Agriculture: Historical Evolution, Practices, and Future Prospects

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ABSTRACT

Agriculture has been the mainstay of human society, as the principal source of food, fiber and raw material for centuries. From early subsistence farming in formative stages to the modern industrialized versions, agriculture has been revolutionized right from the depth to reflect the improvements in technology, science, and socio-economic arrangements. This research paper refers to history of agriculture, various types of agricultural systems and techniques and how the current technologies such as biotechnology, precision agriculture and sustainable agriculture come in. It also discusses the importance of soil management, water management and crop management in maintaining productivity and then on to an analysis of environmental impacts including loss of biodiversity, loss of forests and greenhouse gas emissions. In addition, socio-economic importance of agriculture in the context of employment, rural upliftment and food security is brought out. The article also enumerates challenges facing present day agriculture such as climate change, population increase, resource constraints while describing the future in a focused manner on sustainability, innovation and resilience. Through integration of the historical insights and up-to-date concerns, this research illuminates the important role of agriculture in the development of societies and its potential to play a role in global issues of food security and sustainability

Keywords: Agriculture, Sustainability, Food security, Agricultural technology, climate change, socio-economic Development

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INTRODUCTION

Agriculture is one of the most critical fields in humanity that keeps billions of people in the world alive. Broadly defined by production of plants and animals for food, fibre and other products, agriculture is not only at the heart of human sustenance but also key to driving economic, cultural and social development (Fuglie, 2018). From the domestication of plants and animals some 10,000 years ago, to the use of biotechnology and computerized farming in the 21st century, agriculture has continued to evolve to respond to the changing demands of human societies.

The importance of agriculture goes far beyond food provision. It provides employment to more than a quarter of the world's population, and makes significant contributions to national economies and forms the backbone of rural living (Food and Agriculture Organization [FAO], 2020). Further, agriculture is critical for ensuring global food security, especially as future population is expected to grow rapidly to reach nearly 10 billion by 2050 (United Nations, 2019). However, despite the importance of agriculture, it is facing unprecedented challenges, such as depletion of resources and climate change, biodiversity loss, and socio-economic inequalities.

The 21st century has shown a paradigm shifting in farming too. Mechanized, industrial, and precision-based agricultural system have been gradually replacing traditional agricultural techniques. Though these advancements brought in productivity, they have also come with environmental and ethical problems (Tilman et al., 2011). Maintaining the fine equilibrium between providing food for the population of the world and preserving the world's environmental resources is one of the most important problems facing the world.

This research paper therefore intends to provide a healthy analysis of agriculture through evaluating its historical development, its multifaceted systems and practices, technological advances, resource management approaches, environmental impacts, socio-economic aspects and modern challenges. The discourse also looks to the future with a focus on sustainability and resilience, in order to find the avenues in which agriculture can support humankind in the next few decades.

Historical Aspects of the Development of Agriculture

The history of agriculture is that of the human societies, as it has evolved from ancient subsistence agriculture to industrial and technologically supported agriculture of today. Agriculture was not equally developed in the world, but rather, developed separately in different parts of the world depending on the environmental, cultural, and technological considerations (Bellwood, 2005). Its history gives us an idea of how the nature of agricultural practice has influenced the civilizations and continues to shape present day civilizations.

Origins of Agriculture: The Neolithic Revolution.

The history of agriculture goes back about 10,000-12,000 years ago during the Neolithic Revolution, in which man moved away from the settled farming societies to hunting and gathering (Diamond, 1997). This was a watershed in human history that enabled population increase, fixed settlements and the development of complex societies. Archaeological data show that the Fertile Crescent that encloses areas of the present-day nations of Iraq, Syria, and Turkey was among the earliest centers of crop cultivation, with wheat, barley, lentils, and peas being domesticated (Zeder, 2011). At the same time, other pre-historical centres of agriculture developed in China (rice, millet), Meso-Americans (maize, beans, squash) or Andes (potatoes, quinoa) and consolidate the multiple independent origins of agriculture.

This change was centered on the domestication of crops and animals. Sheep, goats and cattle served as livestock to produce not only meat but milk, hides and power to pull drafts for ploughing. This incorporation of animal and crop farming set the pillars of mixed farming systems that exist in most parts of the world to this date (Fuller et al., 2014).

Ancient Civilizations and Agriculture Expansion

Agriculture developed to be the cornerstone of ancient civilizations such as Mesopotamia, Egypt, Indus Valley and China. These societies developed irrigation systems, crop rotation and productivity supporting equipment. For example, Mesopotamian farmers developed the concept of a canal from the river Tigris and Euphrates, while Egyptians used the flooding of Nile every year, for instance (Manning, 2017).

In Asia, rice agriculture spread around China and Southeast Asia to become the staple sustaining high population densities. Maize in the Americas was also the foundation for the development of the Maya, Aztec and Inca civilizations. Some surpluses generated from agriculture in these areas allowed for urbanization, labor specialization, and an increase in art, science, and government (Fagan, 2004).

The Period of Medieval Age and Feudal Agriculture

Agriculture in Europe during the medieval period was, for the most part, based on the feudal system, in which peasants were working on the land of the noblemen. The method of three field crop rotation, where land was divided into three fields and one was left fallow, became a major innovation, boosting the quality of soil and yields (Campbell, 2016).

Technological innovations such as the heavy plow, horse collar, and water mills made productivity even higher. In the Islamic world, meanwhile, agricultural advancements by farmers and scholars introduced irrigation systems and research in botany as well as such crops as sugarcane, cotton, and citrus fruits into distant areas of land (Watson, 1983).

The Agricultural Revolution (17th -19th Century)

The European Agricultural Revolution (17th - 19th Century) was another time of change. The adoption of such new crops as potatoes and maize from the New World diversified diets and improved nutrition. Enclosure movements in England caused land to be brought together to create both larger holdings because they can better be cultivated, but they also displaced the majority of small farmers (Overton, 1996).

Technological advances included the invention of the seed drill by Jethro Tull; improved plows; and livestock breeding of planned animals by such entrepreneurs as Robert Bakewell. They increased yields to a great extent, which formed the foundation for increased population and urbanization during the time of the Industrial Revolution (Grigg, 1982).

The Green Revolution (Middle 20th Century)

One of the turning points in modern agrarian history is the middle of the 20th century Green Revolution. Led by researchers such as Norman Borlaug, this revolution introduced the high yielding crop varieties, chemical fertilizers, pesticides and irrigation systems to developing countries such as India and Mexico (Evenson & Gollin, 2003).

The Green Revolution greatly increased the amount of food the world produces, which helped reduce famines, and allowed for vast increases in populations. However, it also resulted into environmental concerns such as degradation of soil, water pollution, and decline of biodiversity which raised debates on sustainability (Shiva, 1991).

Agriculture in the year 21st century

Agriculture is now characterised by advanced mechanisation, biotechnology, precision farming and new digital technologies such as artificial intelligence (AI) and Internet of Things (IoT). Though such technologies hold out the promise of efficiency and sustainability, they also challenge the issues of equity, resource distribution and environmental consequences (FAO, 2021).

Additionally, world agricultural systems are more and more entangled with climate change issues and need sustainable ways of supporting the ever-increasing population and reducing the ecological damage (Foley et al., 2011). Therefore, the development of agriculture over time represents a never-ending cycle of adaptability, innovation and balance of human needs and environmental constraints.

Agricultural Systems and Dimensions of Practice

Agricultural practices and systems are the different ways that the human species produce plants and domesticated animals for both food, fiber, and industrial purposes. They vary greatly from location to location, depending upon environmental conditions, tradition, levels of technological development and socio-economic frameworks (Ellis, 2013). It is important to appreciate these differences, as they help to understand the adaptability, sustainability and productivity of agriculture in different settings.

Subsistence Agriculture

Subsistence farming is one of the oldest types of agricultural system, which has been majorly followed in developing regions of Asia, Africa, and Latin America. Farmers grow food and raise animals within the system primarily for family consumption without very little or no surplus for exchange (Njeru, 2013). Subsistence farming also involves the use of basic tools, local knowledge and family members.

Crops typically include staple foods such as rice, maize, cassava and millet which are used to feed the local populations. Shifting cultivation, otherwise known as slash and burn agriculture, is a common subsistence practice in tropical regions, where farmers clear forests, clear the soil for a few years and then move on to new lands to allow soil to recover (Mertz, 2009). Although the system is capable of maintaining small population sizes, it is faced with such limitations as deforestation, soil erosion, and productivity decline with the population pressures of today.

Pastoralism and the Nomadic Herding

Pastoralism is the raising of domestic animals such as cattle, sheep, goats, camels and yaks in the region that is not suitable for intensive crops cultivation. It is prevalent in arid and semi-arid areas like some areas in Africa, Central Asia and Middle East (Galvin, 2009). Nomadic herders move seasonally according to water- and pasture-access and practice transhumance- a system of seasonal migration between areas of low- and highland.

Pastoralism plays a significant role in the food security, cultural identity and ecosystem management of the dryland. It is, however, increasingly under threat due to land privatization, climatic variation and competition for grazing resources (Fratkin & Mearns, 2003).

Mixed Farming Systems

Mixed farming is a system that integrates livestock rearing and crop production, which is more efficient and sustainable. Manure for fertilizing the fields are obtained from livestock and crops provide fodder for animal feed. Being so associated, wastage is mitigated and nutrient recycling is facilitated (Herrero et al., 2010).

Mixed farming is prevalent in Europe, Asia, and also in some parts of Africa. For instance, most Sub-Saharan African smallholder farmers have maize and legumes as they keep poultry or goats such that there are diversified food products and income (Thornton & Herrero, 2015). The system provides resilience from market shocks and climate shocks.

Commercial Agriculture

Industrial agriculture is characterised by the mass production of crops and livestock for sale to the local and export markets. It is reliant on mechanization, chemical applications, irrigation and high technologies. Illustrations are the large wheat farms of North America, the soy bean plantations of Brazil and Indian cotton production (Pingali, 2012).

Monocultures oriented toward commercial agriculture are prevailing, normally achieving high yields at the cost of a risk of soil exhaustion, pest infestation, and reduction in biodiversity (Altieri, 2009). The production system is the backbone of the world's food supply chains, but their sustainability over time depends on striking a balance between making money and protecting the environment.

Plantation Agriculture

There was plantation farming during the colonial period and it still exists in the tropics today. It involves enormous estates which produce cash crops such as sugarcane, tea, coffee, palm oil, rubber, and bananas for export mostly (Beckford, 1972). Plantations tend to rely on labour-intensive methods and sometimes abusive each other migrant or native labour in a harsh condition.

While plantation plays a significant role in foreign exchange earnings, there are also associated environmental downsides such as deforestation, destruction of their habitats and the dependency on chemical inputs. For example, there have been cases where palm oil plantations in Southeast Asia have been linked to mass deforestation of rainforests and loss of endangered species (Wilcove and Koh, 2010).

Intensive farming and Extensive farming

Agricultural systems are also intensive or extensive according to the level of input and productivity. Intensive agriculture: intensive farming is land intensification by high inputs of labour, capital and technology per unit area of land e.g. Asian rice paddy, European greenhouse horticulture. The system has the largest yields but can cause environmental stress because of the high application of fertilizer and water resources (Tilman et al., 2002).

On the other hand, extensive farming involves extensive farming with relatively low inputs and productivity per hectare, e.g. Australian cattle ranching or Canadian wheat farming. Less inputs per unit area, but with enormous land demands which often leads to land-use change and destruction of habitat (Ellis, 2013).

Organic Farming

Organic agriculture has risen in the last few decades as a response to environmental and health issues as well as food quality issues. Organic farming avoids the use of synthetic fertilizers, pesticides and genetically modified crops (GMOs) and instead focuses on crop rotation, composting, biological pest control and natural soil fertility (Reganold & Wachter, 2016).

Although organic farming generally has low yields compared to conventional systems, it provides good support to keep biodiversity, reduces the need for chemical pollution and often also returns higher economic returns due to premium price (Seufert et al., 2012). Its role in the sustainable agriculture is continuing to expand globally.

Agroforestry and Sustainability Practices

Agroforestry combines the trees and agricultural crops and livestock together in various systems that can be beneficial in multiple ecological and economic ways. Trees improve soil fertility and provide shade, helping to prevent soil erosion and sequester carbon; and farmers benefit from a variety of products such as fruits, wood and fodder (Garrity, 2006). Agroforestry is particularly important in the tropics where deforestation and land degradation are most pressing problems.

Other sustainable methods such as conservation agriculture, permaculture, and regenerative farming are also gaining prominence for their capacity to help us reduce climate change and to restore ecosystem function (Lal, 2020). They advocate for low-disturbance of the soil, permanent soil cover and crop diversity to guarantee of long-term productivity.

AGRICULTURE TEHNOLOGIES AND INNOVATIONS

Agriculture has continued to have a strong association with the advancement of new technologies. From the invention of the plow thousands of years ago to the use of artificial intelligence and biotechnology in the 21st century, innovations have toiled tirelessly to maximize productivity, efficiency and food safety (Boserup, 2017). The adoption of agricultural technologies however is faced with important issues of sustainability, equity and environmental consequences.

Mechanization In The Agriculture

Mechanisation of agriculture began in the 18th and 19th centuries and changed farming from a labour-based industry to a capital-based industry. Developments such as the seed drill, mechanical reaper and steel plough increased efficiency and made labour less dependent on manual labour (Grigg, 1982). During the 20th century universal use of tractors, combine harvesters and milking machines revolutionized crop and livestock farming.

Nowadays, mechanization is used to farm large amounts of crops, harvesting and processing them at economical speed. Smallholder farmers in developing nations are lagging behind in this regard, and gaps in terms of productivity and income are created (Pingali, 2007).

Irrigating and Water Management Technologies

Water has always been at the centre of agriculture production. Canal systems had been developed in ancient societies, although modern irrigation technology has magnified agricultural potential drone toeganat has immensely. Sprinkler irrigation, drip irrigation system and sensor-controlled system of irrigation promote directed application of water for optimal utilization of resources coupled with higher yields (Howell, 2001).

For example, drip irrigation, in both Israel and India, has been so useful in raising water-use efficiency that it has become possible to cultivate in arid lands. Excessive irrigation in other regions, though, has resulted in the depletion of groundwater reserves, salinisation and ecological imbalances (Falkenmark & Rockstrom, 2004).

Chemical Fertilizers chemical Pesticides

The early 20th century's revolution in the Green Revolution was made possible by the inventions of synthetic fertilizers and insecticides. Nitrogen fertilizers which were synthesized with the Haber-Bosch process allowed agricultural output to rise worldwide (Smil, 2001). Likeewise, the use of chemical insecticides controlled disease and pests and allowed yield stability.

Although these inputs have helped drastically increase food production, the over-application of these inputs has led to environmental problems including water pollution, soil erosion and loss of biodiversity (Tilman et al., 2002). There has thus arisen interest in integrated pest management (IPM) and biofertilizers directed towards reconciling productivity and environmental sustainability.

Biotechnology and Genetically Modified Organisms

Biotechnology has offered new technologies for the improvement of crop and livestock productivity.

Genetic modification (GM) enables the development of crops with desirable traits such as resistance to pest organisms and herbicides and improved nutritional value. For example, Bt cotton has been widely used in India, decreasing the amount of pesticides used and increasing yields (Qaim & Zilberman, 2003).

The recent developments in genome editing tools, including the development of the alternative of the newer technology called Cas9, open up even more promise for precision breeding as a way of changing genes without the addition of the foreign DNA (Zhang et al., 2018). Biotechnology is also used for the breeding of livestock, disease resistance, and vaccine development and therefore plays the core role in the modern agriculture.

However, GM crops are contentious since they create ecological hazard issues, seed control issues for corporations, as well as consumers acceptance issues (Shiva, 2016).

Precision Agriculture

Precision agriculture uses high-tech tools such as global positioning systems (GPS), remote sensing and geographic information systems (GIS) to make the most of farm practice. Through the collection of real-time data on the soil conditions, crop development, and weather conditions, farmers are able to make informed decisions that reduce waste and maximize efficiency (Gebbers & Adamchuk, 2010).

For instance, variable-rate technology enables farmers use fertilizers and pesticides in precise terms of quantity of application depending on field variability to inflict least damages to environment while ensuring highest productivity. Drones and satellite remote sensing also help in the monitoring of crops and estimation of crop yield.

Digital Agriculture and Artificial Intelligence (AI)

The digital revolution is bringing changes in agriculture with big data analytics, AI, robotics and Internet of Things (IoT). Smart sensors monitor soil moisture, fertilizer content and pest infestations and analyze the data with AI-based algorithms to provide actionable insights (Wolfert et al., 2017).

Robotics

and automation are also increasing in harvesting, weeding and in livestock management activities. Robotic milking systems, for example, have become commonplace on dairy farms in Europe and reduce demand for labor and increase efficiency (Bijl et al., 2017).

Digital agriculture has the potential of improving productivity and sustainability across the world but also has the potential of widening the digital divide between resource-rich and resource poor farmers.

Climate Smart Agriculture (CSA)

Climate-smart agriculture is a holistic approach addressing the challenges of climate change in terms of productivity, adaptation and mitigation. Conservation tillage, crops with drought resistance, agroforestry and efficient irrigation methods are some of the practices of CSA (Lipper et al., 2014).

CSA promotes resilience that will reduce greenhouse gases and insure food security. Governments, research institutions and international bodies such as the FAO are taking an active stance to promote CSA as a trajectory to growth in sustainable agriculture.

Post Harvest Technologies: Supply chain Innovations

Increasing agricultural productivity is not just to do with farming but also reducing post-harvest wastages. Technologies such as cold storage, improved packaging and effective transport systems have reduced the wastage drastically and ensured for a better distribution of food (Kader, 2005).

Supply chain technologies, such as blockchain technology, are also being used to improve transparency, traceability, and efficiency in food trade (Tripoli & Schmidhuber, 2018). These technologies promote food safety and consumer confidence and reduce economic losses to farmers.

MANAGEMENT of Soils, Water and Crop

Soil, water and crops are known as the three pillars of agriculture. Management of these directly affects agricultural productivity, environmental sustainability and food security. Effective management practices work in the direction of optimizing the yields while maintaining the health of the natural resources for the future generations. With increasing global challenges such as population growth, climate change and scarcities in resources and so forth, it has become the focus of sustainable management of soil, water and crops (Lal, 2020).

Soil Management

Soil is the plant growth medium which is extremely sensitive to depletion due to an excessive use, erosion and chemical pollution. The soils of the world are nearly one-third degraded, which threatens agricultural production (FAO & ITPS, 2015).

Fertility of Soil and Nutrients Management

Soil fertility is maintained through proper management of nutrients such as nitrogen, phosphorus and potassium. Conventional practices include crop rotation, green manure and application of animal dung. Contemporary approaches make use of synthetic fertilizers, albeit overuse can result in runoff of nutrients, eutrophication and acidification of soils (Tilman et al., 2002). Integrated soil fertility management (ISFM) is balanced use of the organic and inorganic inputs to maintain soil health in tandem with high yield (Vanlauwe et al., 2015).

Techniques of Soil Conservation

Long term agricultural sustainability depends a lot on controlling erosion. Contour farming, terracing, cover cropping, and conservation tillage are some of the methods to preserve soil structure and discourage erosion (Montgomery, 2007). Agroforestry is also involved with the root-stabilized soils of trees and reduced water runoff.

Soil Health and Diversity

Healthy soils are dynamic microbial ecosystems for the cycling of nutrients with improved resistance. Soil biodiversity and carbon sequestration are enhanced by practices such as reduced tillage, application of organic amendments and crop diversification, which make soil an important component in climate change mitigation (Lal, 2020).

Water Management

Water is an agricultural limiting factor and irrigation accounts for nearly 70% of the freshwater withdrawals worldwide (FAO, 2017). Effective water management is therefore a must to ensure agricultural productivity and resource conservation activities.

Irrigation Systems

Conventional methods of irrigation such as flood irrigation are quite inefficient and tend to, that is to say, wastage of water and salinization. New-age methods such as drip irrigation and sprinkler systems deliver the water to the roots of the plants, and as such are as much as 90% efficient (Howell, 2001). Irrigation systems that are sensory-based make the best use of water because they vary the rate of delivery based on sediment moisture content and crop needs.

Rain water harvesting and water conservation

In rain-fed areas, the shortage of water is the major constraint. Rainwater harvesting, check dams and watershed management practices improve groundwater recharge and ensure the water supply during dry periods (Rockstrom et al., 2010). Mulching and zero tillage conservation are also used to limit the evaporation of water from soils.

Water Use Challenges

Groundwater over-taking where much of Asain and Middle Eastern countries down to receding of water table which aggravate the agricultural sustainability in long term (Rodell et al., 2009). Climate change with its impact on precipitation patterns and enhancing drought frequency also increases the problems of water management.

Crop Management

Crop management techniques aim at maximizing growth, preventing losses, and improving productivity in a way that will ensure ecological balance.

Crop Selection and Breeding

The selection of crops that can fit into the local environment is central to achieving maximum yields. Conventional breeding techniques and modern biotechnology have produced high yielding and climate resistant crop varieties such as wheat, rice and maize (Tester & Langridge, 2010). The generation of drought-resistant and pest-resistant crops are getting importance in climatic variability adaptation.

Integrated Pest and Disease Management or IPM

Protection of crops from insects and diseases is extremely important to food security throughout the world. IPM combines biological control, resistant varieties, cultural management and least use of chemicals to manage pests in a sustainable way (Kogan, 1998). For example, the use of beneficial insects such as lady beetles to attack is expressed by aphids reduces the use of pesticides.

The Diversification of Akole Crop and Crop Rotation

The cultivation of monoculture makes soil nutrients very poor and easily becomes infected by diseases and pests. Crop rotation and diversification breaks pest life cycles whilst enhancing susceptibility, soil fertility and resilience (Altieri, 1999). Intercropping schemes between maize and legumes are quite common among farming households (is when maize is planted with other crops such as legumes) to increase yield and soil health at a smallholder level.

Post-Harvest Management

Effective management of the crops when are being stored or transported ensures that there will be minimal post-harvest losses that contributes close to 30% of the world's food production (Kader, 2005). Better storage technology in terms of hermetic bags and cold chains help to extend the shelf life and preserve the food quality.

Integrated Resource Management Methods

The practice of sustainable agriculture relies more and more on holistic practices by managing soil, water and crops as a whole. Practices such as conservation agriculture, agroecology and climate smart agriculture are putting resource efficiency, resilience and environmental protection at the forefront (Pretty et al., 2018).

For example, conservation agriculture encourages low levels of soil disturbance, year-round soil cover and crop rotations, while enhancing productivity and ecological outcomes at the same time. Similarly, agroecological practices integrate ecological science with traditional knowledge to create farming systems to develop as sustainable to humans as ecosystems.

IMPACTs of Agriculture on the Environment

Agriculture is inevitable to human existence, but agriculture also has significant impacts on the environment. While agricultural advancements have enabled food security for billions of people, it has also led to deforestation, greenhouse gas emissions, loss of biodiversity, soil degradation and pollution of water bodies. Balancing agriculture productivity while safeguarding the environment is one of the greatest challenges of the 21st century (Foley et al., 2011).

Deforestation and Changes in Land Use

Agriculture is the leading cause of deforestation globally contributing to nearly 80% of forest loss (Kissinger et al., 2012). Cropland areas and pastures, especially for soy, palm oil, and cattle grazing have resulted in widespread deforestation of forests in the Amazon, Southeast Asia, and Central Africa.

Deforestation is a disturbance factor for the ecosystems, raises biodiversity loss and reduces carbon sequestration which further worsens climate change (Laurance et al., 2014). Land-use change also means soil erosion, worst water quality, and the fragmentation of habitats.

Desertification and degradation of the soil

Intensive agriculture tends to result in soil degradation by erosion, salinization, a depletion of nutrients and compaction. An estimated 24 billion tons of valuable soil is lost every year globally to unsustainable land management (UNCCD, 2017).

Desertification from overgrazing, deforestation and unsustainable irrigation are most pronounced in semi-arid and arid regions such as Sub-Saharan Africa and Central Asia (Geist & Lambin, 2004). Soil degradation reduces agricultural output and balances farm communities primly.

Water Pollution and Overuse

Agricultural runoff that contains fertilizers, pesticides and animal waste is a major source of water pollution. Excessive addition of nitrogen and phosphorus leads to eutrophication, which leads to blooms of algae and hypoxic "dead zones" in lakes and coastal waters (Diaz & Rosenberg, 2008).

Excessive extraction of ground water for irrigation has led to declining water tables in places such as India, Pakistan and the United States (Rodell et al., 2009). Salinization of irrigated land due to the use of irrigation has also destroyed millions of hectares of irrigated land, particularly in dry environments.

Climate Change and Global Warming (Greenhouse gas emission)

Agriculture contributes approximately 25% to the global greenhouse gas (GHG) emissions that are a major cause of climate change (Smith et al., 2014). Major sources include:

Methane CH4: Enteric fermentation of livestock & from rice paddies.

Nitrous oxide (N2O): From use of fertilizer and from the manure.

Carbon dioxide (CO2): From deforestation, soil erosion and the use of fossil fuel in mechanization.

To give one example, agricultural GHG emissions from cattle alone amount to roughly 14%, most of which is the gas methane (Gerber et al., 2013). Agriculture emissions are therefore at the center of climate change mitigation.

Loss of Biodiversity

Conversion of natural habitats to agricultural land is one of the major causes for extensive biodiversity loss. Monoculture farming reduces the diversity of habitats and pesticide use threatens pollinators such as bees, which are critical to the production of crops (Potts et. al, 2010).

Genetic loss in crops and livestock due to dependence on a few high-yielding varieties of each species also makes the varieties more vulnerable to attacks by pests and diseases as well as climatic variability. According to FAO (2019) about 26% of the world's livestock breeds are under threat of extinction, so it is important to conserve genetic resources.

Impacts from Ecosystem Services

Crop expansion and intensification interfere with the provision of ecosystem services such as pollination, water cycling and soil fertility. Agricultural drainage of wetlands reduces flood prevention and water filtering services while excessive application of chemical inputs reduces soil microbial biodiversity (Power, 2010).

Yet, sustainable practices such as agroforestry, organic agriculture and conservation agriculture have the ability to enhance ecosystem services such as soil health, water content and the preservation of biodiversity (Altieri, 1999).

Emerging Environmental Issues

In addition to traditional environmental impacts, agriculture has implications for other new challenges:

Plastic pollution: The use of plastic mulch film and greenhouse covering causes deposition of microplastics in the soils (Rillig et al., 2019).

Antimicrobial resistance (AMR): Excessive use of antibiotics in animal husbandry leads to the development of antimicrobial resistant pathogens, which are detrimental for human and animal health (Van Boeckel et al., 2015).

Use of energy: Mechanized farming is very energy-some, and it improves the use of fossil fuels and indirectly supports the GHG emissions.

Agriculture & Sustainability Balancing issues

While agriculture is an important environmental stressor, it is also full of solutions to the world's problems. Methods such as carbon sequestration in soils, reforestation, integrated pest management and climate smart agriculture can mitigate environmental impacts (Lipper et al., 2014). A shift towards sustainable intensification - increased amounts of food at lower environmental costs - is a practical way forward (Pretty et al., 2018).

SOCIO-ECONOMICs Aspects of Agriculture

Agriculture is more than an economic activity but also a key driver of the societal system, affecting the livelihood, cultures and lives of societies. Being one of the oldest occupations in humankind, to date, it remains to be a significant source of livelihood and employment for billions, particularly in the rural areas of developing countries. Its socio-economic facets include employment, poverty reduction, food security, gender roles, rural development, trade and identity based on culture. Familiarity with these dimensions is necessary for developing agricultural policies that will balance the three aspects (i.e. productivity, sustainability, and equity) (FAO, 2020).

Agriculture as a source of employment

Agriculture is one of the largest employers in the world, providing employment to more than 1/4 of the labour force globally (World Bank, 2021). In low-income countries the share of agriculture in overall employment is as high as 60-70% particularly in Sub-Saharan Africa and South Asia (ILO, 2019).

Industrialized nations: Farming uses less labor (due to mechanization), but fulfills associated industries such as food processing, transport, and retail.

Developing nations: Subsistence farming is high with millions of livelihood depending upon agricultural produce.

Agriculture is also responsible for the seasonal and migrant workers, who are also important in the cycles of planting and harvesting. Labor conditions, however, are usually insecure, with problems of low incomes, child labor, and absence of social protection (Barrientos, 2019).

Alleviating Poverty and Securing Livelihood

Poverty alleviation is all about agriculture because the majority of the poor in the world live in rural areas and work in agriculture. Agricultural sector growth has been found to reduce poverty rates more efficiently when compare to other sectors (Christiaensen et al., 2011).

Access to land, credit and inputs and markets determine whether or not smallholders can switch to a commercial farming. Initiatives for rural co-operatives, micro-finance and sustainable intensification have the chance to push families out of poverty and increase food security.

Still, challenges such as land fragmentation, lack of infrastructure and exposure to climate shocks are frequent causes of loss of livelihood security. For instance, smallholder farmers in Sub-Saharan Africa are not getting access to markets due to bad roads and poor storage facilities (Jayne et al., 2010).

Food Security and Nutrition

Agriculture has a direct impact on the availability, accessibility and utilisation of food: three building blocks of food security (FAO, 2019). Improvements in the productivity of agriculture brought about during the Green Revolution, had a major impact on reducing hunger in Asia and Latin America. Nonetheless, food insecurity is an important problem given that almost 735 million people were undernourished globally in 2022 (FAO et al., 2023).

Malnutrition involves more than calorie shortages, and it is related to poor diet diversity. Staple food dominance has led to "hidden hunger" - micronutrient deficiencies that cause harm to billions (Pingali, 2015). Diversified agriculture systems in the form of horticulture, livestock & fisheries are essential to improve nutrition outcomes.

Gender and Agriculture

In developing nations, women constitute about 43% of the labor force in agriculture (FAO, 2011). Women play critical roles in food production and processing as well as family nutrition. Women however, often face structural barriers such as limited access to land ownership, credit, technology and extension services (Meinzen-Dick et al., 2019).

Closing the agriculture gender gap would improve the world agricultural production by up to 4% and hunger by 12-17% (FAO, 2011). If women are empowered through having land, being educated, and participating in decision making, productivity and community happiness will improve.

Transformation of Rural Development and Society

Agriculture is the backbone behind rural economies to supporting infrastructures, education and health improvements. Rural development policies connecting agriculture with non-farm activities (e.g. major agro-processing, tourism, and services) are able to diversify incomes and slow down rural-urban migration (Ellis, 2000).

In addition, the agricultural cooperatives and farmers organisation facilitates collective bargaining making it possible for the smallholders get improved prices, reducing transaction costs and access to credits and inputs (Markelova et al., 2009).

Agriculture and World Trade

Agriculture is a major percentage of the international trade and consequently world economic relations. Coffee, tea, cocoa, cotton, and grains are major export earners for the majority of the developing countries (World Trade Organization, 2020).

Export-oriented agriculture: Brazil (soy beans, beef, coffee) and Vietnam (rice, coffee) have become competitive on global world markets.

Trade dependency: Excessive reliance on agricultural exports exposes the economies of the subject to price fluctuations and restrictions in trade.

Subsidies and barriers: Agricultural subsidies in developed countries between the developed and developing countries distort the international markets to the disadvantage of farmers in the developing countries (Anderson, 2010).

Trade liberalization while offering an opportunity also may be a threat to smallholders who cannot compete with industrialized farming systems.

Cultural and Social Differences

Agriculture has been established in cultural identities and traditions together with social practices. Rituals, festivals and food are often associated with agricultural rhythms. Indigenous farming systems such as milpa in Mesoamerica or rice terraces in the Philippines have ecological knowledge, gained by generations (Altieri & Toledo, 2011).

The consequence of this degradation of farming practices following the constraints of modernization and the resulting loss of traditional culture and biodiversity. Encouraging indigenous knowledge and agroecology, it is important in order to protect cultural diversity and sustainable practices.

Socio-Economic Issues for Agriculture

Despite being vital agriculture, agriculture is also beset by some of its serious socio-economic challenges:

Youth lack interest: Young people leave to go to towns and leave aging rural communities.

Income disparities: The large agribusinesses dominate the market and smallholders cannot compete.

Vulnerability: Smallholder farmers are vulnerable to climate change, price volatility and volatility of their policies.

These are issues that can only be resolved through inclusive policies targeting smallholder farmers, rural women and the poor.

Agriculture, Sustainable Development goals (SDGs)

Agriculture has a key role to play in the attainment of the UN Sustainable Development Goals (SDGs), in particular SDG 1 (No Poverty), SDG 2 (Zero Hunger), SDG 12 (Responsible Consumption and Production), and SDG 13 (Climate Action). Investment in sustainable agriculture can yield a number of co-benefits across the spectrum of health, education and environmental sustainability (UN, 2015)

Problems with Contemporary Agriculture

Agriculture in the 21st century is faced with complex and interrelated challenges that are being defined by population growth, globalization, climate change, environmental degradation and socio-economic imbalances. Although due to technological advances and policy measures, it has immeasurably improved productivity, contemporary agriculture still stands hassled with sustainability, equity and resilience. Knowledge about such challenges is decisive in defining agricultural systems that will defeat future demands for food in defiance of these without exhaustion of environment and livelihoods (Godfray et al., 2010).

Increasing Population and Demand for Food

The world population is projected to increase up to 9.7 billion by 2050, and agricultural production level should increase by 60-70% to keep up with the food demand (FAO, 2017). This puts an enormous amount of pressure on land, water and energy resources that are already strained.

Increased incomes and urbanization are also altering food practices towards meat, dairy and processed foods, again causing a demand for land consuming and resource intensive commodities (Tilman & Clark, 2014). Managing production and sustainability remains the main challenge.

Climate Change and Vulatility of Farms

Climate change is a major threat to world agriculture. Temperature rise, erratic changes in rainfall, longer droughts, flooding and extreme weather have a direct impact on crop harvests and on the performance of livestock (IPCC, 2022).

Heat stress: Reduces standards of production (such as wheat, maize and rice).

Water scarcity: Creates competition for use of water for irrigation in dry areas.

Pest and disease epidemics: Causes the establishment of a greater range of alien species in warmer climates.

The smaller holders in the developing countries are most vulnerable due to the dependence on rain-fed agriculture and lack of ability to adapt (Morton, 2007).

Resource Scarcity and Degradation of the Environment

Already, agriculture is the largest consumer of freshwater worldwide and withdrawals (WWAP, 2015) account for around 70% of global withdrawals. Pollution of natural resources from groundwater overexploitation, insufficient irrigation, and chemical inputs causes the natural resources to disintegrate.

33% of the soils around the world are threatened because of soil degradation that lowers fertility and productivity (FAO, 2015). Land shortage is also a serious problem, as industrialization, urbanization, and deforestation compete with the increased farmland.

Technological and Economic Inequalities

Technologies such as precision agriculture, biotechnology, and digital farming have the potential to boost productivity and bring a positive payoff, yet the access is not even. Modern technologies are embraced by big agribusinesses while the smallholders in the developing countries have no access to funds, infrastructures, and training (Van der Burg et al., 2019).

This "technology gap" acts as a tool of entrenchment of inequalities whereby marginal farmers stand vulnerable to attractiveness being left behind in the international markets. Volatility in the market, high input prices, and dependence on the international supply immobilizes more and causes economic risk in smallholders.

Global Trade Pressures and Volatility in Markets

Agriculture is increasingly tied to the international economy with farmers victims of volatile prices, trade tensions and supply chain interruption. Volatility of the prices of commodities as was experienced during the 2007-2008 food crisis, mainly hits poor producers and consumers (Headey & Fan, 2010).

Export bans, developed country subsidies, and discriminatory trade practices also hurt the farmers of developing countries. The weaknesses of international value chains were also revealed during the pandemic of the corona virus (Laborde et al., 2020) and showed the need to strengthen local food systems.

Labor Issues and Rural Population

Agriculture is facing the challenge of shrinking human resources due to migration from rural to urban areas as well as disincentive from the youth to pursue them. Most youth view farming as unprofitable and strenuous labor and choose instead to engage in non-agricultural employment in urban areas

(Brooks et al., 2013).

The population aging of farmers puts in danger the continuity of the farming practices and knowledge. As a result of this, dependency on migrant and seasonal labor contributes to labor shortages and highlights structural weaknesses of agricultural systems.

Health and Safety Issues

Contemporary agriculture generally relies heavily on chemical pesticides, fertilizers and antibiotics in animal husbandry. These methods are fraught with dangers and they include:

Human health effects: Human exposure to pesticides as the cause of chronic diseases (Mostafalou & Abdollahi, 2013).

Antimicrobial resistance (AMR): The inappropriate use of antibiotics in farm animals leads to resistant pathogens (Van Boeckel et al, 2015).

Workplace hazards Farmers face a risk of injury through machinery, heat, and brought on with chemicals.

A balancing act between our productivity and public health remains an issue of the time.

Decline in Biodiversity and Monoculture

Current agriculture tends to favoring monoculture farming systems in order to optimize yields. Efficient as these may be, monocultures reduce genetic diversity, reduce soil quality and increase exposure to pests and disease (Altieri, 1999).

Loss of biodiversity poses the threat of a loss of ecosystem services such as pollination, pest opposition and nutrient cycling. For example, the loss of pollinators has direct implications for the global food security (Potts et al., 2010).

Policy and Governance Issues

Governance of agriculture is typically undermined by fractionalised policies, low capacity institutions and inconsistencies in their implementation. Subsidies at times promote environmental degrading practices and the smallholders are underrepresented in the policy making (Pingali, 2012).

Corruption, lack of land security and lack of enabling infrastructure contribute to inequitable access to opportunities in agriculture. The right governance structure is important for sustainable agricultural change,

Ethical and Social Dilemmas

Current agriculture also creates ethical problems concerning animal welfare, genetic modification and the rights to land. Large-scale corporate and foreign capital land acquisitions ('land grabbing') disproportions local populations from land and the right to food sovereignty (Borras et al., 2011).

Also, controversies have been associated with genetically modified organisms (GMOs), balancing possible benefits of higher yields against ecological risks and corporate control of the seeds (Qaim, 2020).

Interrelationship of Challenges

The problems that face agriculture are extremely interrelated. Climate change exacerbates the lack of resources, which in turn brings added pressures of poverty and migration. Volatility in the markets affects the security of the farmers' income, reducing their capacity to invest in sustainable production. Solutions to these problems have to be integrative, including by bringing together ecological, economic, and social aspects simultaneously.

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The Future of farming is where technology, sustainability and social change intersect. With growing global demand for food while the challenges of climate change, natural resources scarcity and environmental degradation continue to grow, farming needs to become a productive, robust and inclusive system. This change will be in the form of utilizing the latest innovations, changing the way people farm and entrenching sustainability within policies and the institutions (Pretty et al., 2018).

Sustainable Intensification

Future farming needs to produce more food on less resources and with less harm to the environment. Sustainable intensification aims at increasing yields without increases in agricultural land, and the use of such techniques as conservation tillage, integrated nutrient management, and agroforestry (Tilman et al., 2011).

Integrating biodiversity into agriculture systems, reducing the dependency on inputs, recycling resources (circular agriculture) will be on the top. Nations such as the Netherlands are already ahead of the curve in high-tech, low-land-and-water, greenhouse farming models of sustainable agriculture (Schneider et al., 2021).

Climate-Smart Agriculture (CSA)

Climate-smart agriculture combines adaptation, mitigation, and productivity objectives in order to enhance resilience to climate variability. Key CSA practices are:

- Drought resistant varieties of crops
- Drip irrigation systems & Sprinkler irrigation systems
- Soil carbon sequestration
- Agro forestry - Mixed farming

Adopting CSA practices would have a beneficial impact in the lives of over 500 million smallholders around the world, making the food system more food secure and reducing greenhouse gas emissions (Lipper et al., 2014). It still need to define Income Mechanisms to achieve the numerous interventions required by respective project stakeholders.

Technological Innovations and Digital Agriculture

The digital revolution is altering agriculture as data-driven agriculture. Technologies like drones, sensors, artificial intelligence (AI), and blockchain are also assisting in precision agriculture and in transparency of the food supply chain (Wolfert et al., 2017).

Precision agriculture: The use of satellite imaging, GPS, and AI to optimize planting, irrigation, and fertilizing.

Biotechnology and gene editing: Navidad has the potential of breeding organisms such as crops to be stress tolerant and high quality of nutrients (Zhang et al., 2018).

Robotics and automation Planting, weeding and harvesting robots are used to fill the gaps in labour and to help maximise efficiency.

Blockchain in supply chains: Part of the verification of food traceability, reducing fraud incidences and building customer trust.

These technologies will be more efficient but will need investment, training, and access for all so as to not increase technological divides.

Food, Green Agriculture, Renewable energy

The move towards renewable energy in agriculture activities will be crucial to reduce the carbon footprint of agriculture as much as possible. Solar powered irrigation pumps, bioenergy from crop wastes and wind powered farming systems are some of the renewable energy options (IRENA, 2021).

Incorporation of renewable energy not only helps in achieving climate goals, but it also chips in with savings for farmers in energy impoverished areas, thus improving productivity and incomes.

Agro-ecology to Regenerative Agriculture

Agroecology refers to ecological approaches in agriculture with an emphasis on diversity, resilience and community (Altieri and Nicholls, 2017). Regenerative agriculture is adding to these tenets to include regenerating the health of the soil, encouraging biodiversity and storing carbon.

Practices such as cover cropping, rotational grazing and no-till farming are increasingly being referred to in the international community as nature-based solutions to land degradation and climate change (LaCanne & Lundgren, 2018).

Urban and Vertical Farming

With Urbanization on the rise, Urban and vertical farming has the potential to produce food near by its consumers which lead to reduction in transportation emission and food wastage. Controlled-environment agriculture (CEA) systems make use of the practice of hydroponics, aeroponics and aquaponics to grow crops in stacked layers on vertical systems (Despommier, 2010).

Among the world's countries, Singapore and Japan go slack in vertical farming and demonstrate the potential capacity of vertical farming to contribute to conventional food systems in high density cities.

Global Trade, Policy and Governance Futures

International trade, international co-operation modes of governance will determine the agricultural systems of the future. Fair trade practices, ending of pernicious subsidies and food sovereignty will be key (Clapp 2017).

Policies should also include food security in climate efforts, preservation of biodiversity and rural development. Building farmer organizations and cooperatives as well as inclusive policies will help smallholders to cope and compete in the global markets.

Youth And Gender within The Context of Agriculture

Agriculture's future is youthful and female oriented. Promoting the young people to upgrade the agribusiness, innovation and technology based farming can reverse the stagnation in rural areas (Filho et al., 2020).

Closing gaps in access to resources, resources for education and decision making is a key route to increasing productivity and attaining food security. Inclusive agricultural change will mean removal of barriers at systematic level which exclude women and rural youth.

Ethical, Social and Health Issues

Future agriculture will have to put ethics, equity and health in the first place. Animal welfare issues and genetically modified crops and corporate seed ownership will inform consumers choice in the consumer market and narratives of policy (Qaim, 2020).

The contribution of agriculture to nutrition security is also critical - transcendent food systems of the future will have to address not just hunger but obesity, diet diversity and spreading of non-communicable diseases (Haddad et al., 2016).

Towards Resilient And Sustainable Food Systems

In the end, the role of agriculture in the future is based on the change of models focused on productivity towards approaches to food systems that are more holistic in nature, taking into consideration front-negative factors associated with environmental sustainability, as well as equity and resiliency. Building robust local food systems, marathon to innovation and enabling transformation in agroecological production will prove to be key to feed large and growing numbers of people while not breaching planetary boundaries (Rockstrom et al., 2009).

Global collaboration and investments in research, and inclusive governance will determine whether farming is an engine for sustainability or a cause for ongoing crises. Today's decisions will determine the destiny of the world's food systems - their resilience and prosperity - for the generations to come.

CONCLUSION

Agriculture has continued to be the root of human civilization - and that is what has allowed human population to swell, it's economy to flourish, and populated society to evolve. From its first development in Neolithic time until its technological orientation today, agriculture has been responsive to societal requirements. However, this has been at enormous environmental and social expense (e.g. soil erosion, the loss of biodiversity, the pollution of water, carbon emissions).

Agricultural practices and systems vary widely across the world and range from industrial monoculture to subsistence agriculture each with its unique opportunities and limitations. The adoption of new technologies such as biotechnology, digital agriculture, and climate-smart agriculture, has contributed to a significant increase in productivity but has also caused the widening gap between the developing countries and the developed countries. Meanwhile, agriculture is still closely intertwined with socio-economic issues: it is the source of employment, it decreases the poverty rate; it affects food security and cultural identities.

The problems of modern agriculture (climate change, human population population, resource limitation and volatility of trade) point to even the need for radical solutions. These issues are all firmly intertwined, and require heartholistic solutions with trade-offs between productivity and sustainability, equity and resilience. The future is bright with sustainable intensification, agroecology, renewable energy, digital solutions on top of policy reforms and more participation of women and young people.

In the end, the future of agriculture is not necessarily one of more food but of better food - food that is produced in ways that represent the best in terms of sustaining the health of our ecosystems, benefiting the society in terms of equity and creating resiliency to global shocks. It is in realizing this change will be critical to achieving the United Nations Sustainable Development Goals (SDGs) and a sustainable and food-secure future.

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