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# Role of Cooperative Farming and Emerging Technologies in Solving Critical Problems of India's Agricultural Sector

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## Abstract

In India, where the majority of the population still resides in rural areas and is heavily dependent on agriculture, inclusive growth cannot be achieved without taking into account the rural population. Many farmers in India do not view farming as a viable source of income due to the sector's stagnant structure. As a result, the agricultural system needs to be revisited in order to make the required improvements. Furthermore, the incorporation of new technologies is very important, particularly in the contemporary era. As a result, the article begins by outlining the shortcomings of the APMC (Mandi System), which dominates India's current agricultural structure, before moving on to discuss other options, including corporate farming, contract farming, commercial farming, and cooperative farming, all of which are gaining attention among different governmental bodies. It aims to examine the benefits and shortcomings of each model, especially in the context of India. Then it goes on to discuss about the problems that modern agriculture is currently facing and how we may use developing technologies to solve them. It also discusses alternative modern farming practices while taking into account difficulties such as a lack of water, fertile soil, and land-related problems. For this, the research relies on governmental data, websites, and other secondary sources such as books, articles, and papers from various journals.

**Keywords:** Agriculture, Cooperative Farming, Modern Technology, Farmers, APMC, Corporatization, Contract Farming, Development

## Introduction

Agriculture is viewed as a symbol of nutrition, progress, and prosperity of humanity. It not only works to feed our stomachs, but it also employs a large population and helps to lower unemployment. The agricultural and allied sector employs 10.07 crore families, or roughly 54.6

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percent of the nation's total workforce (as of the 2011 Census), and it contributes significantly to the country's Gross Value Added (GVA), accounting for 18.6 percent of the nation's GVA for the fiscal year 2021–22 (MAFW, 2022-23). Additionally, it makes a significant contribution to India's social, economic, and political development. Data indicates that India is the world's top producer of milk, pulses, spices, jute, and other goods. It is also the world's second-largest producer of rice, wheat, cotton, sugarcane, fruits, and vegetables. However, when it comes to exports, India only accounts for 3.1 percent of world exports, compared to 7.8 percent for Brazil and 5.4 percent for China, respectively (Mishra, 2021). The extent of the agrarian crisis can be judged by the fact that 48% of Indian farmers do not want their children to become farmers (Shukla, 2019). This is to be noted that more than 10200 farmers and agricultural workers committed suicide in 2019 according to the State of India Environment Report (CSE, 2021). Agriculture, according to development experts, is a critical component in achieving, at the very least, sustainable development goals i.e. 1 (no poverty), 2 (no hunger), 3 (excellent health and well-being), 10 (reduced disparities), 12 (responsible consumption and production), 13 (climate action), 14 (life below the water), and 15 (life on land).

It is also worth noting that India, with 2.4% of the world's total land area, supports 18% of the world's population. India has 0.12 hectare of agricultural land per capita, while the world has 0.29 ha (PIB, Nov 5, 2019). Currently, Indian agriculture is plagued by a number of issues. It has become an unattractive and unprofitable business because of low productivity, high input costs, technology fatigue, unbalanced fertilizer use, degradation of land and water resources, low level of public investment, low seed replacement rates and inadequate credit and market access for farmers. The market volatility brought on by growing global integration is another issue that farmers are dealing with. This is a result of both trade liberalization, which exposes these farmers to competition from heavily subsidized products in the developed world, and diminished support and protection for farmers in developing nations.

The APMC system was designed to safeguard farmers against exploitation. However, we also see new forms of exploitation in this area, which has caused the governments to reconsider the premise of APMC. The Government of India is currently facing a new challenge in figuring out how to increase farmer productivity in order to increase the income of small-scale farmers and low-income agricultural laborers. We have therefore been pushed to reflect on the models that are in use and

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have been successful in other countries. A few of these include contract farming, cooperative farming, corporate farming, and so forth. The question today is whether these systems would succeed in India, given India has a different backdrop than many of the developed countries. As a result, the article would evaluate all of the choices while keeping the Indian context in mind. The first part of this article covers several aspects of corporate, contract farming and its substantial challenges, as well as commercial cooperative farming, to determine if it may be a viable alternative or not. We must acknowledge that technology, particularly in the agriculture sector, is essential for success and competition in the modern world. Therefore, the topic of agriculture remains incomplete if we did not mention the role of technology in agriculture. Hence, the final section of this article discusses the use of technology in agriculture as well as various alternative farming techniques that might offer a better answer to the problems that the agricultural sector is currently experiencing, including other dimensions related to it.

**Issues Affecting Indian Agriculture:**

- **Subsistence agriculture:** Subsistence agriculture is practiced in most parts of India. The farmer manages a little plot of land, cultivates crops with the aid of his family, and consumes practically all of the farm's output with little left over to market.
- **Lagging Agricultural growth:** The Economic Survey noted that the agriculture sector in the country grew by 3% in 2021, lower than an average growth of 4.6% in the last six years, while the national growth rate has been over 6% (Mishra, A. R., 2021, 07 22). As a result, income growth is outpacing net food production. The high levels of food price inflation are being brought on by a rise in demand that is happening considerably quicker than supply. Additionally, the population is expanding by 1.3% annually and diets are diversifying. As a result, there is now more need for food.
- **Low productivity:** Since the 1950s, agriculture net productivity has increased by four times. However, it lags far behind major economies such as the United States, China, and Brazil.
- **Deficits in infrastructure:** In India, mechanized agriculture is still a faraway dream. The supply chain and storage facilities are still very disjointed. FCI storage facilities are dispersed and mostly crop specific. CAP storage (cover and plinth) is still in use despite efforts to have it stopped.
- **Lack of agricultural credit:** According to the NABARD All India Rural Financial Inclusion Survey 2016–17, more than half of the nation's agricultural households are indebted. A

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sizable portion of this debt is owed to unofficial sources like moneylenders. People continue to rely on informal sources for a variety of reasons, including small landholdings, ignorance, delays in the payment of subsidies and MSPs, and delays in the acceptance of legal loans.

- **Problems with government procurement:** Despite the fact that MSP has been announced for 22 crops, only a few are the focus of collection. The open-ended procurement by FCI creates problems for grain management and storage while inhibiting private involvement in post-harvest activities
- **The issues with APMC**: The APMC has a number of issues that have reduced its effectiveness and occasionally made it redundant, including the cascading effect, cartelization, corruption, and monopoly. This issue has been thoroughly examined below.

**APMC and its Drawbacks:**

The APMC is in charge of regulating agricultural trading practices in India. In order to stop farmers from being exploited by middlemen and compelled to sell their produce at absurdly cheap prices, state governments founded the APMC, a marketing organization.

All food products must be brought to the market (Mandi) under this system, and sales are conducted by public auction. The traders are given licenses to operate in a market. The owners of malls, wholesalers, and retailers are prohibited from making direct purchases of produce from farmers. This has a variety of advantages, including:

• All transactions are conducted only by auction, which guarantees fair prices and prompt payment of farmers for their produce.

• To make the purchase and selling of the commodities easier, commission agents are there. Needless intermediaries are eliminated.

• This system uses a mechanism known as MSP, in which the government fixes a certain category of grains, protecting farmers from the severe decline in farm prices.

• In order to prevent fraud in the transaction process, there is also a system of appropriate recording.

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However, this system has a number of drawbacks that have caused the government to reevaluate the APMC system.

1. **Cascade effect:** The APMC imposes numerous expenses (such as market fees for buyers, license fees, Mandi fees, etc.) of considerable magnitude that would add as an extra burden to the farmers. When introduced at the very first level, this has a cascade effect on the price of the commodity.
2. **Cartelization -** In an APMC, it is frequently observed that agent's band together to establish a cartel and purposefully refrain from making larger bids. Produce is bought at a price that was artificially discovered and then sold for more. Participants then divide the spoils, leaving farmers in the dark.
3. **The monopoly of APMC -** A recent study revealed that APMC has been controlled by a small number of parties, depriving farmers of better consumers and customers from original suppliers and preventing them from receiving higher prices.
4. **Excessive commissions, taxes, and levies -** Farmers must pay commission, marketing fees, Rural Development Cess, and APMC Cess, all of which raise costs. Furthermore, value added tax is imposed by many states.
5. **Entry Obstacles -** Farmers are frequently prohibited from operating in markets. These markets have extremely high license fees. In addition, rent/value for shops is quite high in comparison to license cost, which discourages competition. APMC is typically exclusively used by a few numbers of the rural or metropolitan elite. As a result, businesses and factories no longer participate at all.
6. **Other Manipulations** - Agents frequently withhold a portion of the payment for illogical or fabricated justifications. The farmer is occasionally denied a payment slip, which is necessary for him to obtain a loan and recognizes sale and payment. (APMC, n.d.)

Even though the majority of State governments, including those in Andhra Pradesh, Gujarat, Karnataka, Punjab, and Tamil Nadu, amended the APMC Act to allow agribusiness companies to buy directly from farmers and avoid the regulated mandis, many States still only allow agricultural trade through the APMC. (Chandrashekar and Ghosh, 2003).

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Therefore, in order to make the agricultural sector profitable and feasible for farmers, reform in this area is required. Now the question is: Are there any other workable solutions for turning farming into a successful endeavor?

There are several farming practices that have been called into question in the modern day, and the government is working to revolutionize agriculture by emphasizing such choices. These include corporate farming, contract farming, commercial farming, and cooperative farming. Though the terms are distinct, there is some overlap. As a result, it falls into two categories. The first is corporatization of agriculture and/ through contract farming; the second is commercialization of agriculture and/ through cooperative farming. Which of these two models may provide a better answer to India's present agricultural crisis? In order to boost agricultural growth and alleviate the crisis, this study discusses these and related concerns.

Both these model are considered below:

## 1. Corporatization of Agriculture through Contract Farming

According to Investopedia, corporatization involves transforming the framework of a government-owned corporation into a legal entity with the structure of a public trade company. Privatization and corporatization are not the same. In a comparison between corporatization and privatization, Baker (Baker, 2005) provides a clear explanation of what each term means. "Privatization" refers to the transfer of management or ownership from the public to the private sectors. Corporatization implies changes in resource management practice that introduce commercial (such as efficiency), Methods (such as cost benefit analysis), and objectives (such as profit maximization). Thus, in contrast to corporatization, which involves institutional changes (in the sociological sense of rules, norms, and customs), privatization entails organizational change (Magdahl, 2012). Therefore, corporatization is the transfer of governmental public service functions to a different legal entity that is owned by the public sector and subject to governmental direction. Examples include ONGC (1960) and BSNL (2000). Typically, privatization occurs after corporatization.

The above-mentioned explanation of corporatization was economic in nature. Now, when one discusses the corporatization of agriculture, they mean allowing corporate structures to control the price of inputs like water, fertilizer, seed, electricity, and the market value of the agricultural product. Again, it can be argued that corporate control over the means of production and chain of

distribution for agricultural products constitutes corporatization of agriculture. Furthermore, if we examine the means of production in detail, land would rank first, but corporations are not yet permitted to own land for agricultural use. The newly adopted farming policies in India incorporate certain new trends such as contract farming, leasing of land to corporations for farming, which is the highest level of corporatization in India (Meena, 2016)

Many of the challenges affecting Indian agriculture today can be resolved by corporatizing the sector. *First of all,* farming is not currently regarded as a desirable profession. Inducing a professional mindset through corporatization, which considers agriculture as a business rather than a means of sustenance, would draw young people into the agricultural industries. *Second,* it helps the government lower spending on things like subsidies and price support programs by increasing private investment. *Third,* the concept "minimum investment, maximum return" governs corporatization. As a result, the corporation will attempt to increase agricultural productivity by facilitating farmers' access to inputs such as high yielding seeds and plant breeds, higher quality fertilizers and pesticides, and the development of critical infrastructures, technologies such as pre- and post-harvest treatment, storage, and transportation infrastructure. *Fourth,* the existence of numerous corporate organizations will boost competition, which will improve commodity prices for farmers by lowering the impact of "middlemen," a term that is present in the APMC system.

There are currently some conditions that must be prioritized in order to bring corporatization, such as land consolidation, improved seed quality, storage facilities, a strong financial system, efficient dispute resolution mechanisms, etc.

This discussion demonstrates that contract farming is the most effective approach for corporatizing the agricultural sector. Agriculture produced in accordance with a contract between a farmer and a buyer is known as contract farming. The core of such a deal is the cultivator's promise to deliver an agricultural product of a specific sort, at a specific price, and in the quantity requested by a recognized and committed customer, usually a big business. The farmer is required by the contract to plant the contractor's crop on his property, harvest, and provide a specific quantity of produce to the contractor, based on quality criteria. This could be at a predetermined price, although it is not always the case. The conventional contract calls for the contractor to provide all of the cultivation-related material inputs, with the farmer providing the necessary land and labor. The terms and structure of the contract, however, vary depending on the sorts of crops to be cultivated,

the agencies or businesses involved, the kinds of farmers, and the technologies used and the environment in which they are used (Ghosh, 2003).

Small and marginal farmers are currently finding it difficult to participate in the market due to a number of obstacles, including a lack of necessary inputs, loan availability, lack of technical assistance, and lack of marketing support. With a growing trend of private enterprises through contract farming, supplying inputs, technology, and other services to farmers and purchasing their agricultural produce, the government's burden of input subsidy and food grain purchase under the MSP program will reduce (Singh, 2007). Additionally, it would get rid of the middlemen and guarantee the companies a steady supply of agricultural goods. Furthermore, it encourages farmers to switch from traditional crops to high-value commercial crops like fruits, vegetables, and flowers, which helps to eliminate crop distortion, particularly in agriculturally developed regions like Punjab where monoculture has been practiced to a greater extent. Consequently, those who support contract farming frequently cite these limitations as justification for advocating contract farming as a practical solution for these farmers.

Theoretically, Corporatization and Contract farming appears to be a practical solution for increasing farm income and agricultural output. Despite the above-mentioned benefits of agricultural corporatization, there are some major concerns:

**Concerns Regarding Corporate Agriculture:**

Some of the most important issues concerning contract farming are as follows:

1. It makes sense that private businesses engaged in contract farming are motivated by short-term financial gain. In order to maximize returns per unit of land, they push farmers to utilize more intense agricultural practices, greater and indiscriminate use of pesticides, and genetic engineering, which are not environmentally sustainable. It would disrupt the natural equilibrium, decrease soil and water fertility, and harm biodiversity. Since the majority of these businesses are MNCs, they have no ties to the local community. Additionally, there is no commitment to social justice, social security, or any of the other interests of the farming class. They can relocate their businesses to other locations or countries once the natural resources of the current ones run out. According to Sharma, contract farming is a modern version of 'slash and burn' agriculture (Sharma, 2006).

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2. The contracting companies have oligopolistic strength and can form strategic agreements with other businesses. For instance, Hindustan Lever, Rallis, and ICICI are engaged in contract farming for wheat in Madhya Pradesh. According to the arrangement, ICICI loans the farmers, Rallis supplies inputs and technology, and HLL buys wheat from them (MANAGE 2003). The elimination of the small middlemen, merchants, and small processing firms, as well as the competitiveness in the agricultural market, could result from this system of interlocking credit, inputs, technology, and output, which would be disastrous for farmers in the long run.

These companies have complete monopolies over all types of seeds, technologies, purchases, and production, and they have the power to drastically alter the Indian market. This suggests that in a market with a small number of significant input suppliers and consumers, the farmer will have few options for buyers and will be compelled to accept the prices offered in the absence of bargaining power and in the hope of continuing farming.

3. It is asserted that agribusiness companies that engage in contract farming give farmers access to the most recent farm technology, inputs, and information. Once a new technology is provided to the contracted farmers by a company, it enters the public domain and anyone can use it because farmer to farmer extension is very effective, especially in the irrigated regions. This uncertainty may prevent the company from creating or disseminating novel farming inputs or production techniques, and it may instead encourage it to gain unrestricted access to the results of public sector extension and research. India, which was once self-sufficient in food grains, is now becoming a net importer, undermining the food and livelihood security of poor farmers.

4. The contracted companies use land to grow only those crops which are required by the wealthy domestic and foreign consumers and not as per the suitability of the land or as required by the population at large. This may create food security issues.

5. In this system, production is carried out primarily via the use of machinery and with the assistance of hired labor. All production-related decisions are made by the capitalist or corporate people, and the employees have no say in how the farm is run or controlled. Farmers will be told by corporations what to produce and what not to, which will inevitably result in the loss of natural seeds. They will also choose what consumers eat, how much they pay, and what is in it. The country as a whole will not benefit from the shift from agriculture to agribusiness.

6. Agriculture corporatization necessitates openness in order to attract large investors. This would entail loosening regulations on domestic manufacturing, removing subsidies for irrigation, energy, and loans, among other things, all of which would be disastrous to small and medium farms (Singh, 2007).

7. In the majority of cases, farmers assume all financial risk associated with crop loss or technological failure.

8. It's possible that corporate contractors with local monopoly strength will take advantage of rising prices instead of farmers, depriving them of their benefits. Additionally, it can rely too much on the usage of female workers who are paid less and child labor.

Farmers that join into the contract may be pleased at first because they obtain guaranteed marketing of their products at pre-determined pricing and intermediaries are eliminated, but will they be able to maximize their long-term earnings from such ventures?

These considerations can seem speculative, yet it has been noted that farmers' experiences with contract farming have not always been positive. There is always a chance that farmers will be taken advantage of by the firms because the agreement is between unequal partners. Studies on the operation of contract farming in various parts of the nation have identified a number of issues with the contract farming system (Chandrasekhar & Ghosh, 2003; Ghosh, 2003; Kumar, 2006; Sharma, 2004; Singh, 2004b). Market factors have frequently forced contracting corporations to break their agreements, which has caused problems for the farmers. Resentment among farmers has increased as a result of the increasing instances of predetermined prices being cut under the guise of lower-quality grain or crops.

It is important to highlight that while corporate agribusiness has been successful in some regions and some Indian states, it has not been as successful in other regions and states due to the issues raised above. The Kuppam Pilot Project in Andhra Pradesh's Chittoor district reveals the experience of contract farming that many farmers have been forced out of their profession and only a handful are able to work as hired laborers on the demonstration farms. Subsidiary activities, such as dairying with crop leftovers, have also lost value (Chandrasekhar & Ghosh, 2003). The field studies do not support the firms' claims that providing the newest technology and extension services to the contracted farmers will be beneficial to them. For instance, Kumar discovers that,

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on average, just 35% of farmers who have signed a contract with the company admit to regularly using its extension services and advice. One-fifth of farmers reported never receiving these services (Kumar, 2007).

Now the question is, do we have any other options that can overcome the aforementioned challenges while also being beneficial to farmers? In my view, the second model, which calls for the commercialization of agriculture through cooperative farming, could be a viable option. Now, in order to comprehend why it's stating this, let us first grasp the concept.

## 2. Commercialization of Agriculture through Cooperative Farming

Agriculture commercialization is the farming approach in which crops and livestock are cultivated for profit and sold in the market. It often requires a lot of cash, covers a lot of ground, is highly mechanized, and uses contemporary inputs like high yielding crop types, chemical fertilizers, and irrigation. The above-mentioned first model likewise fits into the Commercialization of Agriculture category; however, it was accomplished through contract farming. However, the one we're talking about here is not through a contract between a farmer and a corporation, but rather through cooperative farming, in which each member-farmer retains individual ownership of his land while farming is done collectively. It should be emphasized that not all Indian farmers are able to commercialize their particular farms because the country's land supply is scattered and tiny in size, which might pose numerous challenges to the process.

In comparison to the global average of 3.7 ha per person, India's average operational size of land holding is 1.08 hectares (2015-16), which in 1970-71 was 2.28 hectares (PIB, Mar 3, 2020). Producers with small holdings frequently experience difficulties as a result of inefficiencies in transportation, using high tech infrastructure, machinery, or seeds, increasing their reliance on middlemen, obtaining agricultural loans. As a result, there is income loss, which turns into the middleman's commission. Therefore, it has a negative impact on efficient farming, affecting the farmer's economic prosperity, particularly for Producers with small holdings. Land consolidation initiatives for high-quality and productive farming must be made in order to promote farmer-centric agricultural growth.

The significance of cooperative farming comes at this point. A cooperative farming society is founded when many farmers in a hamlet pool their land and agree to consider the pooled piece of

land as one huge farm for the purpose of cultivation, purchase the necessary inputs for cultivation, and market the crops cooperatively. It is the perfect solution for regions with small farm holdings and where farmers' individual purchasing power is limited. One member, one vote is the premise through which such a society elects its officers to ensure good operation. Profit is typically divided among the member-farmers in proportion to the amount of land they possess.

Unique features of cooperative farming:

- Farmers can choose whether or not to participate in this scheme.
- Farmers retain ownership of their land.
- Farmers combine their resources such as land, animals, and equipment.
- The management of the entire farm is chosen by the members and operates as a single entity.
- With their contributions of land and labor, each member receives a portion of the overall production.

**Advantages of Cooperative Farming**

Cooperative farming has several benefits. The following lists some of the key ones that are in public knowledge (Drishti, Feb 16, 2019):

• **Economies of Scale:** Cooperative farming can eliminate all of the problems associated with small and uneconomic farms. Members of cooperative farming can gain the benefits of large-scale farming by pooling all of the small and marginal farms. When referring to agricultural inputs, such as seeds, fertilizers, etc., as well as large machinery, such as tractors, harvesting machines, the society can buy in bulk quantities, which lowers the cost.

Farmers who participate in cooperative farming can take advantage of economies of scale by renting services like storage and transportation. It would lower risks while improving the quality of their goods and services thanks to the agricultural cooperative system. In cooperatives, farmers have better information access, more negotiating power, and lower transaction costs when applying for loans.

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• **Workers Shifting to Non-Agricultural Sector:** Increased productivity in cooperative farming will pave the way for workers to transition from agricultural to non-agricultural activities.

• **Marketable Surplus:** Marketable surpluses of food grains and industrial raw materials can be transported and marketed in large quantities by the society and can also bring in lucrative prices.

• **Creditworthiness:** Because cooperative farming has a higher creditworthiness than individual farming, large-scale farming can attract more money for its productive operations

• **Convenience in administration:** From an administrative perspective, cooperative farming helps the government collect taxes, disperse subsidies, and introduce more efficient agricultural techniques.

According to the data above, a large portion of the land in India is only available in small, fragmented pieces. Furthermore, the ever-increasing population, the shrinking amount of arable land, and the depletion of natural resources all contribute to the inevitable fragmentation of the land. To boost productivity and farmer income, this problem needs to be addressed thoroughly. Producer enterprises, agricultural cooperatives, or commodity-based collectives must be encouraged to develop so that farmers can gain directly. As was already noted, farmers retain ownership and authority over their own lands, therefore many forms, levels, and phases of cooperative farming can be developed.

### ➢ Key variations of Cooperative Farming

As was already noted, this is a collection of dispersed land, and cooperative farming has been established in order to reap the same benefits as those who own big tracts of land. Now since there may be numerous ways to increase the size of the land for this goal, numerous cooperative farming arrangements may be established.

### I. Cooperative Joint Farming Society

This farming society comes into being when the members pool their land and productive assets and carry out all pre-sowing, pooling, and post-harvesting functions in addition to the cultivation of the pooled land on a cooperative farming basis. It makes arrangements for the marketing of the produce and buys various inputs from the market. To carry out these efforts, it looks for financial support from outside organizations.

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### II. Cooperative Better Farming Society

Each member cultivates his or her own land in a cooperative better farming community instead of working on shared land together. They work together for pre-sowing and post-harvesting activities. For example, they share costs to jointly purchase various agricultural inputs including seeds, fertilizer, insecticides, machinery services, etc. They sell the crops together, and a cooperative improved farming society may also organize for financial help to carry out these tasks.

### III. Cooperative Tenant Farming Society

Cooperative Tenant Farming Society leases land to its members after buying or leasing it from the government or some private parties. Members cultivate the land and pay the rent that falls to their share and the society.

### IV. Cooperative Collective Farming Society

In this kind of collective community, the members permanently pool their land. A member who joins this organization is unable to take his land out of the community. He can only give away his land to someone else who will take his place in the community. This collective agricultural group performs similar duties as a cooperative joint farming society. In this, each member receives pay and profits based on the labor and land they have contributed, respectively. Such a society is created in defiance of the fundamental tenants of cooperatives, which include voluntary participation and the freedom to leave the group at any moment (Singh, n.d.).

### Challenges to Co-operative farming in India

**1.** Cooperative farming has failed to mount a frontal attack on the prevailing economic inequality because the historic status distinctions of landowners, landless laborers, and sharecroppers are still maintained.

**2.** Agriculture mechanization through cooperative farming would reduce the scope of employment and is likely to make rural employees redundant.

### Key Suggestions:

**A.** Cooperative society members should be involved, watchful, and knowledgeable about their own rights.

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**B.** Fairness in actions, accountability of the executive members, and transparency in operation.

**C.** There is a need for a better understanding of the dual nature of cooperatives as participants in business and civil society.

**D.** Market access, financial resources, and links between agricultural inputs and outputs are necessary for them, particularly if they want to compete on global markets.

In light of this, we may assert that cooperative farming is a pillar of agricultural development and food security. These farming cooperatives are crucial in assisting small farmers and underrepresented populations.

Many countries throughout the world have successfully implemented the cooperative farming approach. Among them, the US, Canada, Mexico, Cuba, Italy, France, Israel, Australia, Japan, and the Netherlands are prominent nations.

### ❖ The Use of Modern Technology in Agriculture

In today's world, agriculture demands more innovation and technology than ever before. The industry as a whole is struggling with a host of issues, including a water shortage, deteriorating soil quality, excessive pesticide and fertilizer use, a lack of fertile land, unfavorable weather patterns and climate change, a labor and time shortage, an increase in population, high input costs, high transportation costs, and shifting consumer preferences for transparency and sustainability. Therefore, despite the possibility that the aforementioned agricultural model i.e., commercialization and cooperative farming could prevent the agricultural industry from collapsing, they are less likely to be able to address the current problems facing agriculture. Because, the current century has brought new difficulties that we cannot overcome if we do not concentrate on using technology in agriculture, which can provide an immediate remedy to the issues that farmers are currently facing.

According to UN research, unsustainable agricultural practices have left 40% of the world's land too damaged for economic farming, and by 2050, 90% of the topsoil on the planet will be further endangered (UN News, Jul 27, 2022.). In addition, agriculture requires 70% of the world's fresh water supply, which is quickly running out. By 2025, more than half of the world's population will

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reside in regions with a freshwater deficit, according to Pew Trusts (Famiglietti, 2019). However, the UN predicts that by 2050, there will be 10 billion people on the planet. According to Harvard Business Review, this will raise food demand by 59% to 98% (Schierhorn, 2016) In order to keep up, food production will have to increase by more than 50%, but even if all other things remain constant, that pace of growth would not be sustainable in the long run (PIB, 2019).

The use of technology can provide us with information on when and what kinds of crops to plant, how to rotate crops for best results, how much water to use when performing precision irrigation, what type of tillage is most effective with a particular type of soil, and when, how much, and what types of nutrients and plant protection chemicals to apply. Technologies used in advanced countries to gather, transport, store, process, and distribute agricultural goods are already extremely efficient and produce far less waste than in nations where the requisite infrastructure and capital are considerably more difficult to come by. Among the agriculturally advanced countries, the United States, United Kingdom, Canada, Australia, China, the Netherlands, Germany, France, Israel, New Zealand, Japan, and South Korea stand out.

The idea of utilizing agricultural and farming technologies to increase productivity, sustainability, and efficiency in the production of food is a relatively new one. The 2018 publication Emerging Technologies by Agri Futures Australia lists a few significant technological applications in agriculture. Blockchain, the Internet of Things, AI/Big Data, Gene Editing, Nanomaterials, Automation/Robotics, Synthetic Biology, 3D printing, Satellite Technology, Drones, and many more technological advancements are included (AgriFutures, 2019). The application of these technologies in agriculture will be covered below in more detail.

1. **Satellite technology**

Through observation, measurement, and response to inter- and intra-field variability, satellite technology aids in agricultural management. Agriculture has benefited greatly from Global Navigation Satellite Systems (GNSS) technology, with Australia setting the standard for very precise Global Positioning Systems (GPS) throughout the globe. This has progressed towards the creation of tractor auto-steer guidance technology. Since then, variable rate technology (VRT), yield mapping, topography mapping, and soil data analytics have all been part of precision agriculture and satellite technology. Farmers may now obtain real-time data on how their farm is

performing, allowing them to make more informed and precise decisions. There is potential for satellite technology to offer novel approaches, such as crop yield estimation using satellite data by monitoring vegetation health and growth at various stages of crop development and with higher geographic resolution. Estimating production has the ability to assist growers in becoming more knowledgeable, to extend the forecasting lead time for crop yield, and to keep them aware of shifting supply and pricing patterns.

**Application and Benefit to Agriculture**

It has the potential to support agriculture in the following ways:

• **Data Collection:** With the aid of satellite technology, farmers may collect details about the soil and crops in particular fields, such as nutrient content and information on prior harvests. When processed and displayed, this data can help farmers make choices regarding different fertiliser, chemical, and water applications. Satellites can also help in providing data on potential yields, soil types, crop or soil color index maps, soil types, and electromagnetic soil mapping.

• **Environmental Protection**: By minimizing fertiliser and chemical runoff and permitting judgments on more effective applications, precision agriculture and satellites have the ability to lessen the environmental risks and impact of farming. With studies demonstrating the technology may cut fertiliser consumption by 10–30% while maintaining the same production, VRT for nutrient application, for instance, directly leads to decreased emissions.

• **Connectivity:** Satellites will increasingly make it possible to connect rural and regional communities.

• **Service Providers**: Bankers and insurance companies may increasingly rely on satellite imaging to provide agricultural services. Insurance firms are utilizing technology to give farmers a just and prompt compensation for crop loss due to weather occurrences as climate change appears to have an increasing impact on agricultural operations.

**2. Drone**

A drone is described as an unmanned, radio-controlled aircraft that can be flown remotely or automatically using flight plans that are handled by software and encoded in the aircraft's onboard sensors and GPS. Although there are many various kinds of drones, aerial drones, including fixed

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wing, rotor, and hybrid systems, are the most popular in agriculture. The phrases drone, UAV (Unmanned Aerial Vehicle), UAS (Unmanned Aerial Systems), and RPA/S (Remotely Piloted Aircraft / Systems) are all interchangeable when referring to aerial drones.

**Application and Benefit to Agriculture**

Drones have the potential to support agriculture in the following ways through quick data collection and processing:

• **Soil and Field Analyses:** Drones are capable of creating precise maps for soil analysis prior to planting as well as additional analysis for irrigation application, fertiliser application, and chemical requirements. Drone data can be applied to gridded management maps using the normalized difference vegetation index (NDVI), a mapping technique that determines whether an area contains live green vegetation. This information can then be used in variable rate systems for sowing, spraying, and other management operations.

• **Crop Spraying:** Drones can scan the ground and apply the appropriate amount of chemicals with greater efficiency and with less negative effects on the environment when equipped with automatic distance-measuring technology. One of the main advantages of drones is the targeted application of pesticides, which lowers input costs and has a good impact on the environment by reducing the usage of fertilizers and chemicals.

• **Health Assessment:** Drones can be used to deliver high resolution imagery that reveals crop health, reveals detailed crop development, and allows for the detection of bacterial or fungal infections on trees. Drone-mounted equipment can determine which plants reflect various quantities of green light and NIR light by scanning a crop using both visible and near infrared light. Multispectral images that track plant changes and reflect plant health can be created using this data. As a result, farmers are better able to keep an eye out for pests and diseases in their crops and, in the event of bad weather, more effectively record losses for insurance claims.

• **Livestock Monitoring:** Drones can be used to remotely monitor livestock doing away with the requirement for manual inspections and possibly increasing earnings through timely monitoring. Drone pilots may keep an eye on livestock to check for missing animals, monitor births, and monitor injuries.

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• **Irrigation:** Drones equipped with hyperspectral, multispectral, and thermal sensors can be used to scan fields for moisture deficits and calculate vegetation index / heat signatures. Farmers can then utilize this data to adapt irrigation operations in a more effective way, concentrating on certain dry areas.

Farmers will increasingly use their own drones and collect their own data as drone technology evolves, enabling beneficial outcomes around timeliness of decision making because a drone can be launched quickly, compared to satellite technology, which can take a day to process imagery. Additionally, this will help farmers manage their land sustainably with an emphasis on soil and water resource conservation methods that customers are increasingly demanding.

## 3. Big Data and Artificial Intelligence (AI) technologies

Big Data describes data sets that are so vast and intricate that conventional data processing tools are insufficient. Artificial intelligence (AI) is intelligence exhibited by computers that can "learn" from experience and can be programmed to carry out specific tasks by analyzing vast amounts of data. Applications range from fairly straightforward feedback mechanisms (such as a thermostat controlling greenhouse air temperature) to sophisticated algorithms that give growers timely decision support (such as suggestions on crop protection strategy) or prescriptively and proactively implement automated management interventions (such as robotic weed control). Its efficiency is further increased by the incorporation of data from many sources, such as weather, market, agronomic, or standards from other farms. It can be used at various sizes, from transforming data gathered on specific animals and plants to displaying information for crop planning and monitoring on a large farm.

### Application and Benefit to Agriculture

Big Data and AI combined can give farmers access to sophisticated data that can guide important decisions made on the farm. Although the technology can be used in a variety of contexts, the following are just a few examples:

• **New plant seed development:** significant advances in biological data collecting and analysis have expedited plant genomics. Data from laboratory research is being analyzed to create new hybrid seeds that are effective in a variety of conditions.

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• **Precision farming:** new tools and software that monitor field conditions, regulate machinery, measure yields, track input levels across fields, and track field conditions are greatly boosting productivity and profitability. Software with machine learning enables smarter and more individualized interactions, opening up possibilities for better farm decision-making.

• **Animal welfare:** Big Data and AI have the ability to assist farmers in effectively managing their livestock with the least amount of supervision. However, in the dairy industry, AI is already being used in automated milking units that can analyze the milk quality and flag for abnormalities. New trials are being conducted where the technology is able to examine individual animals to determine their condition and suitability for market.

• **Lower operating expenses:** Big Data and AI present an opportunity for agriculture in that they may improve cost allocation and lower operating costs through targeted application of inputs like fertilizer and chemicals.

4. **Gene Editing**

One of the contemporary biotechnologies used to alter the genomes of living things for health and/or commercial reasons is gene editing. It enables the exact and modest modification of the human, animal, and plant genomes. Gene editing in plants is done on cultivated plant cells, which are then regenerated into complete plants, resulting in advantages like disease resistance, drought tolerance, or the absence of allergens. In animals, gene editing is carried out on the single cell that gives rise to the embryo, which matures into the animal. To date, advances brought forward via gene editing include virus-resistant pigs, in-egg sex detection for poultry, and polled cattle. While discussing gene editing, CRISPR/Cas9 and other tools of a similar nature (such as ZFNs, TALENs, rAAV, and transposons) are frequently brought up.

**Application and Benefit to Agriculture**

It offers a lot of significant advantages. Here are some examples of important ones:

• **Improved profitability:** It is anticipated that if 60-100 million farms adopt gene-edited seeds by 2030, worldwide production will increase by 100-400 million tonnes, and 5-20 million tonnes of lost production will be removed. As a result, farmer earnings would rise by $40-100 billion.

• **Diversified production:** The cheaper cost (compared to genetic modification) and expedited timeline (compared to conventional breeding) provided by gene editing will allow R&D money to

be invested in a diverse variety of commodities. This will enhance the variety of crops that farmers may profitably add to their cycles and their capacity to profitably create goods that satisfy consumer demands (such as higher protein content).

• **Reduced input costs:** Gene editing may make it possible to create plants and animals that are suited to coexist with other cutting-edge technologies, including robots. In agricultural systems that support both plants and livestock robotic technology decreases the need for labor and enables more effective input usage.

• **Adaptation to climate change:** Consumers nowadays are concerned about how climate change is changing the growth conditions. Farmers will be able to effectively cultivate new crops that are suitable for their environments and consumers, as well as continue cultivating existing crops with the ability to quickly adapt plants to meet changing growing conditions.

• **Greater Animal Welfare:** Breeding animals that don't need human assistance may be made possible by gene editing. Gene editing modifies a gene or a gene group by making minute, discrete, and exact alterations to the DNA of plants and animals. However, there are two significant issues with gene editing. The first concerns the morality of modifying existing animals or plants. The second concerns "gene drives" and their possible effects on ecological systems.

### 5. Automation / Robotics

Robotics is the study of mechanical and movable structures that operate under some sort of autonomous control. In sectors like logistics, mining, healthcare, military, manufacturing, and agriculture, robotic technology is being used with robots that can replace humans to boost productivity or finish activities that are thought to be too risky, boring, or difficult for humans.

Robotics in agriculture have replaced the need for human labor in activities including dairy milking, harvesting, spraying, and surveying, resulting in benefits like greater quality fresh produce and lower production costs. Robotics and automation technology also hold the promise of providing growers with greater information of the state of their business as well as the ability to act in real-time to boost efficiency, dependability, and productivity while reducing environmental impact. Consumers will benefit from the chance that robots provide to potentially reduce food costs through precision farming while also safeguarding the environment.

**Application and Benefit to Agriculture**

It has the potential to support agriculture in the following ways:

• **Crop Management:** Horticulture will gain especially from the usage of robotics for jobs like mowing, trimming, sowing, and thinning crops. Robotic weeding is starting to take the role of labor-intensive and expensive hand weeding for speciality horticultural crops including lettuce, broccoli, tomatoes, and onions. Robotic weeding advancements have the potential to drastically reduce the cost of weed control.

• **Dairies:** Robotics are utilized in dairies to create fully automated milking systems and lessen labor requirements so that labor may be utilised elsewhere on the farm. Installation of robotic dairies can boost milk production, and the cost of automated systems is approaching that of conventional rotary-style dairies.

• **Cropping:** Technology for high-speed planting that is developing quickly has the potential to work with autonomous tractors, sensors, and management software to increase crop yields by 70% by 2050.

**6. Blockchain**

Blockchain is a form of distributed ledger that was developed by the people who founded the cryptocurrency Bitcoin. A distributed ledger is essentially a database. Since the launch of Bitcoin, it has become clear that the distributed ledger logic that underpins the cryptocurrency has significant uses for data management across all spheres of the economy, particularly in agriculture. A transition away from expensive, ineffective, and centralized record keeping is made possible by the distributed ledger. In order to eliminate human error from data entry into the ledger, distributed ledger applications in agriculture are best implemented in conjunction with Internet of Things (IoT) equipment like sensors and scanners. Distributed ledgers have numerous uses in agriculture, but two of the most important ones are cost removal (e.g., middle actors capturing margin) and improved traceability (e.g., food safety control).

**Application and Benefit to Agriculture**

Distributed ledgers have numerous uses in agriculture:

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• **Systems for effective transaction and inventory management:**

It would reduce the risk of human mistake in data entry and make it possible for the many parties who currently participate in agricultural production systems to share and protect transactions. Smart contracts might also be used to speed up the process from order fulfillment to payment, lowering risk and error and boosting efficiency.

• **Supply chain lineage:** End users are more and more interested in learning about the origins, production, and transportation of the food they consume. Distributed ledgers can offer information on origin, production procedures, transaction specifics, product quality and safety, as well as verified regulatory and financial compliance to parties all along the supply chain.

Along with transparency, supply chain source has two other important advantages: it lowers food fraud and promotes food safety.

Food corporations invest a lot of money in emerging regions to enhance their market share, where food fraud is a major problem. It is expensive if that market share is lost as a result of low-quality food goods appearing on the market under their brand names. Food firms can prove the authenticity of a product or identify and get rid of a bad actor in the supply chain by being able to trace their supply chain. These are just two examples of how food companies can use this ability to prove the quality and safety of their products.

For food companies, food safety is an expensive and global problem. A distributed ledger ensures that fewer customers get sick, preserves perfectly safe food that would have otherwise been recalled, and saves food companies a lot of money by enabling them to quickly trace back and perform a targeted recall of only those food packages that come from areas of concern.

• **Premium and differentiated production:** The interconnection of distributed ledgers and the Internet of Things (IoT) holds the promise of enabling customers to place a value on premium and differentiated manufacturing processes (such as certifications, resource efficiency, and welfare standards). Price premiums could encourage the creation of supply chain infrastructure that supports varied production (as opposed to traditional commodity-based supply chains), such as various crops or production methods. Primary producers would therefore have more options and be better able to explain their production decisions to end users while also getting paid more.

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## 7. 3D printing

3D printing, also known as additive manufacturing, is the method of creating a three-dimensional object of practically any shape or geometry out of almost any material. Using a computer-aided design (CAD) file that details the desired product, successive layers of material are added together to create the desired object in 3D printing. Shapes and designs can be manufactured with a great deal of freedom in terms of materials, quantities, and necessary production infrastructure (e.g., casting; machining) thanks to 3D printing, which operates straight from a computer model. Rapid prototyping, small-run manufacturing at a lower cost without the need for expensive tooling, and the production of end-use parts are the three main applications for 3D printing. With the ability to create parts locally, 3D printing has the potential to alter the way that agricultural equipment is supplied.

### Application and Benefit to Agriculture

The agricultural sector could undergo significant change as a result of this technology. The following are the primary advantages:

• **Production diversification:** 3D printing lowers the price and length of time needed to develop and make equipment, which, if widely used in agriculture, might increase the number of small to medium size equipment producers. This might encourage commercially viable agricultural diversification, as well as specialized production and new markets for livestock.

• **Lower costs:** The capacity to print and distribute components on-demand locally will cut downtime and overhead expenses. Additionally, it provides a chance to recycle components or even waste materials by printing them into new components or goods.

• **Enhanced supply chains:** On-site 3D printing will shorten equipment and part supply chains by shifting production from overseas to local facilities, lowering carbon emissions and guaranteeing parts are always available. For instance, without leaving their farm, farmers might be able to 3D print all the parts for their tractor or perhaps a whole equipment (like a drone).

## 8. The Internet of Things (IoT)

The Internet of Things (IoT) is a network of physical items that are wirelessly connected through sensors and are capable of communicating with one another or a larger network without the need for human interaction. Humans, animals, plants, and infrastructure (such as tools, buildings, etc.)

can all be considered connected objects. This covers aspects like food safety, worker and animal welfare, and methods of production (such using organic materials or water).

**Application and Benefit to Agriculture**

It has the potential to support agriculture in the following ways:

• **Precision agriculture:** IoT devices gather data that can help farmers make better decisions, including how to reduce expenses, enhance yields, monitor crops, and overall be more aware of the condition around the farm. Field sensors that are interconnected with the Internet of Things (IoT) can track data on soil moisture and nutrient levels, manage water use for effective irrigation systems, create unique fertilizer blends based on soil profiles, and identify the best times to plant and harvest. IoT sensors can replace manual monitoring in greenhouses by adjusting the perfectly controlled environment to change temperature, humidity, light levels, and trigger automatic irrigation.

• **Livestock monitoring:** Applications for wireless IoT can be used to track the location, reproductive cycle, health, and other characteristics of livestock. Wearable sensors can assess milk fat, protein, somatic cell counts, progesterone, and antibiotics at every milking, and they can also measure disease symptoms that are otherwise difficult for farmers to discover in the dairy business. Farmers may identify which cows are able to produce more milk by continuously monitoring the animal, and they can then take efforts to improve diets that increase output.

• **Improve supply chains:** In order to assure product quality, safety, and efficiency as well as to provide consumers and regulators with traceability, the IoT is being used to monitor commodities along the supply chain. IoT sensors can prevent the deterioration of perishable commodities by monitoring and issuing safety alerts when the condition of the goods deviates from safe levels and by offering visibility. Food makers can discover potentially contaminated products by monitoring the commodities throughout transportation, which, in the event of a food recall, can speed up the investigative process and provide consumers with quality assurance.

## 9. Nanomaterials

Nanomaterials are extremely small; a nanometer (nm) is one billionth of a meter, and a nanoparticle has one or more dimensions that are 100 nm or less or smaller. Nanomaterials have primarily been used in the fields of environmental science, food processing, and medicine so far.

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The use of nanomaterials in agriculture is being investigated for ways to enhance seed germination and growth, protect plants, identify pathogens, and detect pesticide and herbicide residues.

**Application and Benefit to Agriculture**

Due to their small size, high surface to volume ratio, and distinctive optical properties, nanomaterials, particularly in the following areas, offer a lot of potential for agricultural applications.

• **Sensors:** Highly sensitive biochemical sensors have been created and tested using nanomaterials with distinctive chemical, physical, and mechanical properties. These, such as soil analysis and biochemical sensing and control (using, for example, electrochemically active carbon nanotubes, nanofibers, and fullerenes), are particularly pertinent to agriculture.

• **Fertilisers:** Research into fertilizers coated in nanoscale polymers has demonstrated that they can boost product stability and manage the release of nutrients from the granules, prompting interest in the creation of nanofertilizers.

• **Pesticides:** With nanoparticles, nanotubes, and nanocomposites being employed for pesticide detection, degradation, and removal, nanomaterials are being explored as a tool for sensing and remediation of pesticides.

• **Animal Husbandry:** Studies on nanomaterials are also being used to offer chances to better control livestock development and increase fertility, while in other studies, antibiotic use is being reduced in animals raised for food since medication may be given at a target spot and at a sustained rate.

• **Food Safety:** The use of nanomaterials in food packaging has the potential to increase nutritional bioavailability and provide benefits for detecting microbial contamination. Nanomaterials can also be utilized to create nanoscale ingredients for improved nutrient and dietary supplements, with additives such as vitamins, antimicrobials, and antioxidants added for higher absorption and bioavailability. All of this is quite advantageous to consumers.

• **Water Treatment:** Numerous studies have demonstrated the effectiveness of using nanomaterials to effectively remove different types of pollutants from water, which has great potential for use in agriculture, particularly with the reuse of effluent for irrigation or animal feed.

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## 10. Synthetic biology

Synthetic biology, a collaborative subject that includes biology, genetics, chemistry, engineering, and computer science, is the design or (re)construction of biological systems and devices.

In the fields of agriculture and food, there are both immediate and long-term commercial applications. Current uses include: improved understanding of how biological systems work (for example, to support gene editing technology); and the development of lab-grown food (for example, synthetic meat and milk) and fiber (for example, synthetic clothes and footwear). Future applications include crops with biosensors that warn consumers and producers about harmful bacteria, or that warn growers about crop stress via drone imaging systems before any visible weed or pest pressure; and crops with reengineered nutrient uptake systems that will maximize nutrition and production outputs (e.g., amount, size, and quality).

### Application and Benefit to Agriculture

It has a wide range of uses, some of which are listed here.

• **Emerging industries:** Food and fiber products can now be grown in lab settings thanks to synthetic biology. These production techniques will keep expanding their market share as their economics improve. For instance, producers might create entirely new rotations, goods, or value chains for crops, cattle, and other sources of food, fiber, and fuel that are also ecologically and economically sustainable.

• **Reduced or eliminated input costs:** using synthetic biology, we can design crops that use nutrients more efficiently, both in soil and applied, and that are genetically resistant to pests and diseases. As a result, farmers will have less or sometimes no input needs. Advanced antimicrobials are also being developed, which may enhance soil microbiome health, ultimately enhancing plant health and lowering input requirements (e.g., by eradicating dangerous bacteria while preserving good bacteria).

• **Climate change resilience:** Climate change is altering growing conditions. We may be able to create crops using synthetic biology that quickly adapt to varying growth conditions, even within a single growing season. The impact of agriculture on greenhouse gases can also be considerably reduced through synthetic biology through the development of specialized crops and protein substitutes.

• **Effective supply chains:** Synthetic biology may greatly enhance the quality and safety of food for end consumers as well as give farmers the ability to confirm when their products were (or were not) the cause of an issue. This is done by developing biosensors that warn producers and processors of potential contaminants and quality issues.

❖ **Modern Farming Methods**

India still practices traditional agriculture. The main cause for this is a lack of awareness among farmers. However, when compared to other foreign countries, they refer to it as Modern Agriculture. Utilizing technological approaches in agriculture distinguishes one from the other. In contrast to traditional farmers, modern farmers see themselves as playing increasingly central roles in the agricultural system and are keen to use information and technology to manage the majority of its components. Farmers' labor can now be controlled by modern machines.

In addition, there are several technologically advanced modern farming methods that utilize less water and improve the nutritious value of the grains they produce. These include Aeroponic Farming, Aquaponic Farming, Hydroponic Farming and Indoor Vertical Farming, all of which will be covered in greater detail in this article.

Different types of modern farming methods:

**1. Aeroponics Farming**

Without the use of soil or any aggregate media, aeroponics is the method of growing plants in an atmosphere of air or mist. The method of hydroponics known as aeroponics involves suspending plant roots in the air and spraying them with nutrient-rich water. This technique can provide growers more control over the amount of water they use, but if infections are not thoroughly managed, it could leave plant roots exposed.

In comparison to other systems, aeroponic systems are more cost-effective. Less water and fewer nutrients are required in the system at any given moment compared to other nutrient delivery systems because of the decreased volume of solution intake. The following are some advantages of employing aeroponic farming:

1. Plants can be handled easily
2. Economical because irrigation channels won't be necessary.

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3. Promotes disease-free cultivation since there is less plant-to-plant contact and because sick plants can be easily removed from the support structure without disturbing the other plants.

**2. Aquaponics Farming**

Aquaponics is a closed-loop system that relies on the symbiotic link between aquaculture (fish) and agriculture (plants) for fertilization. While fish excrement accumulates in the water and supplies critical nutrients for plant growth, the plants organically clean the water. It offers a harmonious yet less structured setting.

Any technique that combines hydroponics (growing plants in water) and conventional aquaculture (raising aquatic creatures like snails, fish, or prawns in tanks) in a symbiotic environment is referred to as aquaponics. In typical aquaculture, animal excretions can build up in the water and increase toxicity.

For an Aquaponic system to function properly, it needs a variety of live components. Plants, fish (or other aquatic animals), and microorganisms make up the three main living components.

The Advantages of Aquaponics:

- All normal fertilizer sources come from fish waste.
- No reliance on mined and contaminated fertilizers.
- Efficient, sustainable, and extremely productive.
- Fish are free of growth hormones and antibiotics.
- Allows for continuous food production.
- Produces both a protein and vegetable crop.
- The integrated method is sustainable and earth-friendly.

**3. Hydroponics Farming**

The hydroponics technique is a sort of gardening that does not need soil because the plants can thrive without it. Water is used as its growing medium instead. Hydroponics is the study of horticulture without soil. The basic idea is to produce healthy plants using a nutrient like a mineral-rich water solution rather than a conventional soil medium. To grow, a plant requires nutrients,

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some water, and sunlight. Not only may plants grow without soil, but their roots frequently grow far more effectively in water.

The nutrients utilized in hydroponic farming systems can come from a variety of different sources, including but not limited to fish waste, duck manure, or chemical fertilizers that are bought from the store.

Some benefits of Hydroponic Farming:

1. Plants can grow up to 50% more quickly in hydroponic systems than they would in soil since the nutrients are supplied constantly. Furthermore, a hydroponic garden may provide fresh food all year round.

2. Compared to conventional soil farming, hydroponic gardening essentially eliminates the need for herbicides and pesticides, which is great for the environment and the mature product.

3. Any water used in hydroponic farm growing remains in the system and can be reused, minimizing the demand for a continuous supply of freshwater.

4. Gardening area is getting smaller and there is often a shortage of arable land. Hydroponics is a great alternative if you have a small balcony or no yard space. It also works incredibly well for indoor gardening.

4. **Indoor Vertical Farming:**

Vertical farming is the practice of growing fruits, vegetables, and grains inside a structure in a city or metropolitan area, where the floors are made to accommodate particular types of plants.

Vertical farming is the production of medicine and food in vertically stacked layers, vertically inclined surfaces, and incorporated into other structures. The principles of vertical farming make use of controlled-environment agriculture (CEA) technology. These facilities create artificial light, environmental, and fertigation controls. This farming has a number of advantages:

I. One benefit of vertical farming is that it enables maximum crop production. This indicates that since vertical farming is not weather-dependent, food could be cultivated all throughout the year. Since photosynthesis may happen at any time, it can also be grown during the entire day and night since L.E.D. lights are used.

II. Another benefit is that since vertical farms may be built in cities, you won't need to import crops from distant countries, which will result in lower transportation expenses. Since no pests are present to harm the crops, vertical farming also produces food without the use of pesticides. So, it is safer, healthier, and more environmentally friendly.

III. The cost of vertical farming is still another benefit. Although it may be expensive at initially, vertical farming will eventually become a more affordable method of agriculture. Additionally, the cost of plants cultivated in vertical farms will go down.

IV. In comparison to conventional farming techniques, it can greatly minimize the quantity of area required to grow plants.

V. One benefit of vertical agriculture is that in some configurations, plants can thrive without soil. The majority of plants are either hydroponically grown in a bowl of nutrient-rich water or aeroponically grown, where the roots are repeatedly sprayed with water and nutrients.

VI. Another benefit of this farming is that it consumes up to 70% less water than ordinary farms (Jaagdish. 2021, 04 28).

**Conclusion**

In conclusion, it must be acknowledged that because India has a distinct context, it is necessary to examine the situation from all angles before applying any model within the country. If cooperative farming increases agricultural productivity, technology and innovation will enable and solve all of the issues facing agriculture today. Cooperative farming, in conjunction with the proper application of modern technology, is the best possible solution for the farmers in India, who constitute the majority, and would thus be able to provide employment and protect us from major food security concerns in the near future for a country like India, which has the world's largest population, and would also help to achieve the sustainable goal that we have set for 2030. Additionally, in this regard, appropriate professional agriculture programs, governmental initiatives, and entrepreneurship are highly desired in order to position India as an “Atmanirbhar Bharat” (Self-reliant), "Viswa Guru" (global leader) or at the very least on level with the leaders of the globe.

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