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From Origins to Modern Practices: A Comprehensive Review of Sustainable Agriculture and the Influence of Government Initiatives

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ABSTRACT

Sustainable agriculture is an essential component of contemporary agricultural development, utilising sustainable agriculture is a way that can be employed to reduce the challenges, leading to enhanced economic, social, and environmental benefits. This study aims to investigate the historical roots of agriculture practices and approaches, as well as the most current developments in this area. It examines key practices such as conservation practices, organic farming, and integrated pest management, and their impact on soil health, ecosystem, and resource efficiency. Additionally, the study highlights significant government initiatives and policies designed to support and encourage sustainable practices among farmers. Through a comprehensive review of historical developments and an analysis of current governmental strategies, this paper aims to provide an enhanced understanding of the role of sustainable agriculture in fostering agricultural sustainability and adaptability. The findings offer insights that will enable them to enhance their understanding and expertise in the field of sustainable agriculture, contributing to the broader discourse on sustainable agricultural development in India.

1. INTRODUCTION

Agriculture encompasses the science and practice of cultivating plants and animals (Balkrishna et al., 2021). This encompasses a wide range of activities, including aquaculture, agroforestry, forestry, animal husbandry, and crop cultivation (Harris & Fuller 2014). It is also a business, technology, and art that involves the production of vegetation and animals for economic purposes (Sarker, 2017). Agriculture has been proven to be the foremost industry in the global economy plays a crucial role in the economy of all nations worldwide and has a substantial influence on food security, employment, and income (Savari et al., 2023). Gomiero et al., (2011) assert that agriculture, considered the basis of society, is currently confronting its most challenging period of the century with the increasing global population, the exacerbation of climate change, and the depletion of natural resources, conventional farming methods are becoming less feasible. Conventional farming is established with the dual objectives of maximising profits and enhancing productivity. These goals were formulated without considering their potential impact on agroecosystems and biodiversity (Terano et al., 2015). Undoubtedly, traditional agriculture has played a crucial role in enhancing food production and supporting the expanding population (Dethier, & Effenberger 2012). The agriculture sector, which is a significant water consumer, consumes approximately 70% of the world's freshwater resources (Kakkavou et al., 2024). However, conventional agricultural practices encounter significant obstacles, such as inefficiencies in water utilisation and insufficient yields from agriculture. On the other hand, the Food and Agriculture Organisation (FAO) (2017) stated that agricultural production will need to increase food production by approximately 50% compared to 2012 by 2050 to satisfy the global food demand.

Agriculture has been practiced for over 10,000 years, but it is only in the past five decades that farmers have become increasingly dependent on synthetic chemical fertilisers, pesticides, and agricultural machinery powered by fossil fuels (Kovačević & Lazić, 2012). According to a study conducted by Feisthauer et al. (2018), the main reason of the increase in agricultural output over the past few decades has been the increased use of fertilizers and pesticides in agricultural cultivation to meet the increasing global demand for food. These chemical fertilizers and pesticides increase short time production. Meanwhile, the widespread utilisation of these products has raised concerns over soil deterioration, heightened emissions of greenhouse gases, and contamination of water sources (Savari et al., 2023). According to Azam & Shaheen, (2019) The use of several chemical fertilisers and pesticides in agricultural production has steadily risen since the green revolution. Its effect is associated with a decline in biodiversity and potential threats to the stability of ecosystems. The limitations and difficulties of the green revolution created the concept of sustainable agriculture (Gupta et al., 2021).

The concept of sustainability was proposed in the report "Our Common Future" by the World Commission on Environment and Development (WCED, 1987) (Francis & Porter, 2011). A definition of sustainability: Sustainability is the process of meeting the current requirements without compromising the capacity of future generations to meet their own needs. it entails a wide range of practices, regulations, and principles that are all designed to achieve long-term equilibrium and resilience in a variety of systems, including social, environmental, and economic systems (Tama et al., 2021). The idea of sustainability is based on the maximisation and/or preservation of current production without increasing each unit of consumption of inputs (Suresh et al., 2022). Sustainable agriculture is based on three pillars: equality in society, economic feasibility, and environmental wellness. Agricultural practices can promote social responsibility, financial success, and environmental sustainability by adhering to these guidelines (Muhie, 2022). The term "environmental sustainability in agriculture" refers to practices that keep vital agricultural resources safe while also improving their quality Robertson, 2015). On the other hand, agricultural economic sustainability refers to how profitable and financially viable farming practices are in the long run. Communities and nations benefit from these practices because they help stabilise and grow their financial well-being. Social sustainability is the implementation of agricultural practices that are mutually beneficial, inclusive, and equitable for all parties. Adopting ecologically friendly and health-conscious farming techniques that support fair distribution of resources and thereby improve the well-being of workers, farmers, and communities. Climate change presents a significant threat to the sustainability of the environment (Tama et al., 2021).

The term "sustainable agriculture" was first used at an international meeting convened by the International Federation of Organic Agriculture Movements (IFOAM) in 1976 (Ogemah, 2017). Sustainable agriculture encompasses a range of techniques that aim to ensure food security for the present generation while safeguarding the ability of future generations to do the same (Teklewold et al., 2013). Sustainable agriculture has never been more important than it is now when there are problems with the environment, Population growth, and worries about food security. Multiple studies have discovered that the implementation of sustainable agriculture practices (SAPs) had a noteworthy effect on the productivity of farmers (Waseem et al., 2020, and Adenle et al., 2018). There is no single, comprehensive set of practices that constitute sustainable agriculture because every region has its own unique set of conditions, SAPs that work well in one place may not in another (Gupta et al., 2021, Yeong et al., 2012). Sustainable agriculture is a well-established and important idea that helps farmers about alternative farming methods and techniques (Terano et al., 2015). According to the Food and Agriculture Organisation (FAO) (2009), using farming practices that are scientifically sound, socially acceptable, and ecologically benign can increase agricultural crop production by 70%. According to Li et al. (2022), Conventional agriculture has engendered numerous environmental difficulties due to its detrimental effects. The excessive utilization of chemical fertilizers, pesticides, and agricultural waste presents a significant hazard to the environment. Examples of these challenges include diminished soil fertility, limited water availability, widespread deforestation, climate change, and health concerns. To enhance the sustainability of agriculture, it is vital to implement sustainable agricultural practices (SAPs). Sustainable agriculture plays a vital role in attaining the Sustainable Development Goals (SDGs), which encompass objectives such as eradicating hunger and poverty, promoting good health and well-being, addressing climate change, and preserving ecosystems (Muhie, 2022). Recent research suggests that the implementation of sustainable agriculture practices (SAP) at the agricultural level is a viable solution to these issues. (Tey et al., 2014, Nguyen, et al., 2021, Setsoafia et al., 2022). Even though the numerous benefits that SAP provides, its adoption rate remains low (Kassie et al., 2015, Zhang et al., 2018).

The concept of SAP incorporates a dynamic set of practices and technologies that efficiently utilize natural resources to contribute to the economic, societal, and environmental dimensions (Adnan et al., 2017). Sustainable

agriculture encompasses a diverse range of agricultural methods and technologies (Füsun Tatlıdil et al., 2009). Sustainable agriculture has been identified as the optimal approach for maximising the use of natural resources to meet human requirements while minimising harm to the environment (Alwedyan & Taani, 2021). Sustainable agricultural practices (SAP) refer to the efficient utilisation of natural resources and their positive impacts on the economic, social, and environmental aspects (Foguesatto et al., 2019). It includes practices such precision agriculture (Aubert et al., 2012), cover crops (Neill & Lee, 2001), conservation tillage, crop rotation/diversification (Teklewold et al., 2013), intercropping, and straw mulching (Puntsagdorj et al., 2021). The practices of agroforestry, organic fertilizers/composts, and integrated pest management have been studied by (Nkomoki et al., 2018, Mazhar et al., 2021, and Tey et al., 2014). These techniques enhance agricultural resilience to climate change and soil degradation, mitigate water scarcity, and address biodiversity loss while increasing agricultural productivity (Gomiero et al., 2011).
India possesses the second largest agricultural landholding in the world, covering an area of 157.35 million hectares and 46 of the 60 soil types ideal for agricultural activities (Azam & Shaheen, 2019). The Indian agriculture sector, which employs 48% of its 1.35 billion population, holds the key to attaining the global sustainable development goals (Suresh et al., 2022). It accounts for around 17–18% of GDP and the majority of India's rural population relies on agriculture for their livelihood, making improvements in this sector crucial for uplifting rural populations and eradicating poverty (Sharma et al., 2019). The agricultural sector of India is vulnerable to climate change due to its dependence on present weather patterns including fluctuations in temperature and rainfall, as well as the lack of water for crop production (Priyadarshini & Abhilash 2020), particularly in the northern and central regions of the country. In India, Agriculture is responsible for 14% of global greenhouse gas (GHG) emissions. Additionally, it contributes to an 17% of total greenhouse gas emissions through other ways such as deforestation and other changes in land use (Azadi et al., 2021). The extensive use of green revolution technology (Alwedyan & Taani, 2021) is the main factor contributing to significant soil deterioration of India. There is a significant demand for food and other agricultural products in India due to its large and growing population However, these factors are having a negative impact on the agriculture sector (Bhan & Behera 2014). India's agricultural sector is highly dependent to the impacts of climate change due to increasing temperatures, alterations in rainfall patterns, and the occurrence of increasingly frequent and severe weather events (Kishore et al., 2018). These factors are posing significant challenges to crop production and food security in the country. The Government of India launched the National Mission for Sustainable Agriculture (NMSA) in 2014-15, which formally defined sustainable agriculture from an Indian perspective (Ajatasatru et al., 2024). India utilises a diverse range of sustainable agriculture practices, however there is a lack of data regarding their popularity, distribution by region, and adoption rates (Gupta et al., 2021).

2. Origin and Development of Agriculture

In the pre-agricultural era, human communities were primarily hunter-gatherers, they obtained sustenance by hunting animals and collecting wild trees and plants (Martin et al., 2013).

10,000 BC ------------------------> 1,000 AD --------------------> 1,900 AD --------------------> Present

10,000 BC	1,000 AD	1,900 AD	Present
|	|	|	|
Neolithic Revolution	**Early Agricultural Societies**	**Industrialization of Agriculture**	**Modern Agriculture**
|	|	|	|
Domestication of plants and animals	**Plows, Irrigation systems, Crop Rotation**	**Mechanization of Agriculture Synthetic fertilizers**	**Green Revolution, GMOs, Precision Agriculture**
|	|	|	|
Spread to Europe and Asia	**Terracing in Andes**	**Threshing machines & Equipments**	**Sustainable practices**

10,000 BC ------------------------> 1,000 AD --------------------> 1,900 AD --------------------> Present

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|	|	|	|
Spread to Europe and Asia	**Terracing in Andes**	**Threshing machines & Equipments**	**Sustainable practices**

Source: Author creation

2.1. Beginnings (10000 BC)

Agriculture came into being at the time of the Neolithic Revolution that dawned between 11,000 and 10,000 BCE the change from gathering and hunting to farming and building homes, introduced farming to various parts of the globe (Dethier & Effenberger 2011). During this era, humans domesticated various plants and animals (Nene, 2012). The main crops cultivated were wheat, barley, peas, and lentils, while the domesticated animals were sheep, goats, cattle, and pigs (Rindos, 2013). This event signified the beginning of systematic and precise cultivation and harvesting, it was a pivotal moment in human history, as it led to the development of organized society and, ultimately, modern civilization (Pluciennik & Zvelebil, 2008).

2.2. Early Agricultural Societies (8000- 1200BCE)

The Rigveda, (8000 BC), documents ancient agricultural practices encompassing several aspects of crop cultivation, these practices involved the use of a wooden plough for tilling the soil, intercultural methods for weed control, techniques for harvesting and threshing crops, and methods for storing the harvested produce (Nene, 2012). The document also mentions the acquisition of skills related to animal management. Between 8000 and 3000 BCE, early agricultural societies achieved a significant milestone by establishing permanent settlements, During this period, humans formed stable communities centred around agriculture (Harris, 2012). They constructed villages, cultivated crops, and began domesticating animals (Mannion, 1999). The initial development of the light wooden plough took place in Mesopotamia about in 4000 BC (Nene, 2012). These communities remained in one location to tend to their fields and livestock. Early villages were typically located in fertile areas with access to water, such as river valleys (notably Harappa and Mohenjo-Daro 3000BC in present-day Pakistan) (Feynman & Ruzmaikin, 2018). Cohen, (2009) this transition from a nomadic lifestyle to settled agricultural communities was characterised by innovation and adaptation, resulting in significant environmental and social change.

The Bronze Age, spanning from 3200 to 1100 BCE, was characterised by significant advancements in technology (Angelakıs et al., 2020). Furthermore, there were political advancements and expansions in the scale of trade networks (Mohammad, 1992). The adoption of bronze tools and weapons, replacing stone tools, resulted in agricultural progress. Bronze tools were more potent and durable than their stone counterparts, enabling them to perform more effectively and for extended periods (Dani et al., 2003). Pinhas & Ammerman, (2005) this advancement had a substantial impact on agricultural productivity and social organization. The introduction of bronze plows, sickles, axes, hoes, and shovels resulted in the replacement of stone and wooden implements, enhancing the efficiency of land preparation, harvesting, and digging of irrigation channels (Angelakıs et al., 2020). During this time, people built canals, ditches, and reservoirs, which were key parts of irrigation systems used to control the amount of water that supplied crops (The Bronze Age, 2024). Crop rotation and intercropping were also used to keep the land healthy. Egypt, the Indus Valley Civilization, Mesopotamia (Iraq), and Europe are Bronze Age Agricultural Societies examples. The growth during this time would set a precursor for future civilizations to follow.

2.3. Classical and Medieval Periods (500BC-1500CE)

The classical period (500 BCE - 500 CE) was a significant era in the development of agriculture, characterized by advancements in economic frameworks, social structures, and farming techniques (Mazoyer & Roudart, 2006). In this period, agriculture was based on practices that early farmers had followed. Also, they learned new techniques such as crop rotation and diversification, that would help keep the soil fertile they included manure and other organic substances (Stearns, 2021). As more advanced irrigation methods like qanats (underground canals in Persia) and aqueducts (Roman engineering) were created, more land could be used for farming and crop yields were increased by providing water from reliable sources (Angelakıs et al., 2020). This period also saw the emergence of iron instruments such as iron hoes, sickles and plows which improved agricultural efficiency and productivity, Iron tools were favoured over bronze ones because to their superior durability and efficiency (Christensen, 1993). During the Maurya dynasty, agriculture and trade in the Indian subcontinent were highly developed, the Silk Road facilitated a reciprocal interchange of agricultural commodities and farming methodologies across different cultures (Balkrishna et al., 2021). The historical period recorded significant advancements in agriculture by Roman Empire, Han dynasty (china), and Greek agriculture (Angelakıs et al., 2020). These advancements resulted in a surge in both commerce and produce from agriculture. Thus, these advances contribute to the wider economic and cultural achievements of that time period.

The Medieval Period (300 - 1500 CE) went through several key breakthroughs in agriculture that revolutionised the landscape of farming and enabled the growth of populations and economies across Europe, the Mediterranean, and Asia (Angelakıs et al., 2020). In this era, the Heavy plough was introduced along with the implementation of the three-field system, a method of crop rotation that involved dividing the land into three sections, The first section was dedicated to planting winter crops, the second section was used for spring crops, and the third section was left fallow until the following season (Andersen et al., 2016). This contributed to the increase in agricultural output by improving the soil's ability to sustain crops, hence reducing the risk of crop failure (Dreslerová et al., 2021). Some of the irrigation practices of those times was the advancement from previous methods used by Greeks, Romans and Arabs, in which water wheels and complex canal systems were utilized to water dry lands for the purpose of improving crop production (Angelakıs et al., 2020). Tang and Song Dynasties of china popularize new rice varieties. These were the golden ages of innovative progression in the growth of agriculture, but these were serving as a precursor to the agricultural revolution that took place during the early modern period (Blockman & Hoppen Brouwers 2017).

2.4. Early Modern Agriculture (1500 - 1850 CE)

During this time, better farming tools and techniques like the four-field system and the moldboard plough were developed. The four-field system helped keep the soil fertile without needing long periods of fallow land, and the moldboard plough made turning the soil more efficient, which increased agricultural output (Balkrishna et al., 2021). In the early 1700s, the seed drill changed the way people planted by letting them precisely place seeds in rows. This made it easier for seeds to spread, which in turn led to more crops being grown (Sayre, 2010). Advancements in the method of irrigating crops and managing water resources led to more reliable agricultural practices (Deceulaer, 2006). Additionally, the transition from small-scale farming to market-oriented farming, along with these advancements, enabled farmers to cultivate excess crops (Andersen et al., 2016). This was an innovation that changed the way farmers looked at their practices: a shift that led to enhanced food production due to increased crop yields (Federico, 2004).

The period of the Agricultural Revolution between the 18th and 19th centuries: Several machineries were developed to facilitate advancements in agriculture, including the Mechanical Reaper, a thresher invented in 1830, and steel ploughs that emerged in 1837 (Overton, 2000). Towards the end of the 1800s, chemical fertilizers found their way into use due to their ability to boost crop yields and plant breeding was also practiced (Spiertz, 2014) . John Lawes introduced the first 'artificial' fertiliser in England in 1843. With the shift to more efficient agricultural practices and a decrease in labour requirements in rural areas, a large number of people migrated to urban communities (Corbally & Sullivan, 2022). This migration, which significantly contributed to the expansion of metropolitan areas, became closely connected with the Industrial Revolution (Gowdy & Baveye, 2019).

2.5. Modern and Contemporary Periods (19th and 20th CE)

During the second part of the Industrial Revolution, which happened between the late 1800s and early 1900s, traditional farming changed in ways that made it more productive and efficient (Federico, 2004). During that time, many important technological advances happened, such as the general use of electricity and the invention of the internal combustion engine. There were also progress in the chemical, electrical, and steel industries (Auderset & Moser, 2016). This was also the time when synthetic fertilisers were introduced in conjunction with their organic counterparts, such as manure, to increase agricultural yields. Spiertz, (2014) Genetic modification was introduced; in 1924 hybrid maize was introduced with the promise of a substantially higher yield than its conventional varieties. More efficient irrigation methods, such as sprinkler and drip irrigation were introduced.

The expansion of transport and infrastructure, including trains and canals, had a substantial impact on linking farmers in rural areas to broader markets (Brown, 2002). This help allowed farmers to grow extra crops that they could sell, which in turn helped trade in farming goods grow around the world (Hazell & Wood, 2008). Important agricultural advancements helped to provide the required basis for urbanisation processes and population increase supporting industrialization (Pongratz et al., 2008).

2.6. Green Revolution (1940-60)

The word "Green Revolution" refers to a big rise in crop yield, especially in developing countries. This is made possible by the widespread use of chemical fertilisers, high-yielding varieties, and other inputs (Andersen & Hazell, 1985). During the Green Revolution, food production jumped all over the world (Patel, 2013). This was made possible by the development of high-yielding varieties of crops and new technologies in farming equipment and techniques. In the 1960s, CIMMYT created the first high-yielding varieties of wheat and IRRI created the first high-yielding varieties of rice (Khush, 1999). Tractors, combine harvesters, and other machinery had a growing utilized. Norman Borlaug was an innovator in the Green Revolution, while in India, the geneticist Dr. M.S. Swaminathan led the way (John & Babu, 2021). Wheat and rice production were significantly prioritised during the revolution compared to other crops. During the revolution, there was not just a rise in yields per hectare, but also a greater gain in labour productivity (Spiertz, 2014). India had a 10% increase in its per capita food supply between 1965 and 1986 as a result of this Revolution (Harwood, 2019). Furthermore, it resulted in substantial advancements in irrigation systems, including the development of canal networks, tube wells, and the adoption of more effective sprinkler and drip irrigation techniques (Subramanian, 2015). Furthermore, there was an increase in the utilisation of synthetic fertilisers that contain Nitrogen, Phosphorus, and Potassium elements, as well as the use of pesticides and herbicides for pest and weed management (Pimentel, 1996). Farmers received agricultural education and extension services from governments and organisations in order to disseminate new technology and techniques to farmers (Flachs, 2016).

The Green Revolution has both beneficial and detrimental consequences. It significantly boosts agricultural output, thereby mitigating hunger and food scarcity in numerous developing countries. A rise in agricultural production has significantly promoted economic growth, enhanced living conditions, and stimulated rural economies (Evenson & Gollin, 2003). Conversely, the green revolution also yielded adverse consequences, including the excessive utilisation of chemical fertilisers and pesticides, resulting in soil degradation and various environmental problems such as water pollution from chemical contamination and air pollution. These issues have contributed to numerous health complications (John & Babu, 2021). Small-scale agricultural producers did not experience the same level of advantages as larger landowners, who accumulated greater wealth, resulting in social and economic inequalities (Ahmad, 1972).

2.7. Late 20th Century and Present

The Late of 20th century, agriculture faced numerous challenges due to excessive utilisation of artificial fertilisers and pesticides, this activity was causing significant soil degradation, water pollution, and biodiversity loss (Horrigan et al., 2002). Due to the predominantly negative impacts of the green revolution, there is a growing enthusiasm among individuals to discover superior and ecologically sustainable methods of cultivating crops Kumar, (2007). Consequently, the concept of sustainable agriculture has garnered increased attention with the release of the Brundtland Report in 1987. From 1960 to the present, the global population has increased from approximately 2.9 billion to over 7.5 billion and the amount of effort required to cultivate crops worldwide has nearly tripled since 1960 due to increasing global populations (Wik & Brocai, 2008). Sustainable agriculture is the optimal approach for enhancing production and maximising resource utilisation Teklewold et al., (2013).

During this period, there were notable developments in the field of agriculture. Modifications were made to current procedures with the aim of improving food security, sustainability, and productivity. Several genetically modified crops were created to display traits such as tolerance to herbicides, resistance to insects, and enhanced nutrient content Lotz et al., (2014). Farmers utilise remote tracking systems, GPS, the Internet, and drones in the field, all of this is part of precision farming, which advocates for environmentally sustainable techniques (Aubert et al., 2012). Conservative farming methods were used, like no-till, cover crops, efficient irrigation systems, water recycling, rainwater collection, and natural inputs (Doaei et al., 2020). This kept dangerous chemical fertilisers and overuse of natural resources to a minimum. Farmers are offered a wide range of services to support them, such as enhanced market access, transparent pricing, and online platforms (Rao, 2007). These also encompass additional forms of assistance, such as obtaining access to credit, technology, knowledge, and training (Alkon & Urpelainen, 2018). The government periodically implements numerous policies and initiatives to promote climate resilience, conservation, and sustainable practices Mathur et al., (2006).

These innovations have led to increased production of agricultural produce— they promote resource use efficiency while tackling environmental challenges that stand on the way towards a more sustainable agriculture. The development of agriculture in the 21st century will mean that sustainable agriculture is an alternative to industrial agriculture Kovačević & Lazić (2012).

3. Government Initiatives for Development of Sustainable Agriculture

The implementation of policy is a crucial component in the structural framework of the direction and the assessment of advancements achieved in agriculture in relation to crop productivity, farmer well-being, and the shift towards sustainability**.** The Indian government has taken several steps to protect the environment from the effects of farming and promote environmentally friendly methods (Kishore et al., 2018).

Table 1: Government Initiative Policies for Development of Sustainable Agriculture

Sr. No.	Name	Year	Target
1	National Mission on Natural Farming (NMNF)	2023	This initiative seeks to promote the practice of chemical-free agriculture and reduce farmers' dependence on pesticides and fertiliser and promoting sustainable agricultural practices th

			rough natural farming techniques (Barooah et al., 2023).
2	Crop Residue Management	2018-19	To solve the problem of stubble burning the initiative of crop residue management was launched in the states of Punjab, Haryana, Uttar Pradesh & National Capital Territory NCT Delhi. Burning straw is a major source of air pollution and poses a serious health risk. This plan includes a campaign to raise knowledge and training on how to use crop residues. It also helps find markets for products made from crop residues.
3	The National Agriculture Market (eNAM)	2016	e- NAM creates a single market pool with the existing Agricultural Produce Market Committee (APMC) markets so that they can trade using an online trading programme, find better prices, get real-time price information, and give farmers more ways to sell their crops.
4	Agricultural Insurance - Pradhan Mantri Fasal Bima Yojana (PMFBY)	2016	Its motto to provide financial support to farmers' crops failed due to natural calamities, and diseases. It provides financial assistance to farmers in the event of crop failure and motivates them to adopt innovative and modern agricultural practices.
5	Pardhan Mantri Krishi Sinchayee Yojana (PMKSY)	2015	India is currently experiencing a growing problem of water scarcity, as well as unsustainable water usage in agriculture. Additionally, over 40% of India's cultivated land still relies only on rainfall for irrigation (Kishore et al., 2018). The objective of this initiative is to optimise water utilisation and ensure universal access to irrigation for all farms in the country. By implementing this approach, it is possible to increase agricultural productivity and enhance the sustainability of water management. This project promotes the adoption of precision agricultural techniques such as micro-irrigation and rainwater harvesting (Ajatasatru et al., 2024).
6	Paramparagat Krishi Vikas Yojana (PKVY)	2015	This project was initiated under the National Mission for Sustainable Agriculture. It supports organic farming by using bio-fertilizers, bio-pesticides, and other organic inputs and also supports financial aid to farmers. This plan promotes the adoption of traditional agricultural techniques and indigenous systems that are both sustainable and environmentally sound.
7	Soil Health Card Scheme (SHC)	2015	This scheme was launched as a component of the National Mission for Sustainable Agriculture (NMSA). The objective is to promote sustainable farming methods that can improve agricultural productivity and this will be accomplished by providing information regarding the health of their soil and encouraging the adoption of a balanced approach to fertilizer usage (Katsir et al., 2024).
8	National Mission on Agriculture Extension and Technology (NMAET)	2014-15	The objective of NMAET is to enhance the efficacy of agricultural extension and advance the technological resources accessible to farmers. This is achieved by augmenting the skills and knowledge of farmers through extension services and training, offering a range of services and information to farmers, establishing robust extension services and support systems for farmers, and encouraging farmers to adopt new technologies and practices to improve productivity and sustainability.
9	National Mission for	2014-15	The goal of developing the National Mission for Sustainable

	Sustainable Agriculture (NMSA)		Agriculture (NMSA) is to increase agricultural productivity, preserve natural resources, assist farmers, and enhance livelihoods (Gupta et al., 2021). This initiative offers a variety of programs focused on agroforestry, water and soil management, rainwater harvesting, the impacts of climate change, and strategies for adaptation (Ajatasatru et al., 2024).
10	Rainfed Area Development Programme (RADP)	2011-12	Launched initially as part of the Rashtriya Krishi Vikas Yojana (RKVY), RADP is now a component of the National Mission for Sustainable Agriculture (NMSA). The objective is to improve agricultural productivity in rainfed regions and strengthen food security. Develop resilience in the face of adverse weather conditions and climatic variability. The RADP is dedicated to the advancement of sustainable agricultural practices and the integration and diversification of a variety of farming activities.
11	National Mission on Micro Irrigation (NMMI)	2010	The National Mission on Micro Irrigation became part of the PMKSY program in 2015. The target is to enhance water efficiency in the agricultural sector by implementing micro-irrigation technology, such as drip and sprinkler systems. The primary objectives of this initiative are to increase agricultural productivity and effective water resource usage.
12	National Food Security Mission (NFSM)	2007	The primary objective of NFSM is to enhance production levels by implementing sustainable and resource-efficient agricultural practices. The mission focuses on enhancing the productivity of rice, wheat, pulses, coarse cereals, and cash crops (Priyadarshini & Abhilash 2020).
13	Rashtriya Krishi Vikas Yojana (RKVY)	2007	The National Agriculture Development Programme is another name for the RKVY. This initiative was included in the 11^{th} Five-Year Plan and continues to be a key component of India's current agricultural strategy. Its target is to sharply increase the yield of agricultural products and promote balanced growth in the agricultural field (Katsir et al., 2024). It has goals such as 4% Annual increase in Agriculture Production, encouraging state governments to spend more on agriculture and related activities, and developing the necessary infrastructure to support the agricultural sector.

Lastly, the Indian government has a lot of different policies, plans, and actions to support sustainable farming. Sustainable agriculture will still be the main focus because the future will bring more problems, like climate change, limited resources, and the need to feed more people worldwide.

4. Approaches and Practices of Sustainable Agriculture

Various sustainable agriculture approaches are commonly referred to as sustainable agriculture, conservation agriculture, climate-smart agriculture, regenerative agriculture, organic farming, and natural farming. The question is why so many distinct terms were used to describe respective and related concepts, because the absence of universally accepted definitions results in a variety of interpretations (Ajatasatru et al., 2024).

4.1. Conservation Agriculture

Conservation agriculture is a systematic approach to farming that aims to optimize productivity in the long term by integrating farming practices, biodiversity, and environmental management (Kassam et al., 2019). The conservation approach that emerged in the 1970s encompasses measures such as no-till or reduced tillage, cover cropping, and crop rotation. These practices fall under the umbrella of conservation agriculture (Oberč & Arroyo, 2020). These practices aim to increase crop yields by enhancing and supporting environmental conditions (Palm et al., 2014). The key principles of conservation agriculture (CA) encompass minimizing soil disturbance, maintaining permanent and temporary soil cover through crop residues and organic matter, and implementing crop rotation and variety (Lal, 2015).

4.2. Climate Smart Agriculture

Climate Smart Agriculture (CSA) refers to the adaptation and adjustment of agricultural practices to ensure long-term sustainability in the face of climate change (Muhie, 2022). This approach aims to reduce emissions of greenhouse gases (such as carbon dioxide, methane, nitrous oxide, etc.), enhance resistance to climate change, and promote sustainable growth in agricultural output (Azadi et al., 2021). Improving agricultural technologies and strategies to increase agricultural productivity and profitability while reducing the negative effects on the environment (Lipper et al., 2014). The term "climate-smart agriculture" was first used in 2009 by the United Nations' Food and Agriculture Organisation (FAO) (Oberč & Arroyo, 2020).

4.3. Organic Farming

Organic farming involves utilizing natural methods and substances to preserve soil quality, enhance biodiversity, and reduce pollution. Organic farming differs from chemical-dependent agriculture in that it does not utilise synthetic fertilisers or pesticides. Rather, it encourages the use of natural practices, which improve the health of farm ecosystems and contribute to ecological balance (Reddy, 2010). The term "organic agriculture" was initially introduced in 1939, Vogt (2007). During the transition to the 21st century, the recognition of organic farming as a viable alternative was prompted by the negative impacts associated with synthetic chemical inputs (Oberč and Arroyo 2020). Soil, water, and air pollution can be reduced by implementing environmentally conscious practices, such as those found in organic cultivation (Leifeld, 2012).

4.4. Biodynamic Agriculture

Biodynamic agriculture combines the practices of organic farming with spiritual and cosmic beliefs. Rudolf Steiner established it in the early 20th century, establishing it as the pioneering movement in organic agriculture (Oberč & Arroyo, 2020). This approach is holistic, taking into account all interconnected living systems, such as animals, plants, and the entire universe. The primary objective of biodynamic agriculture is to guarantee the long-term viability of soil fertility and the overall well-being of the farm (Muhie, 2022). The distinction between organic and biodynamic agriculture is based on the adherence to natural cycles. Agricultural activities such as sowing, removing weeds, and tilling the soil are performed based on lunar and solar cycles, which are thought to impact the growth and yield of plants (Santoni et al., 2022). Similar to organic farming, biodynamic agriculture promotes the use of natural fertilisers while avoiding the use of synthetic ones (Ponzio et al., 2013).

4.5. Sustainable Intensification

Sustainable intensification (SI) refers to a strategy or series of measures that enable the increase of agricultural production and productivity to meet global food demand without the necessity of expanding agricultural land. This method safeguards ecosystems and biodiversity by avoiding further encroachment on natural habitats (Muhie, 2022). The concept of sustainable intensification refers to the integration of different strategies aimed at optimising resource utilisation and enhancing environmental sustainability (Oberč & Arroyo, 2020). The cornerstone of this concept is the recognition that there must be a careful balance between the growing need for food and the sustainability of resources and ecosystems (Petersen & Snapp, 2015).

4.6. Regenerative agriculture

While sustainable agriculture focuses on the maintenance of natural resources, regenerative agriculture surpasses sustainable agriculture in its efforts. It sustains and enhances the efficiency of resources. It possesses a high capacity for soil regeneration and operates in harmony with natural systems, rather than opposing them (Giller et al., 2021). The idea of "regenerative agriculture" was coined in 1970, but it gained popularity in the early 1980s (Harwood, 2020). The focus is on enhancing soil health, biodiversity, water management, and sustainable practices. The goal is to establish productive farming systems that can support both present and future generations, while also addressing environmental concerns (Oberč & Arroyo, 2020).

4.7. Agroecology

The concept of agroecology was first proposed by Basil Bensin in 1928, and its formal establishment and worldwide adoption occurred in 1990 (Oberč & Arroyo, 2020). Agroecology is a method that can be used to enhance the sustainability of conventional agricultural methods (Altieri et al., 2017). Agroecology is a comprehensive approach that combines research, education, action, and transformation to promote sustainability across all aspects of the food system (Gliessman, 2018). It is a dynamic concept that examines the interactions of plants, animals, humans, and the environment within agricultural systems. Its goal is to ensure that food is produced in ways that are environmentally sustainable, commercially viable, and socially fair (Ewert et al., 2023).

4.8. Permaculture

The term "permaculture" originated in 1970 by David Holmgren and Bill Mollison (Bhandari & Bista, 2019). Permaculture is a term that combines the words permanent, agriculture, and culture, referring to agricultural practices that strive to establish sustainable and self-sustaining agricultural systems. (Oberč & Arroyo, 2020). It is a food production system that enhances production efficacy and minimizes resource waste (Meena, 2023). Permaculture aims to foster beneficial relationships between different elements such as land, resources, people, and the environment to ensure food security, protect the environment, and enhance community strength (Bourmaud, 2019).

4.9. Natural Farming

According to Harwood (1995), this approach acknowledges the correlation between the well-being of ecosystems and their impact on our food, health, and land conditions. It is also known as 'Do Nothing Farming' since it recognizes farmers as facilitators whereas Nature does most of the work (Ranjan & Sow, 2021). Organic farming permits more human involvement, in contrast to natural farming's emphasis on reducing human impact and maximizing soil fertility through natural processes (Devarinti, 2016). For example, preventing soil erosion but still achieving chemical farming-like production.

4.10. Integrated Pest Management

Integrated Pest Management (IPM) is a method of pest control that utilises sustainable practices, including the use of pest-resistant plant varieties and little reliance on chemicals (Despotović et al., 2019). This strategy seeks to reduce the use of pests, limit the use of chemical pesticides, and prevent any negative impacts on the environment and human health (Dara, 2019). In the late 1960s, this approach achieved significant global acknowledgment (Prokopy & Kogan, 2009). Integrated Pest Management (IPM) emphasizes the importance of integrating different techniques and strategies to efficiently manage pests while maintaining high environmental standards (Karuppuchamy & Venugopal, 2016).

5. Sustainable Agriculture Practices

Sustainable farming practices have the potential to mitigate pollution, preserve natural resources, and enhance long-term productivity (Chao et al., 2024).

Table 2: Practices of Sustainable Agriculture

Sr. No.	Practices	Description
1.	Crop Rotation	Crop rotation is an environmentally friendly technique in which various types of crops are cultivated consecutively in the same area during different seasons. This approach has several advantages, including enhanced soil fertility, decreased soil erosion, and economic benefits (Kasu et al., 2019).
2.	Agroforestry	Agroforestry is a sustainable method of cultivating various types of trees and shrubs on agricultural land. It integrates agricultural and forestry technology to manage land, resulting in the creation of land-use systems that are more diverse, productive, and sustainable (Gold & Garrett, 2009).
3.	Organic fertilizer/Compost	Utilizing decomposed organic matter, such as leaves, farm waste, straws, and food waste, in farms is beneficial for enhancing soil health and improving crop

		production (Tey et al., 2014).
4.	Precision farming	Precision agriculture is a systematic approach that utilizes advanced technologies to monitor and enhance agricultural performance. It is a scientific technique that enhances crop productivity by employing advanced sensors and analysis tools (Muhie, 2022).
5.	Intercropping	In this practice, two or more crops are cultivated in the same field at the same time. It can be helpful to increase biodiversity, soil health, and resource utilization (Kassie et al., 2013).
6.	Conservation Tillage	Compared to traditional tillage methods, this technique minimizes the number of times the soil needs to be broken and minimizes the frequency and intensity of these disturbances (Pilarova et al., 2018).
7.	Cover Cropping	A significant practice in this sort of treatment involves the use of soil coverings instead of harvesting it. The soil/air interface is covered by a surface layer consisting primarily of dried grasses and crop waste, such as straw and leaves (De Souza Filho et al., 1999). This method effectively controls soil run-off, inhibits weed growth, and contributes to the enhancement of soil health (Mazhar et al., 2021).
8.	Fallow Land	After cultivation, agricultural fields are often left fallow or unused for a period of time to allow the soil to regain its fertility. This practice helps to maintain soil health and optimize long-term agricultural productivity (Tatlıdil et al., 2009).
9..	Stubble incorporation	Stubble incorporation, also known as residue management or crop residue incorporation, involves leaving the stalks, leaves, and roots of a crop on the soil surface after harvest, rather than removing or burning them. This is achieved by using specialised machinery to chop or shred the residues (Bopp et al., 2019).
10.	Reduced chemical fertilizer/pesticide use	Reducing the use of chemical fertilisers and pesticides has benefits for both the environment and the productivity and profitability of farming (Mishra et al., 2018).
11.	Improved varieties	Mutyasira et al. (2018), the purpose of creating genetically modified crops was to increase agricultural output, make farming more sustainable, and ensure food security.

Consequently, there are various approaches to sustainable agriculture, including regenerative agriculture, biodynamic agriculture, organic farming, climate-smart agriculture, agroecology, and others. These approaches advocate for a broad range of practices that have the common goal of reducing reliance on chemical pesticides, fertilizers, and other substances that harm the environment (Altieri et al., 2017).

6. Conclusion

A comprehensive review of sustainable agriculture and the historical evolution of agriculture highlight the significant expansion and challenges that have affected this industry. The advancement of equipment, techniques, and irrigation systems throughout various historical periods significantly elevated agricultural productivity to superior levels. The Green Revolution in the mid-20th century led to a significant boost in food production through the implementation of high-yielding crops and farming techniques. However, these methods have brought up significant environmental and ecological concerns related to the deterioration of soil, shortages of water, and the decline in biodiversity. Implementing sustainable agriculture is a viable approach to mitigating these issues and promoting economic, social, and environmental advantages. The promotion of sustainable agriculture is centred around various approaches, including conservation agriculture, climate-smart agriculture, organic farming, and regenerative agriculture. These approaches prioritise practices such as crop rotation, agroforestry, and reduced chemical use, which are crucial for enhancing long-term agricultural productivity and sustainability. The Indian government implemented numerous initiatives to encourage sustainable agriculture, with a specific emphasis on minimising environmental effects and improving the welfare of farmers. The future of farming lies in the practice of sustainable agriculture, which aims to achieve economic, environmental, and social objectives. The synthesis of historical knowledge with contemporary sustainable practices is the key to achieving the necessary transition for fortifying our environment and ensuring long-term food security.

7. References

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