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Sustainable Food production through organic farming worldwide and locally in Kingdom of Saudi Arabia

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Abstract: Organic farming is increasingly recognized as a key strategy for sustainable food production, addressing both immediate food demands and long-term agricultural sustainability. This review examines the role of organic agriculture in ensuring food security and environmental sustainability, with a particular focus on its relevance in Saudi Arabia. A systematic review of current research and literature was conducted to evaluate organic farming practices, their impact on soil fertility, and their contributions to sustainable agriculture. Key areas explored include soil health, water conservation, biodiversity enhancement, and the economic viability of organic farming. Findings indicate that organic farming enhances soil fertility, reduces reliance on synthetic inputs, and promotes ecosystem resilience. However, challenges such as yield gaps, economic feasibility, and policy integration require further exploration. The study highlights the need for localized strategies tailored to arid environments to maximize the benefits of organic farming. This review underscores the importance of organic farming in achieving sustainable food systems while addressing global challenges. Practical implications include the adoption of policies that support organic agriculture, investment in research, and the implementation of sustainable farming techniques suited for resource-scarce regions like Saudi Arabia.
Keywords: *Agricultural sustainability, Food security, Organic farming, Soil fertility, Sustainable food production.*

1. Introduction

Agricultural practices have become more intensified throughout recent decades, which resulted in a significant growth of available food supply. The excessive agricultural intensification has generated multiple environmental problems that include reactive nitrogen buildup while simultaneously causing water and soil eutrophication and worsening greenhouse gas emissions together with biodiversity destruction [1]. The United Nations predicts that worldwide population will grow to 9 billion people by 2050, leading to acute agricultural production requirements that will increase by 60% from 2005-2007 figures [2]. The task demands two parallel objectives because food production needs to continue, but the environment must not bear more significant negative consequences from agricultural practices.

Researchers have suggested different approaches for resolving these issues. Three essential holistic approaches to sustainability include agro-ecological production as well as organic farming combined with reduced food waste [3-5]. Sustainable agriculture (SA) stands as the core element of these proposed solutions because it works to satisfy food and fibre requirements of present and future societies by producing maximum environmental, social, and economic advantages [6]. Agricultural sustainability requires an exact balance between food production security and natural environmental protection through management of nutrients as well as protection of water quality and soil fertility and energy utilization effectiveness as well as ecological balance preservation [7].

The advancement of sustainability is greatly supported through organic agriculture (OA) operations in South Africa. The organic farming methods of OA exclude natural farming techniques and the

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implementation of synthetic agrochemicals and genetically modified organisms [8]. OA solves multiple conventional agriculture problems by lowering environmental contamination together with strengthening ecosystem health and functionality. The scientific evidence indicates that OA delivers higher profits and sustainability benefits compared to conventional farming systems because of its positive local environmental effects [9, 10]. The transition to organic agriculture allows for increased agricultural land availability as long as sustainable food demand management stays in place [11, 12]. A group of sceptics questions whether organic farming would produce sufficient results for global food security, but a combination of organic techniques and conventional techniques shows promise for maximising agricultural output [13]. The practice of organic agriculture employs traditional tactics including crop rotation with composting purposes to maintain ecological stability while preserving land sustainability over long periods [14].

Different methods have been created for organic farming to boost biodiversity while reestablishing soil quality, which differentiates these agricultural practices from traditional farming systems that heavily depend on chemicals [15, 16]. Although OA strives to lower chemical usage along with improved environmental health, it does not inherently assure sustainable practices. Real agricultural sustainability needs to resolve environmental resource efficiencies together with economic stability and societal justice standards, yet organic methods fail to fulfill all of these aspects completely by themselves. Multiple sustainable agricultural strategies should be implemented to achieve sustainability in farms, and these methods extend beyond organic farming practices. A comprehensive strategy provides the necessary method to handle environmental consequences from traditional agriculture and guarantee food availability.

Through the implementation of artificial intelligence systems, organic agriculture operators have discovered a solution to maximize their operational effectiveness and operational efficiency. AI improves organic farming sustainability by enhancing its capability to monitor crops and predict yields and manage pests [17]. Scientists have developed two essential natural methods which combine microbial amendments with advanced irrigation techniques for improving soil fertility and organic agriculture water usage efficiency [18]. Saudi Arabia's arid territories benefit from such techniques because the country shows rising interest in organic farming despite its limited water supply and adverse climate [19]. Resource-limited areas consider organic agriculture as an appealing solution for developing sustainable farming practices that guarantee food security without harming the environment [20]. Workers in these areas can use organic methods to enhance environmental protection and future farming performance [21].

1.1. The Concept and History of Organic Farming in Saudi Arabia and Internationally

According to the United States Department of Agriculture, organic farming focuses on resource conservation, ecological balance, and biodiversity preservation through cultural, biological, and mechanical practices. It promotes sustainability by avoiding artificial chemicals and applying agricultural techniques such as the use of legumes to add nitrogen and composting for soil fertility and pest control [22]. Organic farming emphasizes the use of renewable resources over synthetic inputs such as pesticides, fertilizers, hormones, and antibiotics. For example, when it comes to animal production, this is achieved through grazing practices such as rotational grazing, the use of mixed forage pastures, and the adoption of alternative health care methods for livestock. As a whole, organic agriculture aims to establish a self-regulated and stable agroecosystem, leading to a sustainable and productive agricultural system [23-26].

Saudi Arabia has a long history of incorporating organic fertilizers into traditional farming practices, dating back to ancient times. However, with the advent of the Green Revolution, Saudi agriculture underwent significant changes to meet the growing food demands of its population. During this period, high-yield crop varieties were introduced that were optimized to benefit from chemical fertilizers along with modern irrigation techniques. These advancements led to a substantial increase in agricultural productivity. By 1984, these improvements had enabled Saudi Arabia to achieve self-sufficiency in wheat production, and the country even began exporting grain.

According to Hartmann, et al. [27] and Ministry of Environment Water and Agriculture [28] since the early 2000s, Saudi Arabia has recognized that its intensive agricultural practices are unsustainable, relying heavily on non-renewable water sources and chemical fertilizers, raising serious concerns regarding food safety. In 2005, Saudi Arabia joined the World Trade Organization (WTO) and reduced agricultural subsidies as part of its efforts to become more integrated into the global economy, despite ongoing concerns about water scarcity. In 2008, the government decided to phase out wheat production by 2016 in order to conserve water, replacing it with increased imports and consequently reducing the country's food security. Saudi Arabia has recently focused on sustainable agricultural practices, such as drip irrigation and the cultivation of high-value crops such as fruits and vegetables. Organic agriculture has become a crucial element of this new sustainable approach due to its benefits in enhancing food quality and conserving water.

The roots of organic farming as a distinct agricultural method can be traced back to the 1930s and 1940s. Pioneers such as Lady Eve Balfour and Sir Albert Howard in Britain, Hans Mueller in Switzerland, J.I. Rodale in the United States, and Masanobu Fukuoka in Japan were instrumental in its development [29, 30]. By the 1970s, organic food production had become a significant part of the global food system, gaining momentum in both developed and developing nations. This period also witnessed the establishment of the first organic certification standards in Europe and the United States, leading to the proliferation of 283 organic certification bodies across 170 countries by 2021 [31]. This expansion reflects a complex evolution of organic standards and the global demand for certification access.

The organic movement, championed by numerous scientists and the establishment of organic research institutes, has played a pivotal role in promoting organic farming practices. The International Federation of Organic Agriculture Movements, founded in 1972 in Bonn, Germany, advocates for agriculture to adhere to four fundamental principles [32]. The concerted efforts of IFOAM and various scientists have been crucial in establishing research facilities and institutions dedicated to organic agriculture, predominantly in Western countries. However, recent years have seen a notable increase in such institutions within developing nations [33, 34].

There is a growing recognition of the benefits of organic agriculture, leading to increased investment in education, research, and extension services. Universities, especially in developing countries, are increasingly focusing on organic agriculture in their academic and research programs. These institutions, often supported by government grants and other organizational funding, have established organic research centers and laboratories on their campuses, thereby fostering and sustaining the organic movement within the country [27].

Researchers and institutions, both public and private, are dedicated to enhancing knowledge and promoting the adoption of organic, sustainable, and regenerative agricultural systems globally [35, 36]. These centers not only train and certify organic farmers but also develop more sustainable crops, production systems, and market channels. Furthermore, they are involved in creating criteria and regulations to ensure the safe, reliable, and transparent production and sale of organic products.

Internationally, organizations such as the United Nations, the World Bank, and the Food and Agriculture Organization (FAO) are actively involved in promoting organic farming in Saudi Arabia. The FAO, in collaboration with the Saudi Ministry of Environment, Water and Agriculture, is working to develop sustainable agricultural practices and enhance food security in the region. Additionally, the FAO provides training and technical assistance to farmers and producers to help them understand and implement organic agriculture principles [37]. These initiatives aim to facilitate sustainable agricultural production and improve food quality in the region.

2. Growth of the Organic Farming Market

The global organic agriculture market has witnessed significant growth, with a notable expansion since 2020. According to a report by Shaikh Tanveer, et al. [38] the global market value, which stood at

USD 96.1 billion, is projected to reach approximately USD 183.8 billion by 2027. This growth is anticipated to occur at a Compound Annual Growth Rate (CAGR) of 9.8% during the forecast period. Key factors driving this market expansion include the escalating demand for organic food, an increased focus on sustainable agricultural practices, and concerns regarding food adulteration, particularly in developing nations. Additionally, investments in research and development within agricultural domains, coupled with the growing global awareness of climate change issues, are contributing significantly to this growth [39, 40].

In a comparative perspective, the acreage dedicated to organic farming has seen a substantial increase over the years. A report by Willer [41] indicates that the organic farmland, which encompassed 11 million hectares in 1999, has expanded six fold in subsequent years. This surge in organic farming acreage was particularly evident in 2019, where the total organic farmland exceeded the 2018 figure by 1.1 million hectares. This increase has been prominent in several countries, with India adding 18.6 percent (equivalent to approximately 0.36 million hectares), France with a 10.1 percent increase (nearly 0.21 million hectares), Ukraine witnessing a 51.4 percent rise (almost 0.16 million hectares), and Mexico expanding by nearly 0.12 million hectares. Such data illustrates a global trend towards more sustainable and organic farming practices, reflecting a shift in both consumer preferences and agricultural methods.

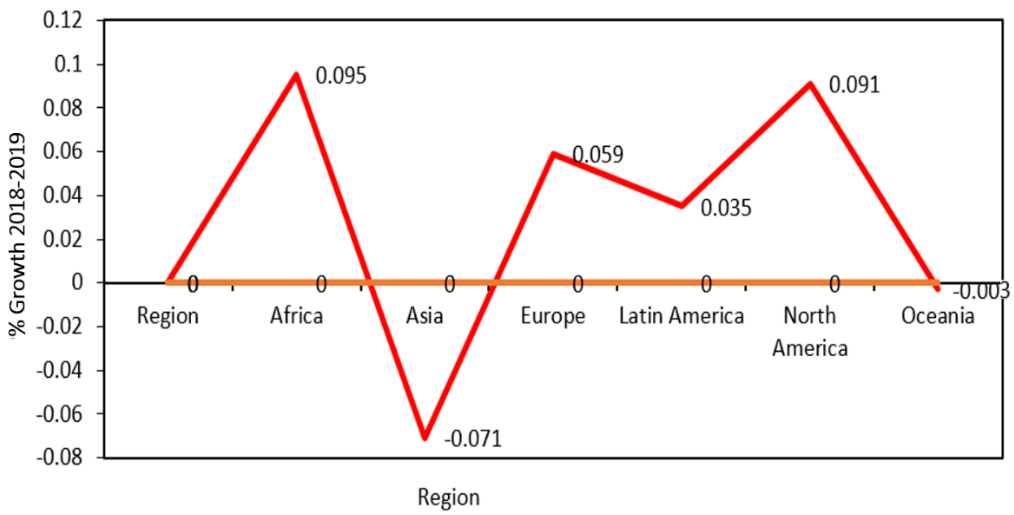

Figure 1.
Organic agricultural land by region growth 2018-2019.

The FiBL database revealed, as shown in Figure 1, diverse trends in organic farming areas across different global regions in 2019. The organic farming area in Europe increased by 5.9% or approximately 0.9 million hectares. Also, North America experienced significant growth, increasing by 9.1%, equivalent to approximately 0.30 million hectares. About 0.28 million hectares of organic farming were added to Latin America's organic farming area by 3.5%. On the other hand, Asia and Oceania have experienced declines in their organic farming areas. Asia's organic farming area decreased by 7.1%, or 0.45 million hectares. Oceania experienced a smaller decrease, with a 0.3% reduction or a loss of 0.12 million hectares. By the end of 2019, 72.3 million hectares were recorded to be under organic management (Table 1and Figure 2). Regionally, Oceania accounted for 35.9 million hectares of this figure, followed by Europe (16.5 million hectares), Latin America (8.3 million hectares), Asia (5.9 million hectares), North America (3.6 million hectares), and Africa (2.0 million hectares) [41].

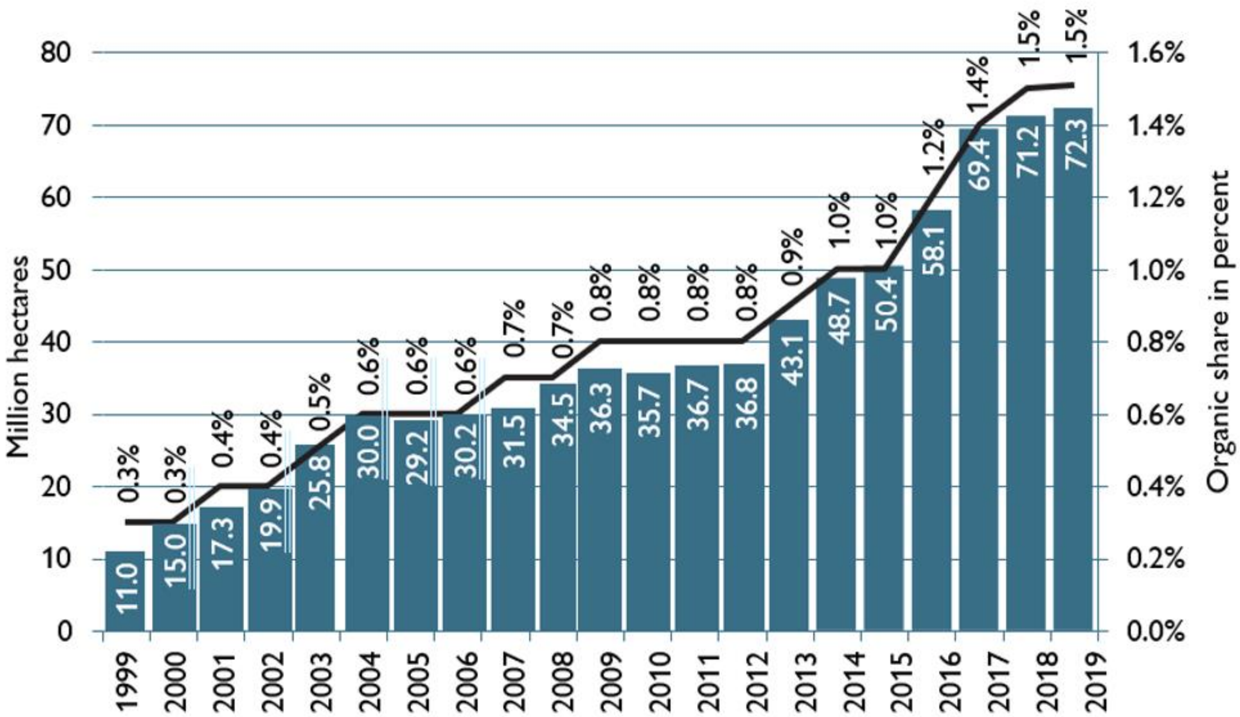

Figure 2.
Growth of the organic agricultural land and organic share 1999-2019 Source: FiBL-IFOAM-SOEL-Surveys 2001-2021.

Table 1.
Organic agricultural land (including in-conversion areas) and organic share of total agricultural land by region 2019. Source: FiBL survey 2021.

Region	Organic Agri. Land (ha)	Share of Total Agri. Land
Africa	2,030,830	0.2%
Asia	5,911,622	0.4%
Europe	16,528,677	3.3%
Latin America	8,292,139	1.2%
North America	3,647,623	0.8%
Oceania	35,881,053	9.6%
World	72,285,656	1.5%

Figure 3 illustrates the distribution of global organic cropland by region. According to the data, Oceania accounts for a substantial portion, encompassing approximately 50% of the world's total organic cropland. This makes it the region with the largest share of organic cropland globally. Following Oceania, Europe contributes 23% to the global total, demonstrating a steady increase in its organic farmland area over time. Latin America is also a significant contributor, representing 12% of the world's organic farmland. In addition to these defined agricultural areas, the report also notes that other land types dedicated to organic use, such as areas designated for wild collection, collectively amount to 34.8 million hectares. This figure highlights the broader scope of organic land use beyond traditional croplands, encompassing diverse ecosystems and land management practices [42].

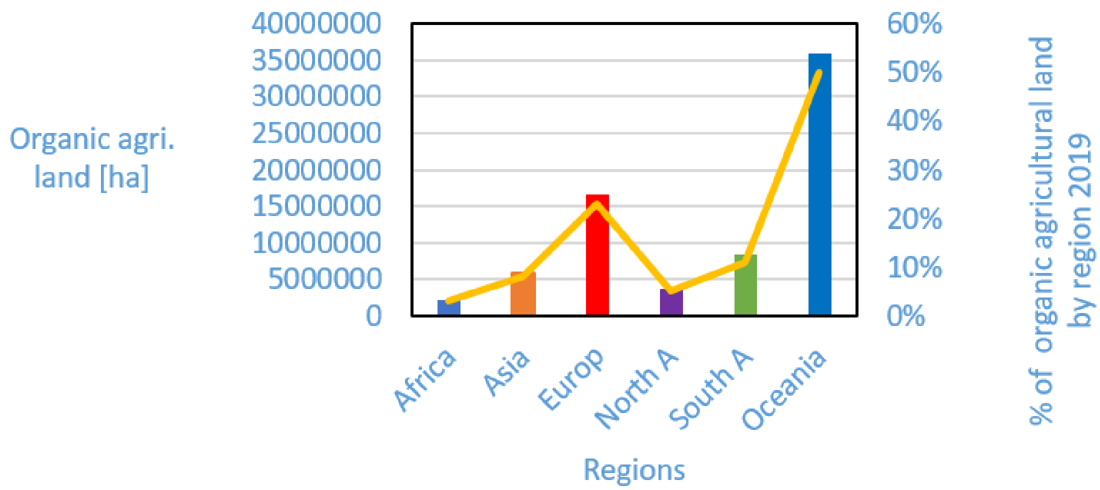

Figure 3.
Organic agricultural land by region 2019. Source: FiBL survey 2021.

Globally, organic agricultural land allocation differs by region. According to the World Organic Agriculture Organization, Australia has approximately 35.69 million hectares of organic farmland, which is a significant margin over the next largest contributor, Argentina, which has 3.67 million hectares, and Spain, which has 2.35 million hectares. The United States follows, followed by India, France, China, Uruguay, Italy, and Germany. Collectively, these ten countries own nearly 80 percent of the world's organic farmland, which is approximately 56.5 million hectares. In 2021, FiBL reported that these nations played a significant role in global organic agriculture.

In the context of Saudi Arabia, notable growth in organic agriculture has been observed. The year 2020 saw a 27.7% increase in the number of organic farms compared to 2019, rising from 244 to 312 farms. This growth paralleled an expansion of the total organic farmland area by 8.8%, from 24,517.89 hectares in 2019 to 26,632.48 hectares in 2020. Additionally, there was a significant surge in organic production volume, which escalated from 6, 1441.45 tons in 2019 to 98,558.81 tons in 2020, marking a 60% increase. These statistics, provided by the Ministry of Environment, Water and Agriculture of Saudi Arabia, underline the country's progressive trajectory in organic farming practices and production.

3. Organic Practices

The organic agricultural approach uses complete ecological principles to safeguard both environmental stability and healthy soil resources by omitting synthetic chemicals including GMOs and antibiotics together with synthetic pesticides and fertilisers [43]. The method focuses on community-linked resource utilisation while making nutrient circulation more effective, while reducing potential environmental dangers [44]. Organic farming maintains three essential principles for maintaining soil fertility alongside biodiversity promotion as well as natural resource management for long-term agricultural sustainability and environmental stability [45]. Organic farmers maintain strict practices and standards which protect the ecological health of their operations to prevent environmental depletion during agricultural activities [46].

Organic farming demonstrates outstanding capability to enhance the health quality of soil [47]. The purpose of organic farming methods is to improve soil features at three levels: physical, chemical and biological, resulting in stronger natural systems [48]. Organic soils contain elevated levels of organic matter that make them better structured and enhance water retention and promote microbial activity [49]. Organic farming successfully erases soil erosion while improving drainage along with maintaining moisture in arid areas, which makes it even more beneficial for those regions [50]. Organic amendments, which include compost and animal manure, help generate organic matter while establishing balanced microbial populations that drive effective nutrient cycling. The soil quality improves steadily with time because organic farming decreases the requirement for external chemical nutrients [51].

The adoption of organic farming practices leads to environmental sustainability as a main advantage [52]. The adoption of organic practices prevents agricultural harm to the environment through chemical synthetic exclusion methods, which otherwise lead to contaminated water sources and endangered biodiversity [53]. The practices of crop rotation and agroforestry and cover cropping allow organic farming to build healthier ecosystems while lowering carbon emissions and increasing soil carbon repositories for climate protection [34]. Through their approach, farms promote biodiversity since they establish living spaces where different species of insects, alongside birds and soil organisms play their ecological roles in pest management and pollination [54]. Increased biodiversity enhances the total resilience of agricultural systems so they become stronger in facing climatic and ecological challenges [55].

Organic farming provides multiple health advantages, which serve as its major benefits. The reduction of pesticide along with herbicide use and synthetic fertiliser applications in organic methods leads to a decreased exposure risk to dangerous food chemicals [56]. Organic produce exhibits reduced pesticide contamination because it contains higher concentrations of antioxidants and beneficial compounds together with lower pesticide traces [57]. Organic farming brings improved animal welfare results because it prevents the use of antibiotics and synthetic hormones to protect livestock from production of ethical food products [58].

Organic farming establishes sustained economic profits with stable financial performance. Investment costs rise during organic farm changes but studies demonstrate that these farms earn more profit throughout the years because they need less fertilisers and pesticides [59]. Organic products earn higher prices in the market, thus driving increased profit opportunities [60]. Local economies flourish through organic farming because this practice supports diverse low-tech farming businesses based on local resources through sales of organic meats and dairy products and processed goods [61]. Organic market development gives farmers multiple revenue sources to protect them from unreliable commodity price fluctuations [62].

Organic farming implements multiple environmentally friendly farming techniques that promote permanent soil health for both the site and its adjacent ecosystem [63]. Farmers employ three main practices for ecological sustainability and reduction of synthetic input dependency through crop rotation and both green manuring and animal manure application [64]. Through practices based on ecological principles, farmers establish sustainable relationships between their farm ecosystem and surrounding areas, which use natural resources efficiently and sustainably [65].

3.1. Crop Rotation

Organic farming depends fundamentally on the well-tested crop rotation method. The practice requires farmers to change the different crops they grow in their fields throughout each year [66]. Crop rotations benefit fields through at least three agricultural advantages, which include diminished soil erosion, enhanced soil nutritive quality and lower presence of pests and diseases [67]. Planned crop succession allows various plants to restore essential nutrients which become depleted through continuous planting of a single crop [68]. Planting peas and beans among your crops serves as an example of leguminous plants that capture atmospheric nitrogen to enrich soil composition ahead of new plantings [69].

Overlapping different crop types in farming seasons functions as a vital method for integrated pest management programmes since it throws off pest life cycles that specifically infect particular agricultural plants [70]. The practice of crop rotation allows farmers to decrease pest population levels because each pest or disease mainly affects distinct plant species [71]. Experimental research demonstrates that alternating crops reduces requirements for chemical pesticides while remaining crucial for organic farming because it does not allow synthetic chemicals [72]. Soil structure benefits from crop rotation and the rotation also minimises weed populations and makes crops more resistant to damage [73]. The arid and semi-arid regions of North Africa established crop rotation as an optimal approach to optimise water usage results and boost plant production output. Scientists have demonstrated that moving between growing soybeans and maize builds soil quality and crop production in tropical environments [74]. Chrome crop rotation practices in Saudi Arabia's water-scarce environment produce better yielding crops while improving water management thanks to central pivot irrigation systems[75].

3.2. Cover Cropping (Green Manuring)

Organic farming relies on cover cropping as an essential practice that uses particular vegetation to improve soil physical and chemical characteristics after ploughing into the ground. Organic farming uses cover crops which include legumes together with grasses and additional plant species among fields either as intermediate plants or as part of rotational crop sequences [76]. The cover crops achieve maturity before they get tillage integrated into the soil to deliver organic material combined with vital nitrogen nutrients demanded by plants [77]. The implementation of cover crops enhances soil structure by developing organic matter levels that produce greater moisture storage capacity and better water filtration and better microbial activity results [78].

Cover crops deliver protective benefits to minimise soil erosion and also act as weed inhibitors and facilitate a better cycle of nutrients in the soil. Several selected cover crop species including sunn hemp, buckwheat and sudangrass enhance soil health by establishing diverse ecosystems while minimising water drainage and drawing good insects that serve as pollinators and beneficial predators [79]. The insertion of roots into the soil by these crops enhances aeration while building soil porosity and structure to avoid compaction [80]. The implementation of cover crops requires extra labour expenses while being susceptible to pest outbreaks when planting the wrong species. Strategic management practices along with consistent monitoring should be used to maximise cover crops' advantages while preventing the creation of new negative effects [81].

3.3. Animal Manure

Organic farming heavily relies on animal manure because it simultaneously strengthens soil fertility and controls its structural health [82]. The manure produced by livestock, including cows, poultry and sheep, contains natural essential plant nutrients including nitrogen, phosphorus and potassium vital for plant vitality [83]. The organic farming practice employs manure as an organic fertilising material to decrease dependence on chemical fertilisers [84]. Using animal manure increases the soil organic matter levels while it enhances the quality of the soil structure and water retention abilities along with beneficial microbial processes [85].

Sustainable nutrient cycling heavily depends on the important role that animal manure provides [86]. Manure possesses dual functions as a fertilizer yet simultaneously functions to decrease agricultural environmental effects by returning essential nutrients while lowering dependency on carbon-heavy manufactured fertilizers that produce emissions during manufacturing processes [87]. The correct handling of manure minimises the leakage of essential nutrients into the environment and decreases the occurrence of waterbody contamination caused by phosphorus and nitrogen runoff [88, 89].

The scientific community pursues ongoing research about how to enhance both the operational outputs and the environmental effects of manure application techniques [90]. The process of composting manure reduces disease-causing organisms in the waste while releasing plant nutrients that boost fertiliser efficiency [91]. The time when manure is applied along with the application method plays a vital role in affecting nutrient absorption by crops and decreasing environmental harm [92, 93]. Luxurious arid conditions of Saudi Arabian soils necessitate animal manure application because it enhances soil structure as well as water conservation properties [94]. The traditional practice of utilising livestock manure for field fertilisation was commonly done by Bedouin and settled farmers in Saudi Arabia before it gained status as a sustainability and organic farming initiative of the region [95-97].

3.4. Standards and Regulations for Organic Production

Organic certification refers to regulations designed to ensure that organic producers and processors adhere to strict quality standards and clearly describe an environmentally friendly production process. Certificates are written guarantees issued by independent certification bodies attesting to a product's compliance with specific standard requirements. Organic certification creates additional market confidence because it is considered a third-party endorsement [98].

The first regulation on organic agriculture in Europe was developed in 1991 (Regulation EEC N° 2092/91 - [99]). Organic standards prohibit synthetic pesticides and artificial fertilizers, growth hormones, and antibiotics in animal husbandry (the minimal use of antibiotics is allowed and strictly regulated in particular cases). Genetically modified organisms (GMOs) and products derived from GMOs are expressly excluded from organic production [100].

In the United States, Congress passed the Amaditz [101]. The OFPA required the U.S. Department of Agriculture (USDA) to develop national standards for organically produced agricultural products to assure consumers that agricultural products marketed as organic meet consistent, uniform standards. OFPA and National Organic Program (NOP) regulations require that agricultural products labelled organic must come from farms or processing facilities certified by a USDA-accredited government or private entity.

A growing number of governments worldwide are supporting the development of agroecological policies by designing new initiatives and programs that will help achieve the set goals. On the other hand, more ambitious governments have announced and launched policies aimed at a complete transition to organic agriculture. According to the latest 2021 data from IFOAM - Organics International, there are 76 countries with fully implemented organic agriculture regulations. Twenty countries do not have a fully implemented organic rule, and 13 countries are in the process of developing legislation (Fig 4). Countries currently undertaking extensive revisions include the European Union and New Zealand. In addition, some countries in Latin America are proposing changes to their existing organic regulations.

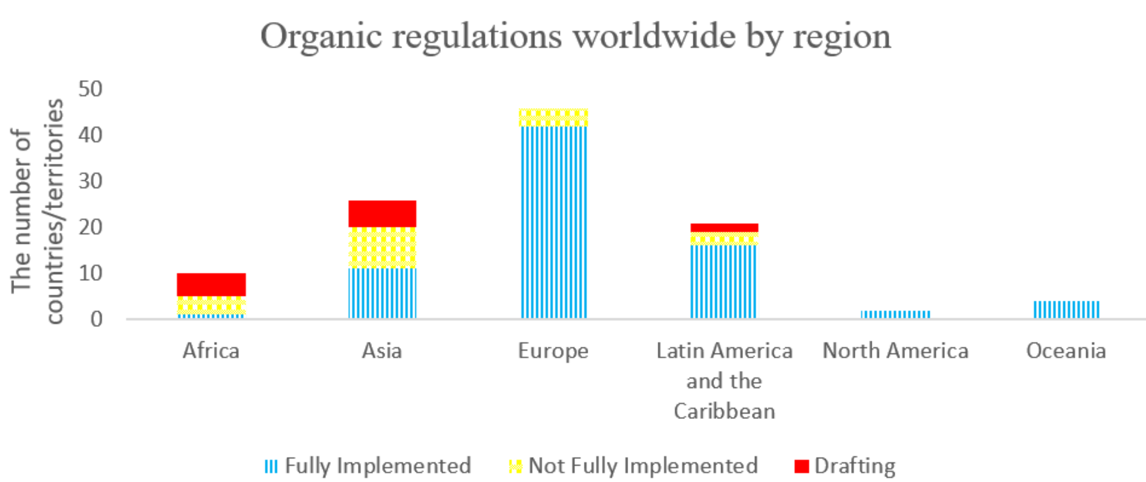

Figure 4.
IFOAM – Organics International 2022.
Source: Organic farming: An international history [100]

Obtaining certification is an important part of verifying a farm's organic status. Certification is mandatory in Saudi Arabia not only for local and regional markets but also at the national level. By preventing the entry of fraudulent products onto the market, this requirement plays a pivotal role in protecting consumer rights. Certification is not only a prerequisite for participating in the organic market, but it is also essential for exporting products internationally. Introducing the Saudi organic logo in 2011 demonstrates the effective collaboration between the Ministry of Agriculture, the Saudi Organic Farming Association, and the German Development Agency. As a marketing tool for organic products, this logo serves as a guide for consumers, ensuring the authenticity and quality of organic products."

Figure 5.
Organic agriculture practices in Saudi Arabia.
Source: Smith-Spangler, et al. [22]

4. Conclusion

Throughout this review, organic farming has been critically analyzed at the global and Saudi Arabian levels in order to promote sustainable food production. Organic farming prioritizes soil health, minimizes environmental impact, and enhances food and nutritional security without compromising ecological integrity. It has proven to be a significant economic driver and job creator, effectively balancing conservation with agricultural productivity.

By reducing the use of synthetic agrochemicals, organic practices reduce environmental pollution and increase the resilience of food systems to climate change and extreme weather conditions. Multidisciplinary research and participatory approaches can be utilized to optimize and expand organic agriculture sustainably. By transforming traditional low-input, low-output production systems into innovative models that require minimal external inputs while maximizing outputs, sustainable organic food systems can be made more efficient.

Moreover, organic farming is a comprehensive model of sustainable living that incorporates biodiversity conservation, soil fertility enhancement, and fair resource distribution. Incentives for organic practices can be implemented in order to make organic products more accessible and economically viable, while maintaining high production standards.

Saudi Arabia has adopted organic farming as a strategic response to environmental challenges and concerns about food security. Saudi Arabia can lead the way in Middle Eastern sustainable agriculture by endorsing policies that support organic agriculture.

Ultimately, the future of sustainable agriculture, particularly in regions like Saudi Arabia, relies on our commitment to advancing organic farming methodologies. By encouraging continuous innovation and embracing the principles of organic agriculture, we can secure the ecological and health prosperity of our planet for future generation.

Transparency:

The author confirms that the manuscript is an honest, accurate, and transparent account of the study; that no vital features of the study have been omitted; and that any discrepancies from the study as planned have been explained. This study followed all ethical practices during writing.

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