Global Perspectives on Agriculture: Food Security and Nutrition

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Abstract

Increasing global demands for food have necessitated a comprehensive and informed approach to meet food and nutritional security. Agricultural policies framed a few decades back were aimed at the production and availability of surplus staple food crops. Green Revolution, as an outcome of the successful implementation of science, technology, strategy, and distribution, helped the world to feed the people. The rising monotony in agricultural staple food crops leads us to the trap of malnourishment and hidden pangs of hunger. Agricultural challenges and mitigation strategies need to be reframed for integrated and planned efforts spanning the complete agricultural cycle ranging from production to the distribution of agricultural products without neglecting effective waste management. Current scenario of increasing global populations, dwindling resources, and scarce reuse/recycle practices highlights the need to employ such frugal steps actively throughout the world. In addition to critical innovations in scientific methods and techniques, effective management of infrastructure, distribution of farm products, waste treatment, skill development of the workforce, and engaging collaborations between public and private sectors would help equip farmers and producers to meet the increasing food security challenges. Moreover,

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effective and dynamic policies need to be tailored and implemented, which would cater to a wide array of economic, geographical, and resource availability for different regions of the world. This chapter briefly explains the building blocks of agriculture and efficient integration among them in terms of global food and nutritional security.

Keywords

Agriculture · Nutrition · Green revolution · Biofortification · Global hunger

1.1 Introduction to Agriculture

Agriculture, being an art as well as the science of cultivating plants and livestock, is a unique and challenging venture. One of the primary reasons behind the advent of a sedentary human lifestyle over the earlier practiced nomadic culture was the key development of agriculture, which provides reliable availability of food. Modern-day crop breeding techniques, use of pesticides and fertilizers, and highly efficient tools and machines have enormously increased the yield to cater to the food requirements of billions of people. In addition to the food supply, the agriculture sector provides the highest employment in the world. In a broader sense, agriculture can be defined as a process of producing commodities that supports life, including fiber, food, horticultural crops, and forest products, with the use of natural resources. Agriculture is a comprehensive term and includes a diverse form of products and activities. Any agricultural product or commodity in raw or processed forms or any product or commodity derived from livestock when marketed for human or livestock consumption can be considered as an agricultural product, for example, flowers, plants, textiles, food, seed, and feed.

In the production of agricultural products, activities like cultivating soil, raising and harvesting of crops, feeding, and rearing and taking care of livestock are included, while in the case of aquaculture, raising and managing of aquatic animals is included. Similarly, floriculture and horticulture include the cultivation of flowering plants and fruits and vegetables, respectively. Harvesting of Maple Syrup and fresh trees are also included in the production of agricultural products, whereas other agricultural derived activities like storing and preservation of raw materials, storing, and processing of dairy raw or finished products or grains are not included in agricultural products. Agricultural products can broadly categorize into four headings, food, fuel, fibers, and raw material. On the basis of economic value and consumption, food crops can be classified into cash crops or staple crops.

Staple Crops: Staple crop or staple food is the food which comprises the significant portion of a meal or human diet and is often consumed in large quantities by a community or a given set of people. It is also responsible for contributing to the necessary nutrients as well. Generally, staple food provides the majority of the energy needs and macronutrients which are essential for the survival and health of an individual. Mostly, the staple diet is consumed very frequently by a group of

Table 1.1 Types and details of major crops involved in agriculture

Staple crops	Cereals	Rice, wheat, maize, millet, and sorghum
	Starchy tubers	Potatoes, cassava, sweet potatoes, yams
	Pulses	Dried legumes
	Sago	
	Misc	Sugar, coconut oil, olive oil
Cash crops	Sugar crops	Sugarcane & beet root
	Oil seeds	Soybean, groundnuts, castor beans, sunflower seed, rapeseed, linseeds and safflower seed
	Fiber crops	Cotton, flax, hemp, sisal, and jute and jute-type fibers-and tobacco
	Vegetables	Cabbage, artichoke, tomato, cauliflower, pumpkin, squash, gourds, cucumber, eggplant, chili, pepper, onion, garlic, watermelon, cantaloupe and similar melons, and several minor vegetables
	Beverage crops	Coffee, cocoa, and tea
	Tree crops	Fruit, oil palm, and rubber

people on an everyday basis for every meal basis. Staple food crops vary from place to place, and most people depend on a very few numbers of staple food crops. Grains, tubers, legumes, seeds, and roots are the typical staple food items. Over time, those food crops which provide a good source of nutrients, higher availability and are easy to store and have significantly high shelf lives were selected as staple food crops by earlier civilizations.

Cash Crops: Cash crops, as per their name, are the crops that are grown in fields for its commercial value rather than for daily consumption or livestock consumption. They constitute an essential role in framing national food security policies for many agriculture-based countries with low-income brackets in order to promote or push forward the domestic market and exports and hence the foreign exchange for the economy. Many critics, although denied the direct benefits of cultivating cash crops to poor or small farm holders but cash crops, do have a catalytic effect on agriculture, and they do add value to productivity in rural produce. The cash crops are broadly categorized on the basis of the requirement of post-harvest processing, export, or domestic produce into six categories, i.e., sugar crops, oilseeds, fiber crops, vegetables, beverages, and tree crops (Table 1.1).

Fisheries: Fisheries or fish farming deals with raising fishes commercially in a tank or ponds for human consumption. It is one of the imperative segments of the economy of any country and for the coastal communities. Besides providing food security, it ensures employment on a vast scale. With the growing demands of fish protein and fish, fish culture is popularly practiced in non-coastal areas as well. According to FAO reports, the global production of fish attained more than 170 million tonnes mark in 2016. Mostly, tilapia, catfish, carp, and salmon fishes are cultivated in fish farming. On the basis of photosynthetic feed or external feed, fish farming is practiced under two major headings, i.e., extensive and intensive farming, respectively. Extensive farming is usually conducted in the small to medium-sized pool under natural photosynthetic conditions without much external help. The investments and costs are comparatively minimal, and production directly depends on the natural productivity of the pond in a specific area. The availability of food is the major limiting factor in these types of farming. Those aquatic species which feed directly on phytoplanktons constitute the major farm. The photosynthetic activity is usually increased by the addition of artificial fertilizers (potash, phosphorous, and nitrogen) in the pond water. In contrast to the most basic type of fish farming, intensive farming is technologically well equipped.

Intensive farming is a technologically, highly advanced form of farming. The density of production is maintained at the highest possible levels in the artificial tanks. The tanks are coupled with a large number of regulators to maintain the optimum nutrient levels and the steady-state as well as the removal of toxins from the water source. The nutrient level in the tanks is maintained by the addition of continuous supply of external feeds, and the toxins and waste are also removed from the water. Oxygen supply and quality of water are maintained to improve the growth of fishes in the tank. A high level of costs and investments are required in intensive farming as compared to extensive ones.

1.1.1 Effects of Global Hunger and Nutrition Demands on Agriculture

One of the most basic human requirements is food. To have access to a proper nutritional value, food is/must be the fundamental objective of all the governments. Despite the backbreaking efforts of national, sub-national governments and international forums, hunger is still persistent in many parts of the world. It is always a significant concern in many third world countries. Acute hunger is the most extreme form of hunger. It occurs in the scenario of no or very minimum amount of food consumption (Fig. 1.1). It mainly occurs during the period of natural calamities like famine, drought, disasters, and even wars, etc. Approximately 8% of the total hunger-stricken population suffers from an extreme form of hunger.

The most widespread form of hunger is chronic hunger. When the lack of insufficient food prevails for a long term of time, then it gives rise to chronic hunger. It designates undernourishment over a considerable period of time. Poverty is the main contributor to this type of hunger. According to various reports, the primary reason for hunger in some areas is not the unavailability of food, but it is the inability of the purchasing capacity of food in some families, classes, or even for some countries. The third form of hunger is hidden hunger. It is a much-diversified form of chronic hunger that rises due to the intake of unbalanced diets, which culminates into lack of iron, zinc, vitamin A, and iodine. It affects both poor and rich people due to different reasons. Poor people consume only staple diet over legumes, cereals, nuts, and fruits which is rich in macronutrients but lack micronutrients due to the lack of purchasing power, whereas people in higher-income groups consume too

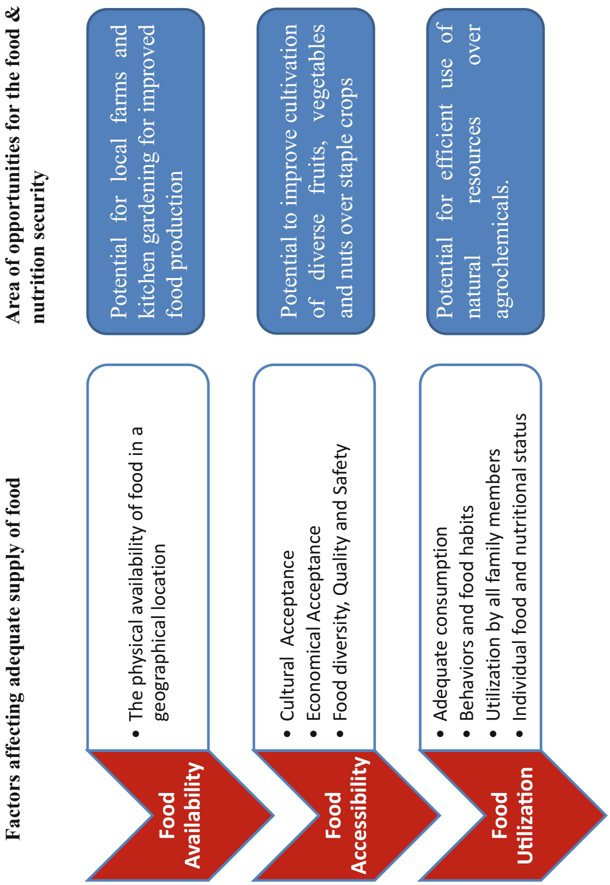

Fig. 1.1 Factors affecting the nutritious diet for sound health: adequate supply and accessibility to nutritious food helps in maintaining body weight and decreasing susceptibility to diseases

much junk food which is high energy diets rich in carbohydrates and fats but lacks micronutrients resulting in obesity and hidden hunger. The intentional/unintentional inability to diversify our diet with fruits, vegetables, or animal-derived food will lead to malnutrition, and it is inevitable. According to the Global hunger index report (GHI report), one out of three or two billion human population all across the world suffer from hidden hunger. More than twice, the population, which feels hunger in the stomach (due to poverty), actually suffers from hunger, which is not felt in the stomach but strike at the core of the health and vitality of a human body.

The deprivation of essential vitamins and minerals leads to the weakening of the immune system, which leads to stunted physical and intellectual growth and, in extreme cases, can even lead to death. Among these groups, the hunger impacts children and women most intensively. In micronutrients intake, 19 vitamins and minerals (Vitamins A, B4, B12, C, D, E, and K; thiamine, riboflavin, niacin, pantothenic acid and biotin, folate and folic acid, calcium, iodine, iron, magnesium, and zinc) are vital for the efficient physical and mental growth, efficient functioning of immune system, and other metabolic processes (Kennedy et al. 2003). Iron, Iodine, and Vitamin A deficiencies are most prevalent across the globe.

Agriculture practices have a vital role to play in the current issue of hunger and hidden hunger on a global scale. Traditionally agriculture practices are aimed at calorie based approaches or protein-energy deficiencies, only to increase yield and productivity to meet the food requirements both in developing and developed countries. Agriculture practices were never targeted for promoting human health. In the 1970s, in developing countries like India, Green Revolution was launched with a vision of providing enough food for the population by the use of fertilizers, pesticides, and improved seeds. It was a myth that if we have enough food, we will have good health. Green Revolution was a successful initiative in a way, but it promoted the production of staple food crops like wheat, rice, and paddy, which leads to simplified diets. Due to the consequences of hidden hunger and malnutrition in the 1990s, the attention was drifted to nutrition with production rather than production only. Research and technological advancements were considered fundamental tools for the improvement of crop species. Supplements and bio-fortified crops are considered as the best possible ways to improve health in vulnerable groups so far. The fortified staple crops with various micronutrients help drastically to eradicate malnutrition in the poverty-stricken groups. Many works have been done to treat such deficiencies like Vitamin A fortified rice to curb night blindness and supplementation with iodine to treat goiter (Burchi et al. 2011). Moreover, the food must be absorbed efficiently in the gut to cure hunger and malfunctioning efficiently. Hence, the research in agriculture plays a vital role in accumulating the nutrients in food crops in the form which is rapidly absorbed in the human gut under the “Farm to Fork to Gut” mission.

1.2 Challenges in Agriculture

It has been projected by the United Nations and many other sources that the world population would be around 8.5 billion by the year 2025 and 11 billion by the end of this century. The production of food, fiber, and feed should be increased at the same pace globally to feed and clothe the growing population. The ever-growing population and urbanization lead to shrinkage in the land area available for agricultural production. The exceeding usage of earth's sustainable resources, increasing population, reducing available agricultural lands has forced us to find ways to improve agricultural yield with a low impact on the environment (Davis et al. 2016). Moreover, the production of yield in agriculture is very much at the mercy of the climatic conditions. The instances of weather (drought or floods) driven yield losses are well evident in all parts of the world from the centuries. Weather also indirectly affects the crop species as well. The increased temperature and humidity conditions can favor the outbreak of a deadly disease (Capinera and Horton 1989; Coyne et al. 1974). There are many examples of an epidemic of a disease reducing crop yields due to the weather. Climate is a very powerful detriment to agriculture. The increasing concentrations of greenhouse gases (CO_2, CH_4, CFCs, N_2O) are though not of much trouble immediately. Still, their impact on the global climate is detrimental by causing the alteration in the distribution of precipitation has tremendous consequences. Moreover, climate change indirectly affects all the other components of agriculture like soil, water distribution, and quality, etc. (Rosenberg 1992).

One of the significant challenges in agriculture despite all the changing scenarios regarding climate change and rising population is the impact of abiotic or biotic stress on the crop species. The productivity of crops is drastically affected by both biotic and abiotic stresses (Sonah et al. 2017; Vishwakarma et al. 2019). The outbreak of a disease can cause the complete loss of the crop in an area in a short time. Similar to biotic stresses, abiotic stresses also drastically reduces crop yield each year across the globe (Bhat et al. 2019; Deshmukh et al. 2014). Abiotic stresses include light (low or high), temperature (low, high), water (drought or flood), and chemicals (salts, pesticides, fertilizers). These abiotic stresses affect the plant at every stage of its growth cycle like inhibition in the germination of the seeds, premature senescence, or reduction in growth or productivity. At physiological levels also, these stresses have a significant effect at the respiration or the transpiration rates of the plant. Some plants accumulate toxic metabolites or growth inhibitors in response to such exposure of light or temperature, and the uptake of water and nitrogen is also severely affected.

The increasing usage of pesticides and fertilizers over the years leads to the increase of soluble salts like sulfates, nitrates, carbonates, chlorides, and calcium and magnesium in the soil causing salinity or sodicity in the soil. The increased salts in the soil interfere with the reduced ability of the plant to uptake the water, which culminates into the slow plant growth (Ahmad et al. 2019; Zargar et al. 2017). Excess amount of soluble salts in the plant cell also causes cellular injury and even chlorophyll degradation. There was a study in which a group of researchers analyzed the impact of increased salt concentrations on seed germination, a number of spikelets per panicle, tiller per plant, and overall yield. They reported the survival of seedling was drastically reduced when the concentration of salt increased higher than 3.4dS/m (Zeng and Shannon 2000). Similarly, another study was conducted to study the effect of salinity on four varieties of 3-week old rice plantlets at different salt concentrations for a week. Afterward, the rate of growth, Na+ uptake, and antioxidant capacities were studied. They concluded that salt-sensitive stress varieties exhibit increased peroxidase activity and lipid peroxidation. The accumulation of Na^+ was also increased along with the electrolyte leakage (Dionisio-Sese and Tobita 1998). These all factors, whether biotic, abiotic, availability of water and nutrients, and climate very strongly affect the plant growth and yield, and to attain them in the optimized state is the major challenge in the successful agricultural practices.

1.3 Work Done During the Past Few Decades

The challenges posed by a growing population, depleting resources, and inefficient management; to global agricultural security necessitate a multi-faceted approach to combat nutritional inequality. Global coherent efforts are aimed at simultaneously achieving food security, improving nutrient availability, minimizing wastage, and prudent distribution of agricultural resources among all sectors of producers and consumers. Several policies have been formulated during the past few decades, which have highlighted stark interdependence of scientific endeavors in agriculture to economic dynamics and resource management across varying population hierarchies.

1.3.1 Successful Strategies

1.3.1.1 Improvement in Agricultural Produce and Utilization by Consumers

Several government organizations, farming community, and components of food industries including production, supply, and marketing have great role in developing novel strategies to eradicate malnutrition (Fig. 1.2). Genetic improvement of crops for nutritional quality is one of the most significant strategies being used worldwide. Domestication of crops and animals started around 10,000 years BC, wherein humans would select for the best seeds or livestock for farming in the subsequent seasons, which is termed as "selective breeding." Eventually, it was realized that the selection of high yielding crops and animals for specific traits/features viz. yield and production decreased their genetic diversity. As genetic variations for many important traits such as resistance to diseases and abiotic stress were being lost (Learn. Genetics GSLC 2018). Selective breeding or traditional breeding was followed by marker-assisted breeding, transgenic technology, and gene-editing methods (Rana et al. 2019). Similarly, mutation breeding is being used to create novel variations that

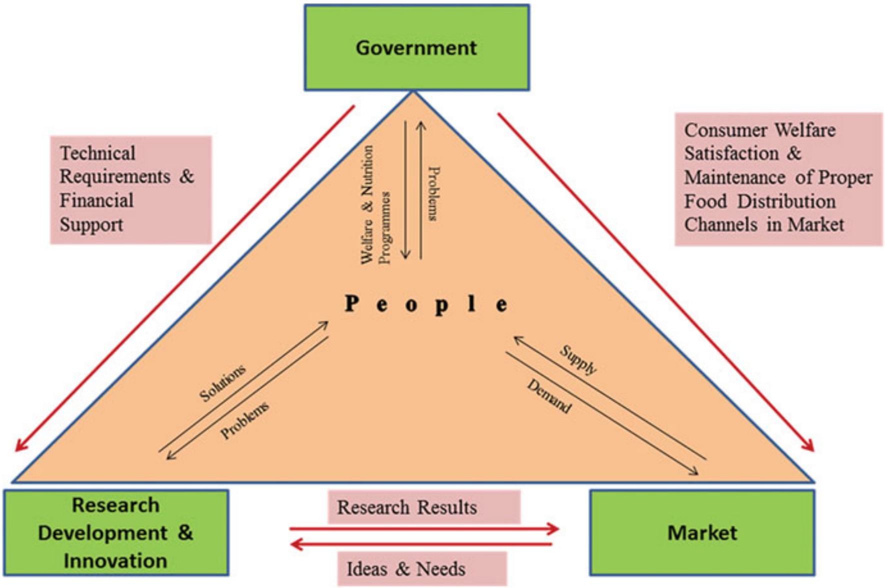

Fig. 1.2 An integrated network depicting roles of different organizations for efficient supply of food to consumers

can directly improve the trait or may help to improve trait with breeding exercise (Bansal et al. 2019; Chaudhary et al. 2019a; Kumawat et al. 2019). Conventional breeding combines desirable traits from elite parents to obtain offspring without information about genes that influence these traits. Conventional breeding is not amenable for traits governed by multiple genes and is often time-consuming (de Ronne et al. 2019). For instance, modern maize with exposed kernels (American Association for the Advancement of Science 2003) and Belgian Blue cow with improved lean muscles (McPherron and Lee 1997) are examples of decades of selective breeding. Marker-assisted breeding, on the other hand, requires knowledge about genes coding for traits of interest, and results can be obtained in a shorter period. This technique focusses on inclusion or exclusion of segments of DNA called markers associated with desired phenotypes (Ram et al. 2019; Yadav et al. 2019). However, this technique is dependent on naturally breeding plant populations and is more fruitful in plants with shorter reproductive cycles only. Several marker-assisted breeding studies have been conducted in maize for corn borer resistance and yield (Bouchez et al. 2002; Willcox et al. 2002), in rice for bacterial blight (Chen et al. 2000), in barley for stripe rust (Toojinda et al. 1998), and in soybean for nematodes and rust (de Ronne et al. 2019; Rasoolizadeh et al. 2018; Vuong et al. 2015). Similarly, several such studies have been undertaken for combating mastitis infection in dairy cattle, double muscling, control of milk fat, etc. (Williams 2005). A more precise and faster method of introduction of the desired gene into crops is transgenic technology (Chaudhary et al. 2019b). Although an advanced technique, it requires comprehensive information about the gene of interest and its functional impact on host plants (Shivaraj et al. 2019). Several transgenic crops with modified stress resistance such as in corn and soybean, starch metabolism in maize and tomato, and yield increase rice have been undertaken in the past decades (Dunwell 2000). Similarly, livestock with enhanced milk, disease resistance, and enhanced growth have been developed for human consumption (Wheeler 2013). Rapid investment in genome editing has enabled rewriting of the genome sequence of organisms (Mushtaq et al. 2020). Multiple techniques such as TALEN (Transcription activator-like effector nucleases) and CRISPR-Cas9 (clustered regularly interspaced short palindromic repeats) are fore-runners in crop improvement methods (Learn.Genetics GSLC 2018; Vats et al. 2019). Several genome editing efforts have been made for increased grain yield in maize, blast resistance in rice, iron content in wheat, and herbicide resistance in potato (Jaganathan et al. 2018; Mushtaq et al. 2020). In addition, similar efforts in livestock improvement have been aimed at increasing milk production, egg yield, litter size, and lean pork meat, among other traits (Tait-Burkard et al. 2018). Biofortification of crop plants is yet another technique that aims at increasing the micronutrient content of edible plant parts. Several methods, such as the utilization of fertilizers, increasing the absorption of minerals from the soil and genetic biofortification strategies, have aimed towards achieving nutrient security. In addition to biofortification of cereals (Garg et al. 2018; Lyons 2018), methods for enhancement of nutrient content have been utilized in vegetables (Junior et al. 2017; O'Hare 2014), pulses (Ghosh et al. 2019; Singh et al. 2015), fruits (Amah et al. 2019; Das et al. 2018), and fodder as well (Novoselec et al. 2018). Moreover, transgenic approaches are being frequently used to increase the phytoavailability of micronutrients, their uptake by the plant, and finally, transport to edible/economically important plant parts (White and Broadley 2009). Such products are termed as functional foods that have been fortified or enhanced with additional nutrients. In order to successfully combat global hunger and malnutrition, nutrient bioavailability also needs to be explored. Nutrient bioavailability is defined as the efficient absorption of nutrients from the diet (Hurrell and Egli 2010). The utilization of absorbed nutrients for body growth and development is further dependent on several factors, one among them being the microbiome of human body. The microbiome is the plethora of micro-organisms that live primarily in the human gut, and it affects immunity, body development, and nutrition (Rogers and Zhang 2016). Nutrigenomics is yet another approach to gauge the effect of diet on individuals and populations (Sales et al. 2014). This method has opened new arenas of personalized nutritional intervention wherein dietary impacts on metabolic diseases have also been studied (Afman and Müller 2006; Phillips 2013). At the consumer level, there is a necessity for a comprehensive study related to the impact of improved products on the health of individuals. For instance, food safety and related diagnostic tools are one such area that needs critical assessment before consumption (Jacxsens et al. 2011). Detection of harmful compounds in food has also been enabled due to developments in other fields of science such as nanotechnology (Yu et al. 2018). Development and improvement in pioneering scientific techniques and practices have played a prominent role to usher in an era of agronomic security.

Concurrently, efficient agricultural practices have played a pivotal role in reaping maximized benefits from improved agricultural production.

1.3.1.2 Development and Adoption of Efficient Agricultural Practices

The first step towards starting agriculture was adopting a settled lifestyle as compared to the nomadic life. With experiences gained by successive generations, human-kind shifted from cultivating only crops like wheat, barley, flax to rearing livestock. Initially, animals were used for plowing of fields as compared to today, where tractors and harvesters are used to achieve agricultural tasks. Crop rotation, wherein different crops are grown on a piece of land according to varying seasons, is utilized even today. Throughout history, humanity has evolved to improve agricultural strategies for obtaining the highest outputs. The widespread use of fertilizers, herbicides, pesticides, and farm machines has enabled increased food production and affordability. Although with increasing awareness about the negative impacts of chemical fertilizers and pesticides on our environment, alternative methods for crop improvement are being introduced to farmers. In addition to better seed selection and efficient water management, integrated farming methods which aim at growing crops with close-knit rearing of livestock and agroforestry has paved the way for efficient utilization of resources and multiple sources of income for farmers. Moreover, the use of vermicompost, biofertilizers, and multi-cropping (growing vegetables alongside cereal crops) has enabled a sustainable increase in crop production. Several studies have emphasized the advantages of sustainable and organic agricultural practices over conventional practices. For instance, total phenolic contents of agricultural products grown using organic and sustainable farming practices were found to be higher in the case of strawberries, corn, and marionberries (Asami et al. 2003). Similarly, steps should be adopted to increase the soil organic carbon using methods such as reduced tillage, growing trees, and grasses and incorporation of farm remnants back into soil (Antle and Diagana 2003). Similarly, instead of using fungicides and pesticides, biological agents can be utilized for pest control. Hydroponics is another new segment of agriculture, which reduces dependence on excessive tilling areas for agriculture. Several governments have made efforts to encourage efficient use of resources, for example, Government of India initiated the Integrated Scheme of Oilseeds, Pulses, Oil Palm and Maize (ISOPOM) under which public funds could be used by small farmers throughout the agricultural process (Ministry of Agriculture and Farmers Welfare 2013). Another such scheme benefiting the farmers has been the "National Agriculture Development Programme," which enables states to comprehensively design plans for their agriculture sector considering the resources and agricultural conditions specific to their region (Callithen and Matthew 2007). In addition to efficient practices of agricultural production, an improved framework is needed for the storage of agricultural produce.

1.3.1.3 Storage of Agricultural Produce

Storage implies post-harvest methods for deferred utilization of agricultural products. It is an integral part of agriculture since the efficient distribution of final products is often hampered due to inept storage. Systematic storage is a significant factor responsible for maintaining the supply and demand in agricultural markets. It is mainly targeted at protecting the produce from fluctuating temperatures, moisture, oxygen content, micro-organisms, insects, and rodents (FAO 2018). For example, contamination of maize by mycotoxin is a major cause of grain damage across the world (Kumar and Kalita 2017). Various storage structures include underground and surface storage units along with cold storage systems. Ideally, agricultural products can be packed in bags or stored in bulk as loose storages. In addition, warehousing facilities improve scientific storage for the quantity and quality of products. Various storage units may be owned by private individuals or maintained by public undertakings. Also, bonded warehouses are maintained by the governments at key places of transport such as seaport and airports. Moreover, storage is not only defined in terms of agricultural products but also in terms of fertilizers, herbicides, and pesticides as well. Several products such as cereals and fertilizers can be stored in general storage units, whereas custom warehouses are required for specific products such as cotton, wool, etc. Refrigerated storage is temperature-controlled for dairy, eggs, vegetables, etc. (Agro Processing 2015). Storage planning and structures are also dependent on duration, scale, and method of storing particular products. Assorting, as well as the grading of commodities, are important factors influencing storage strategies. Various methods, such as physical, chemical, and biological, are key ways for efficiently maintaining reservoirs of products. One such example studying the effect of air-drying and freeze-drying strawberries, corn, and marionberries suggested better preservation of total phenolic content in the case of freeze-drying (Asami et al. 2003). Food fortification has also been employed to decrease nutrition deficiency in populations, vitamin A enrichment of vegetable oil has been one such example (Keding et al. 2013). Storage of grains with natural insecticides such as extracts from *Chenopodium ambrosioides* aids prevents insecticidal damage to grains (Kumar and Kalita 2017). Similarly, edible oils such as soybean and palm kernel oil can be used as fumigants against insects in the case of grains (Kumar and Kalita 2017). Edible food coating is another technique that helps in the preservation of food products. Food coatings allow long-term storage of fruits and vegetables. Next-generation food storage methods are being developed rapidly to reduce product loss due to deterioration. Closely following various storage techniques, the efficient distribution of agricultural products is one of the final steps for successful delivery to consumers.

1.3.1.4 Efficient Distribution of Agricultural Products

An efficient distribution system includes high monetary gain for farmers, low transportation charges, and reasonable prices to be paid by consumers. Previously, the distribution of agricultural commodities was focused on a limited immediate region to a farmer. This has now been replaced with national as well as international exports even for small scale farmers. Distribution is dependent upon the geography, producer–consumer relationship, commodity, technologies utilized throughout the process of agricultural production as well as global conditions prevalent concurrently. Effective prediction of demand and supply through reliable channels helps in making realistic forecasts. A well-organized distribution system helps curb losses incurred through the supply and demand chain. It also paves the way for effective expansion of the market based on multiple commodities and influences the overall economy of a nation. A single effective nation-wide marketing and distribution scheme reduces instability due to regional fluctuations. An environment of competitiveness created as a result of this leads to cost-effectiveness and increases transparency in markets. An efficient marketing and distribution system promotes alternate marketing and selling channels. An unprecedented increase in the price of an agricultural product leads to decreased demand, which in turn triggers shrunken production during the next season. Several models have been suggested for the efficient distribution of agricultural products after harvesting. One such example suggested a stochastic model for fresh farm produce and showed an increase in profit due to planned distribution systems (Ahumada et al. 2012). Similar studies have devised effective models for the management of agricultural products post-harvest and weighing the balance between the freshness of food and labor or transportation charges (Ahumada and Villalobos 2011). With increasing weather uncertainties such as droughts, floods, and extreme rainfall, efficient product distribution demands dynamic updates to various methods of storage and transportation (Ziska et al. 2016). Hence, the distribution system of agricultural products is frail and sensitive to fluctuations at any level of the hierarchy, wherein careful planning can result in decreased losses.

1.3.1.5 Waste Management

In addition to the factors mentioned above, wastage is prevalent and should be prevented at every facet of agricultural production. An efficient waste management system demands sustainable utilization of resources while minimizing waste generation starting from production until the consumption of agricultural produce. Agricultural waste during production varies in type, consistency (solid, liquid, semisolid, and slurry), amount, etc. (United States Department of Agriculture 2011). Also, there is variation in waste production during different seasons and varying crops or livestock. For instance, the majority of water wastage happens in the form of run-off from farms and fields. Such wastage can be managed by maintaining records of facilities, equipment, and waste production. Prior information regarding utilization of resources such as seeds, fertilizers, and pesticides; in case of crops, and proper feed, housing facilities, and waste handling; in case of livestock; helps in minimizing wastage and efficient recycling of resources. In addition to efforts for reducing wastage during production and setting up of agricultural farms; the waste collected during subsequent stages needs to be sorted and transported to treatment plants. Sorting depends upon the consistency, hazardousness, and recycling efficiency of waste, among other factors. Treatment includes physical, chemical, and biological processing for minimizing the pollution potential of natural, animal, and plant waste. Several waste management techniques utilize discarded products from agriculture as the production of biofuels and recycled products. For example, where at industrial levels, wastewater is recycled and reused to decrease water wastage, at smaller levels excreta from farms can be utilized as manure in fields. Another such example has been the production of biogas from waste material generated on farms (Hansen and Cheong 2019). Single-cell proteins (SCPs) have also been produced as a result of the oxidation of agricultural wastes. SCPs are high in protein contents and can be used as a protein-rich supplement in human food (Spalvins et al. 2018). In addition to traditional bioprocessing methods, several methods have been developed for the production of biofuels by various research groups (Champagne 2008). Within India, one basic example is using excreta from milch animals such as cows and buffaloes for fuel in the form of dung cakes. Bioremediation is another approach that is based on the utilization of microbes and their products for combating environmental pollution and contamination. Removal of heavy metal contamination is one such example where bioremediation is used (Perpetuo et al. 2011). An efficient agricultural waste management system minimizes environmental impact and maximizes the recycling and re-utilization of agricultural products.

1.3.1.6 Models and Metrics for Measuring Global Food and Nutritional Security

Several models and metrics need to be developed to efficiently gauging worldwide food and nutritional security. Factors that dominate different world populations such as a number of people, economic status, literacy, and availability of resources across developed, developing, and underdeveloped regions should be considered while formulating models of food security. To address the aforementioned issues, several frameworks have been developed globally during the past decades (Table 1.2). Key features of such global models aim at providing country-specific frameworks such that development programs are tailor-made according to their requirements and resources. Effective policies comprise of private as well as public sector stakeholders as well as encourage the participation of women for increasing productivity. In addition, literacy, development of advanced and sustainable technology, and sound investment in infrastructure and labor training have been few of the salient features for the effective formulation of international policies.

1.4 Steps to Achieve Global Food and Nutritional Food Security

Various steps have been taken at national and international levels to combat global food and nutrition insecurity (Fig. 1.3). From past experiences, it has been evident that an integrated approach aimed at social, economic, and sustainable agricultural development is paramount for achieving safe and nutrient-rich food security (Fig. 1.1). In addition to changing population size, economic status, dietary preferences, and consumer awareness, climate change, resource depletion also affect the sustainability of efforts to curb malnutrition and hunger. Several steps that have paved the way for achieving global food and nutrition security have been enumerated in the following section.

Table 1.2 Various frameworks adopted globally for global food and security

Framework	Details	Reference
International covenant on economic, social, and cultural rights (ICESCR)	Recognized "right to health" wherein a person has a right to food and nutrition; among others	Alston and Quinn (1987)
World food summit plan of action and the Rome declaration on world food security	Aimed at the availability of nutritious food and freedom from hunger	FAO (1996)
The voluntary guidelines to support the progressive realization of the right to adequate food in the context of national food security (VGRtF)	Right to food guidelines by food and agriculture organization (FAO) aims at global food security and nutrition	FAO Council (2004)
The final declaration of the 2009 world summit on food security	Discussed eradication of hunger by agricultural improvements in developing nations	FAO UN (2009)
The voluntary guidelines on the responsible governance of tenure of land, fisheries, and forests in the context of national food security (VGGT)	Aims eradication of hunger and utilization of land, fisheries, and forests for the same	FAO UN (2012)
The principles for responsible investment in agriculture and food systems (RAI)	Globally applicable ten principles aiming at food security	FAO (2014)
The framework for action for food security and nutrition in protracted crises (FFA)	Targets mitigating risks posed towards food security and nutrition	FAO (2015)
2030 agenda for sustainable development	Signed by 193 nations, aims at economic, social, and environmental development	Nations (2015)

1.4.1 Research on Improving Crop Varieties, Techniques, Improvement in Agricultural Practices

Numerous steps and strategies have been taken over the years to ensure global food and nutritional security. One such initiative was the Green Revolution, which began in the 1960s with an aim to increase the agricultural production many folds by the use of high yielding varieties (dwarf rice and wheat) in the presence of fertilizers and reliable water supply. On the verge of famine in the 1960s, India, in the guidance of Norman Borlaug and MS Swaminathan, imported wheat seeds from the Internal Maize and Wheat Improvement Centre (CIMMYT). Similarly, India adopted IR8 rice variety, which is a semi-dwarf rice variety produced more grains in association with fertilizers and irrigation. With the adaption of such high yielding varieties along with the advent of modern agricultural practices, India became a food surplus country.

Various researches were conducted over the years to improve the crop plants with different mineral components to combat malnutrition. Major biofortification strategies are undertaken to fortify the crop species with iron, zinc, copper, selenium,

Fig. 1.3 Integrated efforts to achieve global agricultural and nutrient security

iodine, magnesium, and calcium. Among all the adopted strategies to enhance the mineral concentrations in the crop species, two of them are the most widely accepted approaches. In the first approach, the concentration of mineral element is increased by the application of fertilizers during cultivation of crops with an aim to improve the mobilization as well as solubilization of minerals in the soil, whereas in the second approach the capacity of a crop plant to accumulate the mineral substances in the edible tissues in non-toxic forms is enhanced with the help of various biotechnological approaches and reducing the anti-nutrients concentration (oxalate, polyphenolics, and phytate) in the crop products which reduces the bioavailability of nutrients.

Plants absorb minerals from the soil in the specific chemical forms. For instance, the roots of plants can absorb Iron, Zinc, Copper, Calcium, and Magnesium in their cationic forms, whereas the members of graminaceous species can uptake iron, zinc, and copper as metal-chelates (Marschner 1974). Iodine is taken up by the plants in the form of iodide/iodate (Mackowiak et al. 2005), and selenium is absorbed by the plant's roots as selenate, organoselenium or selenite (White et al. 2007). The presence of these minerals in different chemical forms as free ions or as ions absorbed to the mineral or organic surfaces or precipitates or as compounds in the rhizosphere defines the physicochemical and biological properties of the soil. The pH of the soil, cations exchange capacity, microbial activity of the soil and redox reactions, organic matter and moisture ultimately determines the availability of the elements to the plant (Shuman 1998). An element like silicon has recently been considered as a beneficial element for plant growth even though the reports from the last couple of decades confirmed the numerous benefits (Deshmukh and Bélanger 2016; Deshmukh et al. 2017a). Besides, having plenty of silicon-based fertilizers limited is known about crop-specific silicon requirement, preference for the forms of silicon compounds, and genetic predisposition to uptake the element (Bokor et al. 2019; Deshmukh et al. 2017b; Guerriero et al. 2019). Despite the high availability of minerals in some soils, the phytoavailability of minerals is often restricted due to soil properties.

Plants acquire iron from the soil via two different mechanisms (Grotz and Guerinot 2006; Marschner 1974). The roots of non-graminaceous species acidify the rhizosphere by releasing organic acids and phenolic compounds in order to increase the concentration of Fe^{+3} in the soil. The acids and other compounds chelates with Fe^{+3}. The oxidized form of iron is reduced to Fe^{+2} by the ferric reductases present in the root epidermal cells. These reductases are encoded by the ferric reductase oxidase (FRO) gene family (Robinson et al. 1999; Wu et al. 2005). Numerous other proteins mediate the influx of Fe^{+2} to root cells (Ishimaru et al. 2006; Vert et al. 2002). The second mechanism of absorption of iron by soil is employed by grasses and cereals. In this mechanism, instead of organic acids and phenolic compounds, phytosiderophores are released into the rhizosphere in order to chelate Fe^{+3}, and the complex is taken up by the root cells. The structure and the capacity to acquire Fe^{+3} are different for different crop species (Bashir et al. 2006; Marschner 1974). A number of genes families like multidrug and toxin efflux family (root pericycle to shoot), ZIP family (uptake by shoot cells), natural resistance-associated macrophage protein (iron homeostasis) participate in mineral uptake and redistribution of the minerals to the edible plant parts in the non-toxic forms (Gross et al. 2003; Thomine et al. 2003). It was observed in many studies that the expression of FROs, ZIPs, NRAMPs genes and genes coding for the biosynthesis of Nicotianamine synthase and phytosiderophores was upregulated (Gross et al. 2003; Ishimaru et al. 2006; Robinson et al. 1999; Wintz et al. 2003). The expression of iron accumulation by the first mechanism is regulated by transcription factor LeFER in tomato (basic helix-loop-helix, bHLH) (Ling et al. 2002). However, when a group of researchers overexpressed LeFER in tomato and AtFIT1 in Arabidopsis, it does not lead to constitutive uptake of iron, indicating the involvement of other regulatory cascades (Colangelo and Guerinot 2004; Yuan et al. 2005). In another study conducted in rice ABI3/VP1 transcription factor OsIDEF1 seems to regulate the expression responses through OsIRO2 bHLH transcription factor (Kobayashi et al. 2007; Ogo et al. 2007). Currently, Fe-chelates are used as inorganic fertilizers. In addition to it, acidification of soil with elemental sulfur also enhances the iron uptake. Zinc in the form of Zn^{+2} or Zn-phytosiderophores has majorly transported symplastically and minorly apoplastically across the root to the xylem (White et al. 2002). Similar to iron uptake and distribution, a large number of proteins ZIPs, YSLs, CDF, MHX, ZIF1, NRAMPs are involved in the uptake and distribution of zinc. It was observed that the plants in which hyper accumulate zinc have a high constitutive expression of ZIPs, MTPs, NRAMPs, HMAs, FRD3, and YSL proteins. Similar to Iron, zinc is supplied to plants in the form of $ZnSO_4$ or zinc chelates, and copper is supplied in the form of calcium oxide and calcium carbonates, calcium nitrates, and calcium phosphates.

1.4.2 Adequate Distribution of Food After Production, Effective Management of Financial Resources

It is said that a hungry man is not a free man. Inadequate distribution of food affects the motive of food security badly. Food security is depended on food availability, food access, and food use. Imbalance in any of these three pillars can aggravate the problem of food security. The problem of unequal distribution of food is so grave and contrasting in both developed and underdeveloped regions of the world that in around every 15 min, one person is reported to die of starvation in many parts of Asia and Africa. Contrary to it, millions of people die in the western world due to lifestyle disorders due to obesity. Both extreme cases led to death or improper health in global populations. The major reason that can be linked to this problem is the unequal distribution of wealth or purchasing capacity. When we talk on global levels, it is directly linked to the nation's power on a global scale or on its economy. Although enough food is produced on earth to feed all the population yet due to harmful economic scenarios, some nations are more privileged than others and have better access to resources. Similar economic divisions prevail within the countries also, where some individuals have more access to food than others.

Extraordinary infrastructure and a reliable interconnected transportation network, technological advanced refrigerated storage houses for perishable food have enormously helped to distribute food to a greater extent. In the USA, with the advent of warehouses, factories, commercial retail shops, the infrastructure, it is estimated that the food travels thousands of miles from producers to consumers. Perishable food like meat, milk, and fruits are transported in different fashions. In the USA, many federal agencies, for example, the Food and Drug Administration and US Department of Agriculture, look after the productivity and distribution of the food. Whereas, in India, Food Corporation of India (FCI) maintains the supply of food crops. Statistically, it is probably the most significant supply chain in Asia. The primary mandate of FCI is to provide price support to the poor farmers of the country by determining the minimum support price and to distribute the food grains throughout the country for public distribution system and to maintain the market price for consumers as well. Moreover, FCI maintains operational buffer stocks of food grains to ensure food security in times of crisis. FCI purchases the food crops like rice or wheat from farmers through Mandis and stores the food crops in depots, buffer storage complexes or equity godowns. Later the food crops are transported throughout the country by means of different transport systems like railways, roadways, or waterways. Despite initiatives taken, a lot of developing and underdeveloped countries still struggle to find an adequate means to feed their population in the era of economic crisis. Similarly, in India, to provide a safety net to the underprivileged group of people, certain types of operations or schemes like Jawahar Rozgar Yojana, Integrated Child Development Scheme, and Integrated Rural Development Programme and Public Distribution System are carried out. Despite few leakages and inconsistencies, public distribution system in India is by now the most penetrating, expensive, and successful program which runs parallel to free market to ensure the availability of rice, wheat, sugar, oil, etc. to the weaker sections at the subsidized prices (Ahluwalia 1993). In the absence of proper financial security and food distribution system, it is impossible to eradicate hunger and starvation from the world. Various initiatives have been taken by the national, sub-national, and international governments to frame the more effective policies to eradicate hunger. Green, White revolutions are exemplary examples of such initiatives. There is still a lot of population left with low or no food availability. We need to adopt more sensitive and efficient methods to feed humanity.

1.4.3 International Climate Change Policies and Effect on Agriculture, Multinational Efforts to Manage Agricultural Products Trade Policies

With changes in temperature, humidity, precipitation, CO_2 levels, increasing sea levels, and extreme weather conditions, climate change directly affects agriculture. On the other hand, agricultural practices also contribute to the emission of greenhouse gases. Due to increasing consumer demands, it is imperative that agricultural policies mitigate environmental impacts in addition to supplying calories (Fig. 1.2). Where on the one hand, utilization of renewable sources of energy has gained momentum, organic agriculture is also being practiced on the horizon. Concerted efforts are being targeted towards decreasing reliance on chemical fertilizers and pesticides. Several scientific bodies have been formulated which provide comprehensive data related to climate change. For instance, “The Intergovernmental Panel on Climate Change” (IPCC) assesses climate change and can be utilized by policymakers (https://www.ipcc.ch/). Similarly, “The United Nations Framework Convention on Climate Change” (UNFCCC) aims at reducing the impact of greenhouse gases from human activities on the natural climate system (Hickmann et al. 2019). In addition, “The Kyoto Protocol” was aimed at limiting the emission of greenhouse gases (Maamoun 2019). After the first convention ended, “The Kyoto Protocol” was modified to the “Doha Amendment to the Kyoto Protocol” with a commitment period of 2012–2020 (Amendment 2012). “The Paris Agreement” similarly was drafted with the target of limiting the global temperatures below 2° as compared to pre-industrial levels (https://unfccc.int/process-and-meetings/the-paris-agreement/the-paris-agreement). Climate change affects agricultural crops in developing nations and small scale farmers the most. Therefore, effective steps need to be taken to mitigate the threats associated with climate change on agricultural products (Fig. 1.4).

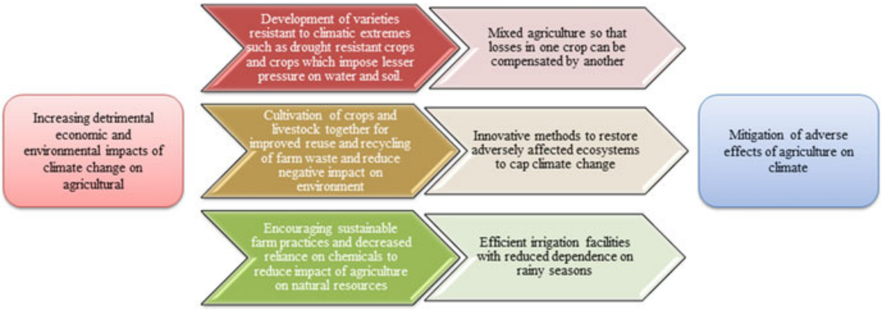

Fig. 1.4 Significant steps towards sustainable agriculture under changing climatic conditions

1.4.4 Skill Development for Production and Management of Agricultural Crops and Practices

Owing to changes in consumer preferences, resources, technologies, agricultural practices, and dynamic climate impacts, it is imperative to foster an environment of constant learning at every level of agricultural production. Globalization necessitates constantly updating the skills of the workforce to combat changing consumer requirements. For instance, farmers can be trained in livestock rearing and utilization of agricultural products according to changing market demands. Similarly, with an increase in pest infestation, several preventive measures must be incorporated in the agricultural chain to minimize losses. Integrated agriculture wherein cash crops are grown alongside staple food is another such example. Management of waste generated from livestock farms and fields sustainably either in the form of recycled goods or reused products demands skill development. Also, the introduction of improved crops and livestock varieties necessitates better cultivation and nutrient management techniques. Training of personnel in subsidiary occupations such as horticulture, beekeeping will ensure better farm management. With an increase in awareness and independent work ethics, entrepreneur-friendly policies must be devised, which encourages innovation in the agricultural sector. Global demand and supply of agricultural produce also invite skilled labor involved in effective storage and transportation. Improvement in agricultural infrastructure calls for the establishment of evolving learning arenas for effective skill development. Hence, it is imperative that the increasing demands for improved agricultural products are simultaneously met with a skilled workforce equipped to meet the changing global requirements. A few government initiatives aimed at the development of skills for farmers, wage workers, etc. For example, “Agriculture Skill Council Of India (ASCI)” under “Ministry of Skill Development and Entrepreneurship (MSDE)” has helped develop programs covering a range of sectors, viz. dairy, poultry, fisheries, forestry, animal husbandry farm management; mechanization, landscaping, and entrepreneurship development (Bhattacharyya and Mukherjee 2019). Similarly, the “Green Skill Development Programme (GSDP)” under the “Ministry of Environment, Forest and Climate Change” suggests youth skill development in forestry, the environment in alignment with climate change, and effects on wildlife (http://www.gsdp-envis.gov.in/). Another such initiative is the "Skill Training of Rural Youth" (STRY), as the name suggests helped rural youth hone their skills in agricultural and allied sections (STRY 2019). Similar initiatives have been adopted throughout the world for securing global food and nutritional security through efficient workforce skill management.

1.4.5 Integrated Public and Private Sector Initiatives

Consolidated partnerships between public and private communities strengthen the framework of any sector. Public and private entities complement diverse agricultural needs. Increasing requirements for agricultural products necessitates either expansion of area under agriculture or production from a defined region. Since an increase in the former is limited; there is a need to enhance the latter. This has been achieved by the utilization of improved technologies and breeds of crops and livestock. Investments in agriculture have been made both at public and private levels. An enhanced production requires an amalgamation of both enabling synchronous efforts to address the changing demands of consumers. On the one hand, the public sector can benefit from innovations and employment opportunities generated by the private sector. On the other hand, private beneficiaries can achieve reduced costs and increased productivity. Both can complement each other in terms of funding and competitive market innovations (Hermans et al. 2019). Public–private partnership (PPP) is one such intervention for improved agricultural output. For a successful partnership, agricultural growth observed should exceed outputs obtained from individual undertakings. Each participant must understand its responsibilities and expertise and achievements must be incentivized. Both the partners must comprehend not only its own but also the vulnerabilities of its counterpart and deploy measures to minimize risks from either side (FAO 2016). Several countries across the globe have benefitted from such partnerships, for example; in Thailand, disease-free okra varieties were developed with the aim of export; in Indonesia, joint public-private efforts have promoted use of renewable energy in industries; in the Philippines, aquaculture has been promoted through development of infrastructure and effective investment options (FAO 2016). Hence, increasing requirements of sufficient and nutritious food supply have paved the way for integrated public and private sector efforts to meet the increasing demands.

1.4.6 Awareness Drives Among Producers (Farmers) and Consumers

The primary objective of awareness drives among producers/farmers is to educate them regarding the improved crop varieties and livestock, technological advances, marketing, storage, and successful risk management. The obstacles faced by farmers, whether in procuring hybrid seeds or adopting better farming methods such as organic farming, need to be addressed for successful agricultural revolutions. Farmers consolidated in a certain area should be provided exposure to producers in other regions for the exchange of ideas and solutions to common problems faced in agriculture. In addition, detailed information regarding novel farming practices curbs reluctance among farmers to adopt innovative farming techniques and resources. Governments across the globe have framed various policies aimed at improving agricultural production and enabling farmers to increase their profits. Subsidized technologies and various training programs explicitly organized to bridge the gap between the scientific community and producer's aim towards achieving food and nutritional security. Moreover, in addition to awareness among producers, consumer knowledge should also be enhanced for a holistic utilization of resources. Whether the benefits of organic produce or bio-fortified foods, the successful management of lacunae in information regarding agricultural products among consumers is imperative for maximizing buyer satisfaction and minimizing wastage and adverse environmental impacts. Awareness about the safety and availability of bio-fortified foods, for instance, can aid the alleviation of global food and nutrition insecurity. Similarly, knowledge about a wide variety of staple and cash crops facilitates meeting the dynamic dietary preferences among consumers. In India itself, several programs have been commenced to enhance agricultural awareness. "National Mission of Agricultural Extension and Technology (NMAET)," for instance, has enabled upgrading of farms with the newest technologies and efficient agricultural practices.

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