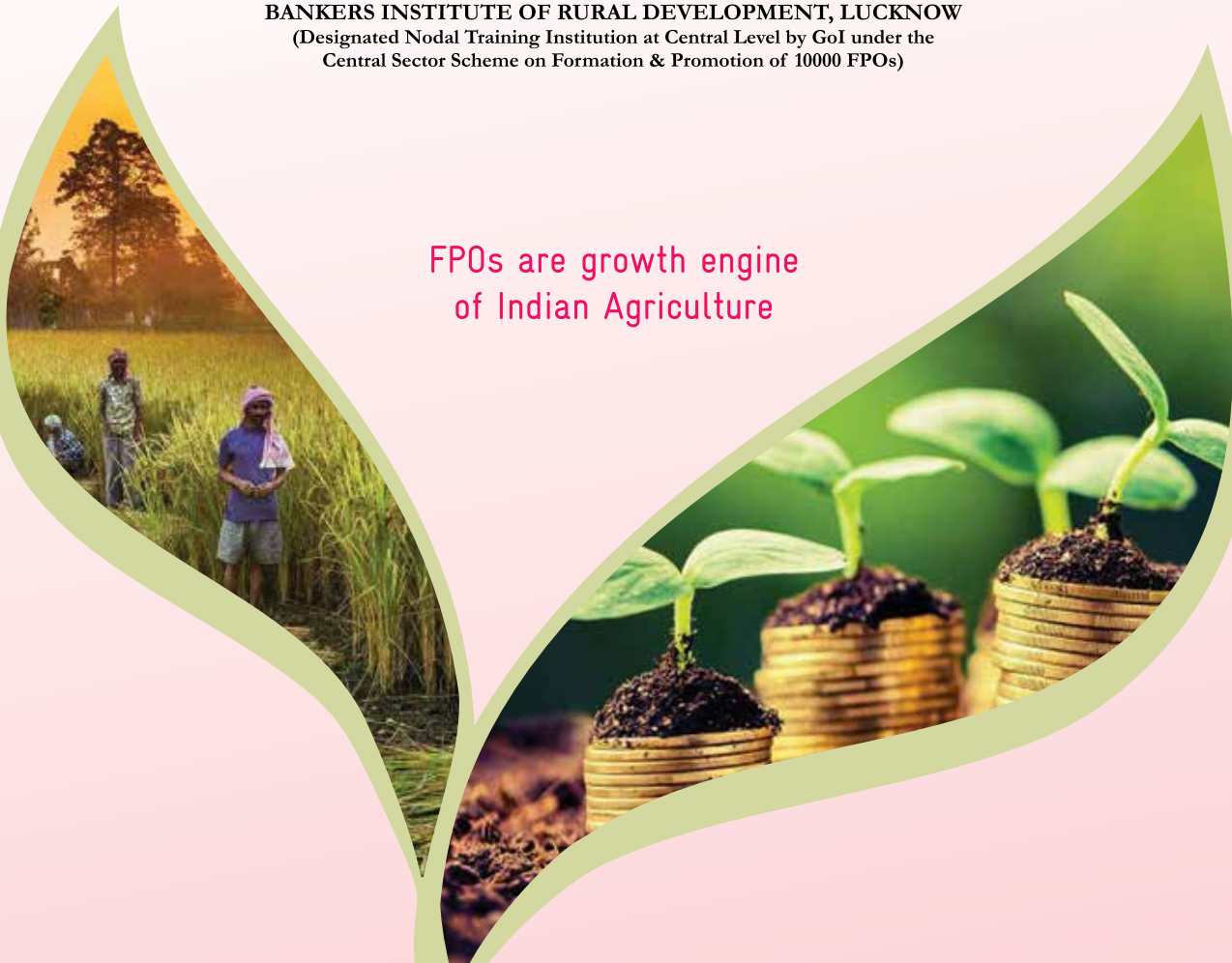




BANKERS INSTITUTE OF RURAL DEVELOPMENT, LUCKNOW
(Designated Nodal Training Institution at Central Level by GoI under the
Central Sector Scheme on Formation & Promotion of 10000 FPOs)

FPOs are growth engine
of Indian Agriculture



Resource Material Hi-Tech Agriculture

under
Central Sector Scheme on Formation &
Promotion of 10000 FPOs



Implemented by

giz Deutsche Gesellschaft
für Internationale
Zusammenarbeit (GIZ) GmbH

CONTENTS

Chapter 1: High Tech Farming - an Introduction	4
Chapter 2. System of Crop Intensification (SCI)	14
Chapter 3. Climate-Smart Agriculture (CSA)	24
Chapter 4. Integrated Farming Systems	29
Chapter 5: Integrated Pest Management and Integrated Nutrient Management	36
Chapter 6: Managing Water Efficiently	43
Chapter 7. Protected Cultivation	55
Chapter 8. Soil-Less Farming	62
Chapter 9. High-Density and Ultra High-Density Plantations	72
Chapter 10. Internet of Things (IoT) for Agriculture	79
Chapter 11. Precision Farming	84
Chapter 12. Collaborations between Agri-Startups and FPOs	88
Conclusion	93

Chapter 1: High Tech Farming - an Introduction

Improving the incomes of Indian farmers is crucial to the well-being of a large population of the country. The Central Sector Scheme on Formation and Promotion of 10,000 FPOs was rolled out with the intent of doubling farmers' incomes by 2022. Farmer Producer Organisations can help farmers access markets with better terms. However, farmers have to produce for the market, FPOs need to support them in their farm operations. Farmers need help to identify crops that have high demand, high market value, and quality standards for urban consumers and export. Farmers also need timely extension services to reduce their cost of cultivation, manage risks and access the technology appropriate to their operations. Knowledge of Hi-tech Farming practices is helpful in this regard. Farmers and their FPOs can then choose from a list of available options of Hi-tech Farming to implement in their farms.

What is Hi-Tech Farming ?

What is Hi-tech? Hi-tech stands for High Technology - according to the Collins Dictionary “any technology requiring the most sophisticated scientific equipment and advanced engineering techniques, like microelectronics, data processing, genetic engineering, or telecommunications including the Internet (as opposed to low technology)”. Hi-tech Farming incorporates high technology to farming operations to varying degrees.

Hi-tech farming uses scientific understanding, and clever and sophisticated technologies to grow crops with the intention to increase yields, ensure high-quality produce and realise increased market value. Growing high-value and exotic fruit and vegetables, developing disease-resistant plants through genetic engineering, and operating a remote-controlled irrigation system, are common examples of Hi-tech Farming. Hi-tech farming is often capital intensive where farmers use specialised equipment and maintain stringent cultivation standards and conditions aiming for high yields and quality produce. Hi-tech agricultural operations use methods, processes, and practices developed through intensive lab research and field testing and require greater training of farmers to use technologies. Hi-tech Farming is a commercial farming system aimed at catering to the needs of niche markets, both domestic and export. Nevertheless, some methods and technologies of Hi-tech farming can be adopted by small farmers with reasonable costs while small farmers who are members of FPOs can easily access high tech inputs like pheromone traps, drip irrigation and polyhouses.

Why does India need Hi-Tech farming?

India is blessed with large arable land with 15 agro-climatic zones as defined by ICAR, having almost all types of weather conditions and soil types. Farmers can grow a variety of crops. India is the top producer of milk, spices, pulses, tea, cashew and jute, and the second-largest producer of rice, wheat, oilseeds, fruits and vegetables, sugarcane and cotton. Why then do we need Hi-Tech

Agriculture?

In spite of all these facts, the average productivity of many crops in India is quite low. The country's population in the next decades is expected to become the largest in the world and providing food for them will be crucial. Besides several countries are not food sufficient and look to India to supply food commodities to them. Food supplies are prone to risks due to conflict, disasters and fuel prices, as we have seen during the Russia-Ukraine conflict.

The country's increasing population needs more food to be produced. Besides with increasing average income and globalisation, Indian consumers are demanding quality, nutritious and variety of foods. In many farming areas, labour shortages are increasing, while existing farmlands are being converted to non-farm uses. Climate change is leading to variations in growing conditions such as excess rain/drought, heatwaves and pest attacks. While many youths are quitting farming other youngsters want to experiment with new forms of farming and cater to urban demand for fresh or exotic produce. Indeed this is a rapidly evolving situation.

Where is the potential for Hi-Tech Farming in India?

The information technology revolution in India, new technologies in agriculture, a younger generation of farmers, private investments especially for research and development, government efforts to address the problems of small producers, etc., are changing the face of agriculture in India.

India is witnessing an explosion of Agri and Tech startups led by its educated youth. It shows their readiness to understand the high potential for growth in agriculture and their willingness to put their money and efforts in this sector. Farmers understand that "market-driven farm products" will help them increase their profitability and employing modern technology is an important way to do so. A new generation of farmers is also shifting from subsistence farming to modern farming methods and practices.

The growth of Hi-tech Farming in India is supported by several factors:

- Land availability: Favourable weather and a large tract of fertile soil conditions across the country
- Consumer demand:
 - High demand for exotic and high-value crops such as fruits, vegetables, flowers, mushrooms, especially in urban centres
 - Untapped market potential for several agriculture products
- Government support:
 - Various incentives are given by the government for investment and inputs
 - Availability of cheap credit facilities for production and for marketing and export promotion
 - Research institutes of repute in the country
 - Investment in the formation of Farmer Producer Organisations (FPOs)

- Easy to use digital payments infrastructure (UPI)
- Private sector support:
 - FMCG companies, startups and entrepreneurial ventures that invest in innovations that support the farming sector
 - Production infrastructure
 - Buyback and other marketing facilitation
 - Inventions, research and development to facilitate Hi-tech farming
- Information: Easily accessible information from social media (such as YouTube)

The increasing demand for High-Value Crops (HVC) in India

High-Value Crops (HVCs) are those where a farmer earns more revenue per unit area than from a conventional field crop. In other words, HVCs give a significantly higher value of productivity or net income per unit of resources used for production, compared to other possible crops. Diversification towards high-value crops such as fruits and vegetables, especially in a country like India, where demand for high-value food products has been increasing faster than for staple crops, has proven to increase the income level of farmers. Some of the important activities under HVC are indicated below:

- Fruit and vegetable cultivation especially catering to urban and metro markets (in the urban peripheral)
- Cultivation of off-season and exotic vegetables under greenhouse for exports (asparagus, celery, bell pepper, sweetcorn, green and lima beans)
- Floriculture - open and greenhouse production for domestic and export markets
- Exclusive production of crops - for processing, specific to user industry needs or under contract farming arrangements - i.e., gherkins, potato, fruits and select vegetables for processing, flowers (for extracts), medicinal and aromatic plants.
- Mushroom cultivation
- Hi-tech nursery units for fruit crops, vegetables, flowers, etc., and also Tissue Culture Plantlets (TCP) - planting material that is 'true to type'.

Prospects for High-Value Crops in domestic and export markets

The demand for HVCs goes up with urbanisation, rising per capita incomes, change in tastes and preferences of consumers and greater participation of women in labour markets. About 35% of India's population lives in urban areas, leading to rapid growth in demand for high-value food commodities. The consumption pattern in rural areas is also changing fast.

Similarly, the export markets are growing for high-value crops.

- **Fresh fruits and vegetables** - India's exports of fresh fruit and vegetable during 2020-21 stood at Rs. 10,582 crore.
- **Floriculture** - Indian entrepreneurs began establishing export-oriented floriculture units under controlled climatic conditions once the Indian economy liberalised. Of the nearly 300 export-oriented units the majority

(50%) are located in Karnataka, Andhra Pradesh and Tamil Nadu. India's total export of floriculture products and fruit and vegetable seeds was Rs. 1,383 crores in 2020-21.

- **Processed fruits and vegetables:** India's exports of processed fruits and vegetables stood at Rs.7,606 crore during 2020-21. Due to the special efforts of the Ministry of Commerce and Industries, Govt. of India and APEDA, the international demand for Indian processed fruits and vegetables has been rising during the last few years.
- **Animal products:** During 2020-21, the export of animal products reached its peak of Rs.26,439 crore.
- **Other processed products:** The value of other products including guar gum, alcoholic beverages, walnuts, cashew, jaggery, miscellaneous preparations and confectionery, etc., was at Rs.29,587 crore.
- **Cereals:** Amongst the agro-export products, cereals (basmati and non-basmati rice, wheat, maize and other cereals) contribute to export earnings of Rs.74,491 crore in 2020-21.

What are the advantages of high-technology farming?

In view of the high and unmet demand for high-value crops, Hi-tech Farming methods offer advantages such as

- Increased crop yield - up to 5 to 8 times per unit area compared to conventional methods
- Significant saving in key inputs like water (up to 50%), fertilisers (25%) and pesticides
- Better growth and uniformity in quality of produce
- Feasible even in undulating terrains, saline, waterlogged, sandy and hilly lands, urban spaces - can bypass the need for soil
- Better disease and pest management
- Better and economical use of natural resources and inputs through the use of nano-technology enabled processes, water conservation, precise nutrient delivery etc.

Where can farmers adopt Hi-tech Farming?

Despite the capital intensive nature, hi-tech farming can be implemented in -

- small and marginal land holdings for adopting intensive production technologies
- areas with limited land and water resources
- areas where the availability of land for cultivation is restricted because of very low or high temperatures that restrict the cultivation of crops under open field conditions.
- both rural and urban peripheries - as agri-business enterprises for and by youth
- urban and peri-urban areas - to meet requirements of fresh produce like vegetables, fruits and flowers around the year

A summary of Hi-tech Farming methods

Hi-tech Farming is an evolving sector and some of the examples are given below:

#	Methods	Details
A	Improvements to existing farming practices	Hi-tech Farming activities that bring in better scientific understanding of growing traditional crops but with lesser capital investment are given below in Section A
1	System of Crop Intensification (SCI)	• Simple changes to cropping practices have given rise to higher yields and lower costs in some of our common crops - like rice, wheat, millets, cotton and sugarcane. • The changes incorporated include transplanting fewer and younger seedlings, greater spacing between plants, maintaining soil conditions that lead to better root growth and health, and weeding at critical times during the crop season. • Systems of Rice Intensification was the first such method adopted under this activity • The SCI methods can also be enhanced using more capital intensive methods like drip irrigation and fertigation.
2	Climate-Smart Agriculture	The effects of climate change are visible on Indian farms and it is necessary for farmers to adapt their farming practices and reduce risks. Climate-Smart Agriculture (CSA) involves a range of strategies and activities such as: • Working with nature (than against it) and making use of natural processes and ecosystems; conserving resources like water, soil and energy • Using less external inorganic inputs (thus saving money while reducing products that are damaging the earth's climate/animal and human health) • Growing a diversity of crops • Smartly mixing both traditional and new farming technologies as appropriate
3	Integrated Farming Systems	• IFS is a system of mixing crops with animal husbandry so that the waste of one becomes an input or resource for another. • E.g., Paddy and fish farming systems grow fish in the rice fields; the fish help in controlling pests of the paddy crop and also fertilise the fields. The farmer's harvest consists of both paddy and fish; the purchase of pest control and fertiliser inputs is reduced. • Several combinations of enterprises are possible in IFS even for small farmers - mixing cereal crops with vegetables, fruit orchards, livestock, aquaculture, beekeeping, fodder crops,

		composting, etc. • Capital intensive IFS is also possible.
4	Integrated Pest and Nutrient Management	• Many farmers depend entirely on chemical fertilisers and harmful chemicals to feed plants and manage pests and diseases on their farm. These inputs are getting costlier by the day and reduce the farmer's profits while adversely affecting ecological and human health. • IPM and INM are methods that cleverly utilise how nature works to reduce buying harmful external inputs. • IPM: E.g., a sticky pheromone trap can reduce certain pests without using pesticides. Bird perches can be used to help birds catch insects in the field. Bacteria, fungi and parasitoid insects are used to control diseases and pests. • INM: testing farm soil for available macro/micronutrients/soil organic carbon is used to plan how to mix bought fertiliser with farmyard manure, compost, use of farm waste, beneficial micro-organisms etc. so that the soil stays healthy and crop stress is reduced. The farmer also gets to save money by buying fewer inputs. • IPM and INM can be easily adopted by small and resource-poor farmers, but more expensive options are also available such as Internet-based monitoring of pests.
5	Water-saving technologies	• Agriculture uses most of India's scarce freshwater resources. Conserving water for agriculture is very important to manage climate change effects too. Several technologies exist to deliver water more efficiently to crops - and they come in low cost and high-cost versions.
a.	Sprinkler irrigation	• Water is pumped through a pipe system and sprayed into crops through sprinkler heads. Sprinkler systems reduce water usage for plants by 15-50% and increase crop yields up to even 50%. They can be low cost with gravity fed water or Hi-tech with internet-based controls
b.	Drip system	• Water with or without nutrients is delivered to the root zone of crops through a network of thin pipes or drippers. Drip irrigation is called micro-irrigation and is the most water-efficient irrigation method. • It can reduce water usage for a crop by 30-70% and increase yields by 15-98% (double the yield). • Drip systems can be simple and low cost for

		backyard gardens or capital intensive and fully automated.
c.	Fertigation	• Fertiliser+Irrigation: When a calculated amount of water-soluble plant nutrients are dissolved in water and applied to crops, plants are better able to absorb the nutrients and less of it is wasted. Plants are fed in smaller doses more frequently. • The nutrient chemicals can clog/block the irrigation pipes. The system this requires to be maintained well. Fertigation systems can be capital intensive.
B	Protected Agriculture	• A farmer can control crop growing conditions light/shade, temperature and humidity to varying degrees by covering crop growing areas using various materials. This climate control helps a farmer to grow different crops for longer periods of time, irrespective of external weather conditions and with reduced pest and disease outbreaks. • Protected agriculture is conducted within greenhouses, polyhouses, shade nets, polytunnels, etc. • The cost of protected agriculture depends on the number of Hi-tech farming methods used within the structure. • Using locally available bamboo, a simple structure can be built by small farmers. A capital intensive system may use more expensive materials like steel, polycarbonate, air conditioning and automatic water and nutrient delivery methods. • Within protected agriculture, a farmer can grow crops in soil (geponics), water (hydroponics), air (aeroponics) or other growing media/substrate (see soil-less agriculture below).
C	Soil-less agriculture	• Soil-less agriculture is a method of growing plants in any medium other than soil. In soil-less culture, all nutrients are supplied to the plants by a nutrient solution sufficient to meet the plants' demands. The media can be anything from water, coco peat, wood chips, perlite, mist, etc. • Soil-less agriculture avoids diseases and pests that normally live in soil and greatly reduces the water and nutrient requirements of crops. • Plant nutrients are also not lost into the earth (leaching) in this system, thus saving some costs.

1.	Hydroponics and Aquaponics	• Here plants grow directly in water enriched with nutrients dissolved in water. The roots get to absorb water, nutrients and oxygen directly from the solution. • The nutrients used in hydroponic systems can come from different sources, including fish excrement, duck manure or chemical fertilisers. Plants commonly grown Hydroponically include tomatoes, pepper, cucumber and lettuces. • Aquaponics systems are designed to grow both fish and a plant crop in a circulating stream of water. The fish excreta fertilises the plants, while the farmer has to feed the fish. • Once again, a small farmer can have an open-air low-cost hydroponics system, while someone with capital can invest in fully automated expensive hydroponics systems within a greenhouse.
2.	Aeroponics	• Aeroponics is the process of growing plants in a moist air or mist environment without the use of soil or an aggregate medium. Aeroponics is conducted without a growing medium and one can see roots literally hanging in the air. Aeroponics is an expensive and highly automated Hi-tech farming system. Disease-free seed potato is a typical crop grown under aeroponics.
3.	Vertical farming	• Vertical farming is a form of protected agriculture and lessso farming that grows several crops arranged one over the other in racks like a multi-storeyed building. • More crops can be grown in a given area, especially within cities. • Mushrooms, poultry, hydroponic fodder, strawberry, leafy vegetables particularly lettuce, herbs, ornamental horticulture and other high-value crops are typically grown in vertical farming. • Though the infrastructure is capital intensive it has the potential to reduce major inputs to crop production like land, water, nutrients, pesticides and others.
D	Nano technology-based farm practices	• A variety of nano-particle based inputs - nano-sized pesticides, herbicides, fungicides, fertilisers and sensors, have been widely tested for plant health management and soil improvement. • Though this technology is at an early stage, it holds promise in improving crop practices through increased disease resistance, crop yield

		and nutrient utilisation - while reducing the total amount of inputs used.
E	Tissue Culture	• Tissue culture is a method of creating seedlings from the fragments of plant tissue in a lab environment. • The technology can help us develop a large number of seedlings which are identical to the mother plant ('true to type') and disease-free planting material with desired traits. • The tissue culture method is commonly used to multiply seedlings of banana plants and flowers like anthurium.
F	Precision Farming and Internet of Things (IoT)	• The availability of the Internet, Mobile Apps, GPS, cameras, sensors and drones has revolutionised farming. Though it is still developing and expensive farmers are able to calculate the exact dosage of nutrients, decide when to irrigate, undertake pest control activities, sow, harvest and even operate their farm machinery by remote control.

How can small farmers attempt Hi-tech Farming?

While high-value crops are mainly associated with big farmers, there is significant scope for small and marginal farmers to diversify towards high-value agriculture by leveraging their membership in FPOs. However, the challenge remains in the development of infrastructure, transfer of technology, appropriate marketing interventions, availability of affordable capital, etc.

Challenges in promoting Hi-tech Farming among small farmers:

- Bringing more and more smallholders under high-value agriculture production systems
- Transfer of technology suitable for small farmers
- Access to adequate institutional credit
- Institutional development for input support, extension, training and capacity building
- Marketing linkages to ensure remunerative price for produce
- Enabling policy interventions
- High-value crops like fruits and vegetables are perishable in nature and we must simultaneously address critical infrastructure needs like packing, cold storages, cold chain, transport facility, etc.
- Absence of specific risk mitigation measures to offset high production and market-related risks.

Government and Private Sector interventions that support farmers in Hi-tech Farming:

Both Central and State Governments are actively developing new

schemes, incentives and projects to support hi-tech farming. Both farmers and FPOs must lookout for the latest information on current schemes through government department websites and local offices. Some interventions are listed below:

- Incentives/subsidy support for adopting high-value agriculture production technologies, especially under the National Horticulture Mission and other programmes of the National Horticulture Board.
- Export facilitation and promotional interventions of Agricultural & Processed Food Products Export Development Authority (APEDA)/ Marine Products Export Development Authority (MPEDA)
- Promotional interventions of Commodity Boards
- Programmes like precision farming supported by the State Governments with focus on high-value crops
- Central Scheme for Promotion of FPOs

Similarly several private sector technology and service providers can help farmers with infrastructure development, machinery, software, extension, credit and marketing.

The Hi-tech Farming sector is new, dynamic and evolving fast. It is imperative that farmers and their FPOs consciously keep in touch with the developments in this field. In the following chapters, we shall review some Hi-tech Farming methods.

Further references:

ICAR. “Technological Options for Enhanced Productivity and Profit”. It contains detailed descriptions in text and pictures about the improved varieties and package of practices of crops; technologies for natural resource management, post-harvest and value addition, and entrepreneurship development; and farm machinery.

- https://www.iari.res.in/files/Atic/Tech_Options_Hindi-15072014.pdf
- https://www.iari.res.in/files/Atic/Tech_Options_English-15072014.pdf
- <https://www.iari.res.in/files/Vegetable%20Crops%20for%20Pritam%20Kalia%20Book%20Final.pdf>

Chapter 2. System of Crop Intensification (SCI)

India is blessed with large arable land with 15 agro-climatic zones as defined by ICAR, having almost all types of weather conditions, and soil types and capable of growing a variety of crops. India is the top producer of milk, spices, pulses, tea, cashew and jute, and the second-largest producer of rice, wheat, oilseeds, fruits and vegetables, sugarcane and cotton. Sadly, the average productivity of many crops in India is quite low. It is often thought that better crop productivity is achieved only by using higher and higher doses of chemical fertilisers and pesticides. Systems of Crop Intensification (SCI) are a good example of small changes leading to big improvements in crop productivity. By making small and often low-cost improvements in farming practices our farmers can reap multiple benefits. At the outset, SCI may not appear to be Hi-tech at all; however, each improvement in farming practices is backed up by scientific research and field trials.

What is SCI?

System of Crop Intensification is a set of principles and practices that improve the productivity and resilience of crops. These methods are particularly relevant in resource-limited situations - where the land and water resources are limited and the farmer is economically poor. SCI essentially entails increasing farm productivity by making better use of resources - soil, water, seeds, nutrients, sunlight and air. SCI starts with the idea that a plant yields well when it has larger, more efficient, longer-lived root systems and these roots have developed symbiotic relationships with soil organisms. This also requires that the soil is healthy and contains diverse soil organisms. The roots sustain soil organisms which in turn provide nutrients and protection to the roots. SCI became well known through Systems of Rice Intensification (SRI) and gradually were developed for several crops like wheat, millets, sugarcane, mustard, pulses, vegetables and spices.

The main elements of SCI include:

- Start with high-quality seeds/seedlings, handle them carefully, and plant them early without damaging their roots - so that the roots have the greatest chance of growing vigorously.
- Space plants widely - so that there is less competition between plants for nutrients, light, water and air. This helps plants to grow to their best genetic potential.
- Keep the topsoil around the plants well-aerated - by using various implements and avoiding permanent waterlogging (as in traditional paddy cultivation). The raking of soil both aerates and removes weeds.
- Irrigate the fields avoiding both waterlogging and extreme drying - maintaining a good balance of air and water at the root zone.
- Feed the soil with organic matter as much as possible maintaining both soil fertility and texture.

- Reduce reliance on bought inputs such as inorganic fertilisers and pesticides - these cost money and are also toxic to soil organisms.

Research from the lab and the field show dramatic improvements in crop productivity.

System of Rice Intensification (SRI)

System of Rice Intensification includes transplanting of younger seedlings, in well-drained and aerated soils using a single seedling per hill as against the conventional rice cultivation in flooded nurseries with no regular spacing between clumps.

A brief summary of SRI Cultivation is given below: (only critical points are mentioned)

1. Nursery Management

- Use carefully selected seeds at a rate of 2 kg/acre (instead of around 20kg/acre in conventional paddy cultivation)
- Sparsely spread seed-treated and sprouted seeds on a raised nursery bed that can be lifted off easily. (see the image of mat nursery-grown over a plastic liner)
- Mulch the seedbed with straw and water carefully.
- The seedlings are lifted off carefully along with the soil for transplantation when they are in the two or three-leaf stage or 12-days old.



http://www.agritech.tnau.ac.in/agriculture/agri_cropproduction_rice_sri_nursery_mgmt.html

2. Preparing the main field

- Level the paddy field so that water can be applied very evenly
- Provide a canal at every 3 m distance to facilitate drainage.
- Mark the points for transplanting by drawing lines on the soil (perpendicular lines) to get a grid 25 x 25 cm apart with the help of a marker/rope and transplant one seedling at each intersection.

3. Transplanting

- Carefully pull out the 8-12 day old seedlings from the seedling block of soil
- Transplant the seedling with seed and soil at a shallow level so that the roots are not bent upwards.
- SRI requires 10-15 persons to transplant one acre.

4. Irrigation, water and nutrient management

- The purpose of irrigation is just to wet the soil, just enough to saturate the soil with moisture
- Subsequent irrigation is only when soil develops fine cracks.
- Regular wetting and drying of soil results in increased microbial activity in the soil and easy availability of nutrients to the plants without creating low-oxygen/anaerobic conditions where roots rot.

- Apply compost / FYM applied instead of or in addition to chemical fertiliser; 10 tons/ha (More plant growth because of better soil health and structure, and more balanced nutrient supply)

5. Weed management

- SRI method has more weeds due to higher spacing between seedlings and lack of standing water
- Incorporate the weeds in the soil by moving a rotary weeder (cono-weeder - see image) between the rows - this removes weeds and turns the soil.
- Weeds close to the hills/tillers have to be removed by hand

http://www.agritech.tnau.ac.in/agriculture/agri_cropproduction_rice_sri_weed_mgmt.html



A comparison of SRI and conventional method of rice cultivation is as follows

Particulars	Conventional Method	SRI
Spacing between hills	15 x 10 cm	25 x 25 cm
No of plants per sq.m	66	16
No. of seedlings per hill	3	1
No. of plants per acre	792,000	64,000
Seed requirement per acre	20 kg	2 kg
Tillers per hill	~15 (or ~5 per plant)	~30-50
1000 grain weight	21.1 g	29.4 g
Total grain yield t/ha	2.19	3.07 (40% more)
Total production cost Rs. /ha	13,775 (Rs./ha)	14,802 (Rs./ha)
Gross returns Rs. /ha	Rs. 26,250	Rs. 36,840
Net Returns Rs. /ha	Rs. 12,475	Rs. 22, 037

(Adapted from Balamatti, A (2017 and Wassan)

Benefits of SRI as observed in various field research programmes:

- Plant looks robust with large root volume and profuse and strong tillers
- Plants resist insects because they absorb soil nutrients naturally
- SRI leads to higher crop yields of both grain and straw
- Reduced crop duration (by 10 days) - as the plant starts to tiller early after transplantation
- Lesser chemical inputs
- Less water requirement
- Less chaffy grain
- More and well-filled grain panicles and higher grain weight
- Grain weight increased without change in grain size
- Higher head rice recovery

- The tillers do not lodge and can withstand cyclonic gales
- Plants are cold-tolerant
- Soil health improves through biological activity



Comparing root growth and tillering between SRI Paddy (left) and conventionally grown paddy: <https://www.globalagriculture.org/flagship-projects/system-of-rice-intensification.html>

Disadvantages of SRI include:

- Higher labour costs in the initial years
- Farmers may face difficulties in acquiring the necessary skills
- Not suitable when no irrigation source available
- Farmers need convincing before adopting SRI.

SRI is also a climate-smart approach that substantially reduces methane emission due to intermittent wetting and drying, instead of inundation. Developed as a best practice, SRI has changed traditional paddy cultivation. Under NABARD's flagship programme of UPNRM, over 20,000 ha of SRI were undertaken and it saved around 89 million cubic meters of water-conserving nearly half the groundwater used for flood irrigation in traditional paddy cultivation practices. Besides water-saving, farmers also could increase the yield by 60%.

References:

- WASSAN-CSA-WWF Manual on SRI
- Prabhakar Adhikari et al. (2017) System of Crop Intensification for more productive, resource-conserving, climate-resilient, and sustainable agriculture: experiences with diverse crops in varying ecologies. International Journal of Agricultural Sustainability. 16:1. Pages 1-28
- Balamatti, A and Uphoff, N (2017). Experience with the System of Rice Intensification for Sustainable Rainfed Paddy Farming System in India. Agroecology and Sustainable Food Systems. March 2017. pp 1-15.

System of Wheat Intensification (SWI)

System of Wheat Intensification (SWI) was first tested in northern India in 2006 by farmers working with the People's Science Institute (PSI). First-year trials near Dehradun, using several varieties, showed average increases of 18-67% in grain yield and 9-27% higher straw yields compared with the yields that farmers usually obtained with these varieties using conventional broadcast methods for crop establishment.



Women farmers in their SCI Wheat Field (Source: <http://sri.ciifad.cornell.edu>)

Core principles of SWI

- Priming of seeds with seed selection/treatment
- Wide and uniform spacing of single plants set out in a square pattern in the field (starting at 20cm × 20cm, but going up to 50cm × 50cm)
- Suppressing weeds mechanically rather than chemically or by hand to increase aerating of the soil by 2 or 3 times.
- Wheat yields are achieved by applying SRI principles (careful transplanting of 8-12 days old seedlings at wider spacing; intermittent irrigation for keeping the soil moist to the point of surface cracking;
- Weeding is started about 10 days after transplanting, with at least 2 rounds of weeding; compost is used instead of chemical fertiliser
- The fully developed root systems make crops more resilient in times of drought because the plant can access moisture deeper in the soil

Benefits of SWI

The results of SWI in Bihar (Gaya and Nalanda districts) as reported by PRADAN are:

- Average yields with SWI methods were 3.6-4 tonnes/ha, more than double the yield of 1.6 tonnes/ha using usual methods.
- The average yield increased by 72%, with households' net income/ha raised by 86%
- With SWI practices, costs per kilogram of grain produced were reduced by 28% due to higher yield
- By 2016, an estimated 500,000 farmers were using SWI methods in Bihar covering about 300,000 ha, with yields of 4–5 tonnes/ha representing an average increase of 60–80%.

The Madhya Pradesh, State Rural Livelihood Mission began introducing SWI to farmers in tribal areas in 2008–2009, starting in the Shahdol district.

- Farmers traditionally sowed their wheat crop quite densely, using about 175 kg of seed per hectare. With wider plant spacing, the seed rate under SWI was reduced by 95%, to just 7.5 kg/ha while giving a much higher yield (nearly double).
- The National Rural Livelihood Program has subsequently taken up SWI promotion in the states of Chhattisgarh, Gujarat, Jharkhand, Maharashtra, Odisha, and West Bengal in addition to Bihar and Madhya Pradesh.

References:

International Journal of Agricultural Sustainability, ISSN: 1473-5903 (Print) 1747-762X (Online) Journal homepage:

<https://krishi.icar.gov.in/jspui/bitstream/123456789/12103/1/System%20of%20crop.pdf>

Source: fao.org (Toward sustainable cereal production)

Sustainable Sugarcane Initiative (SSI)

Conventional sugarcane cultivation is seed, water, and space intensive. High input costs, disease infestation, low yields, varietal degeneration, drought and waterlogging are the major limiting factor for achieving optimum profits for farmers.

Sustainable Sugarcane Initiative (SSI) is an approach of resource-efficient sugarcane cultivation agricultural practice. It aims to promote a sustainable and innovative set of agronomic practices that reduces the ecological footprint of sugarcane growing. SSI is a boon for small and marginal farmers due to better yield, reduced fertiliser and water use and flexibility to do intercropping.

Since sugarcane as a crop consumes about as much water as rice, requiring 1500-3000 litres of water per kg of sugar ultimately produced, management methods that can reduce water requirements similar to SRI's reductions for rice will have substantial economic and environmental benefits. AgSri and the National Bank for Agriculture and Rural Development (NABARD) have jointly published a revised SSI manual (AgSri/NABARD 2012).



A single tray-grown 25-35 day old seedling of sugarcane is being lifted out.

Major principles of SSI:

- Raise nursery using single budded chips
- Transplant young seedlings (25-35 days old)
- Maintain wide spacing (5 x 2 feet) in the main field
- Provide sufficient moisture and avoid inundation by water
- Encourage organic method of nutrient and plant protection measures
- Practice intercropping for effective utilisation of land and additional harvests

Reference: https://agritech.tnau.ac.in/expert_system/sugar/ssi.html

Case Study 1: Sustainable Sugarcane Initiative (SSI) Brings Hope to Distressed Sugarcane Farmers

The NGO NIRMAN partnered with ICRISAT-WWF to introduce and promote SSI in Odisha and subsequently collaborated with Tata Trusts to promote SSI in Karabar Gram Panchayat in Bhapur block during 2015-2018. 812 farmers adopted the SSI method and are getting an increased yield of 10 tons/acre.

- The average yield per acre for SSI field is 52 tons/acre versus 30-35 tons/acre with conventional sugarcane farming
- Lower seed costs at Rs. 1300/acre in SSI versus Rs. 14,400/acre
- Water use reduced by 40%
- Labour requirement reduced by 30%
- Overall cost of cultivation reduced while yield increased by 10 tons/acre.

Case Study 2: Impact SSI project under NABARD's UPNRM

The extent of the area brought under the drip irrigation along with SSI cultivation is approximately 280 acres which is perhaps the largest area among sugar factories in India. The field trials using twin interventions of drip along with SSI cultivation have resulted in increasing sugarcane productivity from 60 MT/ acre using flood irrigation to 92 MT/acre under SSI with drip irrigation.

Overall benefits to SSI sugarcane farmers

- Increase in crop yield by at least 20-30%.
- Reduced cost of cultivation by at least 25%.
- Savings in weedicide and labour cost SSI irrigated plots.
- Reduced cost of fertigation
- Increased sugar recovery
- Increased water use efficiency and savings to the tune of at least 50% thereby acting as an effective strategy to meet extended dry spells.

Sustainable Cotton Intensification

Cotton production clearly contributes to economic growth. However, its production has led to severe social and environmental impacts that are not reflected in the economic value of cotton. These harmful side effects arise in cotton production due to the following practices:

1. **High pesticide consumption:** Cotton consumes 44.5% of the total pesticides used in the country. Cotton crops are highly vulnerable to insect and pest infestation and diseases. The indiscriminate use of pesticides, however, has adverse effects on the natural predators and parasites of bollworms. The use of pesticides also leads to environmental pollution (of soil and water), an increase in the cost of cultivation, and sometimes, the insects develop resistance to insecticides.
2. **Increasing fertiliser consumption:** Cotton accounts for about 6% of the total fertiliser consumption in India. The indiscriminate use of fertilisers results in nutrient [nitrogen (N) and phosphorous (P)] loading in surface and ground waters. The major concern, however, is nitrification in the surface and ground waters from N-based fertiliser application.
3. **Irrational water use:**
 - Agriculture accounts for 83% of total water usage (79.7% in surface water and 89.6% in groundwater). Globally, cotton production is responsible for large water withdrawal. Cotton cultivation also leads to pollution of water due to leaching and runoff chemicals in ground and surface water. This also affects the net available water used for other activities.
 - An inefficient irrigation system and unsustainable water use, particularly in the northern region of India, where cotton is grown under irrigated conditions, has several environmental implications. Rivers are being diverted and dammed for large-scale irrigation projects. This has significant downstream effects, including water shortages with adverse impacts on wildlife and water availability for human consumption.
 - Increased Soil Salinity: The use of irrigation water and excessive chemical fertilisers in cotton production has led to soil salinisation in many parts of the cotton-growing regions in the world. Salinity may arise because of excessive use of irrigation and fertilisers. Soil salinity is the accumulation of excessive salts at the soil surface and results in the degradation of soil and vegetation.

All the above reasons have tarnished the reputation of cotton as a crop.

Better Management Practices (BMP): A Precursor For Sustainability

Indiscriminate use of inputs, such as water and chemicals in cotton production, is the cause of some of the key environmental issues. Sustainable cotton cultivation, therefore, requires an integrated approach at the crop management level, with improved practices. Better crop management practices, such as Non-Pesticide Management (NPM), Integrated Pest Management (IPM), Integrated Nutrient Management (INM), and Integrated Water Management (IWM), have been applied to lessen the burden of inputs

while increasing productivity to reduce environmental impacts. WWF-India has helped develop Better Management Practices (BMP) based on the above parameters that balance crop productivity with agri-inputs. These practices can be broadly categorised into the following areas.

- **Soil Fertility Management:** BMPs on soil fertility management include Soil Test Based fertiliser application. Based on the nutrient status of the soil, fertilisers are recommended for application in soil. Apart from this, BMPs also include Integrated Nutrient Management which requires the use of organic inputs (like tank silt application, crop residues, vermicompost, farmyard manure, etc.) practices in conjunction with inorganic fertilisers. The particular management practices restrict the overuse of mineral fertilisers and thus prevent the loss of nutrients.
- **Pest and Disease Management:** BMPs on pest and disease management advocate proper pest monitoring through sticky, pheromone and yellow traps, encouraging cultural, mechanical and judicious chemical practices to control pests and diseases in cotton. These can effectively reduce the hazards of using an excess of chemical pesticides and insecticides.
- **Water Management:** BMPs on water management have been developed to improve water use efficiency in cotton irrigation. The water BMP includes the adoption of water conservation techniques like drip irrigation and other innovative techniques, such as watering plant rows in pairs. In the micro irrigation system, water use efficiency varies from 70 to 95 per cent, compared with 35 to 40 per cent in traditional irrigation techniques i.e. flood irrigation due to significant seepage, evaporation, distribution, conveyance losses, etc.
- **Clean Picking:** BMPs encourage the safe use of pesticides with proper disposal of containers by the users. Emphasis is also given to clean cotton picking practices that reduce the likelihood of contamination. The BMPs encourage the use of cloth bags, which are used to collect cotton during picking and for cotton storage. Separate, ergonomically designed, aprons are provided to the women labourers for reducing the contamination of hair and threads from polypropylene bags.

Results of case studies in BMP (Best Management Practices) indicate the following benefits:

- 30%–51% water reduction in BMP fields
- 38%–80% lessening of chemical pesticides in BMP fields
- 32%–53% reduction in chemical fertiliser
- 40%–50% reduction in GHG emission
- 31% improvement in gross margin of BMP farmers

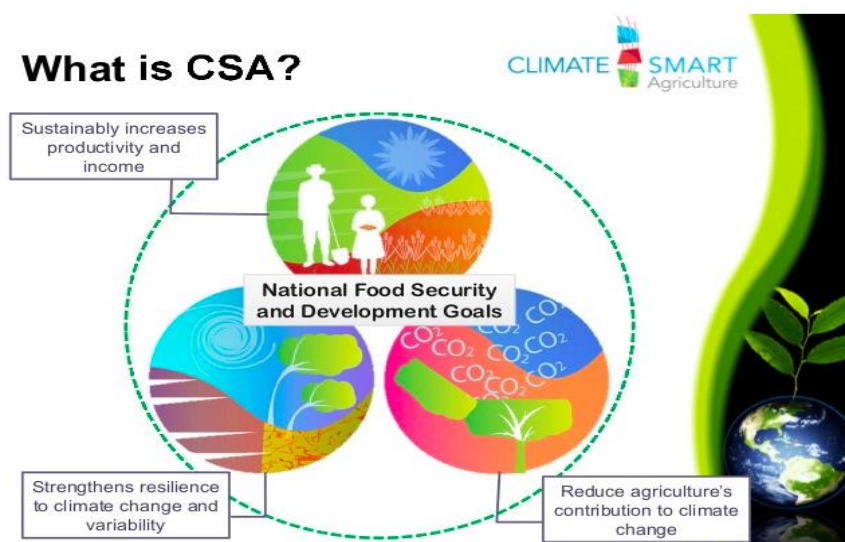
References:

- WWF-India (2010) Better Management Practices for Cotton Cultivation A guide on sustainable cotton production for field & agricultural extension workers. WWF - India.
http://awsassets.wwfindia.org/downloads/better_management_practices_for_cotton_cultivation.pdf

Chapter 3. Climate-Smart Agriculture (CSA)

Climate change and its negative effects on human activities is a serious cause for concern worldwide. Indian farmers are already witnessing the increasing incidences of heat/cold waves, floods/droughts, landslides and wildfires - on scales they have not seen in recent memory. Nearly two-thirds of India's population depends on agriculture and the food security of the population is a national priority. India has to prepare its farming systems and its farmers to manage climate change risks. Climate-Smart Agriculture is an approach to dealing with the climate crisis. CSA rests on three pillars:

1. **Productivity:** Sustainably increasing farm productivity, so that farmers' incomes rise, food security and development are ensured - without damaging the environment; sustainable crop intensification (such as SRI and SWI covered in the previous section) is a key strategy to increase productivity.
2. **Adaptation:** Adapting and building the resilience of agricultural and food security systems to climate change at multiple levels so that farmers' exposure to risks is reduced and ecosystems around farms are strengthened. New approaches and technologies will be blended with existing knowledge and practices to strengthen farming systems against climate change. This will include insurance products and value chain interventions.
3. **Mitigation:** Reducing greenhouse gas emissions from agriculture (including from crops, livestock and fisheries). This includes reducing deforestation and reliance on artificial fertilisers, and reducing energy use in farming while building the soil's ability to absorb and store carbon.



Three pillars of the Climate Smart Agriculture Source: Presentation by Irina Papuso and Jimly Faraby, Seminar on Climate Change and Risk Management, May 6, 2013. <http://www.slideshare.net/jimalfaraby/climate-smart-agriculture-20675751>

Key characteristics of CSA

CSA Addresses climate change by using the climate lens to the plan and develop sustainable agricultural systems.		CSA Integrates multiple goals or triple-win outcomes - increased productivity, enhanced resilience, and reduced emissions.	
CSA maintains ecosystem services of clean air, water, food, and materials. CSA practices are designed not to degrade natural resources	Key characteristics of CSA		CSA is context-specific - climate-smart in one place may not be climate-smart in another. No interventions are climate-smart everywhere or every time.
CSA has multiple entry points at different levels such as the development of technologies and practices, the elaboration of climate change models and scenarios, information technologies, insurance schemes, value chains, and the strengthening of institutional and political enabling environments.		CSA Engages women and marginalised groups who are most vulnerable to climate events like drought and floods thus, most likely to be affected by climate change. CSA strives to involve all local, regional, and national stakeholders in decision-making through learning together.	

Climate-smart agriculture (CSA) practices and technologies

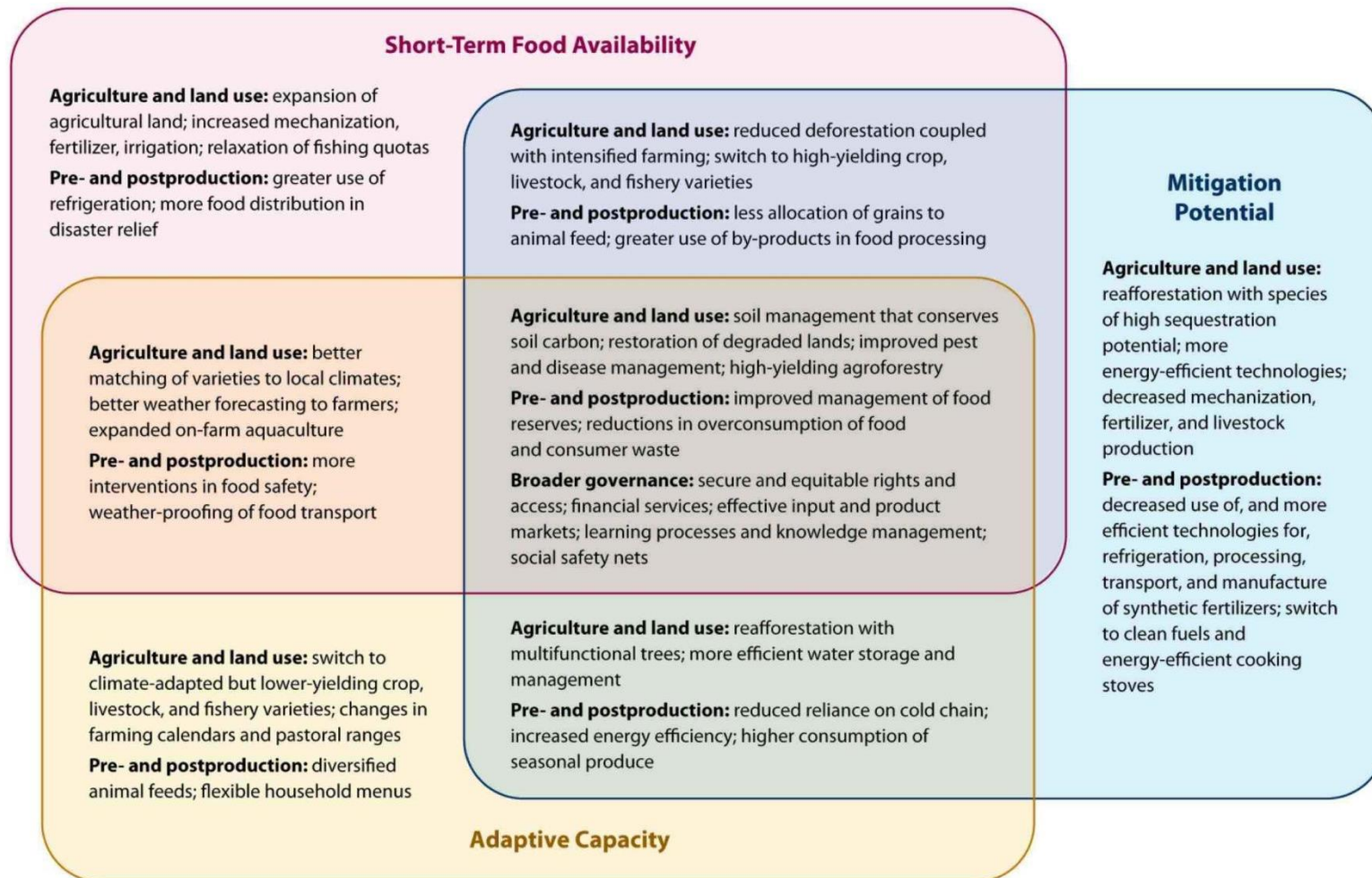
CSA is not a fixed single or set of practices and technologies and it goes beyond a single technology. There are a range of climate-smart agriculture (CSA) practices and technologies within seven entry points for CSA; these practices help farmers modify their farming practices towards resilience to climate change as given below

1. Soil Management and Nutrition Management
2. Crop Management
3. Water Management
4. Integrated farm system
5. Fisheries & Aquaculture
6. Energy Management
7. Livestock Management

CSA also requires agencies to work at a global level modelling climate change, providing weather services and working on policy change. An indicative set of practices of CSA is shown in the figure below

Figure: Synergies and trade-offs for adaptation, mitigation and food security (Source; Vermeulen et al. 2012, p. C-3) <https://csa.guide/csa/what-is-climate-smart-agriculture>

Figure: Synergies and trade-offs for adaptation, mitigation and food security



CSA Case 1: National Innovations in Climate Resilient Agriculture (NICRA)

<http://www.nicra-icar.in/nicrarevised/>

NICRA is a network Project of ICAR launched in 2011. Under the NICRA project of ICAR, several CSA practices have been implemented in 100 “Climate Resilient” villages across India. Here are some of the practices followed:

- No burning of crop residues
- Mandatory greening of wastelands with tree cover
- Water-saving paddy-cultivation practices like direct seeding
- Mandatory groundwater recharge structure
- Utilising of complete surface water harvesting potential
- Use of energy-efficient pumps for lifting water
- Green and brown manuring to the extent feasible
- Fertiliser use based on soil test reports
- Nitrogen application based on better product
- Mandatory vaccination of livestock for seasonal diseases
- Livestock feeding, housing and manure management to reduce wastage of manure and GHG emissions.
- All farmers to learn access to an agro adviser through mobile
- Appropriate weather insurance package identified

1. **Silage making technology for livestock in Kalaburgi, Karnataka**

This climate-resilient technology ensured the availability of green fodder during dry seasons. The supply of required nutrients to animals improved milk production. Now, livestock can withstand severe drought and sickness despite a shortage of green fodder.

Impact:- In 2017-18, 5 farmers adopted this technology and achieved an increase in milk production from 7.85 litres/day without silage to 10.21litres/day.

2. **The Krishi Vigyan Kendra - Hamirpur** conducted different demonstrations on natural resource management, crop production, livestock and fisheries, and fodder production in the adopted villages. The results of CSA technologies are summarised in the table below:

Results of CSA Technology Demonstrations of KVK Hamirpur

Theme	Interventions	Technology Demonstrated	Benefits
Water conservation	Plastic Mulching	Plastic mulching in cucurbits (bitter melon, bottle gourd and cucumber)	Increase in yield, reduced number of irrigation, reduced number of weeding and hoeing
	Biomass	Biomass mulching for	Increase in yield by 150q/ha

	mulching	Elephant foot yam	
Crop production	Short duration summer season crop	Toria (rapeseed) in Zaid season (the short season between Rabi and Kharif)	Increase in yield by 1.5 q/ha
	High yield variety	Maize resistance to lodging	Increase in yield by 2q/ha
	Early sowing	Wheat, early sown variety to exploit residual moisture	Increase in yield by 1.5q/ha and reduced in number of irrigations
	Drought tolerant variety	Brown sarson (KBS3)	Increase in yield by 1.5 q/ha and reduced number of irrigations
	Crop Diversification	Cabbage and cauliflower	Increase in yield by 30q/ha
Pest Management	Pheromone e-trap	Management of Fruit fly in cucumber	Increase in the yield 30 t /ha
Nutrient Management	Tetra Vermibed	Vermicompost preparation	Increase in yield by 20 per cent in crops like vegetables, maize and wheat

Adapted from: Deepika, Suchiradipta, B., and Saravanan, R. 2018.

References:

1. This section has drawn heavily from <https://csa.guide/> - <https://csa.guide/csa/what-is-climate-smart-agriculture>
2. FAO. 2013a. Climate-Smart Agriculture: Sourcebook. Rome, Italy: Food and Agriculture Organization of the United Nations. <http://www.fao.org/3/a-i3325e.pdf>
3. Deepika, Suchiradipta, B., and Saravanan, R. 2018. Climate Smart Agriculture towards Triple Win: Adaptation, Mitigation and Food Security. MANAGE Discussion Paper 5, MANAGE-Centre for Agricultural Extension Innovations, Reforms and Agripreneurship (CAEIRA), National Institute of Agricultural Extension Management, Hyderabad, India
4. <https://www.manage.gov.in/publications/discussion%20papers/MANAGE-Discussion%20Paper-5.pdf>

Chapter 4. Integrated Farming Systems

Modern farming systems depend heavily on bought inputs for fertilising and protecting plants. They also rely on the availability of petroleum products to operate farm machinery. Such farming is often a battle against nature and the resources available locally are neglected. This has led to the degradation of natural resources and resulted in climate change. Modern farming systems are also capital intensive so that poor small and marginal farmers are left behind.

Large scale specialised farming concentrates on maximising the productivity of a single/small number of crops. In such cases, byproducts generated by such farming are often regarded as waste. E.g., wheat stubble in Northern India is no longer fed to livestock. Farmers in their hurry to prepare land for the Kharif paddy crop, are forced to burn crop stubble leading to loss of soil nutrients and also air pollution. Small scale farming however is more amenable to the careful use of resources between different farm activities. After all, traditional farming was always integrated in the past.

Integrated Farming System (IFS)

IFS is a judicious mix of two or more farm enterprises having “minimum competition and maximum complementarity”. IFS aims to:

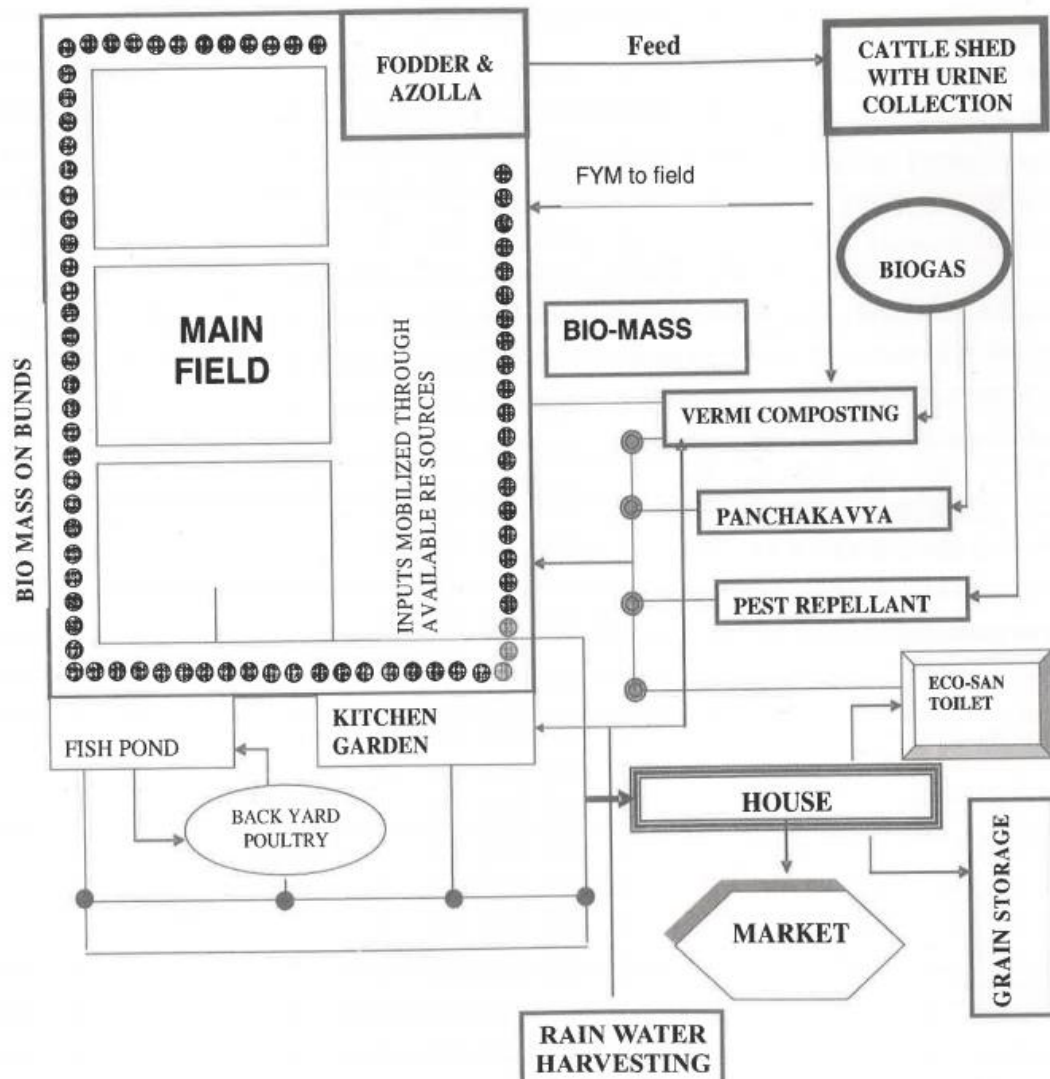
- maximise recycling of farm residues by using the recyclable output of one enterprise as input for another enterprise (e.g., in a duck-paddy-fish system - duck excreta becomes fertiliser for paddy fields or fish ponds, swimming ducks aerate fish ponds and ducks eat paddy pests like insects and snails)
- increase environment-friendly production, farm income and family nutrition
- creation and preservation of bio-diversity (for food, pest management, soil health, climate resilience)

It is possible to reach the same level of yield with proportionately fewer inputs in the integrated farming and the yield would be more sustainable, as the waste of one enterprise becomes the inputs of another. To put this concept into practice efficiently, it is necessary to study the linkages and complementarities of different enterprises in various farming systems.

Components of Integrated Farming System

1. Crops, livestock, birds and trees are the major components of any IFS.
2. Crop may have subsystems like monocropping, mixed/intercropping, multi-tier crops of cereals, legumes (pulses), oilseeds, forage, etc.
3. Livestock components may be milch cow, goat, sheep, poultry, bees, and fish.
4. Tree components may include timber, fuel, fodder and fruit trees.

Integrated Farm Development - Design



A schematic example of Integrated Farming Systems Design with several enterprises and resource cycling options.

(Source: MYRADA KVK (2008) Integrated Farm Development: Effective Utilisation of Farm, Home and Human Waste - A Users' Guide.

https://www.indiawaterportal.org/sites/default/files/iwp2/integrated_farm_development_users_guide_english.pdf

How do we select IFS components?

Farmers can mix and match different components of farming based resources available to them - such as land, labour and capital available for investment, climate, soil, crops, length of the growing period, social preferences and availability of extension and marketing support.

Some common activities that we can see in an IFS are:

- **Crops:** agro-forestry, Horti-pasture, roof-top gardening, kitchen garden, boundary/bund plantation, mushrooms

- **Livestock:** Dairy cattle, sheep, goats, poultry, fish, beekeeping, sericulture
- **Energy:** Biogas and fuelwood, pellets of crop residue, solar panels on water bodies
- **Soil, Nutrients and pest management:** vermicompost/compost/manure, bio-gas (slurry), compost yards, production of fermented crop growth promoters and pest repellents (like Panchagavya, jeevamrut, beejamrut, poochimarundu), eco-san toilets, biochar amendments.
- **Post-harvest and value addition:** small scale processing and value addition of marketable surplus produce.
- **Retail sales counters on the farm:** for farm produce
- **Farm tourism and training:** Hosting guests and those wanting to learn IFS in homestays.

The Four Primary Goals of an Integrated Farming System are to

- Maximise the yield of all components to provide steady and stable income
- Rejuvenate the system's productivity and achieve agroecological equilibrium
- Control insects, pests, diseases and weeds through natural cropping system management
- Reduce the use of chemical fertilisers and other harmful agrochemicals and pesticides to provide a pollution-free environment and healthy produce to the society at large.

Some Prototypes of IFS models are described below:

- The Indian Council of Agricultural Research through the Indian Institute of Farming Systems Research, Modipuram, in association with ICAR institutes, have developed 60 prototype IFS models which are suitable for 26 Indian States and Union Territories.
- These IFS models have the potential to increase the farm incomes by 2.5 to 5 times than existing systems/practices of farmers over a period of 3 to 4 years
- IFS can be started with a one-time capital investment ranging from Rs 2.2 to 4.6 lakhs/ha on-farm infrastructure (farm development, livestock sheds, purchase of large animals, farm ponds, bio-gas, composting units, etc.) depending upon the location and modules integrated is required.

Promising prototype IFS models developed for various ecosystems are given below.

Reference location of prototype IFS model	Eco-system Type	Net income with existing systems (Rs/ha/ye ar)	Promising tailor-made prototype IFS components	Net income (Rs/ha / year)	Improve ment in net income (Number of times)
SK Nagar - Gujarat	Arid	87,743	Cropping systems, arid horticulture, buffalo, farm pond, boundary plantation	3,61,416	4.1

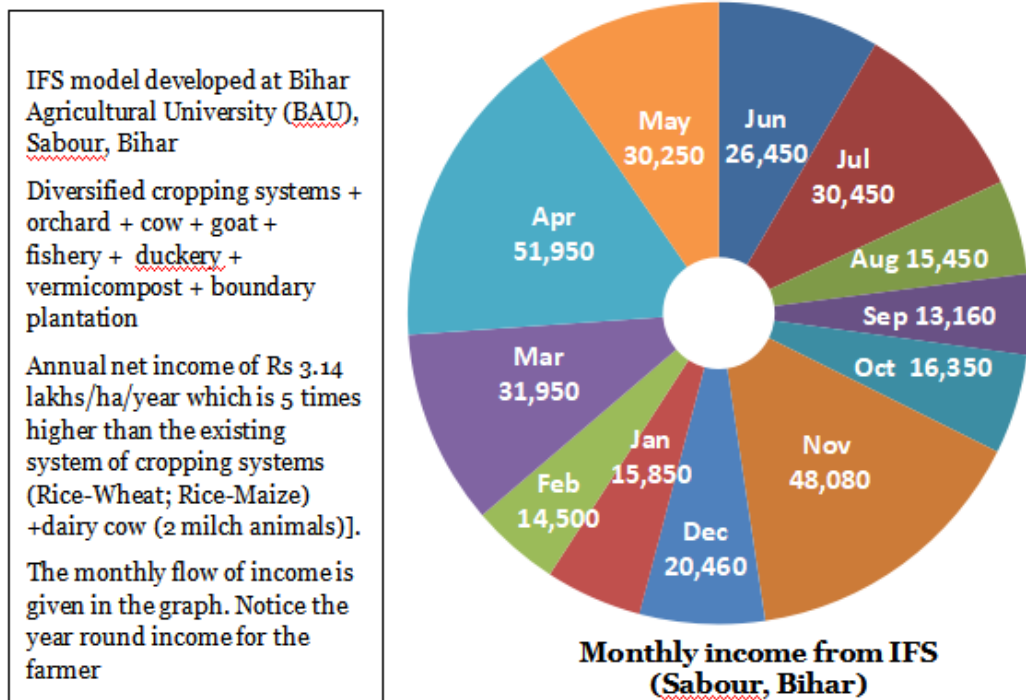
Varanasi -Uttar Pradesh Siruguppa - Karnataka Rajendranagar - Telangana Thanjavur - Tamil Nadu Pantnagar -Uttarakhand	Semi Arid	74,254	Cropping systems, horticulture, Cow, buffalo, back yard poultry, goat/sheep, fishery, Mushroom, Boundary Plantation, farm pond	2,76,396	3.7
Jabalpur - Madhya Pradesh Raipur - Chhattisgarh Ranchi - Jharkhand Sabour - Bihar Jammu - Jammu & Kashmir Jorhat - Assam	Sub humid	66, 919	Cropping systems, horticulture, cow, goat Poultry, duckery, Fishery, Mushroom, Apiary, Biogas, boundary plantation, Agro-forestry	2,46,875	3.7
Umiam - Meghalaya Bhubaneswar - Odisha Goa - Goa Port Blair - Andaman & Nicobar Islands	Humid	57,619	Cropping systems, Horticulture Cashew, coconut with pine apple, arecanut + banana, cow, pig, Poultry, fishery, duckery, Boundary Plantation, land configuration based systems	2,08,134	3.6

From: Panwar, A.S. et. al. (2021)

Complementary benefits of IFS

The major complementary benefits which can be achieved through implementation of IFS models are described below.

- Improvement in cropping intensity (up to 300 %)
- Due to recycling and re-use, market input costs can be saved which range from 30 to 72 % in different IFS models.
- The recycling of organic wastes generated within the farm results in the on-farm generation of nutrients to the tune of 134 kg N, 55 kg P₂O₅ and 106 kg K₂O /ha (on average).
- Soil organic carbon improves by about 22 % in 5 years while the microbial biomass carbon increases by 9% which ensures nutrient availability to crops from the soil.
- IFSs also increase the share of renewable energy (through biogas production and cooking biomass) and improves the system's energy efficiency.
- Water productivity is also improved due to the integration of advanced management practices in all the modules of farming systems and the effective recycling of water within the system. The water productivity ranges from 5.9 to 12.6 kg/m³ in various models which can be further enhanced with the integration of precision water management technologies.
- IFS provides an opportunity to create round the year income from own farm besides significant improvement in income.

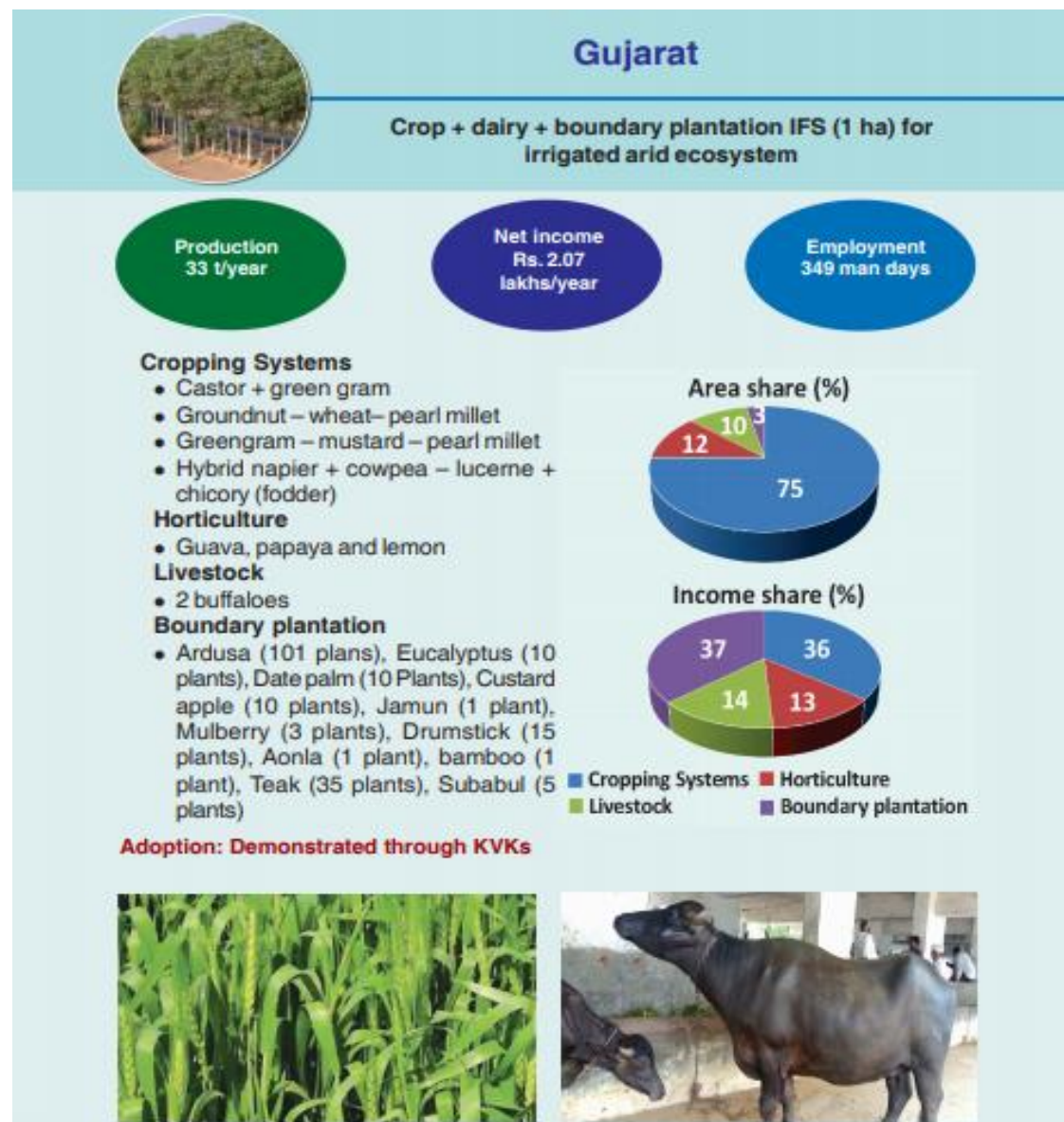


- IFS creates opportunities for year-round employment on farms due to the diversification and integration of various components (ranges from 400 to 950 man-days) ensuring a decent livelihood for the farm family. Around 2 to 3 persons can be employed within the farm and can easily address the out-migration issue at the village level.
- Local varieties of crops and breeds of livestock can be conserved besides improving their productivity.
- Integration of modules such as orchards, boundary plantations, agro-forestry, recycling units, biogas, etc. helps to reduce the emission of greenhouse gases from farming.

How can a Farmer Implement IFS models?

During the period of 2017-20, three states namely Jammu and Kashmir, Kerala and Tamil Nadu promoted the IFS models developed by ICAR-IIFSR, AICRP on IFS and AI-NPOF programmes with a financial outlay of 126.76 crores. Several farmers who have seen good results in IFS are often featured in farm magazines, television, radio and social media and their ideas can be useful.

Example of an integrated farming system for Gujarat state



Integration of schemes for Scaling-up: Different modules of Integrated Farming Systems can be scaled up by leveraging individual schemes under Centrally Sponsored and Central Sector Schemes of the Ministry of Agriculture and Farmers Welfare, Ministry of Fisheries, Animal Husbandry & Dairying and Ministry of Rural development and state government schemes.

References:

1. Tamil Nadu Agriculture University Agri-tech Portal: IFS:
https://agritech.tnau.ac.in/agriculture/agri_majorareas_ifs.html
2. MYRADA KVK (2008) Integrated Farm Development: Effective Utilisation of Farm, Home and Human Waste - A Users' Guide.
https://www.indiawaterportal.org/sites/default/files/iwp2/integrated_farm_development_users_guide_english.pdf
3. Panwar, A.S. & Ravisankar, Natesan & Singh, Raghuveer & Prusty, A K & Shamim, Mohammad & Ansari, Meraj & Noopur, Kohima. (2021). Potential integrated farming system modules for diverse ecosystems of India. *Indian Journal of Agronomy* 66 (5th IAC Special issue). 15-32.

Chapter 5: Integrated Pest Management and Integrated Nutrient Management

Integrated Pest Management (IPM)

Integrated Pest Management (IPM) is an environmentally friendly, common-sense approach to controlling pests. IPM arose as a response to the indiscriminate use of harmful chemical pesticides in farming. India has adopted Integrated Pest Management (IPM) as a 'National Policy' for crop protection since 1985.

“IPM is the careful consideration of all available pest control techniques and subsequent integration of appropriate measures that discourage the development of pest populations. It combines biological, chemical, physical and crop-specific (cultural) management strategies and practices to grow healthy crops and minimize the use of pesticides, reducing or minimizing risks posed by pesticides to human health and the environment for sustainable pest management.” FAO - IPM.

<https://www.fao.org/pest-and-pesticide-management/ipm/integrated-pest-management/en/>

Principles of IPM

Pest control on many farms involves the routine application of pesticides. IPM, Focuses on pest prevention and usage of pesticides only as needed. IPM programs take advantage of all appropriate pest management strategies, including the judicious use of pesticides. Preventive pesticide application is limited because the risk of pesticide exposure may outweigh the benefits of control, especially when non-chemical methods provide the same results.

Why do we need IPM in sustainable agriculture?

- **Sustainable pest control:** IPM uses predator-prey relationships existing in nature, and prevents the killing of beneficial insects like bees and mantises. IPM is used from seed selection to post-harvest levels.
- **Reduce pesticide residues:** many pesticides are not only harmful when sprayed but remain in the environment and accumulate in our bodies. By avoiding them we can ensure that our air, soil, water and food are all safe.
- **Enhances ecosystem services:** IPM methods do not kill indiscriminately unlike a harmful chemical pesticide. Predator insects which feed on pests are not killed. IPM conserves the underlying natural resource base (i.e. soil, water and biodiversity) and enhances ecosystem services (i.e. pollination by bees, healthy soils, diversity of species).
- **Increases income levels:** IPM reduces production costs through reduced levels of pesticide use. Higher quality crops (with fewer residues) can command better prices in markets and contribute to increased farmer profitability.

- **Strengthens farmer knowledge:** IPM encourages the farmer to be a keen observer of his/her environment, watch the behaviour of pests and predators and take more informed actions than merely buying a can of pesticide in the local market.

Which are some common IPM Practices?



There is a wide variety of techniques that can be applied under the IPM approach. The use of individual techniques depends on various factors, including crop type, cropping system, pest complex, climatic and agro-ecological conditions, financial resources available, easy access to IPM resources, etc. Farmers need to use more than one method in IPM. Categories of IPM methods and some examples are given below:

1. **Cultural practices** - pruning plants with clean sharp tools, crop rotation
2. **Mechanical practices** - hand picking of pests, setting up sticky traps
3. **Genetical practices** - selecting disease-resistant planting material, releasing sterile males
4. **Regulatory practices** - such as quarantine of plant material
5. **Biological practices** - use of pathogens, parasites and predators to control pests
6. **Chemical practices** - use of chemicals - pheromones, growth regulators, pesticides

Some common activities are mentioned below:

- **Pest Monitoring activities:**
 - Trapping insects (e.g. pheromone trapping, sticky traps, water traps)
 - Counting eggs, larva/nymphal instars, pupae, adults (sweep nets) etc.
- **Prevent the buildup of pests or decrease their pest status** (using the monitoring activities and taking action before the pest problem becomes serious)
 - Selecting pest-resistant or highly competitive crop varieties
 - Field sanitation (disease and pest free), use of quality seeds and seed

- bed sanitation
- Crop rotation
- Inter-cropping
- Management of sowing, planting or harvesting dates
- Water/irrigation management (reducing stress to plants due to over/under irrigation)
- Soil and nutrient management (including mulching, zero/low tillage, fertilizer management, proper irrigation)
- **Controlling existing pests**
 - Hand-picking of pests or hand-weeding
 - Setting up Traps or planting trap crops (which attract the pest thus saving the main crop)
 - Mechanical/physical controls (including barriers/nets, crushing devices and use of heat)
 - Post-harvest loss prevention (using traps, managing relative humidity, sanitation of storage facilities)
- **Manage pest populations using biological inputs:** In nature the population of harmful pests is kept under control when they are eaten by other animals (predators), repelled by others (competitors), affected by viral/bacterial or fungal diseases or destroyed by other animals which are parasites on the pests (parasitoids) . IPM uses these other organisms to keep pest numbers under control. Biological pest control agents are naturally occurring agents that are distinguished from conventional chemical pesticides by their unique modes of action, low use volume, and target species specificity.
 - Biological control through release of predators, parasites or pathogens (bacterial, viral, fungal, wasps)
 - Biological control through fish, ducks, geese, goats, etc.
 - Release of sterile male insects (so the next generation is not born)
 - Bio-pesticides
 - Biological preparations (e.g. natural plant extracts - like neem oil, chilli-garlic solution (Agni Astra))
- **Manage pest populations using chemical inputs**
 - Chemicals that disrupt insect behaviour (e.g., pheromones in traps)
 - Induced resistance activating compounds - the use of chemicals (natural or artificial) to increase plant immunity
 - Growth-regulators (insect growth regulators disturb how an insect develops and control pest populations - e.g., neem extract is a naturally occurring growth regulator)
 - Conventional pesticides (this is the last resort)



References

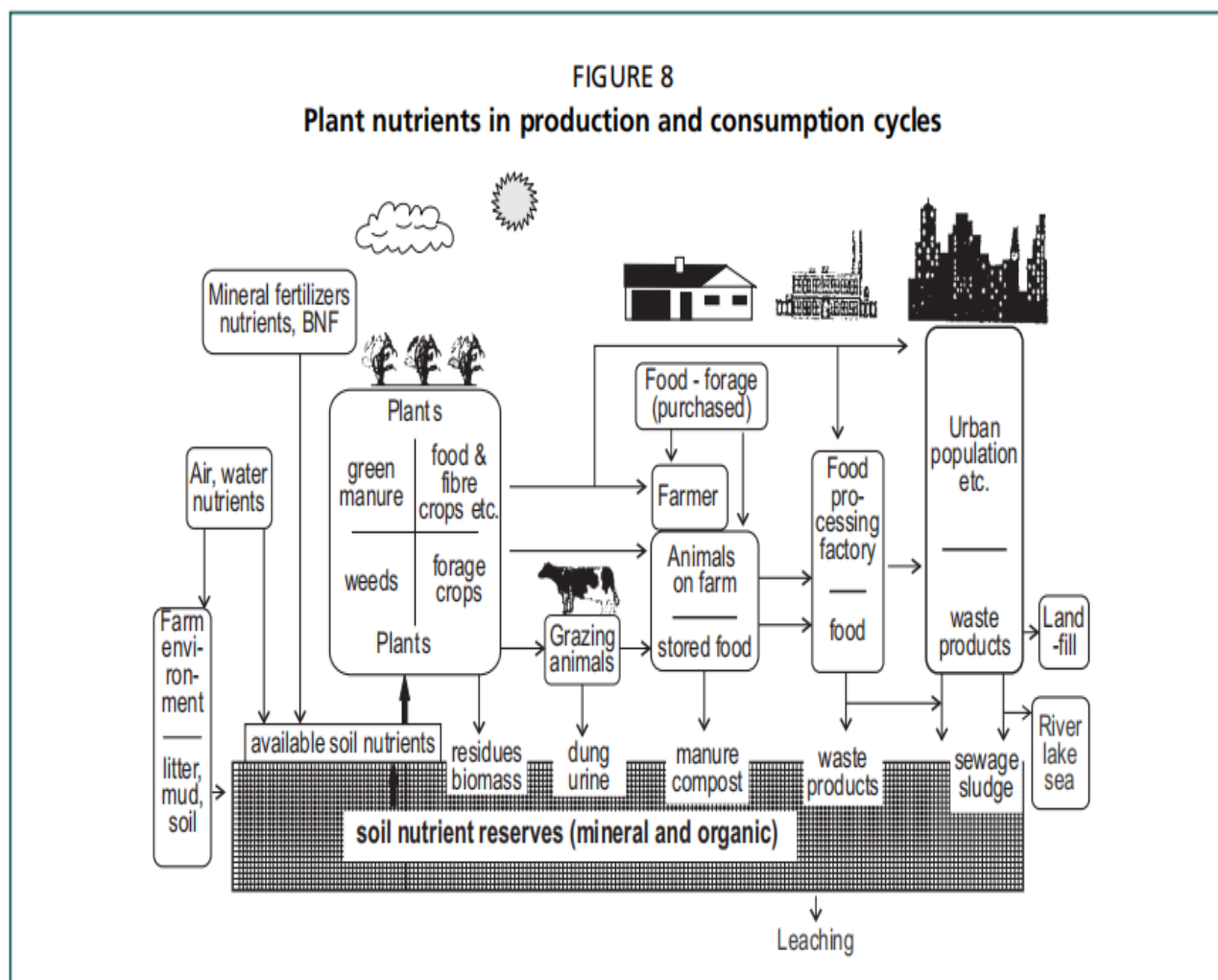
1. For an overview of IPM: <https://www.fao.org/pest-and-pesticide-management/ipm/integrated-pest-management/en/>
2. For crop-wise IPM practices in many Indian languages: <https://ncipm.icar.gov.in/technical-bulletins.aspx>
3. For detailed reference notes on IPM: <https://diragri.assam.gov.in/portlet-innerpage/integrated-pest-management-ipm> and
4. https://diragri.assam.gov.in/sites/default/files/swf_utility_folder/departments/diragri_medhassu_in_oid_4/portlet/level_2/Crop%20protection%20under%20oIPM.pdf

Integrated Nutrient Management

Modern day farming is heavily dependent on artificial inorganic fertilisers to grow crops. Integrated Nutrient Management (INM) is a practice that combines old and modern techniques of fertiliser use and nutrient management. INM aims to maintain soil fertility and plant nutrient supply at an optimum level for sustaining crop productivity. INM utilises a wide range of sources of organic, inorganic and biological components in an integrated manner.

Why does the world need integrated (plant) nutrient management?

Research has proven that the soil is not merely a growing medium but is alive with bacteria, viruses, fungi and many small creatures. The life in soil develops a symbiotic relationship with plants through their roots. Heavy use of synthetic fertilisers, fueled by fertiliser subsidies has reduced the natural fertility of soil while polluting both surface and groundwater. Such soils are prone to erosion and with the increasing price of fertilisers in the international market - farm productivity and food security are at risk. At the same time, a lot of organic matter that can add to soil nutrients is not cycled back to farms as they may be burnt, dumped in urban garbage landfills or released into rivers where they cause pollution. Figure: FAO (2006) Plant Nutrition for Food Security Page 20



Source: Finck, 1992.

Soil is a great reservoir of carbon and enabling the soil to absorb more greenhouse gases is an important climate change mitigating strategy. For soil to sequester carbon, farmers need to adopt ecologically sound farming practices - and Integrated Nutrient Management offers solutions.

Objectives of Integrated Nutrient Management

“Integrated Plant Nutrient Management aims to optimize the condition of the soil, with regard to its physical, chemical, biological and hydrological properties, for the purpose of enhancing farm productivity, whilst minimizing land degradation.” FAO

<https://www.fao.org/agriculture/crops/thematic-sitemap/theme/spi/scpi-home/managing-ecosystems/integrated-plant-nutrient-management/ipnm-what/en/>

The Objective of INM

- Maintenance of soil fertility,
- Sustainable agricultural productivity and
- Improving profitability through judicious and efficient use of organic and inorganic fertilisers as mentioned.

Basic principles of sustainable INM

- Nutrients removed by crops must be returned to the soil.
- Soil physical conditions should be maintained and upgraded.
- Organic carbon levels of soils should be maintained and enhanced.
- The build-up of abiotic stress should be minimal.
- Degradation of land occurring due to soil erosion must be controlled.
- Soil quality with respect to soil acidity, salinity and sodicity or toxic elements

How to work out an INM System for a farm?

- Nutrient requirement of cropping system as a whole.
- Soil fertility status and special management need to overcome soil problems if any
- Local availability of nutrients resources (organic, inorganic and biological sources)
- Economic conditions of farmers and profitability of the proposed INM option.
- Social acceptability.
- Ecological considerations.
- Impact on the environment

Advantages of INM

- Enhances the availability of applied as well as native soil nutrients
- Synchronises the nutrient demand of the crop with nutrient supply from native and applied sources.
- Provides balanced nutrition to crops and minimises the antagonistic effects resulting from hidden deficiencies and nutrient imbalance.
- Improves and sustains the physical, chemical and biological functioning of the soil.

- Minimises the deterioration of soil, water and ecosystem by promoting carbon sequestration, reducing nutrient losses to ground and surface water bodies and to the atmosphere

Sources of nutrients

- **Soil Source:** Mobilising unavailable nutrients and using appropriate crop varieties, cultural practices and cropping system.
- **Mineral fertiliser:** Super granules, coated urea, direct use of locally available rock PO₄ in acid soils, Single Super Phosphate (SSP), Muriate of Potash (MOP) and micronutrient fertilisers.
- **Organic Sources:** By-products of farming and allied industries, farmyard manure, droppings, crop waste, residues, sewage, sludge, industrial waste, and green manures.
- **Biological Sources:** Microbial inoculants for seeds and soil - like nitrogen-fixing and phosphobacteria

Constraints in applying INM

- INM approaches do not show quick results to crop harvests as purely artificial fertilisers do. This can discourage a farmer whose livelihood depends on a threshold output.
- INM is sensitive to changes in climatic conditions and could produce negative effects if soil and crop nutrients are not monitored systematically and changes to fertilizer practices are made accordingly.
- In the case of small-scale farmers, the cost of fertilizers may represent too high a proportion of the total variable cost of production thus ruling out certain inputs as a feasible option.
- INM requires higher and more skilled labour inputs which may be in short supply.

References:

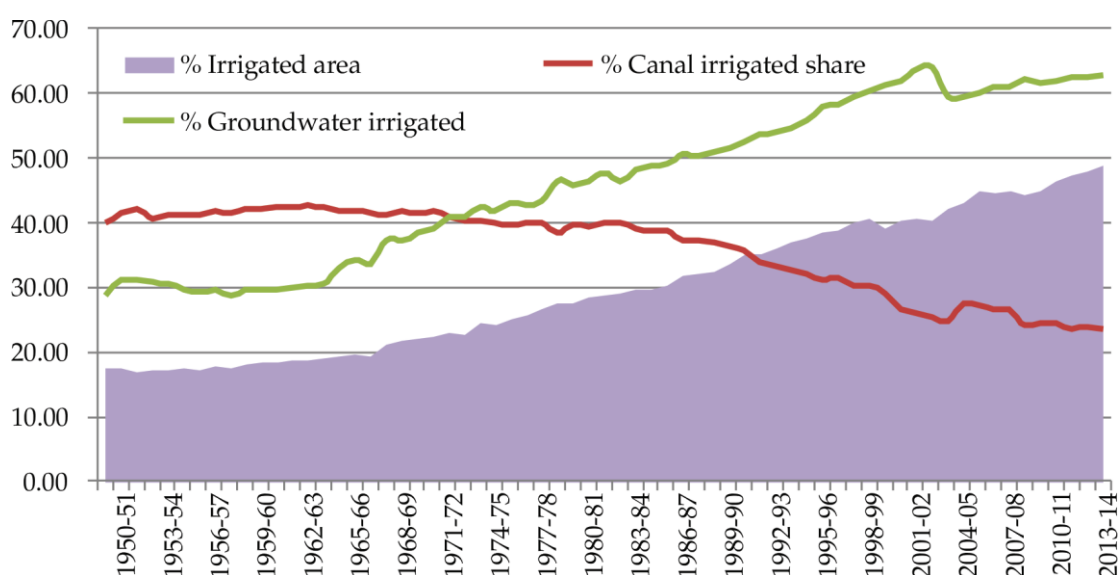
- https://agritech.tnau.ac.in/agriculture/agri_nutrientmgt_integrntrientmgt.html
- IPNM - FAO: <https://www.fao.org/agriculture/crops/thematic-sitemap/theme/spi/scpi-home/managing-ecosystems/integrated-plant-nutrient-management/ipnm-what/en/>
- Vinay, G., Rahitha, G., Shashikanth, M., Reddy, K. K. K., Kumar, E. A. and Jhonson, S. 2020. Integrated Nutrient Management (INM): Meaning, Principles, Goals and Components. Vigyan Varta 1(6): 32-35
https://vigyanvarta.com/adminpanel/upload_doc/VV_1020_11.pdf
- FAO (2000). Guidance and Reference Materials on Integrated Soil and Nutrient Management and Conservation for Farmer Field Schools. FAO. Rome.
<https://www.betuco.be/voorlichting/Guidelines%20on%20integrated%20soil%20and%20nutrient%20management%20and%20conservation%20for%20FFS%20FAO.pdf>
- FAO (2006) Plant Nutrition for Food Security: A guide for integrated nutrient management
https://www.fao.org/fileadmin/templates/soilbiodiversity/Downloadable_files/fpn16.pdf

Chapter 6: Managing Water Efficiently

More Crops per Drop with Sprinkler Irrigation, Drip irrigation and Fertigation

India has 17% of the global population, 2.4% of the land and 4% of freshwater resources. The Southwest Monsoon delivers most of the rainfall – 76 per cent of it in India, between June and September every year. More than half of the rainfall is received in about 100 hours within around 2 weeks of this rainfall. With our rising population per capita availability of average utilisable water resources, which was 5,247 m³ in 1951 is expected to dwindle to 1139 m³ by 2050 (CWC, 2015). Therefore, efficient utilisation of available water resources is crucial for the lives, livelihoods and food security of India's population.

Most of the water in India is used by agriculture - 80% of it. Groundwater irrigates over 60% of irrigated farmlands and of this only 50% is used by plants and the remaining water resources are wasted either as deep percolation or as evaporation. Groundwater levels are unfortunately depleting. Even though India is a leader in irrigation infrastructure, nearly half of the cropped area remains rainfed. While groundwater is being drawn out unsustainably on Northwest India available resources are under-utilised in the East.



Irrigation trends since 1950-51 (Source: based on data from DES, 2017-18); % Irrigated area: Net Irrigated area to net sown area; % Groundwater irrigated: Groundwater irrigated area share in net irrigated area; % Canal irrigated: Canal irrigated area share in net irrigated area (Source Rajni Jain et al (2019))

When should farmers irrigate their crops?

Adequate water supply is important for plant growth. When rainfall is not sufficient, the plants must receive additional water from irrigation. Optimal soil moisture for plant growth varies with the stage of crop growth. Certain periods during crop growth and development are most sensitive to soil moisture stress compared with others. These periods are known as **moisture-sensitive periods**.

Critical stages of crop growth: The term critical period is commonly used to define the stage of growth when plants are most sensitive to a shortage of water. Inadequate water supply during moisture-sensitive periods will irrevocably reduce the yield and provision of adequate water and other management practices at other growth stages will not help in recovering the yield lost. In the case of vegetables, when they are young, though plants transpire less water, need a stress free moisture condition because of the very weak root system which is sparsely distributed and located in the upper 15-20 cm layer of soil that gets quickly dried. Vegetable crops utilise and transpire more water in the later stages of growth during which moisture stress markedly reduces yield.

Critical soil moisture periods of certain crops

Vegetable Crops	Available soil moisture (%)	Critical soil moisture stage of crops
Chillies	50	Tenth leaf to Flowering and fruit development and after periodical harvests
Potato	65	Stolon formation, Tuberisation and tuber enlargement
Onion	60	Bulb formation and bulb enlargement
Tomato	60	Flowering and Fruit development and each harvest
Peas	70	Flowering and pod formation
Cauliflower	70	Curd formation and enlargement
Cabbage	60	Head formation and enlargement
Brinjal	50	Flowering and fruit development and after each harvest
Cucumber	50	Flowering and fruit development
Bhendi	45	Flowering and pod development
Leafy vegetables	70	Entire crop duration
Fruit crops	50	For fruit crops 50% Available soil moisture is taken as critical limit
Citrus	50	Flowering, fruit set, fruit growth
Banana	50	Early vegetative period flowering and fruit formation
Mango	50	Start of fruiting to maturity
Pineapple	50	Vegetative growth
Grape	50	Vegetative growth.
Guava	50	Frequent irrigation during the vegetative growth stage may cause rotting of fruits
Ber	50	A drought-resistant plant; irrigation is required during fruit growth

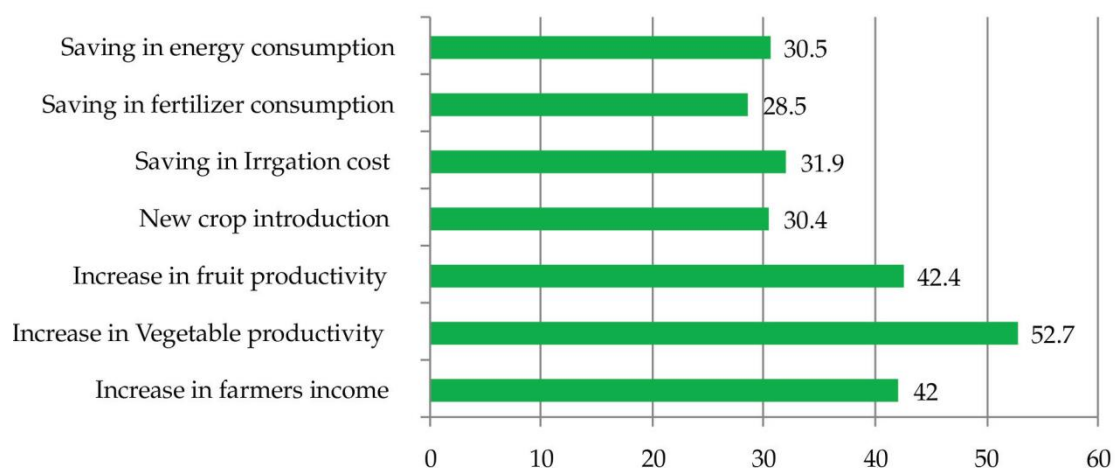
All the stages of plant growth are equally sensitive to soil moisture stress for crops where vegetative parts are of economic importance. The total growth and yield of perennial plants is the sum of the effects of stress at each growth stage. However, adequate water supply is essential at flower bud initiation, flowering and fruit set. Flower bud formation, however, increases due to restricted water supply before flower bud initiation in the case of citrus and mango.

For realising maximum benefit from the scarce irrigation water, irrigation is to be scheduled at moisture-sensitive periods by withholding irrigation at other periods of lesser sensitivity. Such irrigation schedules along with improved practices **increase the water-use efficiency in crop production.**

What Methods of Irrigation should a Farmer Use?

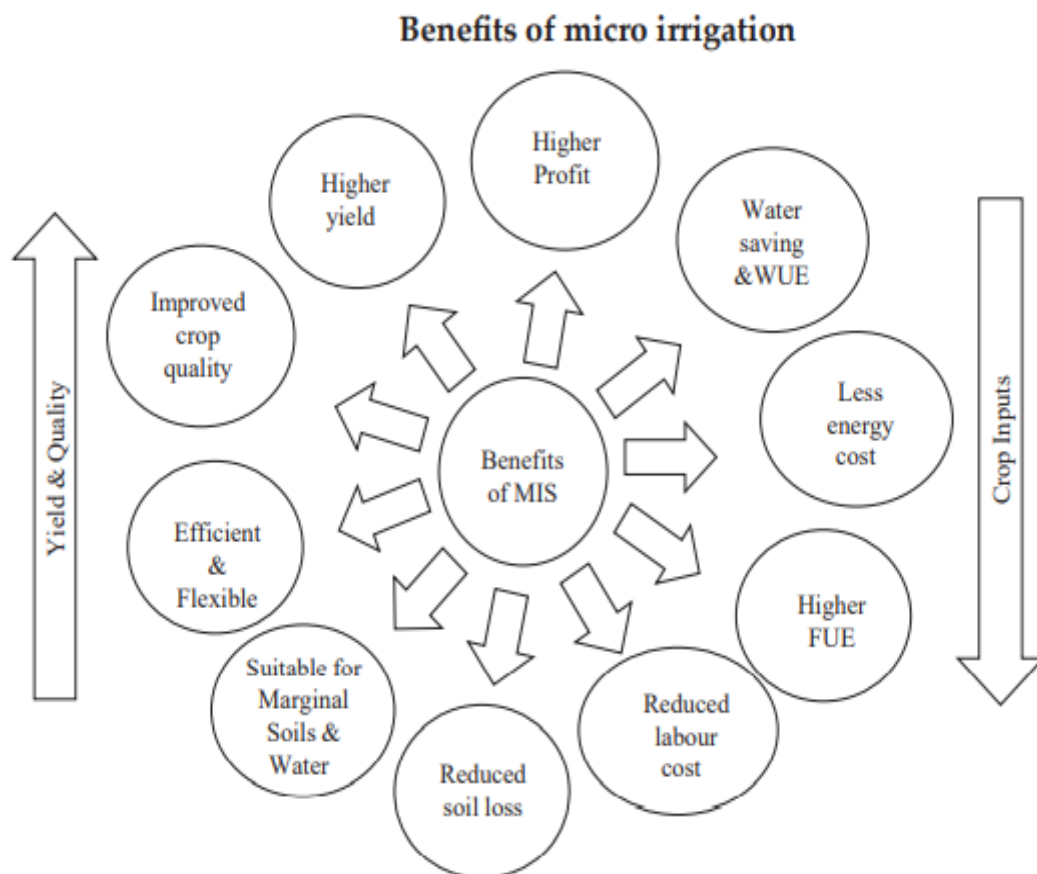
- **Surface irrigation/flood irrigation:** here irrigation water flows overland - either flooding the entire field (basin irrigation) or flowing in channels between crops (furrow irrigation). This is the way humanity has irrigated its fields since ancient times. The water use efficiency of surface irrigation is unfortunately only around 30-70%. In other words as much of 70% of water is wasted in some cases.
- **Micro-irrigation:** Micro-irrigation is a modern method of irrigation; by this method, water is irrigated through drippers, sprinklers, foggers and other emitters on the **surface or subsurface** of the land. Unlike surface irrigation - the water use efficiency of micro-irrigation ranges from 60 to 95% - which means in the best case only about 5% of water is wasted. Micro-irrigation is an important solution to water shortages and the need for irrigation.

The overall efficiency of the flood irrigation system range between 25-40%. Micro-irrigation shows superiority over other traditional irrigation methods in terms of water use efficiency, energy-saving, yield increase and net return per unit volume of groundwater. To meet the food security, income and nutritional needs of the projected population in 2050, the food production in India will have to be almost doubled. Therefore, water conservation and improvement in water-use efficiency to achieve “More Crops per Drop” is of paramount importance. The figure below shows the multiple benefits for farmers after adopting micro-irrigation.



Impact of Micro-Irrigation on beneficiaries - % change:

(Source: National Mission on Micro Irrigation Impact study prepared for the GoI, 2014); the per cent change figures are according to a survey of 5,892 beneficiaries of NMMI across 13 states. Rajni Jain et al (2019))



We will review three major forms of micro-irrigation here

1. Sprinkler Irrigation
2. Drip irrigation and
3. Fertigation - the delivery of plant nutrients in irrigation water.

Sprinkler irrigation

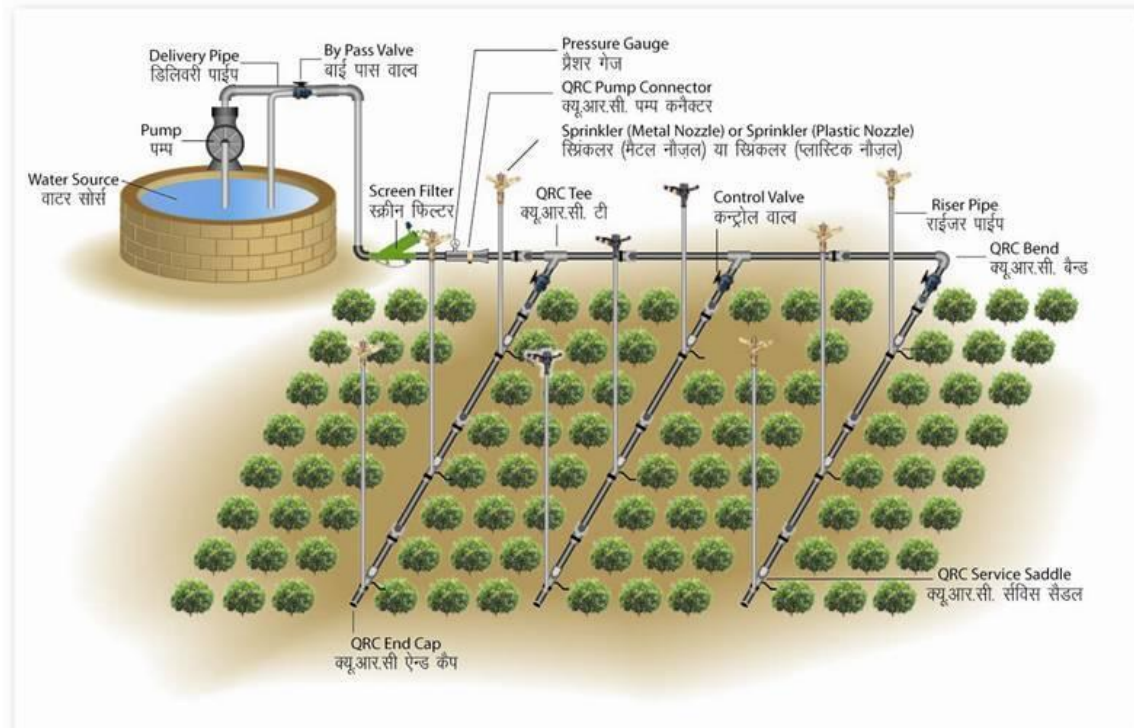
In a sprinkler system, water is pumped through a sprinkler head/nozzle and applied above the ground surface in the form of spray resembling rainfall. Sprinkler irrigation is suited for most row, field and tree crops and water can be sprayed over or under the crop canopy. However, large sprinklers are not recommended for irrigation of delicate crops such as lettuce because the large water drops produced by the sprinklers may damage the crop.

A typical sprinkler system consists of the following four components

1. **Pumping unit:** The type of pumping unit for the sprinkler system depends on the source of irrigation water. Both vertical turbine and centrifugal pumps can be used. Booster pumps may be necessary to develop the required pressure in the case of centrifugal pumps - so that even the distant sprinkler units will have adequate pressure.
2. **Mainline:** Mainlines may be permanent or portable depending upon the situation.
3. **Lateral pipes:** Lateral lines are usually portable for movement after each setting. Lightweight aluminium pipes can be conveniently used for mains

and laterals. Quick setting couplers enable the movement of laterals quickly during irrigation.

4. **Sprinkler unit:** There are different types of sprinkler heads and they can be chosen based on end-use and cost. e.g., Rotating Heads and Nozzle Lines. Some rotate automatically, others have to be manually rotated.



Layout of Sprinkler Irrigation System (छिड़काव सिंचाई प्रणाली का रेखाचित्र)

Image source Vikaspedia: <https://vikaspedia.in/agriculture/agri-inputs/farm-machinery/sprinkler-irrigation-system>

Impact of sprinkler irrigation on yield and water efficiency on different crops

Crop	Water saving (%)	Yield increase (%)
Bajra	56	19
Barley	56	16
Bhendi	28	23
Cabbage	40	3
Cauliflower	35	12
Chillies	33	24
Cotton	36	50
Cowpea	19	3
Fenugreek	29	25
Garlic	28	6
Gram	69	57
Groundnut	20	40
Jowar	55	34
Lucerne	16	27

Maize	41	36
Onion	33	23
Potato	46	4
Sunflower	33	20
Wheat	35	24

Micro Sprinklers

Micro sprinkler irrigation is a low pressure, low to medium volume irrigation system suitable for high-value crops. It saves water because of the high application efficiency and high water distribution uniformity. Micro sprinklers are a great choice when a larger volume of water is needed than standard drip emitters can provide. These low volume sprinkler heads are ideal for watering flowers and shrubs. The flow rates for micro sprayers range from 20 litres to 250 litres per hour.

Foggers

Foggers and Misters are used in protected agriculture - greenhouses, polyhouses and shade nets to maintain humidity or temperature control. Fogging is a system that changes the environment in a short period and provides the moisture needed by the plants. The fogging system in a greenhouse includes incorporating a large number of micro water particles into the ambient air, which remains suspended in the air inside the greenhouse long enough to evaporate without wetting the crops. The water is added in the form of fog using a special nozzle distributed uniformly all over the surface of the greenhouse.

Drip irrigation

Among all irrigation methods drip irrigation is the most efficient. Drip irrigation results in a very high water application efficiency of about 90-95 per cent. Drip irrigation can be used for vegetables, orchard crops, flowers and plantation crops. In drip irrigation, water is applied near the plant root through narrow pipes - emitters or drippers, on or below the soil surface, at a low rate varying from 2 to 20 litres per hour. The soil moisture is kept at an optimum level with frequent irrigation.

Water is conveyed under pressure through a pipe system to the fields, from where it is discharged slowly or at a pre-designed rate through emitters or drippers that are located close to the root zone of the plants.

A typical drip irrigation system consists of the following components:

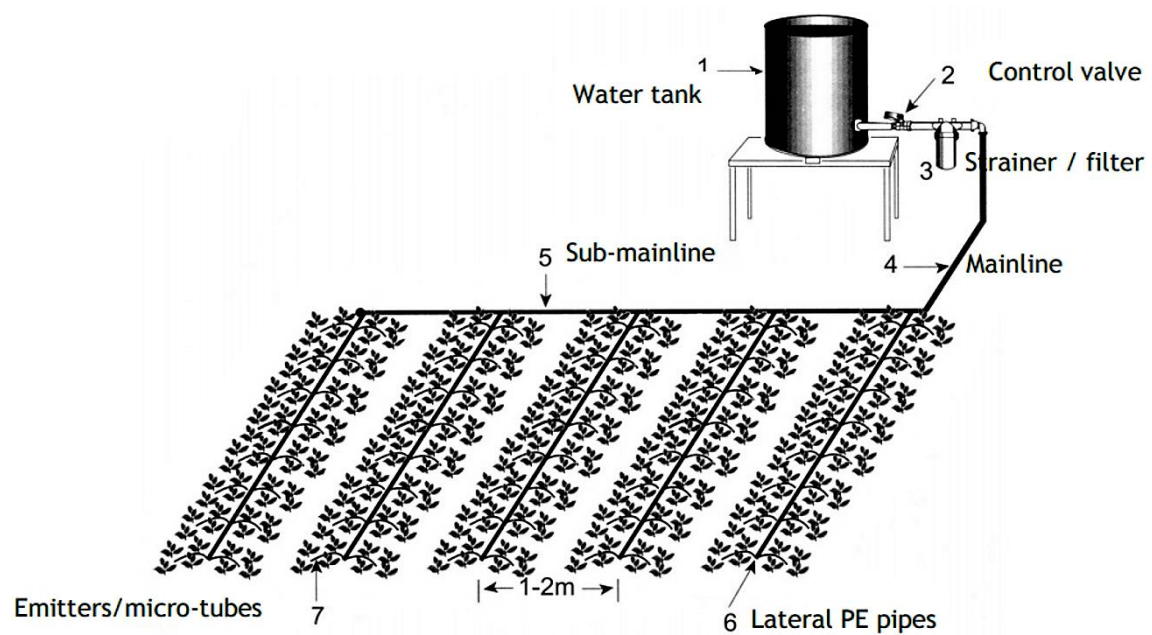
1. Pump unit
2. Control unit
3. Filtering unit
4. Mainline and sub-mainlines
5. Laterals
6. Emitters

Small farmers can adopt a low-cost drip irrigation system with a water tank at

elevation and using gravitational force in place of a pressure pump as indicated below.



Low-cost Drip Irrigation System: Bucket Kit <https://ide-india.org/content/kb-bucket-kit>



Schematic design of a low-cost drip irrigation system. Source: (RCSD 2008)

Drip Irrigation increases crop yields while reducing water use

Crop	Yield increase (%)	Water saving (%)
Mango	80.0	34.8
Banana	52.0	45.0
Grapevine	23.0	48.0
Pomegranate	98.0	45.0
Tomato	50.0	39.0
Watermelon	88.0	36.0
Sugarcane	133.3	49.3
Cotton	88.0	46.6
Onion	53.8	46.1
Potato	79.5	54.1
Lady's finger	16.0	40.0
Brinjal	14.0	53.0
Chillies	44.0	62.0
Papaya	75.0	68.0

Potential of adoption of micro-irrigation in India

The Government of India has actively promoted micro-irrigation. During the Central Sector Scheme on MI in 2005-06, the area covered under micro-irrigation was 2.24 Mha. It has increased to 11.41 Mha in 2018-19. Of the total coverage (11.41 Mha), sprinkler systems constituted 53.1% share and the remaining 46.9% of the area was covered under drip systems in 2018-19. Five states, namely Andhra Pradesh, Gujarat, Karnataka, Maharashtra and Rajasthan contribute three-fourths of the total area covered under MI and 11.8% of the gross irrigated area (96.75 Mha) in the country is covered under micro-irrigation. This shows that there is a great potential to increase coverage under micro-irrigation. As per the policy paper of ICAR on Potential, Adoption and Impact of Micro Irrigation in Indian Agriculture, the existing estimates of the potential area under sprinkler irrigation vary from 30.5 Mha to 51.1 Mha, while the potential area under drip irrigation ranges from 11.7 Mha to 27.0 Mha.

To focus on micro-irrigation and for convergence of investments in the irrigation sector at the farm level, the GoI launched PMKSY on 1st July 2015. The PDMC (per drop more crop) component of PMKSY focus on the promotion of micro-irrigation. The indicative cost for drip and sprinkler irrigation is mentioned in the revised guidelines of PMKSY. For example, the cost of drip irrigation varies from Rs.21,643 to Rs.1,12,237/ha depending on spacing.

(<https://pmksy.gov.in/microirrigation/Archive/GuidelinesMIRevised250817.pdf>).

There are several suppliers of micro-irrigation equipment in India and even low-cost units are available for small and marginal farmers.

Case: Solar Powered Drip Irrigation System



The Gosaba Island of Indian Sundarbans is surrounded by tidal rivers connected to the Bay of Bengal. Farmers in Gosaba are unable to grow Rabi crops due for two reasons. Tidal rivers bring water of high salinity (more than 30 dS/m) and good quality groundwater is also unavailable for irrigation due to various technical reasons. Farm ponds which harvest the rainwater during monsoon are the only source of water for irrigation in the post-monsoon period. Under the CSI4CZ project, solar-powered drip irrigation technology was introduced in Gosaba which cost Rs. 1.66 lakhs.

The project analysed weather data for Gosaba. The average bright sunshine hours (BSH) during the Rabi season is 7-9 hours a day. This is sufficient to harness solar energy for use in agriculture. Under this technology, solar panels were installed near the farm pond and a nano pump (0.1 hp) was used to lift water from the farm pond to a 1000 litre capacity tank. The tank was placed at 2.5 m height on a platform. During the daytime, water is lifted to the tank and the stored water is applied to high-value vegetable crops through gravity-fed drip irrigation. The field was divided into different plots, each plot was controlled by a valve, which facilitated crop diversification.

The solar drip system was installed on the farm of Shri Nitai Hari Mandal in 2017. He cultivated cucumber, bitter gourd and okra during Kharif season by providing supplemental irrigation during deficit rainfall period. From October 2017, he planted chilli, knol-kohl and Okra. knol-kohl and okra were harvested in January 2018. The Chilli crop continued till May 2018 and the farmer earned a regular income by selling both green and dried chillies. After the harvest of knol-kohl and okra, the farmer planted bitter gourd. Thus, he was able to grow vegetables round the year using solar-powered drip irrigation.

The system's effectiveness was enhanced through different mulching materials such as paddy straw, black plastic and white plastic for controlling the weeds and conserving the soil moisture. The yield of vegetables was very promising under black plastic mulching and the crop was free from weed infestation.

The farmer increased cropping intensity by 300%, saved 40-60% of irrigation water, saved 40% of labour costs and saw yield increases of 20-30% than through conventional means. Soil salinity was lower than in unirrigated areas. The economics of the cultivation under a solar drip system for an area of 725

m² indicated that the system is quite profitable in terms of gross return (Rs. 25,679), net return (Rs. 13,876) and output-input ratio. (from Mahanta, K et al (2019))

Fertigation

“Fertigation” is a word of recent origin and is a combination of clipped words of fertiliser and irrigation. So also this method combines the application of water and plant nutrients affecting both water and fertilisers saving and enhancing yields and quality of crops simultaneously.

Advantages of Drip Fertigation

1. Improves efficiency in fertiliser use. A farmer can achieve the same crop yield using 60-80% of the recommended dose of fertilisers in water-soluble form as obtained with the application of 100 per cent straight fertilisers.
2. High nutrient availability due to maintenance of soil moisture near field capacity under drip irrigation.
3. Fertilisers could be applied as frequently as possible and at those stages of crop growth when the demand is maximum - rather than in one go.
4. Higher water use efficiency and 30-40% water savings.

Qualities of Fertilisers used in Fertigation

- Must be completely and quickly soluble in water (< 0.02% insoluble in water) with minimum conditioners/additives.
- Must not react with dissolved elements in water especially calcium and magnesium salts.
- High nutrient content in the saturated solution must not get leached down easily from the soil.
- Should not change the pH of water leading which can precipitate or clog the system.
- Should not corrode the system.
- Should be safer for field use and for mixing with other chemicals.

Good Sources of Nutrients for Fertigation

1. **Nitrogen:** Urea, ammonium nitrate and ammonium sulphate nitrogenous fertilisers in solid form and under saturated liquid form.
2. **Phosphorus:** Generally the application of phosphatic fertilisers through the drip irrigation system is not recommended as a basal application of phosphorus generally satisfies the plant P needs.
3. **Potassium:** potassium sulphate, potassium chloride, potassium nitrate and monopotassium phosphate - these are soluble in water and do not cause any precipitation problem.
4. **Liquid fertilisers:** Liquid fertilisers contain one or more plant nutrients including micronutrients. Raw materials used in liquid fertiliser production

are mainly bulk fertilisers - ammonium sulphate, ammonium nitrate, urea, ammonium phosphate, phosphoric acid, potassium nitrate, potassium chloride, potassium sulphate etc. The liquid fertilisers are pure and do not precipitate. Normally the liquid fertilisers are acidic (pH 5.5-6.5) and help in correcting the soil pH to some extent and also help in the prevention of clogging of emitters. For acidic soils, liquid fertilisers with neutral pH or even higher pH could be used.

Precautions to be taken during fertigation

- Perfect design of irrigation system. Every emitting point must deliver the same volume of water.
- The material used must be free from deposits or residues and must not corrode the system.
- Constant operating pressure to facilitate uniform mixing of water and fertilisers.
- Selection of the most appropriate fertiliser, injection system and crops for fertigation.
- fertiliser injection should not begin until all lines are filled with water and emitters are working.
- The drip irrigation system should be allowed to its working pressure before fertiliser injection.
- Fertilisers/pesticides/chlorine should not be injected at the same time.

Time of application

The frequency of fertigation is governed by the nature of the crop, duration, growth habit and yielding ability. Generally, fertigation is done daily, weekly, or fortnightly and can be considered depending on crop response.

Fertigation equipment

Additional equipment must be attached to conventional micro-irrigation systems to use them for fertigation.

1. Pressure differential method or By-pass tank system
2. Venturi or vacuum pump
3. Displacement pump
4. Hydraulic dosing pumps or non-electric proportional injectors

Precautions while using fertigation:

- Farmers must carefully manage and monitor the fertigation process and ensure that all equipment is maintained well. Otherwise, the following problems may occur
- Uneven nutrient distribution
- Chemical reactions of fertilisers with calcium and magnesium bicarbonates in water
- Use of wrong chemicals - leading to clogging of the system.
- Corrosion of equipment.

- Potential chemical backflow into the water supply source

References and Sources:

1. Jain, Rajni & Kishore, Prabhat & Singh, Dharendra. (2020). Irrigation in India: Status, challenges and options. Journal of Soil and Water Conservation. 18. 10.5958/2455-7145.2019.00050.X.
2. Mahanta, Ksharendra et al (2019). Drip Irrigation for Reducing Soil Salinity and Increasing Cropping Intensity: Case Studies in Indian Sundarbans. J. Indian Soc. Coastal Agric. Res. 37(2): 64-71 (2019)
3. Microirrigation Scheme Guidelines
<https://pmksy.gov.in/microirrigation/Archive/GuidelinesMIRevised250817.pdf>
4. Journal of Soil and Water Conservation 18(4): 0-0, October-December 2019
ISSN: 022-457X (Print); 2455-7145 (Online); DOI.
5. Chand, S., Kishore, P., Kumar, S. and Srivastava, S.K. (2020). Potential, Adoption and Impact of Micro Irrigation in Indian Agriculture. Policy Paper 36, ICAR-National Institute of Agricultural Economics and Policy Research (NIAP), New Delhi.
6. [https://krishi.icar.gov.in/jspui/bitstream/123456789/46404/1/Policy%20Paper 36.pdf](https://krishi.icar.gov.in/jspui/bitstream/123456789/46404/1/Policy%20Paper%2036.pdf)
7. Agritech Page of TNAU:
https://agritech.tnau.ac.in/agriculture/agri_irrigationmgt_microirrigation.html#:~:text=Micro%20irrigation%20is%20a%20modern,irrigation%20system%20is%20as%20follows.

Chapter 7. Protected Cultivation

Greenhouse, Polyhouse, Polytunnels and Shade Net

Crops in open fields are subjected to environmental conditions of light, temperature, rain, wind, and pests and these are near impossible to control. Protected cultivation practices ensure that the micro-environment surrounding the plant body - such as temperature, humidity, light and other parameters are regulated through the use of covering material. This helps farmers raise healthier crops, harvest high quality and quantity produce and grow some crops beyond the season.

The market for and presence of Protected Agriculture

Protected agriculture is capital intensive and farmers must make sure that there is a market for their produce. Most protected agriculture in India caters to the domestic market even though the activities initially began as export-oriented units for flowers. The major states having area under protected cultivation and major crops/plants give us an indication of market potential and to which states protected agriculture can be expanded.

Major States	Major Crops/Purpose
• Karnataka • Tamilnadu • Andhra Pradesh • Kerala • Telangana • Maharashtra • Gujarat • Haryana • Punjab • Himachal Pradesh • Uttarakhand • North Eastern States	• Vegetables: Coloured Capsicum, English Cucumber, Cherry Tomato, Tomato, Pole beans, Red Cabbage, Bottle brinjal, broccoli and other off-season vegetables • Flowers: Rose, Gerbera, Carnation, Tiger lilies, Anthurium, Orchids • Others: Lettuce, parsley, celery, chives, Vanilla • Fruits: Cantaloupe, Water Melon, Strawberry • Nursery: Hybrid vegetable seedlings, hardening of tissue culture plants, micro tubers of potato. Exotic flowers nursery

Advantages of protected cultivation

- Favorable microclimate conditions for the plants.
- Hygienic production due to fewer sprays of toxic pesticides
- Good disease and pest control. Helps in the early raising of nurseries
- Cultivation in all seasons even under extreme conditions
- Longer production cycle
- Needs less irrigation due to moisture conservation.
- More suitable for off-season/high-value crops.
- High yield with better quality per unit area.
- Round the year propagation of elite planting material. Protection from wind, rain, snow, birds, hail etc.
- Generates self-employment for educated youth

Various types of structures and technologies adopted for commercial protected cultivation are:

- Green House
- Polyhouse/Polytunnel
- Shade Net House

The level and type of the adoption of technology depends upon

- The target market and avenues for selling the high quality produce
- Location, climatic and soil conditions
- Type of crops chosen
- Resources available with the farmer
- Availability of government-sponsored schemes, subsidies, incentives for promotion of the technology

Greenhouses

Greenhouses are fully climate-controlled enclosures mainly used for growing exotic varieties of vegetables, off-season vegetables, floriculture, planting material acclimatisation, plant breeding and varieties improvement under adverse agro-climatic conditions.

Green Houses are built around a GI with a plastic covering. The internal environment is artificially controlled to keep temperature, humidity, light intensity, photo-period, ventilation, and soil within suitable ranges throughout the season irrespective of the natural conditions outside. The greenhouse will have different growing media, disease control, irrigation, fertigation and other agronomic practices as required by the crops. Some greenhouses can be quite sophisticated with Polycarbonate sheet roofing (double-walled) and computer-controlled heating, cooling, irrigation and fertigation operations.



Polyhouses and polytunnels

Polyhouses and polytunnels are less sophisticated versions of greenhouses and can be naturally ventilated or climate controlled as against the fully climate-controlled greenhouses. Polyhouses also grow crops as in greenhouses including exotic varieties of vegetables, off-



season vegetables, flowers, planting material acclimatisation, etc.

The degree of sophistication varies from low-cost polyhouses built on wooden or bamboo structures with polyethylene film covering to sophisticated polyhouses built on pregalvanised steel structures with fully automated drip, fogger systems and fertigation systems.

Generally smaller and simpler versions of polyhouses are typically called polytunnels or hoop houses. Polytunnels have a variety of applications, the majority being, the rowing of vegetables, floriculture, and planting material acclimatisation. Polytunnels are built of a Pre-galvanised or bamboo tubular structure and are mainly used in hilly and temperate regions with moderate temperatures. Polytunnels may be a simple plastic covering over crops during cold season farming.



Shade Net House

Net houses are naturally ventilated and have a variety of applications, the majority being, the growing of vegetables, floriculture and nurseries. Net houses are built of a Pre-galvanised channel cum tubular structure/ tubular structure, wooden or Bamboo structures and are mainly used in regions with less rainfall. The shade net comes in several varieties - mostly green and black in colour and different shade percentages (amount of light the shade net lets in).



What are Protected Agriculture Structures made of?

Protected agriculture structures come in many varieties depending on:

- Type of crops proposed for growing
- Level of controlled atmosphere required
- Type of covering structure like greenhouse, polyhouse, polytunnel and shade net
- Type of location

- Budget available with the farmer
- Local resources available - such as bamboo, wood, etc.

Menu of Protected Agriculture Components

- Pregalvanised Iron/wooden/bamboo structure
- UV stabilised covering materials of Polyethylene/ Polycarbonate/Acrylic
- Heating systems in cold climates
- Cooling pad and Fan System
- Shading / Thermal Net
- Trellising system for vegetables
- Trestle system for flowers
- Sidewall roll up curtains
- Micro-irrigation System
- Fertigation System
- Misting System
- Carbon dioxide (CO₂) Generator
- Control System /Weather Station
- Planting material, artificial growing media
- Hydroponics/aeroponics systems

Capital cost and Economics of covered agriculture

Protected Agriculture is more capital intensive and it is important to understand the costing and economics to make the appropriate choice. Some typical unit costs are listed in the table below.

Type of polyhouse	Cost of polyhouse Rs/sq.m	Cost of Planting Material Rs /sq. m		Total unit cost Rs lakh/acre		Economic life of structure
1. Green House (Pad and fan system)	1400	Vegetables	50	Vegetables	58.00	25 years for frame and 4 years for cover
		Flowers	300	Flowers	68.00	
2. Naturally ventilated (GI frame)	800	Vegetables	50	Vegetables	34.00	25 years for frame and 3-4 years for cover
		Flowers	300	Flowers	44.00	
3. Naturally ventilated (wooden frame)	600	Vegetables	50	Vegetables	26.00	5- 10 years for frame and 3-4 years for cover
		Flowers	300	Flowers	36.00	
4. Naturally ventilated (Bamboo frame)	500	Vegetables	50	Vegetables	22.00	5-10 years for frame and 3-4 years for cover
		Flowers	300	Flowers	32.00	
5. Shade net (GI frame)	700	Vegetables	50	Vegetables	22.00	25 years for frame and 3-4 years for cover
6. Shade net (wooden frame)	500	Vegetables	50	Vegetables	22.00	5-10 years for frame and 3-4 years for cover
7. Shade net (Bamboo frame)	400	Vegetables	50	Vegetables	18.00	5-10 years for frame and 3-4 years for cover
8. Walk-in Polytunnels	600	Vegetables	50	Vegetables	26.00	25 years for frame and 3-4 years for cover
		Flowers	300	Flowers	36.00	

Economics of Protected Agriculture

Case 1: Vegetables - Capsicum-Tomato-Cucumber

Coloured capsicum is the leading vegetable cultivated under polyhouses occupies more than 80% of the area, followed by English Cucumber and Tomato. The crop duration under polyhouses varies from crop to crop and region to region. Average of the economics of Capsicum, Tomato and Cucumber under different types of structures are given in the table below:

Sr No	Types of polyhouse	Gross income (Rs/ sq. m)	Cost of production (Rs / sq. m)	Net income (Rs/sq. m)	IRR (%)
1	Green House (Pad and fan system)	350	120	230	12%
2	Naturally ventilated polyhouse	300	110	190	25%
3	Shade net	260	110	150	20%
4	Walk in Polytunnels	230	100	130	20%

Case 2: Flowers - Gerbera-Carnation-Rose

Gerbera, Rose and carnation are the leading flowers being cultivated under polyhouses occupies more than 80% of the area. The crop duration under polyhouses varies from crop to crop and region to region.

The crop duration of the flowers varies from 3 to 5 years. There is an additional investment cost of about Rs 200 to 300 per sq. m for replanting every 3 to 5 years depending upon the type of flower. Average cost-economics of Gerbera, Carnation and Rose under different types of structures are given in the table below:

Sr No	Types of polyhouse	Gross income (Rs/sq. m)	Cost of production (Rs/sq. m)	Net income (Rs/sq. m)	IRR (%)
1	Green House (Pad and fan system)	450	70 plus replanting cost of about Rs 300/sq. m every three years	380	17%
2	Naturally ventilated polyhouse	400	60 plus replanting cost of about Rs 300/sq. m every three years	340	32%
3	Shade net	350	60 plus replanting cost of about Rs 300/sq. m every three years	290	27%
4	Walk-in Polytunnels	300	60 plus replanting cost of about Rs 300/sq. m every three years	240	20%

Naturally ventilated polyhouse is the most popular structure with higher IRR. More than 80% of the protected cultivation is under this category of structures

Case 3: Low-cost polyhouse for off-season vegetable cultivation in Meghalaya

Ri-Bhoi district in Meghalaya experiences different types of climate ranging from tropical climate in the areas bordering Assam to the temperate climate adjoining the East Khasi Hills. The areas bordering Assam experience hot and humid weather during the summer season with an average temperature of 30°C, especially during May to July. In other areas like Lum Raitong and Lum Sohpetbneng Plateaus, the climate is severely cold during the winter months but pleasant during the summer. The major climatic vulnerabilities of Kyrdem village are water scarcity, poor soil health and frost.

Low-cost polyhouse for off-season vegetable cultivation

The Kyrdem village produces a good amount of cucumber, capsicum and tomatoes during the main season, which eventually leads to the market glut and a fall in prices. On the other hand, due to weather extremes - high-intensity rainfall and hailstorms inflict maximum losses to the cucumber and tomato production during the off-season. Therefore, low-cost polyhouse technology was introduced for the off-season production of vegetables in the village under the NICRA (National Innovations in Climate Resilient Agriculture) project of ICAR.



A low-cost polyhouse was constructed using locally available bamboo and metallic wire for developing the frame. UV stabilised film of 200μ (800 gauge) was used for covering the roof and 75% shade net on the side walls. The estimated cost of construction of a 100 m² size polyhouse varied between Rs. 13,000-15,000. Proper drainage channels were developed around the polyhouse to avoid water stagnation. Raised beds of 1 m length and 30 cm height and of convenient length were prepared inside the polyhouse by thoroughly mixing soil: FYM in 2:1 ratio. The beds were disinfected with Formalin (20 ml/l water) and covered with black polythene for 2-3 weeks. The polyhouses are being used for raising of vegetable seedlings as well as off-season vegetable cultivation.



(<http://www.nicra-icar.in/nicrarevised/index.php/2-uncategorised/203-low-cost-polyhouse-for-off-season-vegetable-cultivation>)

Government Support for promotion of protected cultivation

The capital investment subsidy schemes operated by the Government of India and State Governments under MIDH, NHB and RKVY have contributed for the increased areas under protected cultivation. ICAR has established a Centre for Protected Cultivation Technology (CPCT) at IARI, New Delhi to demonstrate and promote protected cultivation. The details of various promotional schemes are given below:

Programme /scheme	Activities funded
Mission Integrated Development of Horticulture (MIDH)	• 50% of the subsidy for construction polyhouse of different types. Up to a maximum of 4000 sq.m per beneficiary • 50% of the cost of planting material and cultivation under protected horticulture up to a maximum of 4000 sq.m per beneficiary
National Horticulture Board (NHB)	• Credit linked back-ended subsidy @ 50% of the total project cost limited to Rs 56.00 lakh per project as per admissible cost norms for greenhouses, shade net house, plastic tunnel etc. & cost of planting material etc. • Credit linked back-ended subsidy @ 35% of the total project cost limited to Rs 50.75 lakh per project in the general area and @ 50 % of project cost limited to Rs. 72.50 lakh per project in NE, Hilly and Scheduled areas for the development of post-harvest infrastructure like grading, packing, ripening chambers, reefer vans etc. • Capital Investment subsidy scheme for construction/expansion/ modernisation of cold storage and storage for Horticulture Products. The assistance will be given as a subsidy @ 35% of the capital cost of the project in plain areas and 50% in the case of NE, Hilly & Scheduled Areas for a storage capacity above 5000 MT up to 10,000 MT.
Rashtriya Krishi Vikas Yojana (RKVY)	• Department of Horticulture and Agriculture of various state Governments are implementing capital subsidy schemes for establishing the various type of structures for protected cultivation. The subsidy varies from 50% to 90% of the capital cost.

Chapter 8. Soil-Less Farming

Hydroponics, Aeroponics and Aquaponics

Conventional Farming (Geoponics) and Soil Less Farming

Geoponics is another name of conventional farming where crops are grown on natural soil. Soil can cause the spread of pests and disease to crops, and water and nutrients supplied to plants get spread beyond the root zone of the crops. In a resource-constrained world, it becomes important to increase the efficiency of water and nutrient delivery to crops while also reducing the use of harmful chemicals for pest and disease control. All this is really difficult when growing crops under open field conditions.

Protected agriculture (that we have explored previously) is a solution that emerged to overcome some of these challenges. A further evolution is Soil-less farming - where plants grow in natural or synthetic media like coir pith, sawdust, perlite, vermiculite, sugarcane bagasse, water and even air. In soil-less farming water and nutrients are mostly delivered to crops through micro-irrigation and fertigation methods. Among soil-less farming, high tech methods like hydroponics, aeroponics, and aquaponics are evolving fast especially to support urban farming. These methods are very capital and energy-intensive, but take up less space and produce more under controlled environmental conditions. Very often they are a part of partially or highly automated systems that reduce pests, diseases and weeds compared to conventional farming methods.



We will specifically look at the high-tech methods of Hydroponics, Aeroponics and Aquaponics.

Hydroponics

A system where the roots of the plant are submerged in a liquid growing medium water is called Hydroponics. The nutrients - both macro and micro are mixed in the right proportions and dissolved in the circulating water medium; they are directly absorbed by the roots and thus not wasted. Hydroponic farming uses less than 80% of water used in traditional farming where water percolates and evaporates freely. In hydroponic systems water pH and nutrients can be calculated with some precision, thus reducing the overall nutrient inputs. Because of their direct access to nutrition, roots (and thereby the plant's stems, leaves, and flowers) can grow up to four times faster compared to their soil-grown counterparts.

How are nutrients supplied to plant roots?

There are several techniques to deliver nutrients to plants and the equipment will be designed for the delivery method.

- Nutrient Film Technique (NFT): NFT is used to grow smaller and quick-growing plants. The system uses a pump to circulate water to the grow trays and pumps out water to recycle the unused water nutrient solution.
- Wick system: Here the nutrients are taken up from the reservoir through a wick into the growing medium.
- Ebb and flow (flood and drain system): Here the grow tray is temporarily flooded with the solution, and then drained back to the reservoir. The flooding and draining processes happen multiple times in a day.
- Deepwater culture: This is also called the reservoir method. Here the roots are suspended in a nutrient solution and an aquarium air pump oxygenates the nutrient solution preventing the roots of the plants from drowning and rotting.
- Drip: The timer schedules the water system in such a way that the nutrient solution from the reservoir drips into the plants as per the scheduled time.

Benefits of hydroponic farming:

- Suitable for vertical farming under greenhouse conditions and other modified structures
- Higher productivity per unit area
- Production can be fully automated with minimum labour requirement
- Efficient use of water and recycling of water
- Efficient use of plant nutrients without any fixation or leaching like in soil culture
- Maintains right pH, oxygen levels for improved growth and productivity
- Less incidence of pest and diseases, especially no soil-borne diseases
- No weed growth
- 3-10 times as many crops can be grown in the same amount of space
- Hopefully innovators will help bring down the cost and complexity of hydroponic systems.

Limitations of Hydroponics:

- Hydroponics requires specialised infrastructure, equipment, chemicals and electricity to run the equipment
- All nutrient inputs have to be bought as water has none of it.
- Currently, the system is highly technical and the farmer must carefully observe the system to ensure all is going well.
- It is a very sensitive system. If the pH or water temperature, or some other critical factor is off, then your harvest might be less than optimal.
- It will not run without a power source

Doubling Yield Using Hydroponics

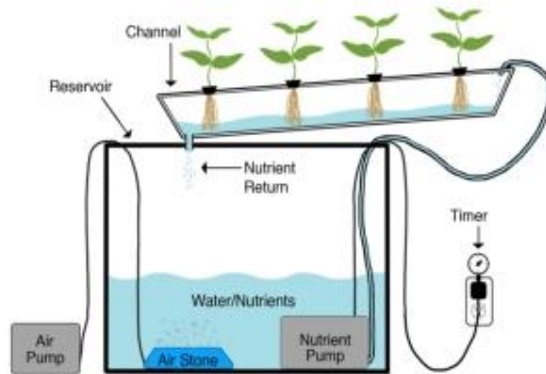
Lettuce grown conventionally in soil requires 60 days to harvest whereas lettuce grown using hydroponics doubles the produce in 28-30 days. This is the experience of Rahul Dhoka, founder of Green Rush Organics and Hydroponic Farming Consultancy 'Aqua Farms', Egmore, Chennai. He grows over 4,500 plants in a limited space of 90 square feet. Using the technique of hydroponic farming, he started cultivating Italian basil, mint, spinach, kale, lettuce and stevia to replace processed sugar.

Schematic Diagrams of Hydroponics Systems

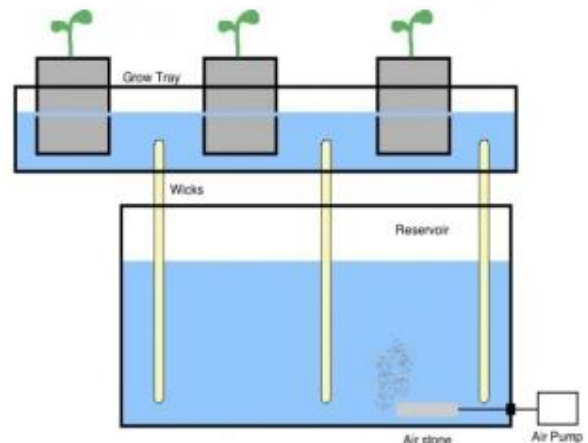
Nutrient Delivery Mechanisms

Source: AgriTecture

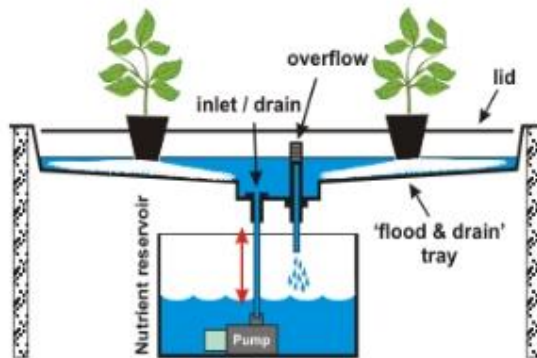
<https://www.agritecture.com/blog/2019/3/7/soilless-agriculture-an-in-depth-overview>



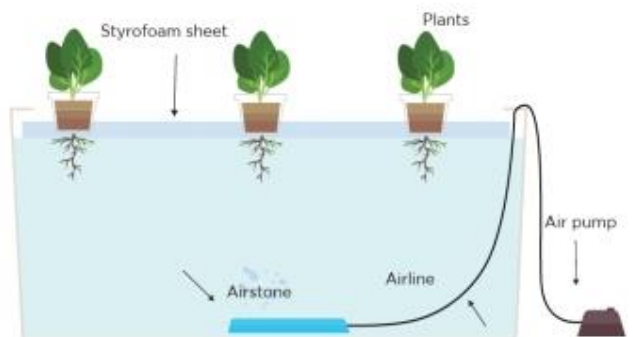
Nutrient Film Technique (NFT)



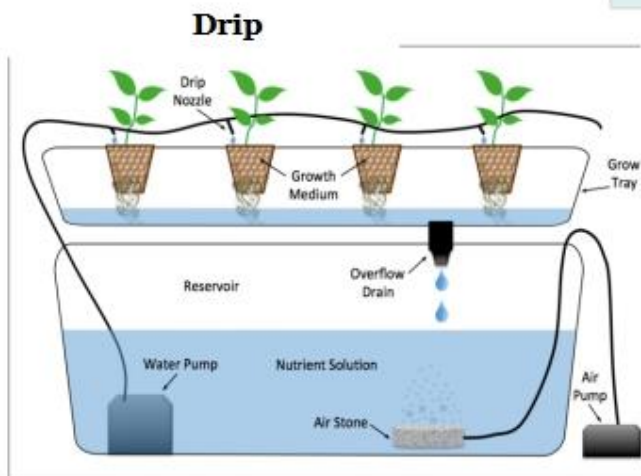
Wick



Ebb and flow (flood and drain system)



Deep water culture



Drip

Case 1: “Kambala” - Small Scale green fodder greenhouse

Small farmers in the coastal areas of South India did not have sufficient space to grow green fodder for their cattle. Hydrogreens, an agri startup has designed “Kambala” - a low cost hydroponically cultivated vertical greenhouse for fodder crops (maize) using evaporative cooling technology. The system is 3x4 feet and 7 feet tall. It is enveloped with a black net cover from the outside, thereby protecting the growing fodder from excessive heat while allowing ample ventilation. Fodder is grown in seven racks stacked vertically. Each rack comprises four trays where approximately 700 grams of high-protein seeds of maize are sown. Within the next few days, the rack becomes covered with fresh, green fodder ready to be fed to cattle. Every day, one rack is sown with seeds, and each day one rack is ready for harvest. This allows farmers to grow quality fodder throughout the year with minimum use of water and electricity. The Kambala requires very little water - around 50 litres every 3 days. In a day, 25 to 30 Kg of fodder is generated in a Kambala unit enough to feed 4-5 cows. (Source: ICAR-National Institute of Animal Nutrition and Physiology, Bengaluru



Within the next few days, the rack becomes covered with fresh, green fodder ready to be fed to cattle. Every day, one rack is sown with seeds, and each day one rack is ready for harvest. This allows farmers to grow quality fodder throughout the year with minimum use of water and electricity. The Kambala requires very little water - around 50 litres every 3 days. In a day, 25 to 30 Kg of fodder is generated in a Kambala unit enough to feed 4-5 cows.

(Source: ICAR-National Institute of Animal Nutrition and Physiology, Bengaluru

Ref: (1) <https://icar.org.in/content/start-%E2%80%99s-low-cost-hydroponic-innovation-%E2%80%99Kambala%E2%80%99D-icar-nianp-bengaluru-address-green-fodder> (2) <https://hydrogreenfodder.com/>

Case 2: Hydroponics Green Fodder by Coop Milk Union

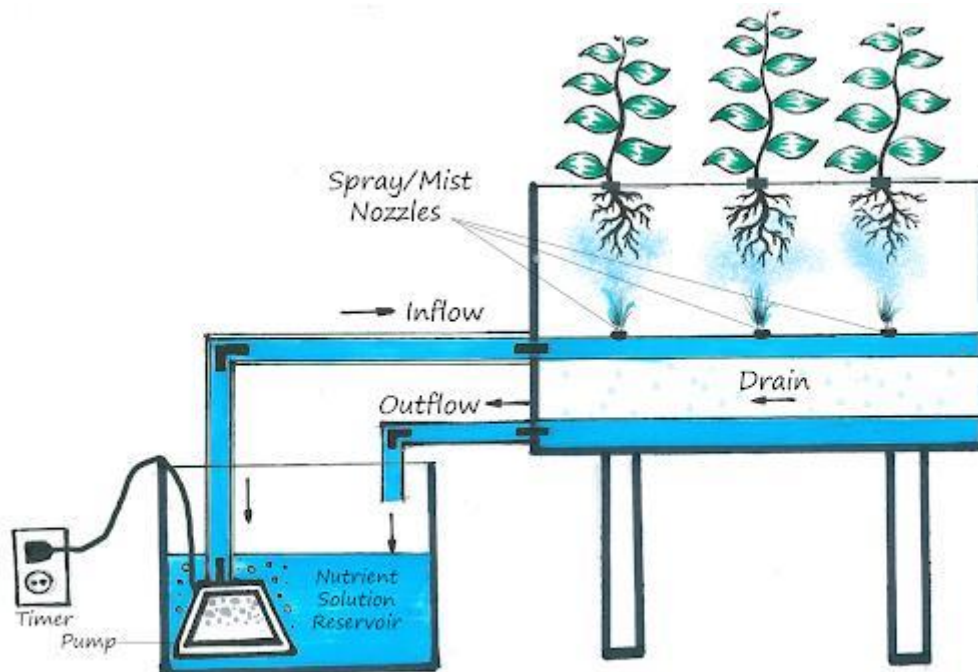


A good example of successful use of this technology is the production of hydroponic green fodder by Goa State Cooperative Milk Producers' Union under Rashtriya Krishi Vikas Yojana, wherein the pilots have proved that Green fodder production through Hydroponics technology can be a real alternative source to overcome the fodder deficiency in the state https://rkvy.nic.in/static/download/RKVY_New_Success_Stories/goa/4.pdf

Aeroponics

Credit: [Modern Farmer](#)

Aeroponics is very similar to hydroponics except that the roots are suspended in air (not submerged in water) while mists of nutrient-rich water keep them hydrated and fed. The principle of aeroponics is similar – when nutrients have direct contact with the root system, plants use all their energy growing stems, leaves, and flowers. (Image courtesy: AgriTecture)



Aeroponics cultivation can produce plants that are up to four times the size of soil-grown plants and takes up considerably less space, as well. However, because the roots only receive water when the system sprays, any fault in the system can stress or kill the plants. Aeroponics setups are recommended only when there is a backup power source in place and when growers can monitor the system's functionality and water level regularly.

Though aeroponics is an expensive system, potato seed growers find it advantageous to grow disease-free seed under aeroponics.

Aeroponics have several advantages over soil-based gardening and hydroponics:

- Aeroponics is conducted in air combined with micro-droplets of water; this helps in faster and better growth of plants with a plentiful supply of oxygen, water and nutrients.
- Plants in true aeroponics conditions have 100% access to the CO₂ concentrations for photosynthesis.

- Aeroponics can limit disease transmission since plant-to-plant contact is reduced and each spray pulse can be sterile. In the case of soil, aggregate, or other media, diseases can spread throughout the system.
- Efficient use of vertical space, aeroponics is ideal for vertical farming. Greenhouse and other structures with modified environments suited for plant growth can be used for production.
- Suitable for commercial horticulture in urban areas and kitchen gardens.
- Aeroponics is being employed in the country for potato seed production.

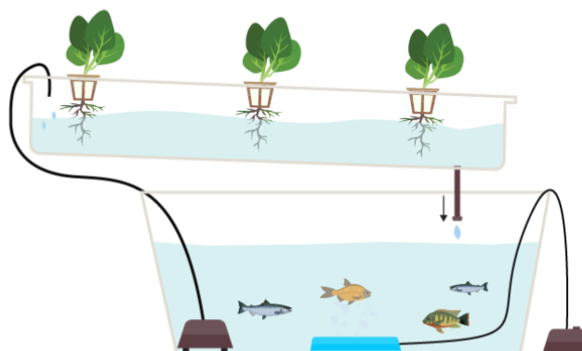
Image below:: International Potato Centre

https://cipotato.org/press_room/blogs/the-sustainability-of-aeroponics/



Aquaponics

Aquaponics is a combination of aquaculture, which is growing fish and other aquatic animals, and hydroponics which is growing plants without soil. In aquaponics, you grow fish and plants in the same system. The farmer feeds the fish, and fish excreta becomes nutrients for the plants. Beneficial bacteria are added to the water to digest the fish excreta for plants and reduce the growth of toxic compounds like ammonia. The plant roots clean the water as they absorb nutrients from it and this water goes back to the fish. Along with the fish and their waste, microbes play an important role in the nutrition of the plants - they are the magic ingredient.



Simple fish-crop culture is a traditional integrated farming method. Aquaponics brings in high-tech equipment and infrastructure and reduces the space required for the system. Aquaponics can help farmers grow fish and crops in urban spaces as well.

Usually, the crops grown in Aquaponics do not need highly acidic or alkaline water conditions - where fish cannot thrive. The crops also tend to be those with low nutrient requirements.

Aquaponics can become nearly completely self-sustaining. The only input needed in an Aquaponics system is fish food and beneficial bacteria to convert fish waste (which is high in ammonia and toxic to plants) into fertiliser for plants. the bacteria only need to be added once to the setup and if kept healthy, will reproduce quickly and begin the waste break-down process almost immediately. (Image courtesy: AgriTecture)

The Advantages of Aquaponics

- The Aquaponics system is a great way to grow both fish and plant crops.
- It also uses a water medium so cleaning both growing sections is very easy.
- It also allows for a fairly controlled flow of nutrients.
- The water filtration process is built-in (plant roots)

The Downside to Aquaponics

- The systems needs to be designed carefully for the fish species and plant crop
- The system can become quite expensive
- In very cold areas the water may need to be warmed or the fish may not thrive

Case 1: Cherai Aquaponic village, Kerala

Cherai is a small coastal village near Kochi in Kerala, and its scenic beach and stunning backwaters are much sought after by people who seek a tranquil travel experience. However, Cherai also happens to have a very unusual attribute to its name—one that has been drawing farmers and agriculturists from across the country. From 2016 onwards, Cherai has the unique distinction of being India's first aquaponics village.



(<https://www.thebetterindia.com/167334/kerala-farmers-aquaponics-diy-how-to-cherai/>)

Reference: FAO/Globefish (2014) Small scale aquaponic food production. Integrated fish and plant farming <http://www.fao.org/in-action/globefish/publications/details-publication/en/c/338354/>)

Vertical Farming



Image Credit: FAO

Vertical farming is a hybrid method of farming which uses systems similar to hydroponics, aquaponics, aeroponics and other protected agriculture - but here the crops are grown in vertical stacks. Artificial lighting becomes a must due to the shading effect of upper layers. These “farms” make use of enclosed structures like warehouses, containers and even abandoned buildings to provide a controlled environment to grow crops. Vertical farming have greater control on environmental factors such as temperature, light, humidity, CO₂ concentration, water and nutrients.

Because of controlled environment conditions, vertical farming uses

significantly less water and pesticides than traditional agricultural methods. Being mainly indoors, the crops aren't subject to seasons and hence give high productivity year-round. Typically salad crops like lettuces, tomatoes and green crops can be grown on vertical farms. The Kambala hydroponic fodder growhouse discussed previously is a form of low-tech vertical farming. However, Vertical Farms have heavy use of electricity for all the equipment and especially for the LED Grow Lighting above each rack.

Comparing Vertical Farming with Conventional Farming

- Effective utilisation of arable area
- Significant reduction in air pollution and CO₂ emissions
- Ensures year-round production of clean and safe (herbicide/pesticide-free) food
- Production - much more water, land and nutrient efficient
- Plant-growing conditions are optimised to maximise yield by fine-tuning temperature, humidity and lighting conditions
- Most produce grown in vertical farms can be taken to nearby market as there will be less post-harvest damage.
- Only as much produce as needed for the market can be harvested at any given time.

Current production under vertical farming focuses on high-value, rapidly-growing quick-turnover crops such as lettuce, basil, and other salad crops.

Vertical farming opens up avenues for urban farming supplying fresh produce to consumers. Hobby farmers can attempt farming without having to buy expensive land and then scale up

Vertical farming technology is still under development and is therefore expensive for small farmers. Over time it is hoped that low cost, low energy requiring models will be developed.

Should a farmer attempt soil free and Controlled Environment Agriculture?

Deciding between aeroponics vs. hydroponics vs. aquaponics vs. vertical farming boils down to cost factors, infrastructure, types of crops you want to grow, as well as geography. Depending on geographical location and considering all different factors we can make a truly informed and effective choice.

How can FPOs benefit from soil-less farming models?

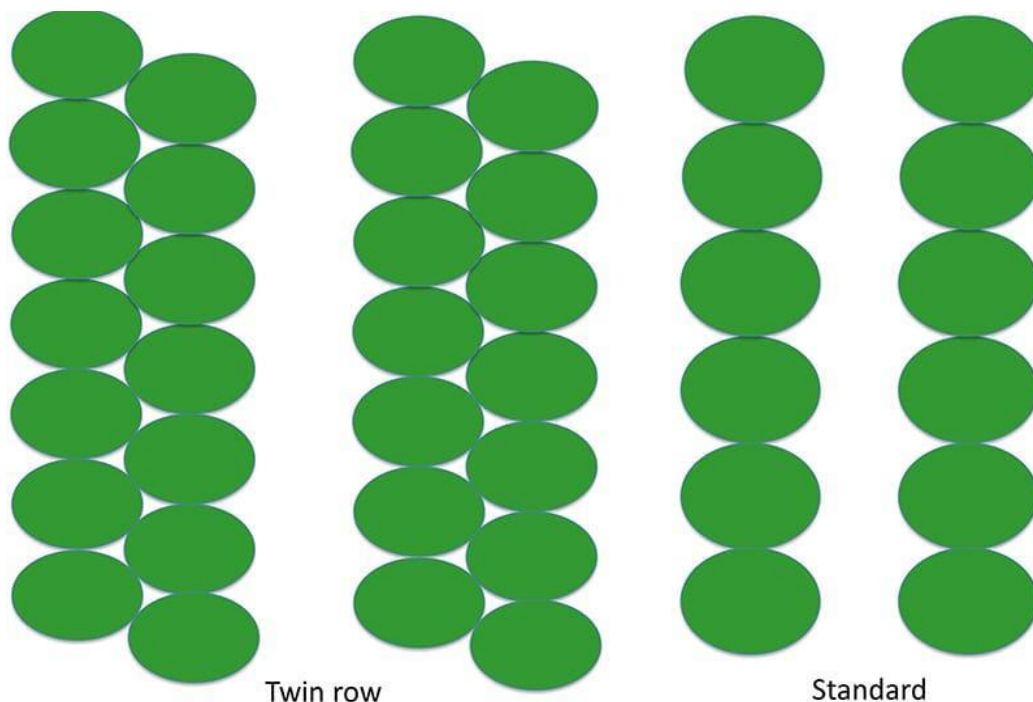
- Encourage and support shareholder farmers to take up these models to increase their income
- Create a group of farmers to invest in these technologies and FPOs can become a selling point for their quality produce
- FPO itself can invest as a business activity to support the fellow farmers with quality green fodder and also leafy greens as part of their product portfolio
- Connect with Ag-startups and become a supply centre for premium vegetables.
- FPOs can also avail support under State / Central sector schemes such as MIDH (Mission for Integrated Development of Horticulture), Agriculture Infrastructure Fund, etc. to establish these units.

Chapter 9. High-Density and Ultra High-Density Plantations

Horticulture and agroforestry systems are gaining importance due to the increasing demand for fruit and tree products in domestic and export markets. India is the second-largest producer of fruits in the world after China. But the average productivity of fruits in India is low because of old and senile orchards, poor orchard management, low yielding varieties, wide spacing and inadequate technological adoption by the growers. It is necessary to achieve higher productivity of fruit crops from limited space. High Density and Ultra High-Density Plantations are a form of tree crop intensification that help overcome these challenges.

What are High-Density Plantations (HDP)?

HDP is the planting of more plants than optimum through the manipulation of tree size. Below is a diagram of twin-row high-density planting versus standard planting of orchard trees. HDP aims to maintain a balance between vegetative and reproductive load without impairing plant health. In India, HDP has been proved useful in many fruit crops e.g. pineapple, banana, mango, apple, guava and citrus.



Principles of HDP

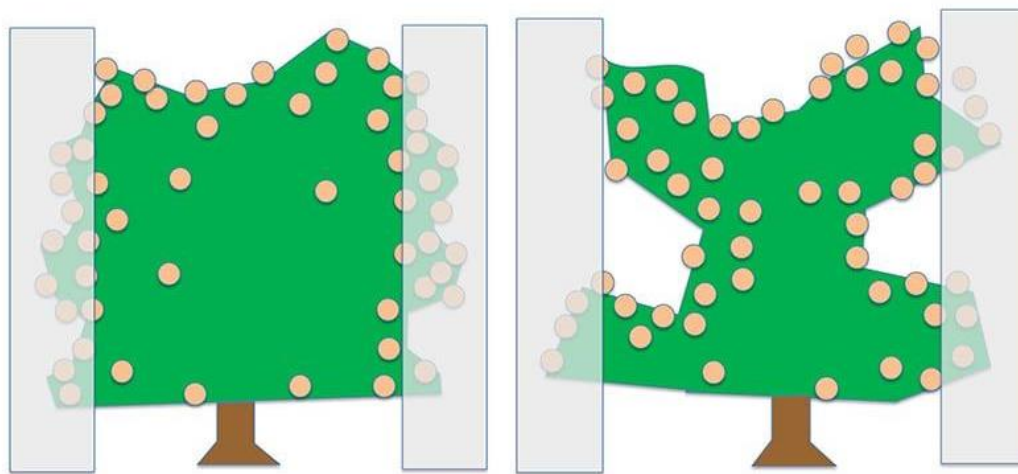
- To make the best use of vertical and horizontal space per unit time
- To harness maximum possible returns per unit of inputs and resources - including labour and mechanisation.

Advantages of HDP

- High-density planting induces early maturing of the tree, increases yield and improves fruit quality.
- Reduces labour cost resulting in low cost of production.
- Enables the mechanisation of fruit crop production.
- Facilitates more efficient use of fertilisers, water, solar radiation, fungicides, weedcides and pesticides.

What do plants look like in HDP?

- Fruit trees have more fruiting branches and fewer big structural branches
- Branches are arranged to that they do not shade other branches.
- Plant shape is influenced by the method of propagation, rootstock and spacing.
- Appropriate vegetative-reproductive balance of plants



An unpruned or poorly pruned tree (left) has left most of the fruit on the outer parts of the canopy which is cut off (grey rectangle) when hedged. An intensively pruned tree (right) has a portion of fruit growing inside the tree that remains after hedging (<https://citrusaustralia.com.au/news/latest-news/high-density-planting-and-pruning>)

Desirable Shape of Temperate Fruit Plants under HDP

- Prevent upright growth and develop horizontal laterals.
- Space small laterals along the central leader.
- Develop and maintain fruiting spurs along the entire branch as it develops.
- Develop rigid, strong, self-supporting laterals.
- Maintain fruiting branches in one position.
- Develop fruiting spurs along the sides rather than the top or bottom of lateral branches.

Techniques of HDP

HDP is primarily achieved through control of tree size and canopy management and an appropriate field layout

A. Tree Size Control

It is possible to control the crop growth both biologically or agronomically.

The quality of planting material and the use of suitable crop management practice plays a big role in the success of HDP. Some of the essential activities are given below:

- Use of genetically dwarf scion cultivars
- Use of dwarfing root stocks and inter stock
- Training and Pruning
- Use of growth retardants

A1. Use of Genetically Dwarf Scion Varieties

The use of dwarf scion varieties is easier to establish high-density orchards if the trees are naturally small. It offers great scope for close plantings, which have the potential for higher yields and returns than traditional plantings.

Crop	Dwarf Cultivar	Desirable Characters
Banana	Dwarf Cavendish	Dwarf stature with high yield
Guava	Pant Prabhat	Less spreading and high yielder
Mango	Amrapali, Arunika	Precocious and regular bearer
Papaya	Pusa Dwarf, Pusa Nanha	Bears at lower height
Sapota	PKM-1, PKM-3	Dwarf stature

A2. Use of Dwarfing Root Stocks

Root-stocks are known to have a profound effect on the tree vigour, precocity, quality of fruits, productivity and longevity of varieties grafted on them. Dwarfing can be due to the rootstock or the scion, or both. Attempts have been made to standardise dwarfing root-stocks, especially in the fruit crops like ber, citrus and grape.

Crop	Dwarfing Rootstock
Mango	Vellaikolumban (Alphonso), Olour (Himsagar and Langra)
Pear	Quince C
Guava	Pusa srijan, Psidium friedrichsthalianum, Aneuploid-82
Ber	Zizyphus rotundifolia, Z. nummularia
Citrus	Trifoliate orange, Sour orange, Flying Dragon
Plum	Pixy
Apple	M4, M7, M9, M26, MM106, M27 (Ultra-dwarfing)

A3. Training and Pruning

Training and Pruning are effective tools in HDP as they impact the shape and size of the tree. If trees are planted closely, orchard access becomes difficult and plants will not receive enough light for photosynthesis, flowering and fruit set and quality. Trees are trained early, soon after planting and continue throughout their productive life. Proper tree forms, branch angle and limb spacing aid in growth control. Pruning is applied to regulate crops in guava, ber and fig, and rejuvenation of old orchards in mango. Tree size control through pruning is limited to grape, apple and some other temperate fruits.

A4. Use of Growth Regulators

Growth regulators are chemicals that prolong dormancy, reduce vegetative growth, delay flowering and reduce fruit drop in trees. e.g., Paclobutrazol has gained commercial application in crop regulation in mango.

B. Planting Systems

Various planting layout options are available for HDP. The systems are chosen keeping in mind the plant species, access for labour and equipment and site conditions.

- Planting systems adopted in fruit crops are square, triangular, quincunx, rectangular, hexagonal, hedgerow (single & double), paired planting and cluster planting, etc.
- Square and triangular systems are followed for HDP in mango, kinnow, banana, papaya and Hedgerow system in apple and pineapple in India

In HDP adoption of suitable crop management practices such as mulching, fertigation, organic farming, Integrated Nutrient Management (INM) and Integrated Pest Management (IPM) are important for care and maintenance of plants.

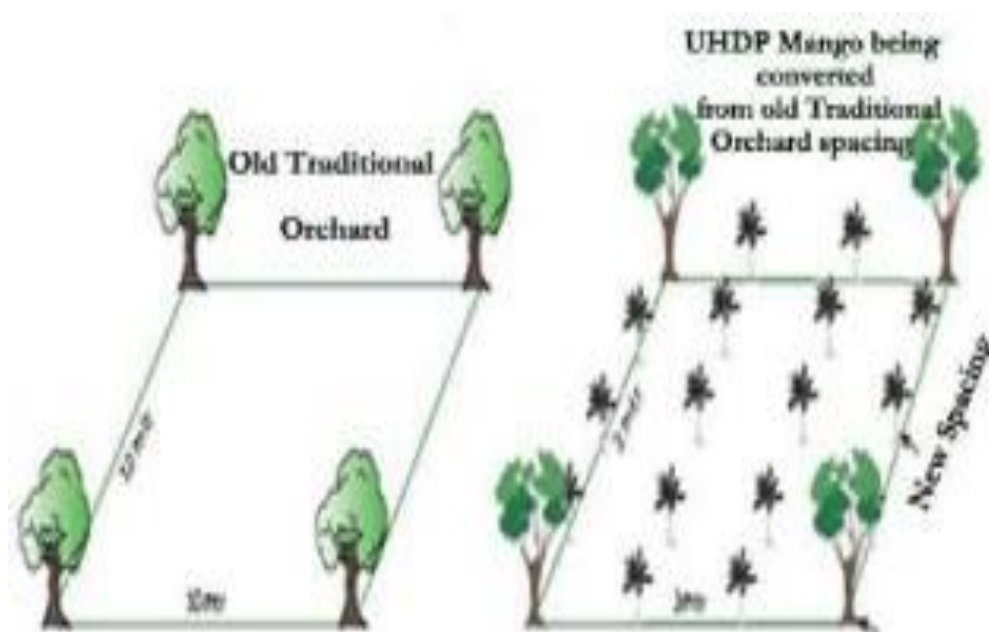
Constraints of HDP

Fruit trees are long-term crops and farmers rightfully worry about investing in methods that may not have the right resources available locally. Implementing HDP for fruit trees is limited by the following factors.

- Lack of standardisation of production technology and extension of technical-knowhow to the farmers - especially for tropical fruit trees
- High initial establishment costs
- Lack of promising dwarfing rootstock in, sapota, peach, sweet cherry, etc.
- In apple, commercial utilisation of dwarf root-stocks for tree size control in HDP is restricted due to their poor anchorage, the occurrence of sloped, shallow and rainfed lands and low fertility
- High incidence of some diseases in HDP e.g. Sigatoka leaf spot and fingertip in banana
- Difficult to manage the tree canopy for a large number of plants

Ultra High Density (Meadow Orcharding) Plantations UHDP

The “Meadow Orchard” is a further intensification of High Density Planting in fruit cultivation using a small or dwarf tree with drastically modified canopy. Better light distribution within the tree canopy increases the number of well-illuminated leaves. It also promotes the rate of photosynthesis that leads to high yield per unit area. Fertiliser dose, spacing, growth regulation by the training and pruning, use of the mechanical devices etc. may also be tried either singly or coupled with other crop management practices for successful adoption of this concept. It also promotes the rate of photosynthesis that leads to a high yield per unit area. UHDP or Meadow Orchard System is a new concept of planting which has been developed in guava for the first time in India at CISH, Lucknow.



Mango Cultivation with UHDP Technology

Advantages of UHDP

- High returns per unit area.
- Maximum use of resources.
- Possibility of adopting mechanization.

Disadvantages of UHDP

- UHDP has not been developed well for tropical plants
- The system is initially costlier than the conventional system.
- The economic life span of the orchard becomes lower.
- Chance of reduction in fruit size and weight due to a high number of fruits.
- Intercultural operation becomes difficult.
- Vigorous growth throughout the year - maintenance of plant shape becomes a tedious job - (regular pruning)
- Non-availability of suitable dwarfing root-stocks for several crops in India
- Tropical trees show poor response for training and pruning.

UHDP Case 1: New Trend In Mango Farming Helps Maha Farmer Reap Profits Worth Rs 6 Lakhs per Acre

Parmanand Gavane of Miraj in Maharashtra, 62, has adopted the ultra high-density planting (UHDP) system, which in addition to higher productivity, also ensures a uniform shape and colour of the fruit while maintaining its flavour and freshness. Last year, the fruits from Gavane's farm, weighing between 250g to 400g were picked up by buyers from Delhi, Hyderabad, Kolkata, Bengaluru and Raipur. From 3 tonnes in 2015, his maiden harvest, to 7.5 tonnes per acre in 2020 — Gavane believes that with proper management of the orchards he can achieve 10 tonnes of mangoes per acre. Each month he welcomes close to 50 farmers to his farm. Last year he had 2,000 footfalls, despite the pandemic. Gavane spends close to Rs 100,000 per acre which includes fertiliser and labour costs and ends up with a profit of Rs 600,000 per acre. Gavane says UHDP increases productivity up to 2-3 times, reduces water used for irrigation up to 50 per cent and improves fertiliser intake by plants.



<https://www.thebetterindia.com/252647/mango-farm-ultra-high-density-planting-uhdp-kesar-alphonso-profits-farmer-success-story/>

UHDP Case 2: High density and meadow orcharding of Guava



<http://icar-ciwa.org.in/gks/index.php/wft/114-meadow-orcharding>

The meadow orchard system of guava accommodates 5,000 plants/ha, planted at 2.0 x 1.0 m spacing and managed with regular topping and hedging, especially during initial stages. Topping and hedging in guava are helpful in controlling tree size and extending fruit availability.

For the detailed package of practices of high density and meadow orcharding for guava please refer https://midh.gov.in/technology/CISH_1_05_09.pdf

Production The production of guava in high density planting (1.5 x 3 m) is 26 tonnes/ha in the third year. The yield goes up to 47 tonnes/ha in the fifth and **55 tonnes/ha in the seventh year of growth - as against 6**

tonnes/ha at 6m x 6 m. The meadow orchard system is more beneficial than any other system. In this system, the production starts in the first year itself giving an average yield of 13 tonnes/ha which doubles in the next year. In the 3rd and 5th year yield is approximately 40 and 60 tonnes/ha, respectively. The meadow orchard system is also woman-friendly as women can take up all cultural operations due to the low height of the hedge.

Comparison between UHDP, HDP and Conventional Method of Planting

Parameters	UHDP	HDP	Conventional Planting
Gestation period (Year)	3	5	10-15
Plant population (trees/acre)	674	200	40-70
Plant geometry	2.5m × 2.5m	2.5m × 2.5m to 5m × 3m	7m × 7m to 12m × 12m
Pruning operation	Easy	Manageable	Very difficult
Spray operation	Easy	Manageable	Difficult
Probability of Insect, Pest and Diseases attack	Low	Moderate	High
Technology required	High	Medium	Low
Resource use efficiency	High	Medium	Low
Fruit uniformity	Highly Uniform	Uniform	Not Uniform
Yield at maturity (t/acre)			
Prolific bearing varieties	10-12	7-8	4-5
Shy-bearing varieties	2-2.5	3-4	5-6
Expected annual income (lakh Rs./acre)			
Prolific bearing varieties @Rs.5/kg	0.50-0.60	0.35-0.40	0.20-0.25
Shy-bearing varieties @Rs.12/kg	0.60-0.72	0.36-0.48	0.24-0.30
Commercial orchard life (years)	25-30	30-50	Up to 50
Cost of orchard till it comes to commercial bearing	1.53	0.60	0.50
Management practices	Easy to manage due to small tree size	Easy to manage due to small tree size	Difficult to manage due to large tree size
Labour intensification	Less labour	Less labour	More labour

(Ref: *Ultra-High Density Plantation of Mango: Indian Farmer 4 (Issue 5):368-375; May -2017, Singh et al*)

Reference:

Choudhary, Sanvar & Sarkar, Tanmoy & Magar, Vaishnavi. (2020). High Density Planting System in Fruit Crops. 1. AgriCos e-Newsletter I Volume : 01 Issue : 04 August 2020 Article No: 57. 167-169.

Chapter 10. Internet of Things (IoT) for Agriculture

Information Technology has found increasing use in Agriculture like in any other aspect of life. The use of IT in agriculture is called Digital Agriculture. A key component of Digital Agriculture is the Internet of Things or IoT.

Internet of Things (IoT) devices include every object that can be controlled through the Internet. IoT devices are commonly available in consumer markets such as smartwatches that can track the wearer's heart rate, sleep quality or footsteps taken in a day. It is estimated that over 30 billion devices could be connected to the Internet of Things by 2020.

Internet of Things are increasingly used in agriculture to monitor the farm and take appropriate action. IoT supports smart farming. E.g., sensors kept in field can send data on soil moisture in that field directly to the internet. This information can help a farmer to decide on how to irrigate the area. The actual irrigation can be organised manually or automatically depending how much a farmer has invested in the farming operations. IoT in agriculture already uses robots, drones, remote sensors, and computer imaging combined with continuously progressing machine learning and analytical tools for monitoring crops, surveying, and mapping the fields, and provide data to farmers for rational farm management plans to save both time and money. IoT devices greatly support Digital Agriculture.

(Adapted from Cropin: <https://www.cropin.com/iot-in-agriculture>).

What is Digital Agriculture?

Digital Agriculture is application of Information Technology in Agriculture. A farmer has to understand many issues and factors before making a decision - whether to select a crop for planting or understand how much crop he/she can expect to harvest and sell. The use of Information Technology (IT) can support a farmer in this regard. Digital agriculture can also connect the farmer with the FPO, the markets, banks and the final customer in many ways. Digital Agriculture helps farming activities to become:

- Precise
- Predictive, and
- Profitable (3 Ps of agriculture)

The major areas of application of IT in Agriculture are:

- Information dissemination
- Improving various farming operations
- e-governance
- e-marketing, e-choupal - virtual marketplace

Role of the Internet of Things in Digital Agriculture

- Internet of Things (IoT) is a combination of hardware, software, sensors and devices that talk to each other that enables collection of data and its analysis which results in useful solutions. In IoT no human operator is needed to feed the data from devices, the devices talk to each other through the Internet as designed.

What aspects of agriculture does IoT measure?

Specialised sensors are available for agricultural applications to measure

- Water and Moisture: Soil moisture, Humidity, Leaf Wetness,
- Sunlight: Solar Radiations, Ultraviolet Radiations,
- Weather: Pluviometer (Rain Gauge), Wind Vanes,

These sensors can be placed in fields, greenhouses, seed storage godowns, cold storages, agriculture machinery, transport vehicles and livestock. Data from IoT devices are stored in the cloud (or internet servers) and used by special software programmes and apps for monitoring and control.

What farm operations can IoT control?

IoT technologies are fast evolving. Some examples of IoT controlled farm operations are given below.

- Remote operations of robots, drones, tractors, harvesters, vehicles
- Irrigation and fertigation systems
- Climate control systems in greenhouses (A/Cs, lights)
- etc.

What operations does IoT Support?

- **Decision making with the right data:** by collecting data from farms, livestock, staff performance, markets, etc.
- **Better Risk Management & Efficient Resource Utilisation:** Better data will help us make better farming decisions and thus lower production risks. Crop planning can be done better to suit market demands.
- **Better Quality Control & volume of production:** Implementation of IoT Technologies will help to achieve better control over the production process and maintain higher standards of crop quality and growth capacity through automation - such as better pest control, timely irrigation, etc.
- **Monitoring and control systems** Various IoT based systems can be used for monitoring and control of environmental conditions in fields and greenhouses.
- **Smart Irrigation system** - Without optimal water, even good seeds and fertiliser fail to achieve their full potential. In terms of water use efficiency, India uses 2-3 times the water used in countries like China, Brazil and the USA to produce one tonne of grain. IoT based solutions can be utilised to improve water use efficiency. Irrigation/fertigation is an area where digital agriculture can be applied more easily.
- **Agri-produce and Agri-resource management** - RFID tags (electronics barcode) or sensor nodes can be attached to the agricultural produce (grain/seeds bags with RFID tags) and the agriculture resources

(e.g. expensive machineries) for effective tracking and management. RFID can also be used for the identification and tracking of livestock, Agro-produce, farm machinery, etc. Similarly, real-time monitoring of products stored or transported in a controlled environment is also a possible scenario.

- **Agri-Business management** - IoT based integrated information environment, with information from farms, storage houses, transportation systems, processing units, markets and export houses available on a single platform, can help in achieving using resources well, quality improvement, cost reduction, competitive sale prices, etc.
- **Livestock monitoring and management** - Just like crop monitoring, there are IoT agriculture sensors that can be attached to the animals on a farm to monitor their health and performance. Using drones for real-time cattle tracking also helps farmers reduce staffing expenses. These IoTs use smart agriculture sensors (collar tags) to deliver temperature, health, activity, and nutrition insights on each individual cow as well as collective information about the herd.
- **Monitoring of climate conditions** - one of the most popular smart agriculture gadget is the weather station with combines various smart farming sensors. Located across the field, weather stations collect various data from the environment and send it to the Cloud. This data can support Precision Farming.
- **Precision farming** - Also known as precision agriculture, precision farming is all about efficiency and making accurate data-driven decisions. It's also one of the most widespread and effective applications of IoT in agriculture. By using IoT sensors, farmers can collect a vast array of metrics on every facet of the field microclimate and ecosystem: lighting, temperature, soil condition, humidity, CO2 levels, and pest infections. This data enables farmers to estimate optimal amounts of water, fertilisers, and pesticides that their crops need, reduce expenses, and raise better and healthier crops.

Sourced from website of Indian Startup Cropin (<https://www.cropin.com/agritech-in-smarter-agriculture-solutions-with-cropin/>) Cropin uses various technologies to promote precision farming

Cases: Use of IoT in Agriculture:

Case 1. Agricultural drones

Perhaps one of the most promising agri-tech advancements is the use of agricultural drones in smart farming. Also known as UAVs (unmanned aerial vehicles), drones are better equipped than aeroplanes and satellites to collect agricultural data. Apart from surveillance capabilities, drones can also perform a vast number of tasks that previously required human labor: planting crops, controlling pests and infections, agriculture spraying, crop monitoring, etc.



Courtesy: Hindu Business Line

Marut Dronetech, a start-up founded by a team of Indian Institute of Technology (Guwahati) alumni, the start-up developed an intelligent, autonomous spraying drone targeted at agriculture. Using drones that can cover 40 km in an hour in low altitudes, the start-up gathers data and takes a few hours to analyse and map the crops for pesticide and/or fertiliser sprays. Another drone, taking the payload with it, does the spraying, using a predefined route. The start-up is presently working with input manufacturers and Farmer Producer Organisations (FPOs) to provide services. Marut Dronetech has covered 5,000 acres working with input makers, FPOs etc.

Case 2. Scientific Soil Health Management in FPO:

NABVENTURES funded AgTech startup **Krishitantra** provides rapid IoT-based soil testing and soil nutrition advisory solutions to farmers, Farmer Producer Organisations (FPOs), soil-testing labs and agribusiness stakeholders.

It has devised a highly portable IoT device KrishiRASTAA that generates soil test results within 30 minutes after analysing macro nutrients, micronutrients, pH, organic carbon, EC and microbial counts. Based on the soil test results, crop-specific soil nutrition recommendations are automatically generated and sent to farmers.

<https://krishitantra.com/>

References:

The Hindu Business Line: <https://www.thehindubusinessline.com>

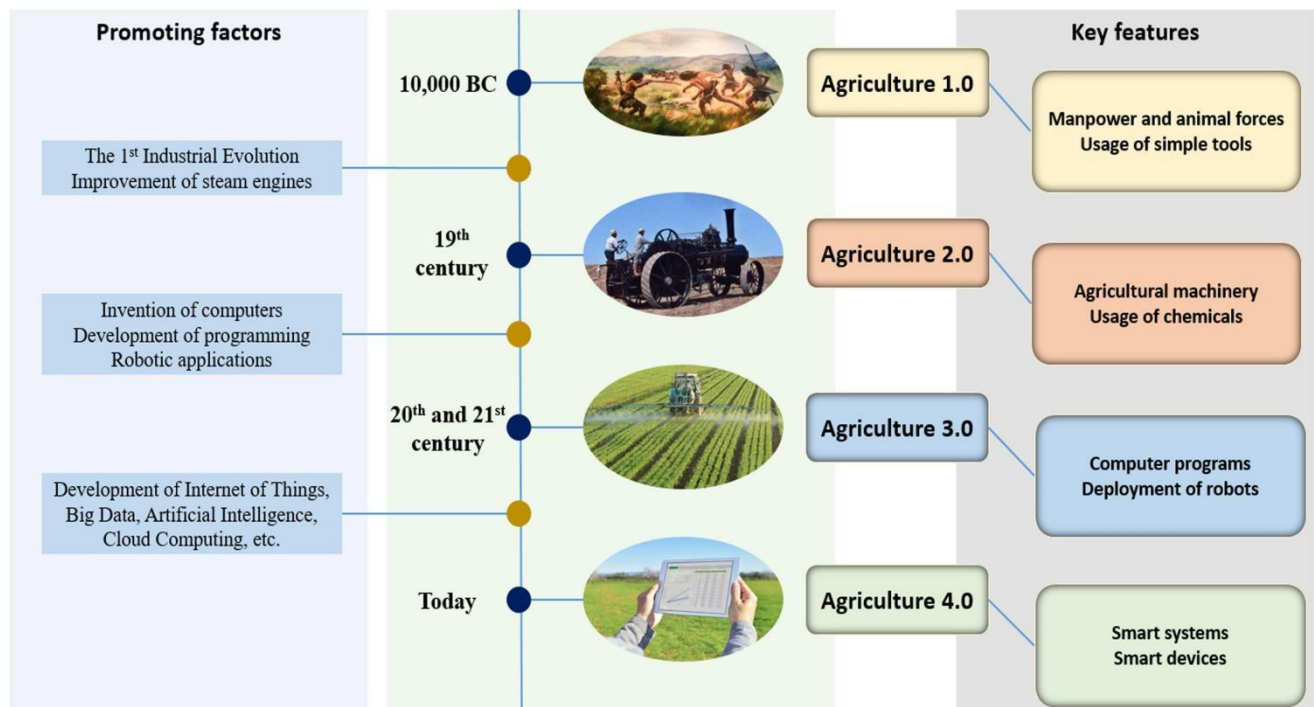
Suggested Reading for Facilitators:

1. CROPIN. Internet of Things in Agriculture: What Is IoT and How Is It Implemented in Agriculture? <https://www.cropin.com/iot-internet-of-things-applications-agriculture/>
2. CROPIN. How is Precision Agriculture Different from Smart Farming? <https://www.cropin.com/blogs/how-is-precision-agriculture-different-from-smart-farming>



Chapter 11. Precision Farming

Precision Agriculture (PA), Satellite Farming or Site-Specific Crop Management (SSCM)



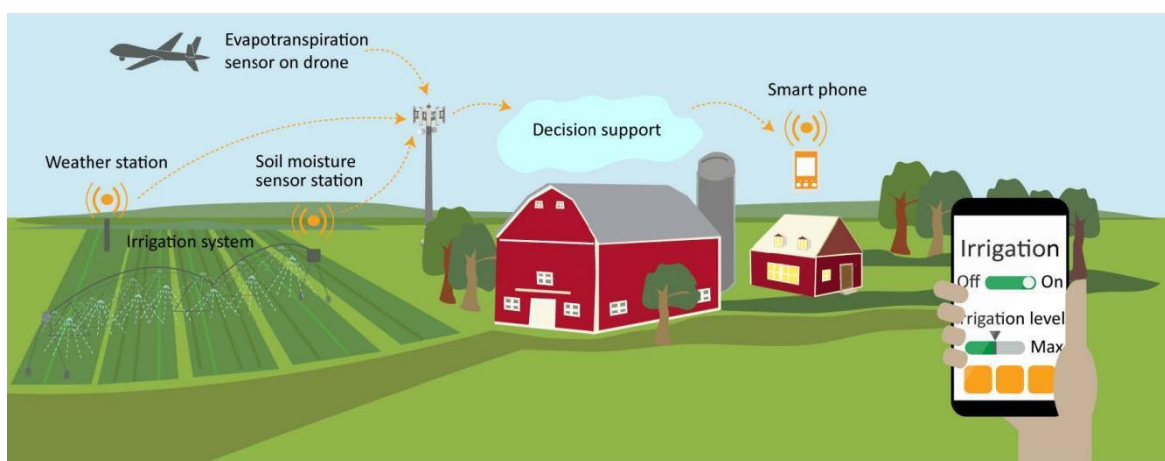
https://ars.els-cdn.com/content/image/1-s2.0-S0168169919316497-gr1_lrg.jpg

‘Precision agriculture is a management strategy that gathers, processes and analyzes temporal, spatial and individual data and combines it with other information to support management decisions according to estimated variability for improved resource use efficiency, productivity, quality, profitability and sustainability of agricultural production.’

Definition of Precision Farming adopted in 2019.

In simpler terms, Precision Farming is a digital farming management concept relying on internet and communication technologies in four phases:

1. Data collection - of farm variables
2. Analysis of data
3. Decision making based on analyzed data
4. Managing field operations based on the decisions using geo-location information



1. **Data Collection:** Observing, recording and measuring how crops appear to be growing differently within and between fields. This information is gathered using various electronics and information and communications technologies like:

- Global Positioning System (GPS) receivers
- Differential Global Positioning System (DGPS)
- Geographic Information Systems (GIS)
- Remote sensing - satellite and drone images
- Combine harvesters with yield monitors
- Sensors

2. **Analysis of data:** The data received from all the above technologies is analysed by different software platforms.

3. **Decision making based on analysed data:** After analysing all the data, a special software called Decision Support Software Platforms and Apps. The software is programmed to imitate a good farming expert - so that the most appropriate farming decisions can be taken.

4. **Managing field operations:** based on the decisions using geo-location information. Here technologies to automatically manage irrigation, fertiliser application, pesticide spray, etc. are used. These technologies can both adjust the timing and rate of application. Technologies used include

- Variable Rate Applicators
- Robots and self-driving equipment.



Tevatronic's wireless sensors collect precise data from soil in each zone of the farm. A smart controller converts this cloud-stored data in real-time into a precise irrigation-fertilization cycle without human intervention. <https://www.israel21c.org/5-israeli-precision-ag-technologies-making-farms-smarter/>

It is now possible to practise precision agriculture as tools like Global Positioning System ([GPS](#)) and Global Navigation Satellite System ([GNSS](#)), satellite images, drone cameras, sensors and remote controllers, and smartphones connected by the internet are available in the market. Many of these technologies are called the Internet of Things (IoT).

Because we can precisely locate each field, we can now create maps and images of the area. Certain software can identify various features from these maps - such as crop yield, terrain features/topography, organic matter content, moisture levels, nitrogen levels, pH, EC, Mg, K, and others.

Based on these measurements appropriate action can be taken on the farm - such as changing the nutrient composition, identifying moisture stress, decide on when and how much to irrigate. Sensors mounted on combine harvesters can give a farmer yield data from different parts of the farm. By the use of Variable Rate Technology inputs can be applied at different rates to different parts of the field - as per need. We can even monitor farm animals with chips embedded in them.

To summarise, PA is an innovation in farm management is based on using Information and Communications Technologies. Precision farming is an approach where:

- Inputs are utilised in precise amounts to get increased average yields, compared to traditional cultivation techniques
- Agricultural inputs are applied in precise measures based on soil, weather and crop requirements to maximise productivity, quality and profitability.

Why should Farmers adopt precision farming?

- To increase agriculture productivity
- To conserve soil and water
- Efficiently use water resources
- The right application of chemical inputs reduce soil and water pollution and degradation
- PA can support climate-smart agri-business - with a basic, affordable, and effective mix of technologies and practices.
- PA enables agricultural extension via digital advisory services
- We can use Green Technologies such as micro-irrigation, and solar pumps which can be remotely controlled

Drawbacks of precision farming, especially for small farmers:

- High cost of the systems
- Lack of technical expertise knowledge and technology
- Not applicable or difficult/costly for small landholdings
- Not designed for the variety of cropping systems and market imperfections as in India

Precision farming is not only new but a very complex system. The Decision Support Systems - or the way a PA system should “think” are not available for many cropping systems and geographical areas. These systems have to be developed jointly by experts and participating farmers. So, we can say that it will take some time before it is available for small farmers with diverse farming.

Potential for adopting Precision Farming in FPOs:

Of all Digital Agriculture methods, Precision Agriculture is the most complex because of the decision making involved in calculating farm management precisely. Internet of Things technologies are becoming increasingly common in India. Precision Farming can be tried incrementally by JLGs/aggregation-mode in command areas of minor irrigation projects - where farmers grow a single crop variety over large tracts of land. Precision farming technology for field crops could be taken up by farmers and FPOs through convergence with

centrally sponsored programmes or State-supported programmes.



References:

- Amit Kumar Mungarwal & SK Mehta (2019) Why farmers today need to take up precision farming. Down To Earth (2019).
<https://www.downtoearth.org.in/blog/agriculture/why-farmers-today-need-to-take-up-precision-farming-64659>
- Abigail Klein Leichman (2017) 5 Israeli precision-ag technologies making farms smarter. Israel21C. <https://www.israel21c.org/5-israeli-precision-ag-technologies-making-farms-smarter/>
- Zhai, Zhaoyu et al (2020). Decision support systems for agriculture 4.0: Survey and challenges. Computers and Electronics in Agriculture 170 (2020). 105256.
<https://doi.org/10.1016/j.compag.2020.105256>

Chapter 12. Collaborations between Agri-Startups and FPOs

Farmer Producer Organisations are now recognised as institutions that represent the collective interests of their members. Established corporates and business houses are increasingly looking to include FPOs in their supply/distribution chain and that can help FPOs to build capacities and create efficiencies.

The sustainability of FPOs is a major challenge. There are successful case studies and models where the collaboration between FPOs and AgTech Startups is creating value for farmers besides enabling these FPOs to compete successfully with other players in the market.



www.Farmerp.com

The need for Collaboration in agriculture

Problem of Information Asymmetry: The major problem of the agriculture sector in India is that some market players have more information than others (information asymmetry) and that farmers in general, are the least aware of happenings in research, technology and markets. A buyer is unsure if they are paying for the right quality of produce. The farmer is unsure of the price they will get for their crops.

The problem of match-making: A farmer is a specialist in cultivation but with few resources and safeguards. Food and Agri companies, on the other hand, are specialists in converting farm commodities to value-added products; but they do not control production. And, it has been practically difficult for them to work directly with farmers. This is where Farmer Producer

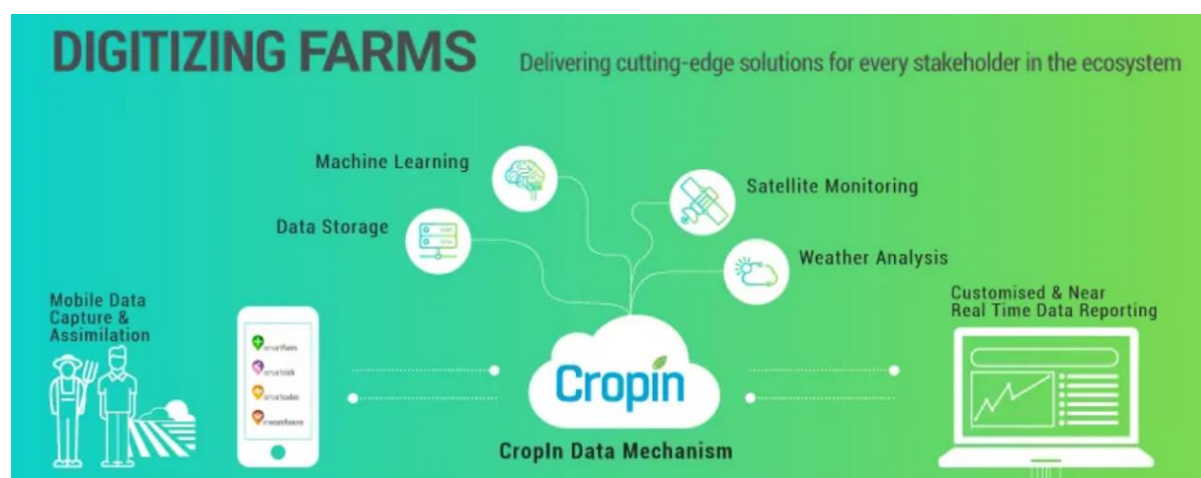
Organisations (FPOs), Agri companies and Agri-tech companies, together can solve this value chain issue.

FPO as Farmer Representatives – Missing efficient Communication: FPOs help in bringing together small farmers to strengthen their farming and bargaining capabilities. At the same time, FPOs make it easier for corporates/buyers to have direct conversations with farmers. Through FPOs, farmers can have access to high-quality inputs, and information and trade directly with reseller companies and large processors and better value for their produce.

Shifting from Demand-Supply to Quality-Based Pricing: there is a need to shift the primary focus of marketing from a demand-supply mapping context to quality-based pricing which is possible by FPOs and AgriTechs coming together.

AgriTech startups play a crucial role in removing the information asymmetry both on the upstream (supplies to farmers) and downstream (market linkages) sides. With the advent of Internet and Communication Technologies, good internet connectivity even in remote rural areas, penetration of smartphones/tablets, cloud-based internet services, and remote sensing possibilities, AgriTech companies have an opportunity to address concerns in the agriculture sector, specifically faced by smallholders.

Role of AgTechs to Support/Guide/Facilitate FPOs



Communicating Quality & Building Traceability

There are various instances when bad quality gets sold at a higher price due to scarcity; and due to oversupply, good quality produce gets sold at a lower price. Agritech startups can play a significant role by making it easy to check and communicate quality across different key points in the supply chain, from collection/mandi centres to consumers.

The ability to measure and communicate quality will enable the supply chain to create incentives for everybody in the supply chain to focus on quality. Hence, this will make the farmer grow quality produce and others in the value chain provide quality inputs and ensure careful packing, storage and transport

and reduce wastage.

Protecting farmers – Ensuring quality input and services

For farmers to produce high-quality in-demand crops with lower risks and higher returns, they need timely and valuable information, and supplies that range from seeds/fertilisers, tools, weather information, insurance, etc. Agritech companies can tailor a package of services/information which will be easily accessible to the farmers. These services will develop confident and smart farmers willing and able to adopt innovations in cropping. If done well, the farmer's high dependence on advice from biased sources (e.g.: input shops) will come down leading to potentially better earnings for the farmers.

Integrating Technology with Farm Management

Farm management requires knowledge and understanding of the varying nature of different crops as every crop has different needs. It requires input and advice on practices to be followed. AgTech assists farmers in taking up the best-suited farming practices, in turn increasing efficiency and maximising harvests. Integrating technology with daily agronomic activities would allow individuals to focus more on the bigger picture, focusing on sustainable agriculture, climate resilience and traceability.

Financial Freedom

Technology platform, that can help farmers analyse the economics of their farming operations is a need of the hour. This includes cost analysis assistance, so that funds can be allocated in the right manner for every task the farmer carries out, or every purchase or sale that is made.

Digital Supply Chain

AgTech works towards the establishing of a digital agricultural supply chain, streamlining the process. Various stakeholders are being brought onto a technological platform. Thus, farmers can expand their buyer base, reach more consumers and increase their profitability. Platforms like e-Mandis are also gaining importance and are working toward creating a uniform national market for agricultural commodities linking millions of farmers, processors and consumers.

Cases of AgTech-FPO Collaboration

Case 1: Samunnati

India's largest agri enterprise, Samunnati is an open agri network to unlock the trillion-dollar plus potential of Indian agriculture with smallholder farmers at the centre of it. Samunnati works closely with FPOs to



build production capacities using new farming technology to cater to international markets. Samunnati develops collaborations with Agri Finance, Agri Commerce and Farmers' Collectives. <https://samunnati.com/>

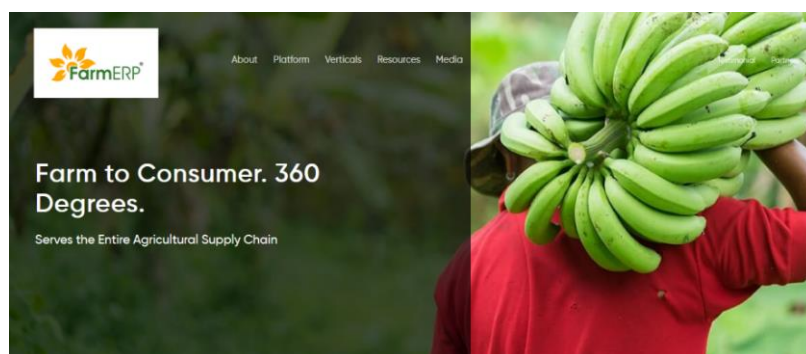
With Samunnati's intervention, FPOs now manage members' output purchase and demand seamlessly with the latest technology in agriculture.

Through agricultural advisory services, it offers training skills ranging from situation analysis and business planning to agricultural finance literacy and disaster preparedness.

Samunnati helps to boost operations and eventually increase the scale of production. A significant portion of their effort goes towards the creation of centres for excellence to demonstrate new cropping techniques and modern technologies in agriculture.

Case 2: FarmERP

FarmERP's farm management platform has made it easier for FPCs and FPOs to manage inputs, outputs, technology, services, and payments without any hassles. This is enabling them to build advanced agriculture management frameworks for the farmers and ensure high-quality yields with maximum efficiency. It helps both input and output FPCs in managing procurement, inventory management, post-production as well as accounting activities.



It mainly supports farmers by way of

- Farmer Data Management With Cutting-edge ERP Platform
- Control Input Supply Chains With Digitalised Frameworks
- Strengthen the Bargaining Power of Smallholder Farmers
- Encourage Climate-smart Farming through AI and ML-based Advisory

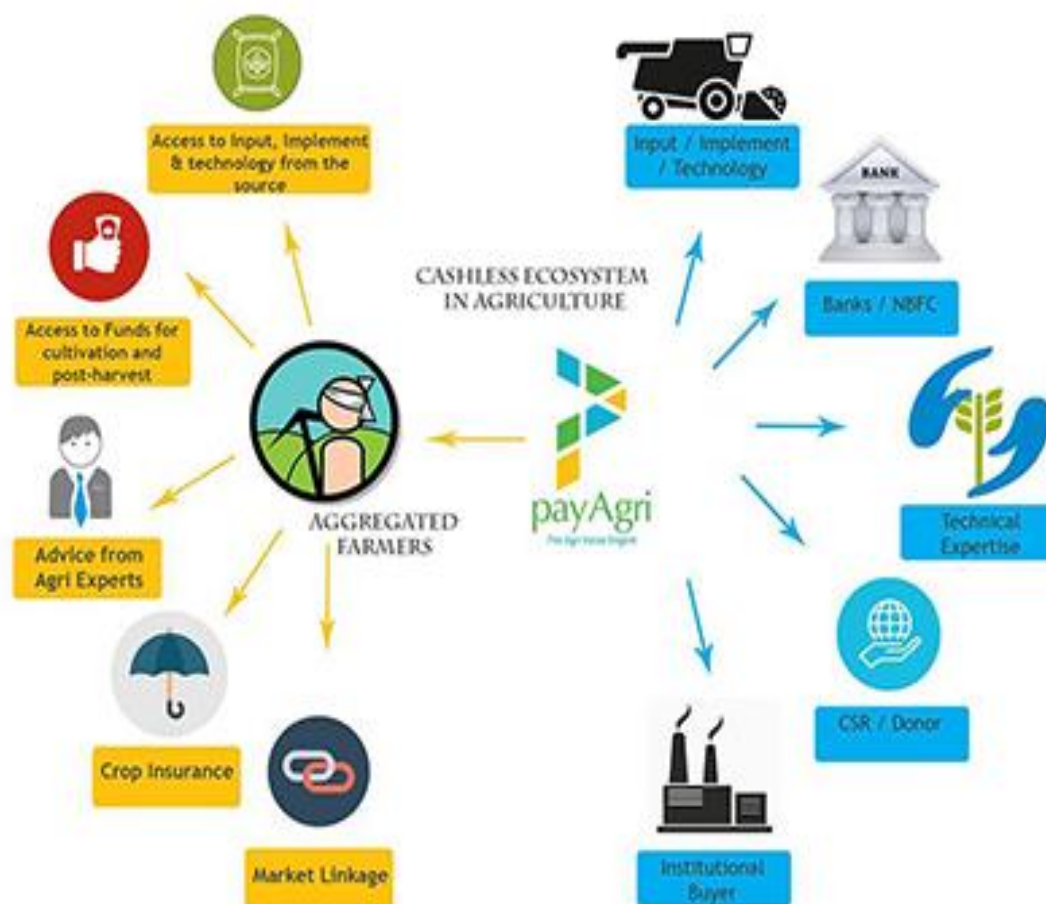
<https://www.farmerp.com/>

PayAgri Innovations Pvt Ltd

PayAgri Innovations Pvt Ltd is an agri-fintech organisation that captures all transactions in an Agri Value Chain and digitises these transactions. The three principles on which the model functions are:

- Remove the array of middlemen in the Agri Value Chain through direct linkages
- Create a cashless ecosystem
- Provide the benefits of large scale farming to smallholder farmers

<https://www.payagri.com/>



Conclusion

Agriculture is witnessing a rapid pace of change – the drivers of this change are many. The entry of a new generation of farmers, easy availability of technological products – hardware and software, market demand for high value crops, shortage of agricultural labour, cost reduction, etc. High-tech farming would have been out of the reach of small and medium farmers and women farmers – if not for the entry of FPOs into the game. The FPO acts as an intermediary to both assess demand for farm products and develop backward and forward linkages to make high-tech farming processes available to resource poor farmers.

This Training Module is designed to provide members, directors and staff of FPOs and CBBOs – a bird's eye view of new trends in farming. With this information, FPOs can develop detailed plans to implement the most beneficial of these technologies to their farmers.



Bankers Institute of Rural Development (BIRD), Lucknow is an autonomous institute promoted by National Bank for Agriculture and Rural Development, the Development Bank of the country. It is a premier institute for providing training research and consultancy services in the field of agriculture and rural development banking in India and abroad. The Institute was established in 1983, for addressing the capacity building needs of stakeholders. BIRD, Lucknow is an ISO 9001: 2015 certified training Institute.

Clients

All Banks, Government agencies, MFIs, NBFCs, Financial Sector, NGOS and Civil Societies.

Coverage (Training, Consultancy, Research)

Project Lending-Agriculture and MSME, Climate Finance, Rural Banking, Farmer Producer Organization, Micro Finance, Human Resource, Financial Inclusion, Training of Trainers, Executive Development, Management Development Programme, IT based Banking, Green Finance, Responsible CSR, Group approach to Development, Women Empowerment, Organizational Development, Investment & Treasury Management, Risk Management.

Faculty

Faculty are drawn from NABARD, banks and scholars of respective fields and have pan-India level field experience. The faculty have specialization in Banking Finance, Financial Inclusion, Agriculture & Allied sector, Fisheries, Forestry and Human Resources, etc.

Infrastructure

43 acre green campus has world class infrastructure in terms of class rooms, simulation and AV Rooms, Board Room, Conference Hall, Auditorium, Library, Gym, Air-conditioned Hostel Rooms, Local and International cuisine.

