Review

Land Resources in Organic Agriculture: Trends and Challenges in the Twenty-First Century from Global to Croatian Contexts

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Abstract: Organic agriculture (OA) is a continuously growing global concept that emphasizes the use of sustainable and environmentally-friendly practices. By adopting OA, it is possible to improve ecosystems services, increase biodiversity, decrease environmental pollution, reduce carbon footprints and mitigate greenhouse gas emissions, generating food that is free from harmful residues of agrochemicals, thereby enhancing food safety and security. This study provides a comprehensive review of the latest insights on the global utilization of land resources in OA, focusing particularly on some EU countries that experienced a notable and rapid progress in organic farming during the past two decades. With negligible 1.6% (75 Mha) of global cropland is currently dedicated to OA, there is ample opportunity to expand the adoption of OA and realize its multi-beneficial potential for farmers (by premium prices), and consumers (by healthier and nutritious food). The importance of OA has been recognized by the most recent EU agro-environmental policies and green strategies, with an ambitious goal to have at least 25% of agroecosystems under organic management by 2030. Despite numerous financial supports and a multifold increase in OA land area, many member states are unlikely to achieve this goal, including Croatia, which currently has a share of only 8% (~109,000 ha) of lands in OA. Furthermore, converting conventional land to organic farming has not always led to an increase in value-added final OA products. EU policies related to OA have been focused on the area of land cultivated organically, rather than overall production performance, and financial subsidies have been essential to achieve this policy. Therefore, some of critical obstacles and challenges for OA under rising pressures due to global climate change, public health and geopolitical crises need to be managed by specifically designed policies and regulations, which would contribute to more sustainable OA, i.e., food safety and security.

Keywords: organic farming; ecologic farming; biodiversity; environment protection; agroecosystems

1. Introduction

Out of ~13.0 billion ha of global land area, in 2020 agricultural land resources were represented by 4.74 billion ha (36%), mostly by permanent meadows and pastures of 3.18 billion ha, while the rest of only 1.56 billion ha (11.7%) were represented by agricultural croplands, comprising 1.39 billion ha of arable land and 1.74 billion ha of permanent...
crops [1]. The predominant agricultural crop production system globally is conventional rain-fed, which on 1.21 billion ha (78%) contributes to 60% of the global food supply [2]. The rest of 349 Mha (22%) cropland is represented by irrigated agroecosystems [1], responsible for the generation of 40% of the global food supply. Between 2000 and 2020, there was a remarkable 52% increase in global production of primary crops, resulting in a total of 9.3 billion t, which is 3.2 billion t more than in 2000 [3]. Cereals emerged as the dominant crop group in 2020, accounting for ~30% of the overall production. In terms of meat production, the global output reached 337 Mt in 2020, marking a notable 45% increase, equivalent to 104 Mt compared to the year 2000 [3]. However, recent projections indicate that the global population is set to increase by 20%, reaching 9.7 billion by the mid-twenty-first century [4]. This unprecedented growth will place significant demands on the agri-food sector, requiring substantial improvements in productivity and efficiency throughout the entire food system, including crop and livestock production, processing, distribution, and food waste reduction [5]. However, these challenges are further compounded by climate change, as well as other environmental and anthropogenic pressures like urbanization, deforestation, and desertification. To address these pressing issues, sustainable and resilient food systems that can adapt to changing conditions are urgently needed. It is imperative that these food systems align with the most recent agro-environmental and health standards, initiatives, activities and long-term goals, such as the Paris Agreement [6], Sustainable Development Goals [7], and the Green Deal [8]. Achieving such goals will require a concerted multisectoral effort from all stakeholders, including farmers, policymakers, researchers, and consumers, to build a sustainable and resilient food system that can meet the needs of a growing global population while also addressing the challenges posed by climate change and other environmental pressures.

However, while conventional agriculture is the predominant global food-generating and land use system [9], there is a growing interest in alternative approaches that prioritize sustainability, environment protection and human health. Organic agriculture (OA) is one such sustainable farming concept that places a strong emphasis on utilizing natural techniques and approaches to produce high-quality crops and livestock for food and/or feed (Figure 1). The latest agrostatistical reports indicate that OA is practiced at only 1.57% of the world’s agricultural land areas, which equates to approximately 75 Mha [1]. OA incorporates a holistic approach to farm management and food production, emphasizing the use of environmentally-friendly and climate-friendly practices, the conservation of natural resources, the promotion of biodiversity, and adherence to high standards of animal welfare and production [10]. In OA, the concept and consumers’ perception of organic products excludes the use of ionizing radiation, animal cloning, artificially induced polyploid animals, and genetically modified organisms (GMOs), including products produced from or by them (Figure 1). Therefore, the use of these techniques and their products is not permitted in OA [10]. In contrast, OA involves using of natural fertilizers (e.g., manures, composts), soil conditioners (bioash, biochar, limestone and dolomite fractions) and pesticides, crop rotation, and other techniques that promote sustainable farming without relying on synthetic agrochemicals (fertilizers, herbicides, fungicides, insecticides, plant/animal growth regulators, antibiotics, nutrients supplements). Furthermore, farms that aim to transition from conventional practices to OA need to undergo a transition period of no less than three years, when they must adhere to the obligations and regulations of OA [10]. The ultimate goal of organic farming is to create a healthier, more sustainable agroecosystem that benefits both the environment and the people who consume the products.

The growing popularity of OA during recent decades has been driven by a combination of factors, including (i) health and environmental benefits [11], (ii) consumer demand and government support [12]. One of the most frequent motives explaining why consumers are increasingly oriented towards organic food is that it is perceived as healthier compared to conventional food. Farmers in OA emphasize the production of high-quality natural products, with a focus on quality over quantity, and although organic crops can generate lower yield, their higher prices reflect consumer willingness to pay more for safer and more
natural products [13]. For instance, numerous studies have validated that products derived from OA typically exhibit higher levels of nutrients, antioxidants, and/or vitamins [11], while being comparatively lower in toxic metals [14], antibiotic-resistant bacteria [15], and pesticide metabolites [16] than products obtained from conventional agriculture. Moreover, OA practices promote biodiversity, reduce soil erosion and depletion, conserve water, and reduce pollution [17] (Figure 1). Incorporating OA methods into a variety of land management practices can promote a sustainable bioeconomy and address equity concerns. Land-use techniques like agroforestry, intercropping, organic amendments, cover crops, and rotational grazing offer climate change mitigation and adaptation benefits, including food security, livelihood support, biodiversity conservation, and improved health (Figure 1). By strategically incorporating appropriate biomass production systems into agricultural landscapes, bioenergy and other bio-based products can be obtained, while enhancing landscape diversity, habitat quality, nutrient and sediment retention, erosion control, climate regulation, flood regulation, pollination, and biological pest and disease control [18]. These practices can mitigate environmental damage caused by intensive agriculture while preserving or enhancing land productivity and biomass output [19].

Finally, governments are providing financial incentives and support known as agro-environmental (green) payments/schemes to farmers and landowners to adopt OA practices that benefit the environment and promote sustainable land use, to implement practices that go beyond traditional agricultural activities to protect and enhance natural resources [13,20]. For instance, during the last 20 years up to 140 billion US$ were spent globally on subsidies such as green payments, mostly in the EU and USA [4]. Under the Common Agricultural Policy (CAP) in the EU, up to 30% of the direct payments to farmers (Pillar 1) have been green payments [21], including some actions that could increase C sequestration or reduce GHG emissions. Similarly, at least 30% of the rural development payments (Pillar 2) are used for measures that reduce environmental impact, including
reduction in GHG emissions and carbon storage. There is limited evidence that these policies contributed to the 20% reduction in GHG emissions from the agricultural sector in the EU between 1990 and 2018 [4]. Moreover, the EU provides financial support to encourage the expansion of organic farming. This support is intended to strengthen the organization of organic producers in associations, promote the processing and marketing of organic products, and educate and inform consumers about OA. The EU aims to have at least 25% of its agricultural land dedicated to organic agriculture by 2030 and is providing funding and support to help farmers reach this goal [22]. Accordingly, EU member states offer an annual non-refundable subsidy per hectare to offset income loss and additional expenses incurred by farmers who adhere to specific conditions for organic farming. Compensation for organic farming varies across member states; for example, in Croatia, subsidies range from 310 EUR/ha for permanent grassland to 868 EUR/ha for permanent crops [23], while in Romania, organic farms and those transitioning from conventional to organic can receive between 510 EUR (farms larger than 21 ha) and 611 EUR (for farms between 5–20 ha), depending on the farm size [13]. However, despite the significant financial resources supporting OA, only a few EU countries have achieved (Austria 26.5%), or are close (Estonia 22.4%; Sweden 20.4%) to achieving, the ambitious goal of having at least 25% of their agricultural area under organic farming.

This study presents up-to-date insights into the worldwide use of agricultural land dedicated to OA, with a specific emphasis on the EU and Croatia, as the youngest EU member state that has demonstrated significant advancements in OA over the last decade. Our findings highlight the spatial disparities in the distribution of OA across agroecosystems, and could serve as important insights for policymakers and stakeholders in terms of promoting sustainable agricultural practices and enhancing the environmental and socio-economic benefits of OA. Finally, we discuss the main challenges, perspectives and solutions for OA, especially in the face of climate change, and some other global public health and geopolitical crises.

2. A Global Overview of Organic Agriculture Land Areas

In recent decades, organic farming has been experiencing a rapid expansion, as evidenced by the global organic farmland area which has grown by over 104% between 2010 and 2020 (Table 1). Moreover, between 1999 (11 Mha) and 2020 there has been an almost seven-fold increase [12] in the same organic farming sector. However, the area under OA varies greatly by region and country. According to the most recent analyses, the global OA management is practiced on nearly 75 Mha, or only 1.6% of the global agricultural land (Table 1). Oceania holds the highest global share of OA land area with 35.9 Mha (48%), followed by Europe with 17.1 Mha (23%), Latin America with 9.9 Mha (13%), Asia with 6.1 Mha (8%), N. America with 3.7 Mha (5%), and Africa with 2.2 Mha (3%) (Table 1). In addition to land dedicated to OA, there are other organic land areas allocated for various purposes such as wild collection, beekeeping, aquaculture, forests, grazing, etc. The total area of these organic areas is 30.0 Mha, and when combined with OA land, the total reaches 104.9 Mha [12]. Regarding the land use management, permanent grasslands accounted for more than two-thirds or 50.8 Mha of the global OA land. The remaining quarter was made up of cropland area, including arable land with 13.1 Mha and permanent crops with 5.2 Mha, totaling 18.4 Mha (Table 1). In the African region, nearly two-thirds of OA land was utilized for permanent crops (e.g., nuts, olives, coffee), followed by arable crops (e.g., cotton, sesame, soybean, root crops). In Europe, dominating (47%) OA arable land is mainly used for the cultivation of cereals (3 Mha) and green fodder (2.7 Mha), whereas among permanent crops (11%) dominate olives (Table 1) [12]. The majority of Oceanian and Latin American farmland area is covered with extensive grazing areas, 34.6 Mha and 7.6 Mha, respectively (Table 1).
Table 1. Global organic agricultural (OA) land and land use in OA (Adapted from [1,12]).

<table>
<thead>
<tr>
<th>Continent/Region</th>
<th>2010</th>
<th>2010–2020</th>
<th>2020</th>
<th>Land Use Mha</th>
<th>Arable Crops</th>
<th>Permanent Crops</th>
<th>Permanent Grassland</th>
</tr>
</thead>
<tbody>
<tr>
<td>Africa</td>
<td>1.070</td>
<td>1.017</td>
<td>2.087</td>
<td>2.8</td>
<td>0.2</td>
<td>0.619</td>
<td>1.384</td>
</tr>
<tr>
<td>Asia</td>
<td>3.686</td>
<td>2.460</td>
<td>6.146</td>
<td>8.2</td>
<td>0.4</td>
<td>2.731</td>
<td>0.844</td>
</tr>
<tr>
<td>Europe</td>
<td>10.548</td>
<td>6.550</td>
<td>17.098</td>
<td>22.8</td>
<td>3.4</td>
<td>8.070</td>
<td>1.876</td>
</tr>
<tr>
<td>L. America</td>
<td>6.508</td>
<td>2.983</td>
<td>9.949</td>
<td>13.3</td>
<td>1.4</td>
<td>0.450</td>
<td>0.770</td>
</tr>
<tr>
<td>N. America</td>
<td>3.020</td>
<td>0.724</td>
<td>3.744</td>
<td>5.0</td>
<td>0.8</td>
<td>1.218</td>
<td>0.217</td>
</tr>
<tr>
<td>Oceania</td>
<td>11.384</td>
<td>24.525</td>
<td>35.909</td>
<td>47.9</td>
<td>9.7</td>
<td>0.052</td>
<td>0.147</td>
</tr>
<tr>
<td>Total</td>
<td>36.666</td>
<td>38.259</td>
<td>74.926</td>
<td>100</td>
<td>1.6</td>
<td>13.140</td>
<td>5.238</td>
</tr>
</tbody>
</table>

The ten countries with the largest OA areas comprise 59.1 Mha, representing nearly 80% of the global OA land. Australia with 35.69 Mha of OA land has the top global position, followed by Argentina with 4.45 Mha and Uruguay with 2.7 Mha. India, France, Spain, China, the USA, Italy, and Germany complete the list with total OA areas ranging from 2.1 to 1.7 Mha (Figure 2). However, in respect to the largest share of OA in the total agricultural land, the situation is completely different. Liechtenstein has the highest share of OA (41.6%) in its total agricultural land. Austria follows with 26.5%, while Estonia, Sao Tome and Principe, and Sweden complete the top five with 22.4%, 20.7%, and 20.4%, respectively. Uruguay, Switzerland, Italy, the Czech Republic, and Latvia also have significant shares of their agricultural land dedicated to OA, ranging from 19.6% to 14.8% (Figure 2).

3. An Overview of Organic Agriculture Land Areas in the European Union

Organic agriculture has a long history in Europe, dating back to the early twentieth century when farmers began experimenting with alternative farming practices that emphasized soil health and natural inputs [22]. However, during the 1970s OA emerged as a
distinct movement in Europe, and national organic farming associations were established in several European countries. In the following decades, organic farming grew steadily in Europe, driven by organic programs, regulations, providing financial and technical support to organic farmers and creating certification standards for organic products. At the European level, the first OA regulations were introduced in 1991, with the adoption of Council Regulation (EEC) no. 2092/91. This regulation established a legal framework for OA in the EU, including rules for organic certification, labeling, inspection and monitoring. The regulation also created a system of control bodies and control authorities responsible for verifying compliance with organic standards. In the years that followed, the EU’s OA regulations were revised and expanded several times, reflecting the growing importance of OA. For instance, some of the most important regulations from OA domain include: Council Regulation (EC) no. 834/2007 on ecological production and labeling of ecological products; Council Regulation (EC) no. 889/2008 establishing detailed rules for the implementation of Council Regulation (EC) no. 834/2007 on organic production and labeling of organic products with regard to organic production, labeling and control; Regulation (EU) no. 1307/2013 of the European Parliament and the Council establishes rules for direct payments to farmers within the support scheme under the Common Agricultural Policy and repealing Council Regulation (EC) no. 637/2008 and Council Regulation (EC) no. 73/2009; Regulation (EU) no. 1306/2013 of the European Parliament and the Council, on the financing, management and monitoring of the Common Agricultural Policy and repealing Council Regulation (EEC) no. 352/78, (EC) no. 165/94, (EC) no. 2799/98, (EC) no. 814/2000, (EC) no. 1290/2005 and (EC) no. 485/2008, as well as one of the most recent EU Regulation 2018/848 dedicated to OA. Finally, the new, greener CAP 2023–2027 program strongly supports the conversion of as much land as possible to OA in order to meet environmental, climate, and rural community goals that are in line with the EU Green Deal, the Farm to Fork strategy and other national green strategies. For instance, the Green Deal aims to reduce GHGs emission and increase C sequestration by protecting and expanding C sinks, as well as addressing emissions from conventional agricultural practices (e.g., Figure 1). In addition, the CAP plans will provide incentives for farmers and other beneficiaries to store C in soil and biomass, and reduce GHGs emissions on 35% of the EU’s agricultural area through more sustainable management practices (e.g., organic fertilization, agroforestry, crop selection/rotation, reduction in synthetic agrochemicals, etc., Figure 1). By 2027 the CAP will ensure €387 billion through eco-schemes (at least 25% of funds), different measures of the rural development program (at least 35% of funds) and other support [24]. This will be a key factor in supporting EU member states to meet their national objectives for increasing organic agricultural areas.

The EU has made notable progress in its financial policies, particularly during the upcoming mid-term period [22]. This progress involves prioritizing the production of organic agriculture in areas that face specific natural constraints, such as mountainous regions. Additionally, there will be a shift in income support payments from larger farms to smaller ones, as a means of promoting equitable distribution of resources in the agricultural sector. These developments align with current scientific research on sustainable agricultural practices, which emphasizes the importance of supporting environmentally-friendly farming methods and promoting social and economic equity in the agricultural sector [22]. As a result, over the last two decades, OA in the EU has increased by almost four-fold, from 3.8 to 14.9 Mha, now representing 9.2% of the total agricultural land in the EU (Figure 3a). Arable crops, including green fodder, cereals, and dry pulses, were the most dominant crops in EU organic farming, accounted for 45% of total OA land use in the EU, while permanent grasslands represented 42%, and the remaining 11% was allocated to permanent crops such as olives, grapes, and nuts (Figure 3b). Consequently, land use in the EU’s OA was dominated by arable land, accounting for 6.7 Mha (6.8% share of the total agricultural land), followed by permanent grasslands with 6.4 Mha (12.4% share of the total agricultural land), and permanent crops with 1.8 Mha (13.5% share of the total agricultural land) (Figure 3b).
4. An Overview of Organic Agriculture Land Areas in Croatia

In recent years, OA land areas have been growing in many EU countries, including Croatia, aiming to reach the mid-term goal by 2030 of at least 25% of the agricultural land under OA [22]. The adoption of the National Action Plan for the Development of Organic Agriculture 2023–2030 in Croatia is the most recent strategic framework to guide the future development and progress of OA over the mid-term period. During the 13-year period of analysis from 2007 to 2020, Croatia’s OA areas underwent a substantial and consistent expansion, increasing by over fourteen-fold, from 7577 ha (representing

Figure 3. Total area of land under organic agriculture (in million hectares, Mha) and its share (as a percentage, in brackets) in the total agricultural land per EU member state in 2020 (a), in the EU from 2000 to 2020 (b), and land use in organic agriculture in the EU in 2020 (c) (Adapted from [1,12]).

The top five countries with the highest total land dedicated to organic agriculture (OA) in the EU are: France with 2.55 Mha, Spain with 2.44 Mha, Italy with 2.1 Mha, Germany with 1.7 Mha and Austria 0.68 Mha. Collectively, these countries account for 65% of the total OA land in the EU (Figure 3c). On the other hand, the top five countries with the highest share of OA in their total agricultural land are: Austria at 26.5%, Estonia at 22.4%, Sweden at 20.4%, Italy at 16%, and the Czech Republic at 15.3%. Only Austria has already met the goal of dedicating at least 25% of its land to OA, while Estonia and Sweden need less than 3% and 5%, respectively, to achieve this target (Figure 3c). Some EU member states have even more ambitious mid-term targets in respect to organic farming. For instance, in Germany [25] and Sweden [26] the target is a 30% share of OA area by 2030. However, the most recent studies indicate that expanding organic farming could compromise food safety, resulting in a caloric deficit of 44% or 7–8 kcal/capita/day [25], due to significantly lower (on average by 80%) and highly variable (standard deviation > 20%) yields compared to conventional farming [27]. This means that the current cropland area needs to be expanded (e.g., 1000–5000 km² in Germany) beyond its limit to meet the demands of the population and current export levels, or there will not be enough food produced to satisfy the food
Although Germany and Austria have experienced positive and ongoing advancements in organic farming over recent decades, further expansion of OA poses significant challenges not only in these two countries but also in other member states, including Croatia.

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Therefore, it appears that financial incentives for the adoption of OA in Croatia are not yet appealing or prioritized enough for conventional farmers to transition to organic practices. This may be due to various challenges faced by organic farmers, as elaborated in previous sections. Recent studies conducted at a national level [20] and in the Northwest Croatian territory [29] have indicated that organic farmers are primarily motivated by environmental and human health awareness, lifestyle choices, love of nature, and the desire to maintain biodiversity and a clean environment, rather than financial incentives such as subsidies. Similarly, [30] found that price premiums and European subsidies for OA are often justified, as they compensate farmers for providing ecosystem services or avoiding damage to the environment. However, in Romania the support provided by CAP and inland financial allotment has significantly contributed to the potential of increasing organic agriculture, while also playing a crucial role in attracting new farmers and converting traditional agricultural areas into organic ones [13]. In Croatia, there is substantial potential for the growth of OA on a considerable percentage of uncultivated (abandoned) agricultural land, which is present in all regions and almost all counties. Long-term deagrarianization, depopulation, and deruralization processes have led to approximately 25% of the total national agricultural land area, or nearly 600,000 ha, remaining uncultivated in 2017 [28]. This land can be used for OA without requiring a transition period, as it has not been cultivated for almost 30 years. Additionally, much of the uncultivated land is located in rural areas which are relatively close to larger consumer centers and attractive tourist destinations, making it an attractive option for further growth of OA. The creation of formal bio-districts [31] (more in the next section) and joint activities to promote OA for the purpose of tourism presents another synergistic opportunity for the development of OA in Croatia. Croatia is an attractive tourist destination for countries with relatively higher supply [25]. Although Germany and Austria have experienced positive and ongoing advancements in organic farming over recent decades, further expansion of OA poses significant challenges not only in these two countries but also in other member states, including Croatia.
consumption of organic products, higher GDP, and/or relatively higher OA production, such as Austria, Germany, Italy, Slovenia [20], Czechia and Switzerland. Finally, the sustained growth projected for the organic food market at global, regional, and national levels presents an advantageous opportunity for Croatian organic producers to expand their reach beyond the domestic market and tap into the increasing demand for sustainable and healthy food products.

![Figure 4. Total area of land under organic agriculture (in hectares, ha) and its share (as a percentage, in brackets) in the total agricultural land in Croatia for the period 2007–2020 (a). Organic agricultural land use (in hectares, ha) in Croatia for the period 2007–2020 (b).](image)

Based on the graphical representation of OA land areas in Croatia, it is evident that there is an uneven distribution of OA, with the lowest area (up to 1000 ha) observed in the northern, eastern, and southeastern regions (Figure 5a). In general, OA is more widespread in the continental region of Croatia as compared to the southern (Mediterranean) part [29]. Out of the twenty counties, only one in the continental part (Osječko-baranjska county) and one in the Mediterranean part (Ličko-senjska county) exhibit the highest share of OA (>15,000 ha) in total agricultural land areas (Figure 5b). All other counties (18/20) fall into the categories from 1000 to 10,000 ha under OA (Figure 5b). For instance, in Ličko-senjska County, permanent organic grasslands dominated the majority of OA (>10,000 ha), while organic arable land occupied about 2000 ha (Figure 5c). In general, organic areas in this county are overlapping with the lowest agricultural land use intensity (e.g., application of fertilizers and agrochemicals), and are situated on the naturally-constrained, karstified mountainous terrain with shallow and low-fertility soils [28], suitable for extensive (free-range) livestock production. However, a recent study shows that despite a significant rise in organic karst grasslands and pastures in this region, there has not been a corresponding
increase in livestock production. This suggests that some organic farmers may be more focused on obtaining subsidies for maintaining organic land rather than converting grassland production to the meat e.g., [20], i.e., adding an extra-value to organic grassland farming. In very close Mediterranean organic agroecosystems in Greece, that utilize green fodder, several phenomena have been confirmed [32] after long-term financial policy very similar to that in Croatia (based on the area of land being organically cultivated rather than overall performance). This suggests an unbalanced development of the organic agricultural sector in Greece. The study found that only 10% of the produced organic fodder is needed to meet the demand for organic stock farming, while the remaining 90% is sold as conventional livestock feed rather than organic. This indicates that the introduction of green fodder in organic farming in Greece is primarily motivated by the desire to obtain subsidies, rather than to add value to organic farming practices.

Figure 5. Distribution of organic agricultural land use categories and total areas by national territory (a) and county (b) in Croatia, with a focus on two dominant counties in the Mediterranean (c) and continental (d) regions (Adapted from [28]).

On the contrary, in Osječko-baranjska county arable land accounted for the largest share of OA land areas, with approximately 16,000 ha, dominated by grasslands and pastures (almost 3000 ha), followed by oilseed rape (2100 ha), alfalfa (2000 ha), chamomile...
The category of perennial crops amounted to around 2000 ha, primarily consisting of orchards (Figure 5d). Interestingly, organic areas in this Slavonian county are adjacent to regions with the highest agricultural land use intensity (e.g., fertilization rate, cultivation, irrigation) and are situated on some of the most fertile pedore-sources [28]. In addition, this county belongs to a long-standing agricultural region where farmers have continuously adopted new trends in the agri-food sector [20], including the increasing demand for organic products. These results are opposite to those in Mediterranean Greek organic agroecosystems, which are typically associated with small-scale farming, constrained land resources and limited farmer knowledge [32].

In both mentioned counties with the largest share of OA, the areas under OA have expanded most intensively in the last few years. However, it is very unlikely that this trend will continue in the mid-term period, not only in two dominant counties, but also in the entire territory of Croatia. Although there is substantial financial support, conventional farmers are still facing significant resistance and challenges when attempting to switch to organic farming.

5. Challenges and Perspectives for Organic Agriculture under Climate Change

Throughout history OA farmers have encountered various challenges in terms of expansion and sustainability. One of the main challenges that OA still faces is significantly lower yields compared to conventional agriculture [17] (Figure 1), which poses a significant obstacle for the future expansion of OA, especially with the projected population growth and climate change. However, the agricultural performances between organic and conventional farming particularly those related to yield gap, significantly vary due to numerous agroecological variables [17], and their complex interactions, making the outcomes not always straightforward. For example, while one study [33] found no significant differences in crop yields between leguminous and non-leguminous crops under organic and conventional farming systems, in other conditions it was demonstrated that soybeans, oilseeds, rice, and corn generally exhibit smaller yield gaps between organic and conventional farming compared to wheat, fruits, and vegetables [27,34]. Several factors have a significant impact on the yield gaps between organic and conventional farming, including: (i) soil quality (soils rich in organic matter have better structure and soil-water-air relations, and tend to have smaller yield gaps), (ii) weather conditions (drought greatly reduces yields in both organic and conventional systems, but as explained above, organically-enriched vs. organically-depleted soils are more resistant to drought), (iii) crop rotation (improves soil health and helps in pest/disease management), farmer experience and technology (in developing countries organic farmers often have less experience and resources than conventional farmers) and some others. In addition, all these factors can interact with each other and the yield gap can vary depending on the specific farm and crop. While lower yields may present a challenge for organic farmers in the short-term, the long-term benefits of organic farming, including improved soil health, reduced environmental impact, and greater resilience to climate change, can make it a more sustainable and viable option for farmers in the long-term e.g., [30]. According to the same study it was confirmed that over the long-term, OA outperforms conventional farming in achieving a better balance across four key sustainability goals, including: (i) production (crops yield and quality), (ii) environmental (soil/water quality, biodiversity) sustainability, (iii) economic (profitability, input costs) sustainability, and (iv) overall wellbeing (human health). Similarly, studies conducted in organic agroecosystems in Romania [13] and India [35] have demonstrated that organic systems can be economically efficient compared to conventional, while also reducing environmental impacts and the risks of crop failure and increasing net returns. Eliminating the use of high-carbon footprint agrochemicals in OA production can have significant benefits for the climate and natural resources. Synthetic N, P, K fertilizers, pesticides, and other agrochemicals contribute to degradation soil organic matter loss [36] and water contamination [37], making them key focus areas for future studies aiming to minimize their negative impact. To gain a comprehensive understanding of how OA...
impacts environmental resources, it is essential to prioritize research on quantifying the per-acre effects of eliminating agrochemicals on C emissions from manufacturing, soil organic matter volatilization, and water contamination in specific agroecological contexts. Unlike conventional farming, OA relies less on non-farm energy and resources (e.g., crop rotation, cover crops, animal and/or green manures, compost, and vermi-composts; Figure 1; Table 2), and places greater emphasis on the agroecological capacity of the land, making it more resilient to supply chain disruptions. To overcome the challenge of lower yield in OA, one strategy is to enhance crop varieties that are better suited for organic farming systems (Table 2). Recent developments in plant breeding and genomics have developed some crop varieties with increased yield potential in wheat [38] and vegetables [39], improved stress resistance [40], and disease tolerance [41]. Therefore, in organic farming, breeders should treat specific environmental conditions as a separate environment with a strong local adaptation component, and incorporate necessary traits and selection methods to address genotype × environment interaction [42]. Specifically, research confirms that OA is frequently practiced in agroecosystems with limited resources, such as those found in karstified terrains with shallow, stony soils that are prone to water imbalances and erosion [43], as well as areas with land fragmentation [32]. Moreover, these areas represent valuable niches for the production of highly value-added organic products, including high-quality wines [29], extra virgin olive oil [44], and meat [20]. Unfortunately, up to date OA has received significantly less research and development funding from both public and private sectors compared to conventional systems worldwide, leading to a shortage of crop and livestock breeding for organic farming conditions and a lack of information resources to support organic farmers [30]. Moreover, OA receives less support from governments, particularly in developing countries and in the USA, compared to conventional agriculture, whereas in Europe, the level of support tends to be higher for organic farming [45].

<table>
<thead>
<tr>
<th>Challenge</th>
<th>Solution</th>
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<tbody>
<tr>
<td>Pest and disease management</td>
<td>Crop rotation, Consociation, Natural predators, Physical barriers, Organic pesticides (e.g., neem oil, pyrethrin)</td>
</tr>
<tr>
<td>Postharvest management</td>
<td>Value-added processing (e.g., drying, freezing), Investments in storage capacities</td>
</tr>
<tr>
<td>Nutrient management</td>
<td>Selection of nutrient-more efficient crops/varieties/genotypes Recycling of nutrients obtained from renewables Intensification of cropping pattern with N-fixing crops</td>
</tr>
<tr>
<td>Reduced yield</td>
<td>Development and creation and of higher-yielding genotypes Selection of crops/varieties/genotypes with a higher yield</td>
</tr>
<tr>
<td>Stronger institutional (top-to-bottom) support</td>
<td>Development of national strategies, policies and targets</td>
</tr>
<tr>
<td>Access to the markets</td>
<td>Better promotion of products at local levels (municipality, towns), regional clustering, investments in distribution centers, Urban gardening</td>
</tr>
<tr>
<td>Consumers’ confidence</td>
<td>Education of consumers, Transparency, Certification (logos)</td>
</tr>
<tr>
<td>Certification costs</td>
<td>Group (cluster) certification, Government subsidies, Alternative certification models,</td>
</tr>
<tr>
<td>Climate change</td>
<td>Crop diversity, Agroforestry, Improved water management (modern irrigation systems, conservation agriculture), Improved genotypes, Innovative solutions (organic fertilizers, soil amendments)</td>
</tr>
<tr>
<td>Dispersion and insufficient organization of farmers</td>
<td>Association to bigger entities, farm associations, cooperatives, clusters, Urban gardening</td>
</tr>
<tr>
<td>Lack of knowledge, education and technical capacities</td>
<td>Combination of education, training, and technical assistance for farmers, Increased access to capital</td>
</tr>
<tr>
<td>Depopulation, aging and deagrarianization</td>
<td>Improved population/agricultural policies, increased access to services and infrastructures in rural areas</td>
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</table>
Organic farmers face challenges and obstacles in conducting their business due to discrepancies and frequent changes in regulations, inadequate access to information and clear interpretation of the legislative framework by relevant authorities, as well as significant administrative and technical requirements [23]. Furthermore, OA faces obstacles arising from a lack of knowledge and education [32] under capacitated technical and financial resources [22], as well as misperceptions and cultural biases [30]. Specialized knowledge and skills are required for successful organic farming (Figure 1), and many farmers lack the necessary knowledge to implement organic practices effectively. Interestingly, in Croatia, the majority of organic farmers possess a secondary or higher level of education, indicating that organic farming tends to attract individuals with advanced education [20]. To overcome this obstacle, education and training on organic farming practices and principles (Figure 1) need to be provided to farmers in many countries.

Multiple studies have confirmed that cultivating land in OA requires greater labor intensity compared to conventional methods, which may have positive implications for rural employment and development opportunities [20,46]. However, at the same time this presents a challenge in many rural areas that are already facing issues such as depopulation, aging [20,24], deagrarianization [28], and horizontal non-equity, which impede the further development of OA (Table 2). For example, in 2020 the average age of farm managers in the EU was 57 years, with 69% being men and only 31% being women, while only 20% of farmers were under the age of 44 [24]. To address these issues, different CAP initiatives are planned to provide support for young farmers and generational renewal with at least EUR 8.5 billion by 2027 [24] at the EU level. Furthermore, some member states are allocating additional resources to encourage farm succession, promote gender equality in rural areas, and strengthen horizontal (gender) equality in farming [23].

In many countries worldwide, including Croatia [23], Romania [13], and Greece [32], OA farmers are not well organized and have limited access to the market. For instance, supermarket chains followed by specialized stores are the primary distribution channels for organic products in the European markets [44]. Organic products often command a premium price, but accessing markets for these products can be difficult for small-scale organic farmers. This is due to a variety of factors, such as lack of market information, limited market channels, and certification costs. Namely, a large number of smaller OA entities (e.g., small agricultural holdings), are usually not well associated, which usually increases operational (postharvest, transport) costs, and reduces their competitiveness on the international/regional market. Establishing a local association of organic producers could be a successful solution to this issue. For instance, the bio-districts as an innovative approach for sustainable, integrated and participatory territorial development can be a strong support to OA by: (i) promoting participatory landscape design and adopting agroe-cological system approaches at the field level, (ii) finding and creating solid and equitable local markets, (iii) enhancing land access to potential farmers, (iv) supporting certifications, and (v) enhancing environmental awareness [31]. Furthermore, in urban areas, there is significant potential for promoting organic production through (i) the development of canteens that prioritize organic food and provide organic food vouchers to vulnerable populations, (ii) the implementation of green public procurement practices [47] and (iii) urban gardening. Copenhagen and Vienna serve as notable examples, with Copenhagen being the first city to achieve 100% organic public canteens supplied by approximately 25,000 ha of organic farmland, while Vienna has developed a network of around 860 ha of organic urban gardens, primarily catering to the supply of public canteens [47]. In the Zagreb city area, there are fourteen locations with urban gardens encompassing more than two thousand one hundred fifty plots, primarily dedicated to organic farming on ~23 ha. Urban gardens have proven to be a positive model for the sustainable utilization of urban land, improving the quality of life for citizens in social, economic, and ecological aspects [48,49]. Thus, urban gardening, particularly those practicing organic farming, have the potential to improve access to nutritious food, alleviate financial burdens, foster environmental health, preserve biodiversity, cultivate ecological awareness, establish a
connection with nature, promote a healthy lifestyle, and strengthen collaborations between local government and the community (e.g., Table 2). The concept of urban gardening could help reduce the C footprint associated with food production and distribution. Namely, by growing food locally, urban gardeners minimize transportation emissions and energy consumption typically associated with long-distance food supply chains. Moreover, urban gardens often utilize recycled or locally sourced materials (e.g., compost generated from the bio-waste) [50], reducing environmental impacts and contributing to green bioeconomy. Furthermore, urban gardens provide green spaces in cities [49], contributing to urban cooling and mitigating the urban heat island effect. Vegetation in urban areas helps regulate temperature, reduce air pollution, and improve air quality, creating healthier and more sustainable urban environments in the face of climate change. Overall, urban gardening in conjunction with organic farming can be viewed as a sustainable and climate-friendly practice, which not only fosters local food production and enhances food security but also contributes to the mitigation of climate change (Table 2), addresses public health concerns, and helps in adapting to geopolitical crises in urban environments.

Despite future trends, some challenges such as climate change have become increasingly severe in recent decades and are currently under intensive study. Conventional agri-food production heavily relies on environmental resources like water for irrigation, which is expected to be impacted significantly by climate change due to pronounced water imbalances in agroecosystems. This may make OA more vulnerable to the effects of climate change since it depends on natural pest and disease management and soil health. However, integrating precision agriculture technologies such as advanced sensors [13] and machine learning algorithms via IoT [51,52] can help organic farmers optimize their water management practices and improve yields while minimizing environmental impacts. The use of digital technologies, including big data processing and IoT has been recognized as a promising approach for enhancing productivity and competitiveness in the agri-food business, while also promoting more sustainable use of agro-environmental resources [44]. The use of advanced technologies can also enhance the resilience of organic agriculture to the effects of climate change. Therefore, it is crucial for the agriculture sector to invest in and adopt sustainable technologies to ensure the continued production of healthy and nutritious food while preserving the environment for future generations.

6. Conclusions with Future Research Remarks

Despite a century of intensive growth, organic farming which relies on sustainable and environmentally-friendly methods, still represents a minor agricultural concept, occupying only 1.6% (75 Mha) of total agricultural land areas. However, OA has gained momentum and been incorporated into recent agro-environmental and human health policies and goals, with expectations of further expansion. Unfortunately, OA still faces many old (lower yields, depopulation, aging, deagrarianization, lack of knowledge and support), as well as contemporary (horizontal non-equity, lack of market information, certification costs, regulatory discrepancies, administrative and technical requirements) challenges and obstacles. In the EU, policies and financial supports for organic farming have been focused more on areas under organic agriculture than on overall production performance and value-added products. However, with rising pressures from global climate change and different crises, redesigning policies is necessary to ensure more sustainable OA and food safety and security. Digital technologies, including big data processing coupled with AI, have been recognized as a promising approach to enhancing productivity and competitiveness in the (organic) agri-food business, while promoting more sustainable use of agro-environmental resources. Therefore, decision-makers should seize the opportunity to expand OA, realizing its benefits for all stakeholders, notably farmers and consumers, and address critical challenges to ensure its sustainability and contribute to food safety and security.

Finally, to address some important knowledge gaps in OA, future studies should focus on the following areas:
(i) conducting comparative analyses between organic and conventional farming systems to gain a comprehensive understanding of the benefits and limitations of organic practices in diverse contexts. This research will provide insights for informed decision-making and policy development;

(ii) exploring the value chain derived from OA is crucial. Detailed assessments of market potential, consumer preferences, and economic benefits to farmers will illuminate the dynamics of the value chain. This knowledge can identify opportunities to enhance market competitiveness and profitability for organic farmers; and

(iii) investigating the long-term effects of OA on ecosystem services, biodiversity, environmental pollution, and carbon footprint is essential. These studies should evaluate the sustainability and effectiveness of OA over longer spatial scales, providing valuable insights into the long-term benefits and challenges associated with organic farming.


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