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Review

Balancing food security and environmental safety: rethinking modern agricultural practices

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Abstract

Agriculture has played an important role in human life, both for sustaining life and livelihood. The population explosion has necessitated huge agricultural production. Consequently, there has been modernisation of agriculture not only in farming practices, but also in introducing improved agricultural implements, irrigation, chemical fertilisers, synthetic pesticides, and high-yielding seeds. Agricultural intensification and monoculture make it possible to increase crop production, to a large extent gaining food security, but paying no or little attention to environmental well-being. Intensive tillage leads to soil erosion, nutrient loss, and soil organic carbon loss, which affects the soil biota. Extraction of underground water for irrigation causes groundwater levels to drop and hinders aquifer recharge. Monoculture and the cultivation of high-yielding crops lead to the loss of many indigenous crop varieties and the prevalence of pests and pathogens. Extensive chemical fertiliser application can cause soil acidification, eutrophication, and nitrate contamination in groundwater through leaching. Indiscriminate use of pesticides is a potential threat for non-target organisms, including humans. The agriculture sector contributes a considerable portion of greenhouse gases to the atmosphere. Therefore, the only way to protect our mother earth and create a healthy environment is through sustainable agriculture to ensure food safety and security.

Key words: agriculture, environmental health, food demand, modern practices, sustainable agriculture.
Abbreviations: DDT, dichloro-diphenyl-trichloroethane; FAO, Food and Agriculture Organisation of the United Nations; HYV, high yielding varieties; UN, United Nations; UNEP, United Nations Environment Programme; ZBNF, Zero Budget Natural Farming.

Introduction

Overpopulation is a major problem in the modern world. The global human population exceeded one billion people early in the 19th century. Overall growth rates have risen dramatically since then, reaching an astonishingly high peak in the 20th century before beginning to somewhat decline (Bavel 2013). Approximately 55% of the global population was reported from Eastern and South-Eastern Asia and Central and Southern Asia in 2022 (UNDESA 2022). China and India support a major portion of this population. It has been anticipated that the human population in India may exceed that in China in 2023 (UNDESA 2022). It has been assumed that the global population may reach 9.7 billion by 2050, and over half of the predicted growth will be contributed by eight countries only: the Democratic Republic of the Congo, Egypt, Ethiopia, Nigeria, the United Republic of Tanzania in Africa; India, Pakistan, and the Philippines in Asia (UNDESA 2022). In 2020, nearly 1/3rd people of the world population did not have adequate food supply and human hunger was most severe in Africa, Asia, Latin America, and the Caribbean (FAO et al. 2021).

Growing human populations always have a high demand for food grains, which can be met in two ways: agricultural area expansion and crop yield increase (Kumar, Sharma 2020). Agriculture can be expanded on degraded land through restoration. However, climatic fluctuations, particularly in temperature and rainfall, soil salinity, alkalinity, or acidity, and water logging frequently make agricultural production uncertain (Singh, Singh 2017; Kumar, Sharma 2020). In addition, pest infestation accounts for around 45% of yearly food production loss (Sharma et al. 2019; Skendži et al. 2021).

Modern innovations and farming practices have replaced traditional, age-old agricultural practices. Application of advanced implements, improved irrigation, chemical fertiliser, synthetic pesticides, and high yielding seeds open a new horizon in modern agriculture both in terms of crop production and to minimise labour costs (Nelson et al. 2019). The delicate balance between a healthy ecosystem and agricultural production is jeopardised. Moreover, the widespread application of chemical pesticides weakens the ecosystem, leaves non-target organisms vulnerable, and is dangerous for human health (Choudhary et al. 2018).

In her best-selling book "Silent Spring", published in 1962, Rachel Carson issued dire warnings about impact of pesticides on non-target organisms and foresaw the massive destruction of delicate ecosystems in the absence of any effective action to stop the "rain of chemicals" (Bhattacharyya et al. 2009). In this context, an attempt has been made in the present review article to highlight the necessity of rethinking modern agricultural practices and exploring sustainable agriculture to keep a balance between food security and environmental safety, based on an overview of articles published in peer-reviewed scientific journals, books, press releases, and reports of the Food and Agriculture Organisation of the United Nations (FAO), the United Nations Environment Programme (UNEP), the United Nations, and online documents of government and recognised non-governmental organisations of international repute.

Green Revolution – a new vista in agriculture

Agricultural practices through the application of traditional knowledge for food production are an age-old custom (Singh, Singh 2017). Mostly, the indigenous people are the flag-bearers of this practice. Around 1.9 to 2.2 billion people all over the world still have immense faith in cultivation through traditional methods, even though development has taken place in agriculture in the past few decades (Altieri 1993; Pretty 1995). In the 1960s and 1970s, Dr. Norman Borlaug made a significant contribution to the Green Revolution with his unique rapid-growing and disease-resistant wheat varieties (John, Babu 2021). This had far-reaching consequences in terms of massive crop production and saving innumerable people from hunger. Dr. Norman Borlaug, the father of 'Green Revolution' was awarded the Nobel Peace Prize in 1970 for his achievement. Dr. M. S. Swaminathan, an eminent geneticist, oversaw the "green revolution" in India (Somvanshi et al. 2020).

The Green Revolution made it possible to enhance production per unit area of land through the use of high-yielding varieties of seed (HYV), double-cropping, the application of inorganic fertilisers and synthetic pesticides, abundant irrigation facilities, better crop protection measures, and modernised farm equipment (Singh 2000; Brainerd and Menon 2014). Agricultural intensification, one of the remarkable happenings of the twenty and twenty-first century, is the outcome of the successful Green Revolution (Ray 2022). Typically, the term "modern agricultural practices" is used to depict agricultural progress in terms of invention and innovation to meet global food challenges and economic growth simultaneously. Modern agricultural systems are gaining popularity not only by satisfying the increasing food demand but also by being profitable from an economic point of view. The majority of farmers use the most cutting-edge farming strategies and instruments to generate plenty of food, fuel, and fibre for an expanding universe. The importance of increasing food production in the face of climate change has been widely debated. Not all the techniques and modifications practiced by farmers for increasing output or productivity are safe for the environment, as presented in Fig. 1.

Intensive soil tillage

Intensive soil tillage and crop residue removal are the two common practices in agricultural systems (Rahman et al. 2021). Intensive soil tillage prepares the seedbed. The use of different types of ploughs, power tillers, hand tractors, tractors, and other farm equipment makes tillage easier. A looser soil allows for better water drainage, faster root growth, and easier seed planting.

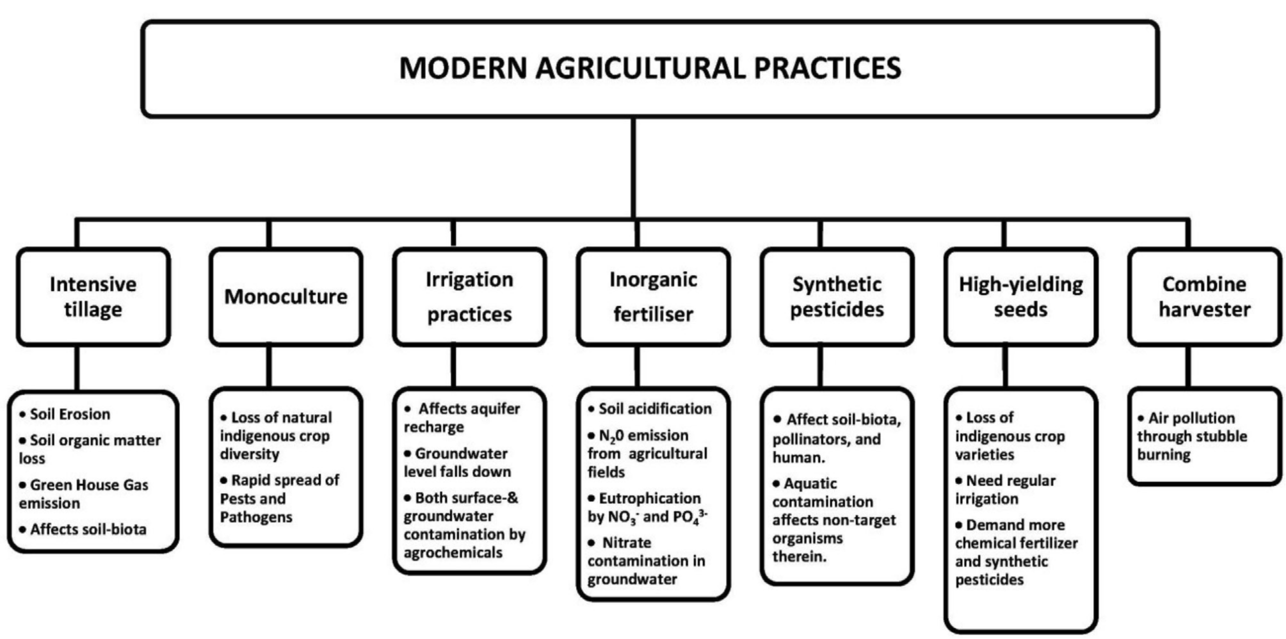

Fig. 1. Effects of modern agricultural practices on the environment.

On the other hand, this practice causes soil aggregates and compactness to be disrupted and also decreases the spaces between soil particles (Gupta et al. 2022). Additionally, tillage alters the movement of water and gas into the soil, which in turn affects soil microbes and other living organisms (Wang et al. 2017; Gupta et al. 2022). Loss of both soil fertility and soil organic carbon are the two major adverse outcomes of soil tillage (Haddaway et al. 2017), which also leads to soil erosion. Cropland loses its top layer of rich soil due to excess water supply. This results in the loss of nutrient-rich soil, which reduces productivity. A major portion of greenhouse gas emissions, e.g., methane (CH_4) and nitrous oxide (N_2O), mostly from rice fields, are the result of intensive soil tillage (Hussain et al. 2021). In a nutshell, tillage has adverse effects on overall soil properties, whether physio-chemical or biological (Quadros et al. 2012).

Monoculture practices

Modern agriculture is based on large-scale consumer demand. Monoculture agriculture means the cultivation of a specific single crop species repeatedly year after year in a region or farm (Franco et al. 2022). It has become a suitable option in agriculture compared to mixed cultures of crops for its ease in plantation, management, harvesting, marketing, processing, and high yield and profit. It was introduced as part of intense cultivation (Lenné, Wood 2022). Monocultures are practiced on around 80% of the arable land in the world (Altieri, Nicholls 2020).

However, monoculture is not free from adverse environmental effects. Reliance on inorganic fertilisers and synthetic pesticides, deterioration of soil qualities, and detrimental effects on biodiversity are a few of the negative issues raised against monocultures (Bourke et al. 2021). With the adoption of modern agricultural practices, a few selective, high-yielding crop varieties gradually replaced many traditional varieties. Selective breeding and intensive crop cultivation are gaining popularity day by day (Bourke et al. 2021; Lenné, Wood 2022). In consequence, natural ecosystems lose their diversity, and a few new agricultural ecosystems may appear with low species richness. Another possible outcome of genetic diversity loss in multiple crops is the rapid spread of pests and pathogens in crops (McDonald, Stukenbrock 2016).

Irrigation practices

Agriculture has a large dependence on irrigation in arid and semi-arid regions (Borsato et al. 2020). Irrigation accounts for 70% of the total freshwater withdrawals globally only for cultivation (Rockström et al. 2017). Irrigated areas cover around 20% of the cropland in the world and produce 40% of the total crop (Borsato et al. 2020). In agriculture, surface irrigation, sprinkler irrigation, drip irrigation, and sub-surface irrigation systems are commonly used (Abd-Elaty et al. 2023).

Apart from surface irrigation systems, all three systems hinder aquifer recharge (Eltarabily, Negm 2019; Mohamed 2020). As a consequence of decreased aquifer recharge, the groundwater level will fall and land subsidence may occur (Abd-Elaty et al. 2023). One of the main reasons for the loss of arable land is salinisation. Salinity affects 77 million ha (5%) of the world's 1.5 billion ha of arable land and 8 million ha of India's 329 million ha (Sheng et al. 2008). Improper irrigation may enhance the chances of water logging and salinisation of soil, which can cause low agricultural production (Kumar, Sharma 2020). Leaching of nitrogenous fertilisers and other agrochemicals used in intensive agriculture contaminate groundwater (Gao et al. 2012). Agriculture with arsenic and fluoride contaminated water causes pollution in the soil and also affects cultivated crops, posing a serious threat to human health when transferred through the food chain (Baboo et al. 2022).

Inorganic fertilisers and mineral input

The practice of repeated crop cycles instead of crop rotation for enhancing production depletes soil nutrient levels (Srivastava et al. 2020). Because intense cropping practices allow no crop leftovers or organic matter to return to the soil, soil organic carbon is gradually lost. Monoculture causes silt to flow to subsurface layers from the surface, reducing soil organic carbon (Singh, Benbi 2016). Soil microbiotas are also affected by intensive tillage (Wang et al. 2017; Gupta et al. 2022). All of these variables cause soil fertility to deteriorate. Farmers hurry to apply chemical fertilisers and mineral contents in the fields to restore soil fertility and replenish nutrient levels instead of using animal manure like cow dung, mustard oil cake, neem cake, castor cake or almond cake; green manure, and vermicompost (John, Babu 2021).

The functioning efficacy of inorganic fertilisers is beyond any question, but they are harmful so far as the safety of the environment and animal health are concerned (Kakar et al. 2020). Following the green revolution, excessive inorganic fertiliser use resulted in acidification of the soil (Aryal et al. 2021), a decrease in soil organic carbon, and a change in the diversity of soil biota (Lu et al. 2020). Synthetic nitrogen fertilisation increases the emission of greenhouse gas nitrous oxide (N_2O) from agricultural soil (Menegat et al. 2022). The majority of the nitrogen pollution (60%) is caused by crop cultivation alone (Aryal et al. 2021). Nitrate (NO_3^-) and phosphate (PO_4^{3-}), along with other nutrients present in fertilisers, like other agrochemicals, may contaminate nearby freshwater bodies via agricultural runoff or rain. Such nutrient enrichment increases primary productivity of water bodies and results in growth of aquatic plants and most notably algal blooms, a situation known as 'eutrophication', which ultimately reduces the dissolved oxygen level of the water bodies, rendering adverse effects on aquatic organisms (Khan et al. 2018). Nitrate pollution, both in surface as well as groundwater, is a matter of concern for the world community in a situation when the use of N-fertilizer in agriculture has been rising (Banerjee et al. 2023). This nitrate might enter groundwater by leaching. Nitrate-contaminated drinking water can cause serious human health hazards like methaemoglobin formation in infants' blood (blue baby syndrome), and the possibility of stomach cancer (Khan et al. 2018).

Synthetic pesticide application

In modern agriculture, the role of pesticides in protecting crops from pests, weeds, and diseases cannot be denied. Pre-harvest pests destroy an estimated 35% of global crop production (Oerke 2006; Popp et al. 2013). However, the major portion of the applied pesticides does not reach the target pests and instead affects non-target organisms or even stays in the environment as pesticide residue (Sun et al. 2018). Pesticides have been around for a long time. They rose to prominence, however, with the development of dichloro-diphenyl-trichloroethane (DDT) by Swiss chemist Paul Muller in 1939. Initially it was used to control malaria, typhoid, and other vector-borne diseases, but later, more particularly after World War II, its chaotic use as an insecticide in agricultural fields and consequent adverse effects on pollinators drew the attention of so many international environmentalists, that DDT and all forms of organochlorines were banned or restricted after the 1960s. The organochlorines were thus replaced by other synthetic pesticides such as organophosphates in the 1960s, carbamates in the 1970s, and pyrethroids in the 1980s (Samanta et al. 2023). There has been continuous research on pesticide formulation and combinations of one pesticide with another to make it suitable for better use in the field, less environmental persistence, and also to rule out the possibility of resistance building up among the pests against these compounds (Hazra, Purkait 2019).

However, synthetic pesticides quickly get adsorbed and retained by the components of soil due to their hydrophic tendency (Gupta et al. 2017). They affect a number of soil biota (Srour et al. 2020). One of the major reasons for the present decline of herpetofauna globally is the indiscriminate pesticide use in their native habitats and breeding grounds as well (Ghosh, Basu 2022). Pesticides affect pollinators (Kumar et al. 2022) and natural predators of agricultural ecosystem as well (Das, Basu 2023). Similarly, pesticides contamination in nearby freshwater bodies via agricultural run-off, and rainfall and their adverse effects on aquatic food chains, from plankton to fish is a serious concern for environmentalists (Chukwuka et al. 2022; Saha et al. 2023). Several researchers detected pesticide residues in surface as well as in ground water, sediments, and in fish tissues (Akoto et al. 2016). Agricultural workers should take necessary precautionary measures during the application of pesticides in the field to avoid health hazards (Samanta et al. 2023).

High-yielding seeds

The introduction of high-yielding varieties (HYV) of crops has played a crucial role in huge food production since the Green Revolution. Due to their desirable quality traits, massive production, and commerce through well-established marketing channels, their cultivation has gained popularity around the world. Another advancement in modern agriculture that has enabled the development of hybrid seed, which combines two or more crop strains to increase yields. HYV crops complete their yield within a short span of time, allowing farmers to grow multiple crops throughout the year. However, HYV crop cultivation requires a constant water supply and large chemical inputs in the form of inorganic fertilisers and synthetic pesticides (Nelson et al. 2019). Due to monoculture practice and recurrent pesticide application in the field, insect pests gradually become resistant to insecticides (Ray 2022). Then, recombinant DNA technology is used to modify plant genes and create transgenic seeds with desirable traits (Samal, Rout 2018).

A number of indigenous crop varieties found earlier in the Green Revolution are no longer in existence due to the introduction of HYV seeds in the agricultural market (Nelson et al. 2019). Aus rice varieties are gradually becoming extinct in Bangladesh and West Bengal of India with the promotion of HYV crops in agriculture (Ray 2022). Only 15 crops generate the majority of the world's ingested calories, with rice, wheat, and maize accounting for 2/3rd of them (FAO 1995). However, during the last 50 years, the industrial food chain has removed 75% of the genetic diversity associated with our food chain (Montenegro de Wit 2016). Crop variety, both genetic and intraspecific, has frequently been valued from the standpoints of nutrient requirements and climate resilience. Additionally, growing a variety of crop types lowers the risk of pest infestations and pathogenic infections in crops. Mixed-variety cropping practices are more able to endure biotic stressors. Thus, preserving crop species diversity has become crucial for agriculture, especially in the context of climate change. Concern over the effects of genetically engineered seeds or genetically modified crops on populations is growing.

Combine harvesters in modern agriculture

The use of combine harvesters in modern agriculture makes grain gathering simpler and faster. A harvester is able to finish reaping, threshing, and winnowing all at once. It produces huge stubble with stalks up to 15 cm in length that cannot be incorporated into the soil. Stubble burning is the deliberate combustion of crop leftovers by farmers after harvest. Tropical regions account for over 80% of total worldwide biomass burning. Stubble burning accounts for one-quarter of worldwide biomass burning (Abdurrahman et al. 2020). Burning stubble accounts for around 34% of the biomass burned in Asia. The two countries that contribute the most to biomass burning in Asia are China and India. The rotational rice-wheat cropping practice is used throughout much of the world. Tropical regions account for over 80% of total worldwide biomass burning. Stubble burning accounts for one-quarter of worldwide biomass burning (Abdurrahman et al. 2020). Burning stubble accounts for around 34% of the biomass burned in Asia. China and India are Asia's two major contributors to biomass burning. The rotational rice-wheat farming method is widely practiced in various places of the world. In this region, combine harvesters are used by most of the farmers to collect grains and the burning occurs immediately following harvest. Because collecting the residue can be difficult and *ex situ* treatment might be costly, farmers frequently select stubble burning as a viable option to swiftly prepare the field for the next crop to be sown (Chandel, Upadhyay 2019).

Stubble burning is one of the major causes of air pollution in the winter. When burning rice stubble (October to November) mostly in the tropical countries of the world, an air inversion caused by the cooler winter temperatures makes it possible for pollutants to spend more time in the atmosphere, which leads to difficulty in dispersion and a delay in smoke diffusion. Consequently, the smoke that accumulates in the atmosphere causes massive air pollution in comparison to the stubble burning of other seasons (Keil et al. 2021). Burning stubble also affects the nitrogen budget of the soil, fertility, and soil biota (Arunrat et al. 2023). Apart from adverse effects on the environment, stubble burning hampers socio-cultural, educational, economic, and day-to-day activities in major cities like Delhi in India (Abdurrahman et al. 2020).

Sustainable agriculture: a promising alternative

Definition

The Sustainable Development Goals of the UN aim to improve the living standard within the limits of ecosystems and remove any poverty or hunger by 2030. All 17 Sustainable Development Goals collectively focus on economic growth, social welfare, social equality, and the sustainability of the environment (United Nations 2015). However, attempts to achieve sustainable development have often failed during planning and development (Filho et al. 2020). Global economic inequality is still huge, the environment is deteriorating quickly, and biodiversity is decreasing. In addition, there has been a constant price hike for agrochemicals, resulting in a rise in farming expenditures, which is making it difficult for the poor farmers to meet up. Rich farmers alone can afford all this in agriculture with less regard for the environment. In this context, adopting sustainable agriculture for food production may become a promising alternative.

Sustainable agriculture, in general, follows a few common practices all over the world, as presented in Fig. 2 (Popp et al. 2013; Nelson et al. 2019; Velasco-Muñoz et al. 2019; Kakar et al. 2020; John, Babu 2021; Morugán-Coronado et al. 2022; Oberč, Schnell 2020). Sustainable agriculture should consider the three key pillars of sustainable development: environmental, social, and economic sustainability (WCED 1987). Agroecology, nature-inclusive agriculture, permaculture, biodynamic agriculture, organic farming, conservation agriculture, regenerative agriculture, carbon farming, climate-smart agriculture, high nature value farming, low external input agriculture, circular agriculture, ecological intensification, sustainable intensification, etc. are the landscapes of a variety of terminologies used in relation to sustainable agriculture (Oberč, Schnell 2020).

Biodynamic farming

Biodynamic farming, which is a promising and alternative method of agriculture to promote sustainable production, first appeared in Europe in the early twentieth century

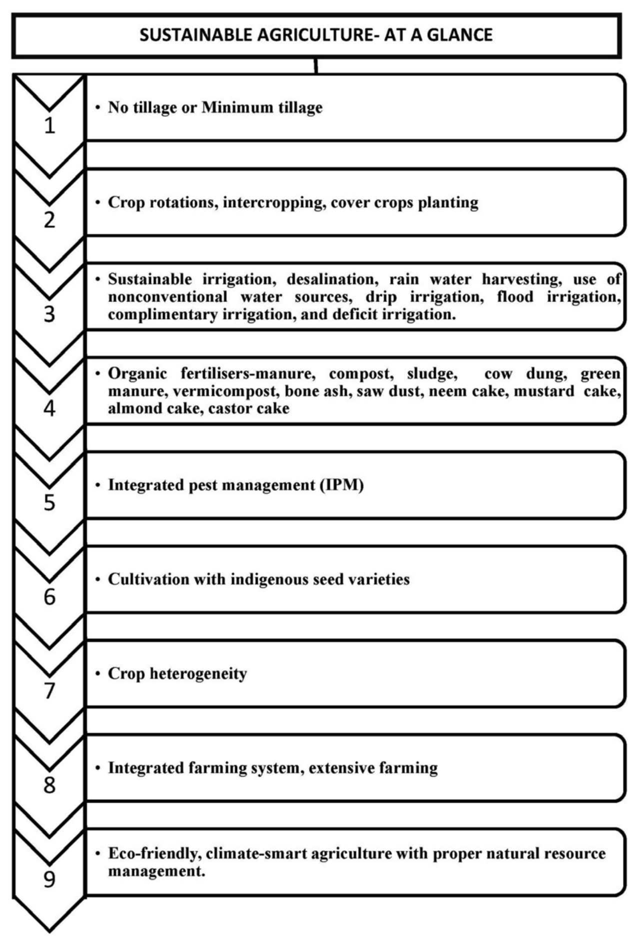

Fig. 2. Multiple strategies for sustainable agriculture.

(Brock et al. 2019). Biodynamic agriculture is thought to be "beyond organic" (Phillips, Rodgriguez 2006). It has many similarities with organic farming, but it also includes esoteric concepts based on the views of Rudolf Steiner (Steiner 1924; Muhie 2023). Biodynamic farming is a combination of the 'spiritual–ethical–ecological approach' (Jaeger et al. 2023), which always prioritises the use of biodynamic preparations and awareness of biological and cosmic rhythms in agriculture, while synthetic fertiliser and chemicals are strictly prohibited (Rigolot, Quantin 2022; Muhie 2023). It places a high value on spiritual and metaphysical concepts, treating the fertility of soil, the growth of crops, and livestock care as comprehensive environmental tasks (Jaeger et al. 2023; Muhie 2023). Biodynamic farming is not only a mere set of techniques; it is a philosophical concept that applies to the overall structure of a farm (Muhie 2023). The creation of a farm that operates holistically as a self-regulating, self-sustaining, and self-generating system that can be considered an intact living organism is the foundation of biodynamics, where soil, animals, humans, and plants function as "organs of a living organism" (Brock et al. 2019).

The most important tenets of biodynamic farming include respect for nature, incorporating organic matter to restore soil fertility, viewing the soil in the form of a living system, developing a system that restores balance to all factors that support life, motivating and comprehending the importance of green manure, crop rotation, and cover crops, and treating manure and compost biodynamically (Muhie 2023). From a biodynamic point of view, keeping ruminants is a must for a farm. Biodynamic preparations are of two types: field/crop spray preparations and compost preparations. Spray preparations include No. 500 (cow horn manure), No. 501 (cow horn silica), and No. 508 (horsetail). Compost preparations are No. 502 (yarrow flowers), No. 503 (chamomile flowers), No. 504 (stinging nettle shoots), No. 505 (oak bark), No. 506 (dandelion flowers), and No. 507 (valerian extract) (Steiner 1924). Biodynamic preparations are believed to be effective in achieving better root growth, developing stress resistance, and improving crop health with better yields and nutrient quality of produce. Additionally, they may improve soil health by increasing soil organic matter, nutrient cycling, recycling of waste, microbial diversity, etc. (Goldstein et al. 2019; Santoni et al. 2022; Muhie 2023).

Insect pest and disease prevention and preserving native biodiversity are other areas where biodynamics is growing in acceptance and attention (Muhie 2023). Demeter is an internationally recognised brand for certified products from biodynamic farming. The Biodynamic Federation Demeter International is providing support to its member associations, which in turn represent more than 7000 farmers across 63 nations on all continents, with an estimated 250 000 ha of land (https://demeter.net/about/organisation/). Still, there is a paucity of established scientific evidence to substantiate that certified biodynamic agriculture techniques are different from similar organic and integrated farming practices; so far, beneficial outcomes are a concern (Khadse et al. 2021; Santoni et al. 2022). Biodynamic agriculture has been dubbed a pseudoscience due to a lack of compelling empirical evidence for its usefulness and reliance on esoteric concepts and mystical ideas (Khadse et al. 2021; Rigolot, Quantin 2022).

Organic farming

Organic farming has been raised as an alternative to modern agricultural practices (FAO 2003). Today, it is considered a well-established approach as far as market and legislative supports are concerned (Oberč, Schnell 2020). It is a holistic production management approach that excludes the use of synthetic pesticides while emphasising the importance of maintaining ecosystem health. Organic farming is practiced in over 190 nations around the world, with 76 countries completely implementing organic regulations. The top three countries with organic agricultural land are Australia, Argentina, and Uruguay (Helga 2022). Organic farming boosts overall biodiversity (Rahmann 2011). However, the improvements required to transition to organic agriculture necessitate substantial financial assistance. The United States and the European Union among the northern states, as well as developing countries such as Tunisia, offering funding for this purpose (FAO 2023). The resuscitation of seeds that were on the verge of extinction because of HYV pressure and their proper conservation are the two most pertinent aspects today. Seed preservation is a most familiar practice among the farmer community. The availability of high-quality seed can be ensured by community seed banks, which can also maintain the best-adapted seed varieties in a region, whether they are indigenous or the result of selective breeding (FAO 2014). When the variety of seeds in banks increases, they may be exchanged or marketed to nearby communities, which ultimately increases revenue.

Diverse crops and their variations are seen to be crucial for ensuring global food security and fostering community resilience. Global interest in organic farming is demonstrated by the "Biodynamic network of farmers and breeders" in Germany (Henatsch 2002), the "Navdanya" movement to save seeds in India (http://www.navdanya.org/component/content/article?id=622), and the "Nayakrishi Andolon" farmer-led organic farming movement in Bangladesh (https://ubinig.org/index.php/nayakrishidetails/index/2/english). There is currently a strong drive for the evergreen revolution, which supports the nature, the underprivileged, women, and sustainable on-firm and off-firm livelihoods through effective ecotechnology and knowledge empowerment (Kesavan, Swaminathan 2008). New frontiers in organic food production must be explored because of the continually growing demand for organic food worldwide. Farmers, traders, and consumers must actively collaborate for a sustainable development model to thrive. When consumers' preferences for organic food, even at higher prices, can be developed, farmers' profit will rise (FAO 2003). It is also crucial to empower underprivileged farmers to utilise natural resources sustainably.

Natural farming

Japanese scientist and philosopher Masanobu Fukuoka, motivated by Buddhist philosophy, introduced "natural farming," also referred to as "do-nothing farming" in his book "The One-Straw Revolution" in 1975. Natural farming is an agroecological approach that does not require any machinery, chemicals, ploughing, or prepared compost (Kumar et al. 2023). He practiced it on the southern Japanese island of Shikoku. Fukuoka's concept advocated for minimum human intervention in the agricultural process and instead fostering conditions where crop outputs are maximised by natural processes left to their own devices. His methods require no ploughing of the soil; instead, enhancing soil health ensures that the natural balance is maintained. Fukuoka recommends sowing at strategic times so that crops can grow and flourish themselves before weeds can. This is an alternative to weeding (Fukuoka 2009). Fukuoka rejected all sorts of modern agricultural practices and suggested cultivation as per the laws of nature.

India has many indigenous forms of natural farming; the most well-known is Zero Budget Natural Farming (ZBNF), which is practiced in Andhra Pradesh, a state in Southeast India. ZBNF is a holistic agroecology that emphasises growing crops without the use of artificial chemicals or other external inputs at zero cost of production, enhanced soil fertility, climate-resilient farming with indigenous seeds, intercropping, and the building of sustainable agricultural livelihoods (Tripathi et al. 2018; Korav et al. 2020). The four wheels of ZBNF include "beejamrutham", which treats seeds using local cow dung and urine-based formulations; "jeevamrutham", which ensures soil fertility and raises soil microbes by applying a bioinoculum made of local cow dung, cow urine, jaggery, pulse flour, and water; mulching, which creates a favourable microclimate in the soil by covering it with a layer of organic material to prevent water evaporation and aids in the formation of soil humus; and "waaphasa", which aerates the soil. ZBNF promotes the use of several "kashayams" (decoctions) produced with local cow dung, cow urine, lilac, and green chilies for insect and pest control (Tripathi et al. 2018).

As ZBNF reduces farming input costs, and farmers' net income rises, which reduces credit dependency. ZBNF is concerned about the environment and socio-economic aspects and emphasises establishing a sustainable and equitable approach in agriculture (Duddigan et al. 2022). ZBNF also aspires to build the social capital needed for thriving and inclusive agricultural production by forming self-help groups and farmers' federations and giving the farmers the role of the flag-bearer of knowledge generation and dissemination (UNEP 2018). Renowned agriculturist Subhash Palekar has contributed to popularising ZBNF practices throughout India (Kumar et al. 2023). The government of Andhra Pradesh, a state in Southeast India, implemented ZBNF as the first state in India through a non-profit organisation called Rythu Sadhikara Samstha (Duddigan et al. 2022). However, yield efficiency, nutritional profile of crops produced, farming practices, and the concept of zero production cost of ZBNF all demand more research to be well accepted among the scientific communities.

Conclusions

Modernisation of agriculture is quite obvious in order to achieve food security in the context of overpopulation and the worldwide shrinkage of agricultural lands. Every year, a considerable portion of the yield gets affected due to pest attacks. Climatic fluctuations make agricultural output uncertain. However, agricultural intensification occurs at the expense of social, economic, and, above all, environmental costs. The perfect balance between increasing demands for food and nutrition from growing populations on one side and environmental well-being on the other is not so easy to implement in reality. Minimisation of greenhouse gas emissions from agriculture, soil fertility maintenance, prevention of groundwater misuse for irrigation purposes, agrochemical contamination of surface and groundwater, and conservation of agricultural biodiversity are the major thrust areas that need to be addressed at the earliest possible possibility. A long-term, proper plan should be taken so as to minimise, as best as possible, the stepwise reduction of chemical fertilisers and synthetic pesticides in agriculture and how to promote and popularise organic farming to satisfy global food demands. Those countries that have already implemented organic farming successfully can become models for others, and their experience can be beneficial to other countries as well. Combined applications of inorganic fertiliser and organic compost may boost soil fertility. Crop rotations, sowing legumes that are able to fix nitrogen, and fallowing also revive soil fertility. Research should be carried out to design and develop new generations of plant-based insecticide formulations, or insecticides with less residual toxicity, environmental persistence, and precise target pest specificity. Cultivating indigenous crop varieties can cope quite easily with the local environment, reduce agricultural costs, and availability of diverse food crops ensures future food security. Thus, agricultural biodiversity can also be conserved. Environment-friendly agriculture can only successfully implement the most-awaited dream of sustainable development into reality. Above all, organic agriculture opens a new avenue of research area and is yet to prove its efficacy to meet up huge food demand of the global human population in an environment friendly way.

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