advantages to the clinical laboratory in terms of sensitivity achieved through amplification methodologies. The major platform technologies of this *in vitro* diagnostics can be generally grouped into three approaches: the polymerase chain reaction, commonly known as PCR, nucleic acid hybridization, and the high-throughput next-generation sequencing. Molecular diagnostics can be used to diagnose/ identify/ genotype any parasite and can differentiate between the closely-related species. Current laboratory diagnostic methods for the identification of parasites include: polymerase chain reaction, random amplified polymorphic DNA, amplified fragment length polymorphism, restriction fragment length polymorphism, microsatellite marker method, loop-mediated isothermal amplification, and real-time PCR.

The flexibility of the versatile PCR technique has brought about many improved versions like AP-PCR or RAPD-PCR that does not require prior knowledge of the target DNA sequence, nested PCR, qPCR, Multiplex PCR, Recombinase Polymerase Amplification or RPA, Loop-mediated isothermal amplification (LAMP), the reverse line blotting assay in short RLB assay, ligase chain reaction or LCR for more sensitive detection and genotyping. Real-time polymerase chain technique enables the monitoring of PCR amplification in real time. Currently, RT-PCR enables quantification of the original sample using multiple fluorescent agents including SYBR Green dye, TaqMan probes. Using RT-PCR it is possible to quantify parasitic nucleic acids from environmental samples or tissues, as well as to estimate the intensity of infection and/or viability of parasites. The AFLP technology is an extension of PCR based analysis that allows detection of a DNA polymorphism in the entire genome of parasites. A useful method for identification of markers for understanding the genetic variability without prior information on the sequence and with high reproducibility of the results. The RFLP technique is one of the most commonly used molecular methods for diagnosis of species and genotypes of parasites. The technique is also suitable for environmental samples because it permits detection of multiple genotypes in the same sample. The LAMP protocol is unique as there are no post-PCR steps involved in this highly specific rapid technique, which is approximately ten times more sensitive than PCR and it requires less complicated equipment. This approach has been tried successfully with both animal and human parasites including vector mosquitoes carrying *Plasmodium* and *Dirofilaria* parasites and snail intermediate hosts of trematodes. Microsatellite technology has a low approval in molecular parasitology, although microsatellites have been described and used in some parasites of both humans and animals. The principles and applications of microfluidics, lab-on-a-chip, and nanotechnology for the development of point-of-care tests are also increasingly being explored and already applied or under development for application in field diagnosis of animal diseases including parasitic diseases.

The Concept of Vaccine Design

Ant-parasitic drugs continue to play an important role in control and management of parasitic diseases in animals and food animals. But these are constantly threatened by the widespread appearance of drug-resistant parasites than ever before. Therefore, the need to develop novel and sustainable control procedures with potent vaccines is much greater today. With the growing consumer demands for chemical-free food coupled with concerns regarding the environment and animal welfare, there is a renewed interest in the development of safe and effective vaccines. The advent of molecular tools has increased our understanding of the pathogenicity, virulence, and host-parasite relationships of the parasites, provided information on the genetic structure and taxonomy of the parasite and allowed the zoonotic potential of previously unidentified agents to be determined. However, emergence of newer strains and establishment of atypical or subclinical infections are posing new challenges in sustainable control of parasitism.

The components of a successful vaccine development programme require a good molecular understanding of the parasites interaction with the host immune systemand recognition of the complex parasite antigens by the host immune systemand importantly, identifying the relevant antigens of diagnostic and prophylactic importance.

Precise definition of immune effector mechanism(s), identification, production and validation of protective parasite antigens and establishment of an immune model for a parasite of interestare essentially needed for a successful vaccine design. The next step would be to explore how these antigens can be produced, modified, combined and presented in novel ways to achieve more focused and controlled immune responses. These innovative means of antigen presentation include liposomes, virus-derived vectors or even self-amplifying RNA encapsulated in liposomes. Epitope level control over the immune response is now being achieved by grafting epitopes onto protein scaffolds. Whole genome sequencing is being used to predict antigens of parasites, and to maximize coverage of diverse isolates by enabling vaccination with composite, or mosaic antigens. Systematicapproaches to predict protective immune responses from transcription and expression profiles of cohorts of genes involved in early immune responses are also being used to guide and accelerate vaccine development.Collectively, these novel approaches greatly help high throughput sequencing and bioinformatics to identify promising antigens, molecular adjuvants to target specific innate cellular receptors and drive the desired inflammatory responses.Further,advanced DNA, RNA, and protein delivery systemsmake use of detailed molecular insights gained from studying the protective immune responses generated in the context of natural infection, leading to greater appreciation of naïve immune repertoires. The ability to produce recombinant parasite proteins in the early 1980's was heralded as a major breakthrough for vaccine development,while today development of next-generation sequencing and proteomic techniques has enabled researchers to mine the entire genomes, transcriptomes and proteomes of organisms to identify novel candidate immunogens. During the course of the last 40 years, good progress has been made in development of efficacious vaccines against parasitic diseases of livestock.

Antigen Selection through Genomic Insights

Parasite genome sequencing projects are rapidly providing the resource to define the full potential protein complement of a parasite and, using transcriptome analysis platforms such as microarray to correlate parasite gene expression with life-cycle requirements and to define how a parasite might adapt to evade the host immune responses. Downstream bioinformatics analyses followed by *in vitro* and *in vivo* hypothesis testing are also being explored in identifying further potential vaccine antigens. Another approach is to identify proteins secreted by the parasite or expressed on a surface which may be accessible to the host immune system. Model organisms are being used to identify potential key genes required for parasite survival. The best example of this is the application of the *C. elegansgenome* to identify targets in parasitic counterparts. The function of most *C. elegans*genes has been defined usingtraditional reverse genetics approaches and RNA interference (RNAi). Many of the genes have close homologues in parasitic nematodes and the hope is, to identify gene knockdown which results in a lethal phenotype would point at parasite homologues which may be useful vaccine targets. The development of RNAi opens the possibility of defining, if a vaccine target is critical for parasite survival by specific gene-knockdown.

The New Omics Era

Omics, understandably aims at the collective characterization and quantification of pools of biological molecules that translate into the structure, function, and dynamics of an organism (Farhana *et al.,* 2019). Functional genomics while aims at identifying the functions of as many genes as possible of a given organism, it combines different omics-based techniques such as transcriptomics and proteomics with saturated mutant collections. The suffix -ome as used in molecular biology refers to collectivity of all units or simply, a totality of some sort. The use of multiple omics techniques (*i.e.,* genomics, transcriptomics, proteomics, and metabolomics) is becoming increasingly popular in all facets of life sciences, as they provide an all-inclusive perspective of the studied biological organisms by integrating multiple types of quantitative molecular measurements to untangle the complex living systems and processes.

The modern era of genomics began in the mid-1980s with the development of the PCR technique that enabled researchers to characterize the genome at the candidate gene level. In the early 1990s, scientists leveraged semiconductor manufacturing techniques to develop microarrays that enabled large-scale genotyping and gene expression profiling studies. These enabling technologies have not only transformed genomics research, but they also opened the door to clinical genomic *i.e.,* molecular diagnostics. In the clinic, genomic techniques have revolutionized testing across the areas of infectious disease, cancer and inherited disease by enabling measurement of new analytes, improving analytical performance (e.g., sensitivity) and in some cases providing faster turnaround time compared with traditional testing methods.

With the wealth of information on parasite genomics, proteomics, and immunology that has been forthcoming together lately, the future holds a great promise to apply these modern functional genomic, proteomic and modelling techniques to understand the basic biology of parasites and address important problems of practical relevance such as epidemiology, drug resistance, vaccine and new generation diagnostics development and delivery, improved control through better management of disease, *etc.* High-throughput screening technologies and diverse small molecule libraries offer great promise of accelerated discovery of new drug targets, thereby reduce disease burdens imposed on livestock and humans. For solving the vexatious issue of identifying protective genes, gene function annotation provides investigators with much more power to analyze their genes using many different biological aspects in a single space. Undoubtedly, these functional "omics"-based technologies will have problem-solving ability to make informed choices about where to focus time, money, and effort developing tools and pragmatic and sustainable parasite control programmes in the future.

Concluding Remarks

Disease control programmes in food animal production systems in general, and management of the ubiquitous parasitic infections in particular, have an important role to play in increasing livestock production to meet future protein needs. This is particularly appropriate in the context of a changing natural resource base for livestock production and the need to reduce greenhouse gas emissions from the livestock sector to meet the internationally agreed emissions targets. The growing social and economic pressures demand not just more production, but more efficient and more sustainable production while also safeguarding animal welfare. Due to the pervasive presence of parasitic infections in livestock and their pernicious effects on production efficiency, effective control of these parasites will be key to achieving such aims. Given these challenges, new scientific knowledge will be needed for management and to enhance the capacity of food animal production systems using precision diagnostic tools, innovative control approaches based on vaccines and selective breeding, sustainable use of existing antiparasitic drugs and potentially new compounds, and rational integration of promising control strategies. There is a new outlook for transformation of new diagnostic technologies to manage parasitic disease on-farms from laboratory-based tests that focus on population-level species diagnosis to on-farm tests, which can be used as real-time decision tools for impact assessment and mitigation.

Current Scenario of Indian Fisheries

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India with a vast coast line of more than 8000 km. is a source of livelihood for more than 20 million fishers and fish farmers and contributes considerably (about Rs.1.75 trillion annually) to India's exchequer and that is the reason the Government of India is going ahead with development of ports, coastal connectivity, shipping industry and coastal economic zones. The fisheries sector is a direct source of livelihoods; and is a major export earner, with fish being one of the most important agricultural commodities to be exported from India. Fisheries and aquaculture go hand in hand in food production, nutritional security, employment, and GDP in India.

Prior to 1976, there were no maritime regulations, such as the Exclusive Economic Zone (EEZ), Territorial Waters, and other maritime zones. This meant that mechanised fishing boats could freely exploit near shore waters, leading to a decline in fish catch. During 1980s as technological advances improved the overall ability to find, catch, and preserve greater quantities of fish, which continued to bring in ever-increasing revenues and export earnings. In order to control the decline in target species and rising conflicts with traditional fisher folk the Govt. of India has imposed in 2015 a uniform annual fishing ban (61 days) on all mechanized and motorised vessels operating in India's EEZ. Kerala was the first state to introduce fishing ban as early as 1988 to save juvenile fish being caught indiscriminately in the fishing nets and later many of the states followed suite to announce fishing holiday In 2011, labour-intensive trawl fisheries dominated more than half of India's marine capture fish production, and it is likely that they continue to do so even today. First introduced to India in the 1950s, trawling is a form of mechanized fishing that involves actively dragging a net through the water efficiently and indiscriminately catching everything on the sea floor. Bumper catches, combined with government subsidies, fuel tax rebates, and growing competition lured a large proportion of India's traditional fishers into motorising their traditional fleets. But, the global pandemic has taken away the livelihoods of the millions of people involved in India's fish production and Govt. of India is taking up all steps revive and give a boost to this sector..

One of them is *Pradhan Mantri Matsya Sampada Yojana* (PMMSY) involving a whooping Rs.20,500 crore grant to marine fisheries, inland fisheries, and aquaculture. PMMSY aims at enhancing fish production by an additional 70 lakh tonne by 2024-25, increasing fisheries export earnings to Rs.1,00,000 crore by 2024-25, doubling of incomes of fishers and fish farmers, reducing post-harvest losses from 20-25% to about 10% and generation of additional 55 lakhs direct and indirect gainful employment opportunities in fisheries sector and allied activities. PMMSY is designed to address critical gaps in fish production and productivity, quality, technology, post-harvest infrastructure and management, modernization and strengthening of value chain, traceability, establishing a robust fisheries management framework and fishers' welfare. While aiming to consolidate the achievements of Blue Revolution Scheme, PMMSY envisages many new interventions such as fishing vessel insurance, support for new/up-gradation of fishing vessels/boats, Bio-toilets, Aquaculture in saline/alkaline areas, Sagar Mitras, FFPOs/Cs, Nucleus Breeding Centres, Fisheries and Aquaculture start-ups, Incubators, Integrated Aqua parks, Integrated coastal fishing villages development, Aquatic Laboratories Network and Extension Services, Traceability, Certification and Accreditation, RAS, Biofloc & Cage Culture, E-Trading/Marketing, Fisheries Management Plans, *etc.*

Another proposal mooted by Govt. of India is Marine algal utilization and Cultivation**.** Marine algae (seaweeds) are an auxiliary resource of fisheries and realizing the importance of it as food, nutritional supplement and its products for industrial applications and also with a view to popularize the marine algae as food, Government is going in a big way to cultivate some of the economically important marine algae such as *Kappaphycus alvarezii,Gracilaria edulis etc.*, and handed over this task to ICAR institute, Central Marine Fisheries Research Institute,Kochi.

The marine algae are an important and unique marine living resource as they contain proteins, carbohydrates, lipids, vitamins, minerals and trace elements, antioxidants *etc.*, that is why they have been used from time immemorial as food, fodder and manure and have lot of potential for human welfare. Marine Algae are the only source of phycocolloids such as agar-agar, algin and carrageenan that have been used widely for decades in food, medicine and pharmaceuticals. They are otherwise called as "Sea vegetables" and are traditionally consumed in many Asian countries such as China, Japan, Korea, Malaysia, Indonesia, Australia *etc.,* and their use as food and medicine prior to 2000 BC are found a mention in Ancient Chinese medicinal literature. A particular type of red marine alga *Gracilaria edulis* is being used since decades for making gruel in the coastal areas of Tamil Nadu. Numerous reports are available on compounds derived from macro algae such as antibiotics, antifungal, antiviral, cytostatic antitumorals, antihelimenthic and anti inflammatory products. Marine algae are supposed to be best cure for more than 60 diseases, especially Breast cancer, Prostrate cancer and goiter.

Role of Drones in Empowering Farmers

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India being vast country with world's second largest population is always in an urgent need for agricultural sector in adapting latest technologies and innovation to increase production and yield of different agricultural crops. Global population is expected to reach 9.6 billion by 2050. Farming sector is under huge stress in meeting the demands of the growing population and suitably adapting to environmental and climate changes.

Precision agriculture techniques come to aid of farmers in leveraging evolving technologies like data analytics, Artificial Intelligence, Internet of Things (IoT) and much more. Drones or UAV (Unmanned Aerial Vehicles) are powering the modern agriculture techniques in collection of real-time data and on field actions.Farmers are empowered with real time inputs to enable decisions on farm management in minimizing wastage and maximizing outputs.

Drones in Support of Precision Agriculture

Precision agriculture even though not limited to only drone technology is highly enabled to wide number of operations. Drones with on board infrared and thermal cameras, sensors and ability to navigate farms in very less time, collect crucial vitals of the farm to support backend software applications in analyzing data points and coming up with inputs to farmers on decisions to optimize resources like fertilizers, pesticides, water, seeds, human resources *etc.* and thereby increasing profits to farmers.

Emergence of technologies like IoT(connected devices and sensors), big data ecosystems like 'Hadoop', readily available Artificial intelligence (AI) and Machine Learning (ML) trained models for agriculture, computer vision technologies like OpenCV is propelling drone based farming in coming up with advanced innovative solutions.

With Single Board computer (like Raspberry pi) phenomenon picking up, drones can carry onboard computers easily and leverage AI and ML in coming up with learning models on weed and insect pest identification supporting with timely advisories to farmers.

Onboard computers can share the data to high end servers which can process the real time data in understanding the crop condition and come up with counter measures. Internet being readily available as part of digital India initiative, AI can leverage trained models available on internet in coming up with predictive analytics to help farmers with decisions.

Thermal images help farmers in understanding which part of farm needs more water support. Artificial intelligence helps in pest detection and coming up with suggestions on pesticide to be used has become just in time support for farming.

Precision agriculture software provides predictive analytics with details on expected yield, profitability, wastage in helping farmers on farming decisions.

Drones powered by robotics can now pluck fruits from trees, count number of fruits on a trees, analyze the growth of crop, kill the pests which make farming far effortless comparing to manual or traditional farming operations.

Use of Drones to the Rescue of Farmers

One of the major problems faced by agriculture in rural areas is availability of enough Labor for manual operations in the field. Rural sector is crippled by lack of human resources on time for various agricultural operations which is forcing farmers in thinking of adaptation to robotics and drones to mitigate the challenge.

Drones come in different form factors like quad copter, hexa copter, octa copter, fixed wing used for different applications. Agriculture drones are heavy (each weighing more than 25Kg) can carry 12L to 20L of pesticide and has average flight duration ranging from 25 minutes to 45 minutes. Smaller VTOL(Vertical Takeoff and Landing) and fixed wing drones are used for collection of real time data from farms using onboard cameras and sensors(Temperature, humidity, air quality, LIDARs for mapping *etc.*)

Spraying pesticide on time is one of the crucial phases of modern agriculture. It was observed that pesticide spraying with drone can cover over 40 acres of crop in a single day comparing to two acres by manual spray. Spray nozzles can be customized for different crops and spray quantity can be controlled based on the need. Optimized pesticide spraying using drones saves 30% of pesticide cost to farmers. Faster pesticide spray ensures crop is secured fast and damages due to insects and pests are minimized.

In conclusion, using drones farmer is empowered in taking up agricultural operations "**Faster, Cheaper and Better**" resulting in reduction of agriculture costs and prosperity to farmer.


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12. గులాబి రంగు పురుగు
13. క్యాబేజి రెక్కల పురుగు
14. వరి కాండం తొలుచు పురుగు
15. వరి కాండం తొలుచు తెల్ల రెక్కల పురుగు
16. చెఱకు తలకొట్టు పురుగు
B.O. 1) 23-6-129, Shop No. 15, Sri Ranganayaka Swamy Complex, Patnam Bazar, GUNTUR. A.P., Ph : (0863) 664320
2) 20-29-11/A, Near Chinnaravur Rly. TENALI - 522 001, A.P. Ph : (08644) 232105
3) Shop No. 6, Shiva Baba Complex, Station Road, Warangal, TS. Ph : (0870) 6690545