



Challenges and perspectives of organic farming in the 21st century

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ABSTRACT

Organic farming is experiencing significant global growth, with an increase in the area under organic production, the number of producers, and the market value of organic products. In 2023, organic farming covered 98.9 million hectares worldwide, while the organic product market exceeded 136 billion euros. This paper analyzes the current status of organic farming, the main challenges it faces in the 21st century, and the opportunities for its further development. Key challenges include lower yields compared to conventional agriculture, limited land availability, the consequences of climate change, high certification costs, and a lack of infrastructure and education. Additionally, consumer trust and competition with conventional farming systems pose further obstacles to the expansion of organic production. On the other hand, technological innovations, policy support and subsidies, the development of local markets, and consumer education offer opportunities for improving the sector. Precision agriculture, biological pest control, artificial intelligence, and agroecological approaches can contribute to increasing the productivity and resilience of organic systems. Furthermore, investments in infrastructure, simplified certification processes, and greater consumer involvement through educational campaigns are key factors for the long-term success of organic farming. It is concluded that the further development of organic farming requires coordination between government institutions, research organizations, and the private sector. Through innovation, education, and strategic support, organic farming can become a key pillar of sustainable development and the preservation of natural resources for future generations.

Keywords: organic farming, sustainability, climate change, policy support, consumer trust, local markets

ИЗВОД

Органска пољопривреда доживљава значајан глобални раст, са повећањем површина под органском производњом, броја произвођача и тржишне вредности органских производа. У 2023. години, површине под органском пољопривредом заузимају су 98,9 милиона хектара широм света, док је тржиште органских производа премашило 136 милијарди евра. Овај рад анализира тренутни статус органске пољопривреде, главне изазове са којима се суочава у 21. веку, као и могућности за њен даљи развој. Кључни изазови укључују ниже приносе у односу на конвенционалну пољопривреду, ограничену доступност земљишта, последице климатских промена, високе трошкове сертификације и недостатак инфраструктуре и едукације. Поред тога, поверење потрошача и конкуренција са конвенционалним пољопривредним системима представљају додатне препреке ширењу органске производње. С друге стране, технолошке иновације, подршка кроз политике и субвенције, развој локалних тржишта и едукација потрошача нуде могућности за унапређење сектора. Прецизна пољопривреда, биолошка заштита биља, вештачка интелигенција и агроеколошки приступи могу допринети повећању продуктивности и отпорности органских система. Такође, улагања у инфраструктуру, поједностављени сертификациони процеси и веће укључивање потрошача кроз образовне кампање кључни су фактори за дугорочан успех органске пољопривреде. Закључује се да је за даљи развој органске пољопривреде неопходна координација између државних институција, истраживачких организација и приватног сектора. Кроз иновације, образовање и стратешку подршку, органска пољопривреда може постати кључни стуб одрживог развоја и очувања природних ресурса за будуће генерације.

Кључне речи: органска пољопривреда, одрживост, климатске промене, подршка политикама, поверење потрошача, локална тржишта

1. Introduction

Organic agriculture aims to introduce an ecological dimension into agricultural production, i.e., managing agriculture while respecting the principles of environmental conservation. By eliminating the use of all synthetic plant protection products and adopting crop cultivation technologies based on organic production principles, it contributes to the preservation of soil fertility, and soil physical and

chemical properties, stimulates soil microbiological activity, and results in higher-quality products (Golijan Pantović et al., 2023; Dimitrijević et al., 2024).

Organic agriculture is a sustainable approach to food production aimed at preserving natural resources, increasing biodiversity, and reducing negative environmental impacts (Golijan and Sečanski, 2022; Golijan, 2022). However, in the 21st century, organic agriculture faces numerous challenges that may

threaten its development and sustainability (Golijan and Sečanski, 2021a).

Agriculture today is considered one of the contributors to increased greenhouse gas emissions. According to the FAO (2008), the increase in air temperature and humidity would lead to the survival and spread of pathogenic microorganisms, their resistance, and the emergence of microbiological hazards in animal feed production (mycotoxins), accompanied by increased use of antibiotics in veterinary medicine. Intensive land use has degraded soil quality, leading the FAO in 2015 to declare soil as a non-renewable resource (FAO, 2015). Organic agriculture, which combines traditional methods with modern technologies, offers a sustainable approach to preserving ecosystems and producing safe food. This practice contributes to biodiversity preservation, soil fertility, and human health, which are key elements of sustainable development (Šeremešić, 2014; Reganold and Wachter, 2016).

The "Green Revolution" (1950–1970), led by Norman Borlaug, significantly increased yields through the use of new crop varieties, chemical fertilizers, pesticides, irrigation, and mechanization (Cotter, 2003). While it brought high yields and profits, it also caused serious negative consequences for human health, biodiversity, and the environment (Šarčević-Todosijević et al., 2023). Rachel Carson, in her book *Silent Spring* (1962), highlighted the harmfulness of pesticides, inspiring the ban of DDT in the United States in 1972 (Paull, 2013).

Demographers estimate that it took humanity 4 million years to reach a population of 1 billion (by 1850), while in just 160 years this number grew to 7 billion. By 2050, a population of 9.1 billion is expected, with 70% living in urban areas (FAO, 2011). Increased food demands will require an annual production of 3 billion tons of cereals and 480 million tons of meat (FAO, 2008). Simultaneously, the irrational use of food remains a major issue, with food worth \$940 billion wasted annually (FAO, 2015).

One of the key challenges of the 21st century is the loss of biological diversity, especially due to intensive agriculture (Veličković et al., 2016). Although biodiversity was recognized as essential for ecosystems at the UN Summit in 1992 (Rio samit, 1992), conservation problems remain unresolved. The Paris Agreement of 2015 introduced measures to mitigate climate change, with agriculture remaining a significant source of greenhouse gas emissions.

The aim of this paper was to analyze the challenges facing organic agriculture in the 21st century, as well as the possibilities for improvement through innovations in technology, policy support and subsidies, consumer education, and the development of local markets.

2. The state of organic agriculture in the world

Organic farming expanded significantly in 2023, reaching 98.9 million hectares worldwide – a 2.6% increase (+2.5 million hectares) from 2022 (Figure 1). The global organic market grew to over 136 billion euros. Latin America led the increase with an additional 1 million hectares (+10.8%), while Africa experienced the highest relative growth (+24%), reaching 3.4 million hectares (Willer et al., 2025).

Oceania remained the leading region with 53.2 million hectares (over half of the global organic area), followed by Europe (19.5 million hectares) and Latin

America (10.3 million hectares). Australia had the largest organic farming area (53 million hectares), followed by India (4.5 million hectares) and Argentina (4 million hectares). The European Union's organic area expanded to 17.7 million hectares (10.9% of total farmland), with a 3.6% increase.

Europe's organic farmland grew by 4.1%, adding over 0.6 million hectares. Spain overtook France as the EU country with the largest organic area (3.0 million hectares), followed by France (2.8 million hectares) and Italy (2.5 million hectares). Spain and Ukraine had the most significant increases, gaining 0.3 and 0.2 million hectares, respectively (Willer et al., 2025).

Europe's organic farmland accounted for 3.9% of total agricultural land, while the EU reached 10.9%. Liechtenstein had the highest share globally (44.6%), followed by Austria (27.3%). Sixteen European countries reported that at least 10% of their farmland was organic (Willer et al., 2025).

Europe had almost 495,000 organic producers, with nearly 435,000 in the EU – a 1.4% and 1.8% increase, respectively. Italy led with 84,191 producers. Europe also had 94,627 processors and 7,955 importers, with Italy leading in processing (25,000) and Germany in imports (almost 2,000) (Willer et al., 2025).

Retail sales of organic products in Europe reached 54.7 billion euros, including 46.5 billion in the EU. Germany remained the largest market (16.1 billion euros). After a slight decline in 2022, the market rebounded with 3.0% growth in 2023. Estonia (+13.0%) and the Netherlands (+12.5%) had the highest growth rates. European consumers spent an average of 66 euros per person on organic food (104 euros in the EU), with Switzerland (437 euros) and Denmark (362 euros) leading per capita spending. Denmark had the highest organic market share globally (11.8%), followed by Switzerland (11.6%) (Willer et al., 2025).

The global area under organic farming increased by more than 20 million hectares in 2022, reaching a total of 96 million hectares. The number of organic producers also grew significantly, exceeding 4.5 million, while organic food sales reached nearly 135 billion euros in the same year. The latest data from the 25th edition of the publication *The World of Organic Agriculture*, jointly issued by @fibl.org and IFOAM – Organics International, was presented at the international organic food trade fair BIOFACH in Germany. The statistics show that the growth of organic farmland and the number of farms in 2022 far exceeded the growth of previous years, primarily due to increases in Australia and India (Willer et al., 2024).

In the last decade, organic agriculture has been experiencing continuous growth on a global scale, as reflected in the expansion of areas under organic production, the number of producers, and the value of the organic product market (Figure 2), as confirmed by data from various sources, including FAO and FiBL (2024), as well as reports by Lernoud and Willer (2015, 2016, 2017, 2018, 2019) and Willer et al. (2020, 2021, 2022, 2023, 2024):

1. Organic farming area:

2014: Global organic farming areas amounted to 43.7 million hectares;

2018: Areas increased to 71.5 million hectares, marking significant growth compared to previous years;

2021: Organic farming areas reached 76.4 million hectares;

2022: Further growth was recorded, reaching 78.1 million hectares.

2. Number of organic producers:

2014: 2.3 million organic producers were registered;

2018: The number of producers grew to 2.8 million;

2021: 3.4 million organic producers were recorded;

2022: The number of producers reached 3.7 million.

3. Value of the organic products market:

2014: The global organic products market was valued at 80 billion USD;

2018: The market value increased to 97 billion euros;

2021: The market reached a value of 120.6 billion euros;

2022: Organic food sales reached 125.2 billion euros.

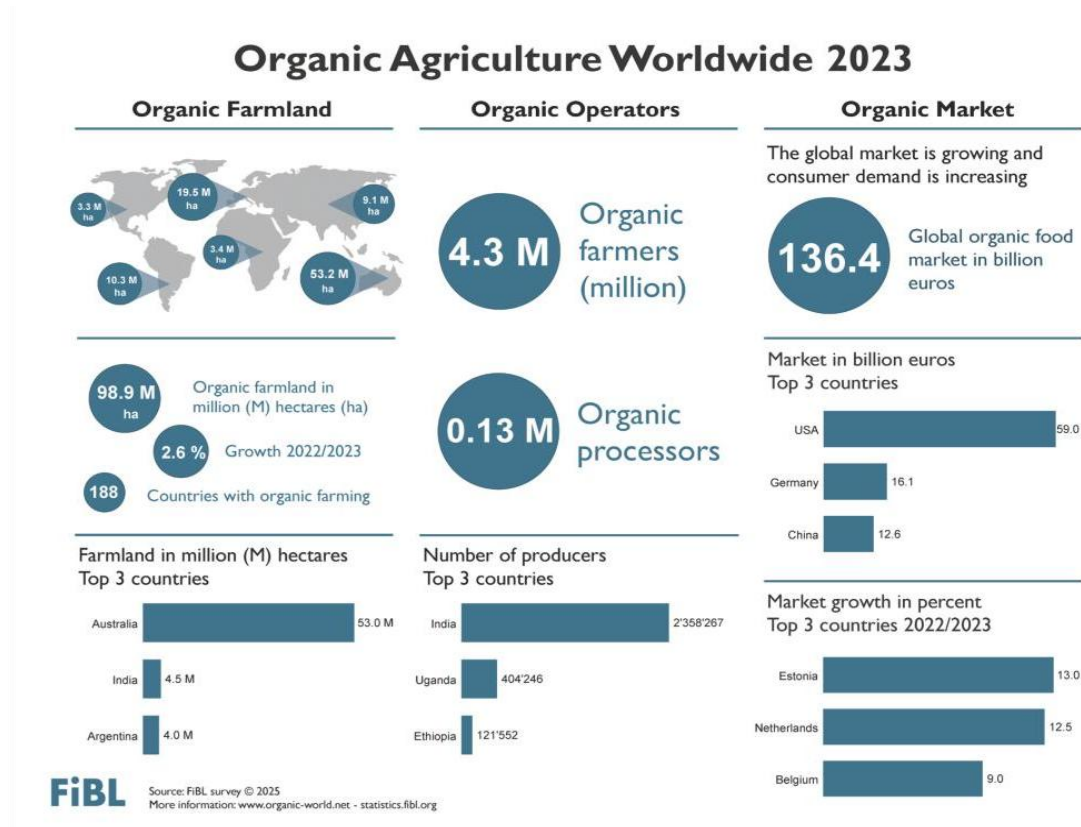


Figure 1. Organic agriculture worldwide 2023
Source: Willer et al. (2025)

These data indicate continuous growth in organic agriculture over the past decade, with significant increases in organic production areas, the number of producers, and market value. This trend also reflects the growing consumer awareness of health and sustainability, as well as increased policy support for sustainable agriculture.

Consumption is distinctly uneven across different regions and countries worldwide. Over the past decade, several countries have emerged as the largest producers of organic food globally (Lernoud and Willer, 2015, 2016, 2017, 2018, 2019; Willer et al., 2020, 2021, 2022, 2023, 2024):

1. Australia has the largest area under organic farming in the world, with over 35 million hectares, accounting for more than half of the global organic farming area.

2. Argentina is among the leading countries with significant areas under organic production, primarily focused on pastures and livestock.

3. China is one of the largest organic food producers, with substantial areas under organic farming and a growing market for organic products.

4. The United States has one of the largest organic product markets, with consistent growth in demand and production over the past decade.

5. Spain leads Europe in organic farming areas, with significant growth in the last ten years.

These countries stand out for their organic farming areas, production, and market value of organic products, contributing significantly to the global growth of this sector. Organic agriculture continues to grow globally, supported by policies and initiatives aimed at sustainable development.

In the European Union, the Common Agricultural Policy (CAP) for the 2023–2027 period aims to increase environmental and climate ambitions. However, according to a report by the European Court of Auditors, while the plans are greener than before, they still fall short of achieving the EU's climate and environmental goals (eca.europa.eu).

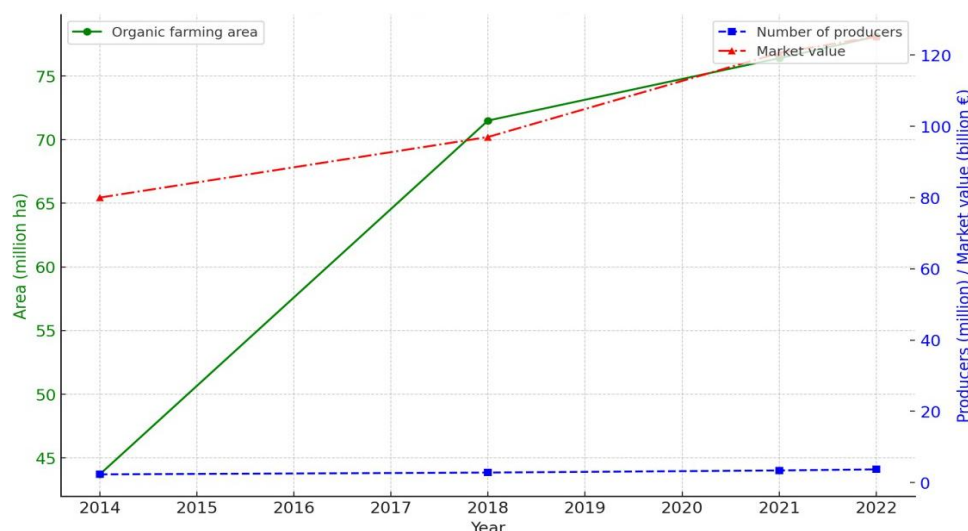


Figure 2. Analysis of organic farming worldwide in the period 2014–2022

As part of efforts to promote organic agriculture, the European Commission awarded prizes for organic production on September 23, 2024. The South Savo region in Finland was named the best organic region, Bremen in Germany the best organic city, and Sörmland in Sweden the best organic district. These awards recognize outstanding contributions across the organic agriculture value chain (cor.europa.eu).

Despite positive trends, the European Union faces challenges in achieving its goal of having 25% of agricultural land under organic production by 2030.

Current trends suggest that additional efforts are needed to meet this goal (cor.europa.eu).

Overall, organic agriculture continues to develop globally, supported by policies, initiatives, and growing consumer awareness of its benefits.

3. Main challenges of organic agriculture in the 21st century

The main challenges faced by organic agriculture in the 21st century are presented in Table 1.

Table 1.

Key challenges, description of challenges, and innovations or solutions that can contribute to overcoming challenges in organic agriculture.

Challenge	Description	Solutions/Innovations
Yields and productivity	Lower yields compared to conventional agriculture (19–25% lower yields). The need to increase productivity while maintaining sustainability.	Agroecological methods (crop rotation, use of plant and animal residues, integrated pest management). Technological innovations (drones, sensors, biotechnology).
Land availability	Increased competition for land due to urbanization and global population growth. Organic agriculture requires specific soil conditions.	Bringing abandoned land back into organic production. Support from government and international organizations for the development of ecological policies.
Climate change	Extreme weather conditions, droughts, floods, and changes in biodiversity affect soil fertility, biodiversity, and crop resilience.	Developing more resilient agroecosystems. Implementing policies that take into account the specifics of organic agriculture and adaptation to climate change.
Lack of education and infrastructure	Lack of specific educational resources, technological support, and infrastructure for the distribution of organic products, especially in developing countries.	Investment in educational programs, technological training, and infrastructure development for better distribution.
High certification costs	Expensive and complicated certification process, especially for small farmers..	Support programs (subsidies, collective certifications, simplified processes). Development of local certification systems that are cheaper and region-specific.
Consumer confidence	Consumer confusion due to different certifications and false labeling. The need for greater education about the certification process and product authenticity.	Consumer education about the benefits and certification process. Introduction of clearer and more transparent certification systems.

3.1. Yields and productivity

One of the biggest challenges of organic farming is its lower productivity compared to conventional

farming. According to a study by Ponisio et al. (2015), average yields in organic farming are 19–25% lower compared to conventional methods. This can be a problem in meeting the growing global demand for food. Although organic farming is often criticized for its

lower yields compared to conventional farming, studies show that, with the right approaches and practices, yields can be competitive. For example, studies have shown that using agroecological methods (such as crop rotation, use of plant and animal residues as fertilizer, and integrated pest management) can contribute to higher productivity in organic production (Seufert and Ramankutty, 2017).

Technological innovations can significantly improve the efficiency and sustainability of organic farms. For example, new technologies for precision agriculture, such as drones, soil condition sensors, and automated machines for sowing and harvesting, can help farmers optimize production while minimizing negative environmental impacts. Additionally, biotechnology (e.g., the development of disease- and pest-resistant plant varieties) can improve crop resilience and reduce the need for synthetic pesticides (FAO, 2019).

Sustainability is a key issue in organic farming because this system of production aims to reduce environmental impacts, conserve biodiversity, and enhance social and economic sustainability. Organic farming often favors the use of natural resources, reduces carbon dioxide emissions, and promotes soil health through composting, green manure, and reduced use of chemicals. While sustainability offers long-term benefits, it also presents challenges in adapting conventional systems to ecological standards, which sometimes leads to an initial decrease in yields (Badgley et al., 2007; Tiwari, 2023). By combining technological innovations and agroecological practices, organic farming can significantly increase its productivity while contributing to sustainability. Focusing on sustainable practices and utilizing new technologies can help overcome challenges, including reducing environmental pressures and increasing resilience to climate change.

3.2. Land availability

Global population growth and urbanization are leading to a reduction in available agricultural land. Organic farming, which often requires more space due to crop rotation and avoidance of synthetic chemicals, may face competition for land (Reganold and Wachter, 2016).

The availability of adequate land is a key challenge for the development of organic farming in the 21st century. Organic production requires specific land conditions, such as rich humus, good soil structure, and minimal use of synthetic pesticides and fertilizers. Due to increased pressure on land caused by urbanization, agricultural industrialization, and global population growth, organic producers face growing problems regarding access to quality land (Satterthwaite et al., 2010).

Global competition for land between agriculture, urban areas, industry, and ecosystem conservation further complicates the situation. In some regions, such as Europe and North America, there are initiatives to return abandoned land to organic production, but this requires significant investment in infrastructure and education. Additionally, in many countries, policies that promote ecological standards in agriculture are underdeveloped, limiting access to subsidies and government support for organic production (Ondrasek et al., 2023). Given that organic farming is subject to

stricter regulations compared to conventional farming, the land must be completely free of synthetic chemicals and pesticides for at least three years before organic food production can begin. This transition period often makes land less accessible to new organic farmers, who face higher startup costs (Fialas et al., 2023).

3.3. Climate change

Climate change, including extreme weather events and increased frequency of droughts, represents one of the biggest challenges for agriculture in the 21st century, and organic farming is not exempt from its negative effects. These conditions affect soil fertility, biodiversity, and crop resilience (Niggli et al., 2009). Rising global temperatures, extreme weather events, droughts, floods, and unpredictable rainfall patterns threaten the stability of production and efficiency in organic farming (Bloch et al., 2016). Although organic systems often have better adaptive capacities compared to conventional farming practices, climate change increases the pressure on their ability to maintain stability and productivity.

One of the key issues is the reduction in the quality and quantity of natural resources, such as water and fertile land, which are essential components in organic production. Longer drought periods can reduce the availability of water for irrigation, directly impacting yields, while floods, which have become more frequent due to climate change, can erode soil and reduce its fertility. Additionally, climate change leads to changes in biodiversity, affecting natural predators and pollinators, which are crucial for successful organic production (FAO, 2011b). Organic farming, which relies on natural management methods, may have advantages in sustainability due to its ability to create more resilient agroecosystems. However, conditions that have become more extreme due to climate change, such as high temperatures or sudden weather changes, present challenges even for sustainable production systems (Semeraro et al., 2023). In some regions, such as South America and Africa, climate change increases the risk of unstable agricultural practices, making organic production unfeasible without additional investment in technology and infrastructure.

Agricultural policies addressing climate change in many cases do not consider the specificities of organic production. Therefore, it is important to implement strategies that integrate climate change into organic farming policies to help farmers adapt to new conditions and reduce their negative impacts (FAO, 2021).

3.4. Lack of education and infrastructure

One of the key challenges for expanding and improving organic farming in the 21st century is the lack of adequate education and infrastructure. Organic farming requires specific knowledge, skills, and technologies that differ from those used in conventional farming. However, in many regions, especially in developing countries, there is a serious lack of educational resources and expertise to support the development of sustainable and efficient organic farms (Golijan, 2016). Many farmers do not have the necessary knowledge or access to the resources required to transition to organic production.

Additionally, many regions lack infrastructure and market opportunities for distributing organic products (Gomiero, 2018).

Education about organic farming principles, such as biodiversity, crop rotation, composting, natural pest management, and soil conservation, is not sufficiently present in educational institutions, and many farmers do not have access to modern methods or fail to recognize the value of ecologically friendly practices. Moreover, there is also a lack of technical support for implementing new technologies and practices, further hindering the transition from conventional to ecological production systems (Sharma, 2024).

Infrastructure is also a significant factor limiting the expansion of organic farming. In many areas, particularly in rural and less developed regions, there is a lack of access to markets, cold storage, processing, and transportation infrastructure, which makes it difficult to distribute organic products. Insufficient infrastructure for storage, packaging, and distribution can reduce the competitiveness of organic products in the market and affect the economic sustainability of farms (Górska-Warsewicz et al., 2021). Additionally, poor transportation connectivity can hinder access to agricultural materials, equipment, and labor, negatively affecting productivity and efficiency in organic production.

To overcome these barriers, investing in education and training for farmers, as well as developing infrastructure that will enable better conditions for organic production and distribution, is crucial. Programs that offer advice on ecological farming techniques, access to new technologies, and improved agricultural practices can contribute to improving productivity and reducing costs in organic production. Furthermore, increasing support from government agencies and NGOs for infrastructure development can reduce market access barriers and enable organic producers to achieve greater competitive advantages (USDA, 2024).

3.5. High certification costs

Another significant challenge faced by producers in organic farming in the 21st century is the high cost of certification. Certification is crucial for recognizing organic products, but the certification process can be expensive and complicated, especially for small farmers (Barrett et al., 2021). This often discourages producers from transitioning to organic farming. Organic certification is a process that confirms that production meets specific ecological standards, including the use of organic methods, a ban on synthetic pesticides and fertilizers, and environmentally responsible land and resource management (Golijan, 2016; Golijan Pantović et al., 2024a). Although certification provides access to markets with higher prices for organic products, the certification process can be expensive and bureaucratically demanding.

High certification costs include audit fees, inspections, laboratory analyses, and administrative costs, which can be a significant financial burden for small and medium-sized farmers. For many producers, particularly in developing countries, the initial costs may be unaffordable, and the process may seem too complicated, discouraging potential candidates from certification. Additionally, many certification organizations require ongoing monitoring and re-

inspections, which further increases the financial burden (FAO, 2007). For small farms, certification costs can even exceed the potential profit from higher prices for organic products, making the economic sustainability of organic production in some cases highly questionable. Also, there is a market access issue because without certification producers cannot sell their products as organic, which reduces competitiveness in a market where certified products are increasingly in demand (Jouzi et al., 2017). Many organizations and governments have recognized this challenge and started implementing support programs to reduce certification costs for small and medium-sized producers. These include subsidies for certification, collective certification for group producers, and streamlining administrative procedures, which help reduce barriers to accessing the organic market. Some organizations are even working on developing local certification systems that are cheaper and specific to regional conditions, while still allowing consumers to trust the quality of the products (Giovannucci, 2006). Moreover, increasing public awareness of the benefits of organic farming can help reduce these barriers, as the growing organic product market can increase demand and contribute to reducing relative certification costs due to economies of scale (Jensen et al., 2011).

3.6. Consumer trust

Consumer trust in organic farming plays a key role in the success and sustainability of this sector in the 21st century. Although consumers worldwide are becoming increasingly interested in health and sustainability, there is a significant challenge in gaining and maintaining their trust in products labeled as organic. In a market flooded with various certifications and eco-labels, consumers can become confused and skeptical about the authenticity of products, which can affect their final choice (Golijan, 2016; Golijan and Sečanski, 2021b).

One of the key factors shaping consumer trust is transparency and awareness about the origin of products. While organic products often come with certifications that guarantee environmentally friendly production, many consumers are not fully familiar with the certification process or the meaning behind these labels. There is an evident need for greater consumer education about the benefits of organic food and the processes behind certification to increase trust in the market (Murphy et al., 2022).

Additionally, the increased availability of information about fraud related to fake eco-products also contributes to consumer caution. Since some producers may use "green" marketing strategies or fake labels to take advantage of the growing demand for organic food, there is a need for stronger regulation and standardization of certifications to protect consumers and support the legitimate development of the sector (USDA, 2023).

Moreover, consumer trust is linked to the perception of quality, taste, and nutritional value of organic products compared to conventional ones. While many consumers believe that organic products are nutritionally superior, research suggests that it is not always possible to prove a significant difference in nutritional values between organic and conventional food, which can reduce consumer trust in organic

production (Smith et al., 2020b; Golijan and Sečanski, 2021b, 2021c; Golijan et al., 2021, 2022; Golijan Pantović et al., 2024b).

Although interest in organic food is growing, consumers often doubt the authenticity of products. Mislabeling and the lack of standardization in some regions can undermine trust (Golijan, 2016; Willer and Lernoud, 2019).

To maintain and increase consumer trust, it is important to invest in education and promote transparency. Consumers also demand assurance that products carrying eco-labels are truly produced

according to strict standards, which is why it is crucial to develop clear, consistent, and easily understandable certification systems (Murphy et al., 2022). This approach not only increases trust but also encourages long-term consumer loyalty to organic products.

4. Opportunities for improving organic agriculture in the 21st century

Table 2 presents a summary of key opportunities for improving organic agriculture in the 21st century.

Table 2.
Key opportunities for improving organic agriculture in the 21st century

Opportunity	Description	Examples/Innovations	Challenges
Innovations in technology	Technological innovations improve production efficiency, resource conservation, and resilience to climate change. They include precision agriculture, biological controls, and biotechnology.	Precision agriculture (sensors, drones, satellite imaging); biofertilizers, biopesticides; AI and machine learning.	High implementation and maintenance costs, lack of technical training for farmers.
Support policies and subsidies	Support through subsidies, educational programs, and investments in research and development. Policies can facilitate the transition to organic farming and reduce competition with conventional farms.	EU Common Agricultural Policy (CAP); subsidies for certification; incentives for organic farming in India.	High certification costs, limited market access, competition with conventional farms.
Consumer education	Informing consumers about the benefits of organic food, its nutritional value, and its environmental impact. Education helps increase demand for organic products.	Educational campaigns, school programs, digital platforms, video campaigns.	Lack of knowledge about the differences between organic and conventional products, high price of organic products.
Development of local markets	Developing local markets allows direct sales between producers and consumers, reducing distribution and logistics costs. It encourages the local economy and reduces dependence on large retail chains.	Community Supported Agriculture (CSA); local markets, cooperatives, direct sales.	Lack of infrastructure, competition from cheaper conventional products, logistical challenges.

4.1. Technological innovations

Technological innovations are among the major drivers of organic farming development in the 21st century. Technological progress enables more efficient production, conservation of natural resources, and better adaptation to challenges such as climate change, labor shortages, and the need for higher yields. For example, the implementation of precision agriculture, which includes the use of sensors, drones, and satellite imaging, allows farmers to monitor crop and soil conditions in real-time, optimizing resource usage such as water and nutrients (Getahun et al., 2024).

The application of new technologies, such as precision agriculture and biological controls, can help increase the productivity and resilience of organic production (Godavari et al., 2024). The development of biotechnology in organic farming, such as biofertilizers and biopesticides, also plays a key role. These products allow for crop protection and soil fertility improvement in a sustainable manner, without the use of synthetic chemicals that are banned in organic production. For instance, innovative biofertilizers based on microorganisms not only increase yields but also contribute to the regeneration of degraded soil (Daniel et al., 2022).

One of the most significant innovations recently is the use of artificial intelligence (AI) and machine learning in organic farming. These technologies allow

for the automation of processes such as irrigation, planting, and harvesting, as well as the analysis of large datasets to make informed decisions. For example, AI systems can predict the spread of diseases or pests and recommend timely measures, reducing losses and increasing efficiency (Mishra and Mishra, 2023).

Technologies related to the circular economy, such as organic waste recycling systems and compost production, are also becoming increasingly relevant. These innovations not only reduce the ecological footprint of organic farming but also increase the resilience of systems to external changes, such as input price fluctuations or climate stress (Sulewski et al., 2021). However, the implementation of new technologies in organic farming faces certain challenges, including high implementation and maintenance costs, as well as the lack of technical training for farmers. Despite this, many governments and non-governmental organizations are investing in projects that enable the broader application of technologies by offering subsidies and educational programs to ease farmers' transition to innovative production methods (Rahmann et al., 2017).

4.2. Policy support and subsidies

Policy support and subsidies play a key role in the development and sustainability of organic farming in the 21st century. As an environmentally friendly

method of production, organic farming has the potential to contribute to global sustainable development goals, including combating climate change, conserving biodiversity, and enhancing rural economies. However, without adequate institutional and financial support, organic producers may face serious challenges, such as high certification costs, competition with conventional farmers, and limited market access (Smith et al., 2022).

Governments can provide financial support and educational programs to encourage the transition to organic farming and increase the competitiveness of producers (Scialabba and Hattam, 2002). Governments worldwide are increasingly recognizing the importance of supporting organic farming through policies that include subsidies for transitioning to ecological production methods, certification incentives, and investments in research and development. For example, the European Union has implemented the Common Agricultural Policy (CAP), which provides significant funding to subsidize organic farms and promote sustainability in agriculture. These policies include direct financial incentives, as well as technical assistance and training for farmers (European Commission, 2021).

One of the key aspects of policies supporting organic farming is subsidizing certification costs, which often represent a financial burden for small and medium-sized farms. Government subsidies or support from non-governmental organizations help reduce these costs, making certification more accessible and encouraging the transition to organic production (U.S. Department of Agriculture, 2024). Additionally, many countries are developing programs to improve market infrastructure to facilitate consumer access to organic products. This includes subsidizing the construction of local markets, logistics centers, and distribution systems. For instance, in India, policies have been implemented to provide subsidies for infrastructure specific to organic production, contributing to the increased participation of organic products in both domestic and international markets (Deveshwar and Panwar, 2024).

In addition to subsidies, investment in research and development is crucial to finding solutions to specific challenges in organic farming, such as low yields and disease resistance. Subsidies supporting innovations, such as biopesticides, biofertilizers, and irrigation systems adapted to organic practices, can significantly improve the productivity and sustainability of this sector (Indurthi et al., 2024).

With the appropriate policy support and effective implementation of subsidy programs, organic farming has the potential to contribute to long-term sustainability and economic development in rural areas while meeting the growing demand for healthy and eco-friendly products.

4.3. Consumer education

Consumer education is one of the key aspects of developing the organic farming market. Informed consumers make better purchasing decisions by recognizing the values and benefits of organic food, which directly contributes to the growth of demand for these products. In the 21st century, when health, sustainability, and ecological responsibility are increasingly emphasized, education is becoming a

crucial tool in raising awareness about the importance of organic farming (Tapas and Desai, 2020).

One of the main challenges is recognizing the difference between organic and conventional products. Research shows that many consumers have limited understanding of what the "organic" label actually means and how these products differ from others. This can lead to skepticism or unfavorable attitudes toward organic products due to their often higher price (USDA Economic Research Service, 2022). Additionally, marketing campaigns that use "green" terms for conventional products further confuse consumers and make it harder for them to make informed decisions.

Educational campaigns, supported by governments, non-governmental organizations, and producers, can play a key role in addressing this issue. Organizing workshops, lectures, and seminars on the benefits of organic food, its nutritional value, and its environmental impact can significantly increase consumer confidence. For example, school programs that include topics related to organic farming not only educate children but also indirectly influence their parents' behavior as consumers. Digital platforms and social media also offer great opportunities for spreading information. By using interactive campaigns, video materials, and testimonials from satisfied customers, producers and sellers can bring the benefits of organic food closer to consumers. For instance, short video clips showing the process of growing and certifying organic food can make this topic more accessible to a wider audience (NIFA, 2016).

In addition to educating about the products themselves, it is important to inform consumers about the impact of their decisions on the broader ecosystem. Purchasing organic food supports sustainable practices, reduces negative environmental impacts, and promotes local economies. This awareness can encourage consumers to choose organic food, even when its price is higher than conventional alternatives (Muhammad et al., 2016).

For successful implementation of educational strategies, it is necessary to collaborate with various stakeholders, including governments, non-governmental organizations, educational institutions, and the media. Increasing consumer awareness of the benefits of organic food can help strengthen the market and reduce skepticism. Long-term education, which starts with basic education and continues throughout life, can significantly contribute to the sustainable development of the organic market (Moroşan et al., 2025).

4.4. Development of local markets

The development of local markets offers significant potential for improving organic farming in the 21st century, as it allows for direct connections between producers and consumers, reducing logistics and distribution costs. Local markets provide a platform for selling fresh and high-quality organic products while strengthening local economies and promoting sustainability. In an increasing number of communities around the world, local farmers use markets, cooperatives, and direct sales programs to distribute their products and build trust with consumers (Golijan and Dimitrijević, 2018). Encouraging local sales of organic products can reduce transportation costs and improve the economic sustainability of farmers.

One of the main benefits of developing local markets is reducing dependence on large retail chains. Traditional retail systems often impose strict requirements regarding quantity and standardization, which can be challenging for small organic producers. In contrast, local markets allow producers to sell seasonal products and smaller quantities without significant investments in packaging and distribution (Gunasekaran and Murugan, 2021).

In addition to economic benefits, local markets contribute to community strengthening and raising awareness about the advantages of organic food. Consumers who shop at local markets often have the opportunity to speak directly with producers, which increases their trust in the quality of products. This personalized approach can motivate consumers to support the local economy and recognize the broader value of organic products, including their contribution to health and environmental preservation (Warsaw et al., 2021).

One successful example of local market development is the Community Supported Agriculture (CSA) concept, or community-supported cooperatives. This model allows consumers to prepay for membership or a seasonal product package, giving farmers a stable income and resources to improve production. The CSA model has become particularly popular in developed countries, where it is recognized as a way to reduce food waste and increase the availability of fresh products (Voge et al., 2023).

However, the development of local markets also faces challenges. The lack of infrastructure, such as storage capacities and cooling systems, can limit farmers' ability to deliver products in optimal condition. In addition, logistical problems and competition from cheaper conventional products in retail represent obstacles to expanding local markets. To overcome these challenges, investments in local infrastructure and support in the form of subsidies and educational programs for small producers are needed (Jarman et al., 2023).

In the future, a combination of local markets and digital platforms can provide additional opportunities for connecting producers with consumers. Online markets and direct order apps allow farmers to reach a broader audience, even beyond their immediate community, while maintaining transparency and a personalized approach (Victor and Manida, 2024).

Conclusion

Organic farming is a vital component of sustainable development in the 21st century, but its progress requires overcoming numerous challenges. Limited land availability, high certification costs, lack of education and infrastructure, as well as the consequences of climate change, slow the expansion of the organic sector. At the same time, opportunities such as technological innovations, local market development, increasing consumer trust, and support through policies and subsidies provide a foundation for long-term success. Achieving these goals requires connecting relevant actors, including government institutions, the private sector, and non-governmental organizations. Consumer education and promotion of the benefits of organic food contribute to increasing awareness and market demand. On the other hand, subsidies and investments in infrastructure can reduce

the burden on producers and increase their competitiveness. Through the combination of these strategies, organic farming can overcome current barriers and become a pillar of sustainable development in the global agricultural sector. Investing in this area is not only economically beneficial but also essential for preserving natural resources and the health of future generations. Organic farming has the potential to significantly contribute to sustainable development and the conservation of natural resources. However, to address the challenges it faces, coordinated action by governments, research institutions, and the private sector is necessary. Only through innovation, education, and support can we ensure that organic farming fulfills its potential in the 21st century.

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Declaration of competing interests

The author declare that they have no conflict of interest.

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