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THE DILEMMAS OF SUSTAINABLE AGRICULTURE – EXTENSIFICATION OF PRODUCTION OR SUSTAINABLE INTENSIFICATION

Key words: sustainable intensification, organic farming, sustainable agriculture, sustainability, European Union

ABSTRACT. The main objective of the research was to determine the potential increase in demand for agricultural land in the European Union countries due to increasing the share of organic production to an average of 25% (assuming that the volume of agricultural production is maintained at the current level). This analysis was carried out against the assumptions of sustainable intensification as an alternative option for building a more sustainable agricultural production system. Based on the literature, established views on the advantages of organic farming were verified, confronting them with the lesser-known concept of sustainable intensification. The simulations' results indicate that, on average, across the EU, the introduction of the required proportion of organic crops would require an increase of 8.2% in agricultural areas and 7.4% in livestock numbers. This leads to the conclusion that sustainable intensification is a more reasonable path towards a more sustainable food production system, which seeks to maximise production efficiency while respecting existing environmental constraints.

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INTRODUCTION

Consciously cultivating plants began more than 23,000 years ago [Snir et al. 2015], although larger-scale farming did not become widespread until around 8,500-7,000 BC [Dawkins and Wong 2004]. The first primary human environmental intervention was the transition from gathering and hunting to agriculture as the main food source [Snir et al. 2015]. Over the years, the scale of this impact has remained small, although locally, primitive tribes were already able to wreak considerable havoc on the ecosystem [Diamond 1991]. The scale of human environmental impacts accelerated significantly with the onset of the Industrial Revolution [Nerilie et al. 2016]. Modern agriculture can intensively impact, among other things, the loss of biodiversity, the disruption of nitrogen and phosphorus cycles, and greenhouse gas emissions [EEA 2019]. In this context, a fundamental challenge is to reduce negative environmental impacts while ensuring food security and safety [van Dijk et al. 2021]. Strategies to address this problem have been under consideration for years, among which the concept of organic farming occupies a special place [Muller et al. 2017]. The European Union (EU), as part of the so-called European Green Deal (EGD), has proposed to cover, on average, at least 25% of the Utilised Agricultural Area (UAA) with organic farming by 2030 [EC 2020a]. Despite some advantages, this system is also controversial [Clark and Tilman 2017], with organic production increasingly being contrasted with "sustainable intensification" (SI) as a way to achieve a more sustainable food production system [Weltin and Hüttel 2022, Ajibade et al. 2023]. One of the critical risks associated with the uptake of an organic production system is the fear of increased demand for agricultural land, which would consequently increase deforestation, leading to negative environmental consequences.

In this context, the main objective of the research was to determine the potential increase in demand for agricultural land in EU countries due to increasing the share of organic production on an EU scale to 25% (assuming that the volume of agricultural production remains unchanged). This analysis was conducted against the assumptions of sustainable intensification as an alternative option for building a more sustainable agricultural production system.

INTENSIFICATION OF AGRICULTURAL PRODUCTION AND POPULATION

Over the 10,000 years preceding our era, the number of people grew from around 4 million to 200 million, and by 1800 AD, it had reached almost 1 billion. A doubling of this number occurred in 1928, and less than 100 years later (in 2022), the Earth was already inhabited by 8 billion people. Available projections indicate that the world's population will continue to increase (albeit at a slower rate) and is likely to exceed

10 billion people before 2080 [UN 2022]. The increase in the global population has translated into human interference with the environment on a scale not previously observed [Oldfield and Dearing 2003]. A significant contributor to this process is agriculture, which, despite many concerns [e.g. Malthus 1798], has successfully increased food production without a commensurate increase in the area used for agriculture. For example, between 1961 and 2020, the agricultural area increased by 6%, the global population increased by 255%, and cereal production increased by as much as 343%. At the same time, however, the global consumption of synthetically derived nitrogen fertilisers, for example, increased almost tenfold, and phosphate and potassium fertilisers more than fourfold. This means that over the period indicated, there has been a significant improvement in land productivity as a result of the intensification process[2] [Ritchie 2021] and the implementation of the so-called "green revolution" programme implemented by FAO in developing countries [Wik et al. 2008, Pingali 2017]. The most positive effect of the intensification of agricultural production is the reduction in global hunger scale[3], despite the world population's rapid growth [Gowdy and Baveye 2018].

NEGATIVE CONSEQUENCES OF THE INTENSIFICATION OF AGRICULTURAL PRODUCTION

The negative consequences of agricultural intensification are mainly evident in processes such as eutrophication of water bodies, excessive greenhouse gas emissions, loss of biodiversity, antibiotic pollution and soil devastation [Moonen and Barberi 2008, EEA 2019]. In the case of the EU, the amount of nitrogen supplied to fields is estimated to be 37% over plant needs and phosphorus by 8% [EEA 2019]. Globally, the contribution of agriculture to marine and ocean eutrophication processes is estimated to be almost 80% [Ritchie et al. 2022]. At the same time, nitrogen losses from mineral fertilisers introduced into the soil by farmers range from 50% to as much as 75% [Galloway et al. 2004, Raun and Johnson 1999, Hirel et al. 2011]. Overfertilisation of soil with nitrogen compounds, leading to groundwater contamination and eutrophication of water bodies, poses a threat to both nature and human health [Galloway and Cowling 2002, Follett et al. 2010, Withers et al. 2014]. At the same time, the economic importance of agriculture declines as the economy develops; for example, in the EU, the sector's contribution to GDP is only

2 Production intensity is defined as the degree of intensity of human activity in the production process and, in the case of agriculture, is measured by the inputs incurred per unit area. Most commonly, agricultural production intensity is assessed by comparing inputs of fertilisers and pesticides [Ziętara and Olko-Bagieńska 1986].

3 Currently, hunger and malnutrition are caused by political factors (including conflict) and social inequalities [Hasell 2018]. At the same time, it is important to note that up to 30-40% of food globally may be lost in different links of the food chain.

about 1.4% [Eurostat 2022a]. A comparison of this value with the environmental burden generated leads to the conclusion that, from an environmental efficiency point of view, it is one of the more carbon-intensive (less efficient) sectors of the economy.

Globally observed environmental changes, particularly the consequences of climate change (rising temperatures, extreme weather events, the spread of pests and diseases), significantly threaten global food security in the long term [Hasell 2018]. Faced with these conditions, scientists and policymakers are increasingly asking how to ensure sufficient food for the growing global population while also meeting the challenges of the need to protect the environment under conditions of increasing production risks and changing consumption patterns (e.g. the rise of meat in the diets of developing countries) [FAO 2021, Loon and Sarkar 2021, Wilks 2022]. Available analyses suggest that there will be an increase in food demand of around 50% by 2050. However, several studies indicate this rate could be even higher [Tilman et al. 2011, Alexandratos and Bruinsma 2012, van Dijk et al. 2021].

KEY PRINCIPLES OF THE PLAN TO INCREASE THE SUSTAINABILITY OF FOOD PRODUCTION IN THE EUROPEAN UNION AND ORGANIC FARMING

The set of possible solutions to improve agricultural sustainability seems quite broad – they include, for example, measures to increase agricultural resilience, reduce food waste, and implement adaptation measures, including, for example, improving soil moisture conservation [EC 2020b, FAO 2021, Loon and Sarkar 2021]. The EU's response to the challenges posed by increasing climate change and progressive environmental degradation has become an economic and social policy concept referred to as the "European Green Deal" (EGD) [EC 2019]. One of the specific strategies encompassing this plan is the "Farm to Fork Strategy", according to which a sustainable European Food System should have a neutral impact on the environment, support climate change mitigation and enhance biodiversity, as well as ensure food security, food safety and the competitiveness of EU agriculture, respecting fair trade principles [EC 2020b]. The objectives of the biodiversity strategy [EC 2020c] also correspond with some of these demands.

One of the crucial assumptions of the cited documents is to allocate at least 25% of the EU's arable land to organic crops on average across the EU by 2030 (different countries have different targets in this respect; e.g. for Poland, it is 7%). For comparison, in 2020, the total area of UAA under organic crops accounted for 9.1% of UAA, corresponding to 14.7 million ha [Eurostat 2022b]. It is worth noting that the importance of organic production, as measured by the share of area under organic cultivation, varies from country to country – the leader in this respect is Austria (more than 25% of UAA with organic crops). In contrast, at the other end of the scale are countries such as Malta, Ireland, Bulgaria, Romania and Poland (with a share of UAA with organic crops of less than 5%).

In the context of calls for an increase in the share of organic farming, it seems reasonable to ask to what extent this production system can meet the expectations placed on sustainable food production and whether it fits in with the global Sustainable Development Goals (SDGs) referred to by the EGD. It is worth noting that among the recommendations in Scientific Opinion No. 8 prepared for the EC, the promotion of sustainable intensification [EC 2020a] was included alongside agroecological measures.

In the public mind, organic farming is often perceived as a production system that is unconditionally environmentally friendly and produces food with high health-promoting qualities [Rana and Paul 2017, Ritchie 2017, Rodriguez-Bermudez et al. 2019, Gundala and Singh 2021]. For many, the main doubt relates to whether organic farming can provide enough food [Reville 2022]. Some authors suggest that it is possible [Badgley et al. 2007, Reganold and Wachter 2016], although other studies emphasise that this would, however, also require adjustments in the structure of agricultural production (e.g. increasing the importance of legumes) as well as in the entire food supply chain (e.g. reducing food waste and wastage and reducing meat consumption) [Muller et al. 2017]. However, many researchers question the production potential of organic farming to ensure food security and the resulting environmental benefits [Tuomisto et al. 2012]. It is also somewhat challenging to provide soils with the right balance of nutrients when mineral fertilisation is abandoned, especially in the absence of livestock production as a source of organic fertiliser [Reimer et al. 2023].

Another concern with the uptake of organic farming is the fear of increased demand for agricultural land (as a result of reduced yields), which could exacerbate nature- and climate-destructive deforestation [Ritchie 2021]. Results from various studies suggest yield reductions for organic farming of 20-25% in experiments and up to 50% under field conditions [Seufert and Ramankutty 2017, Meemken and Qaim 2018]. There is a concern that closing this gap would involve acquiring additional areas for agricultural production. In some studies, authors suggest that the lower yields obtained in organic production may lead to increased production intensity in other regions (also naturally valuable) [Bellora and Bureau 2016]. The threat of territorial expansion of agriculture also carries the risk of further loss of biodiversity, even though organic farming is considered more environmentally friendly due to the non-use of pesticides [Bengtsson et al. 2005, M. Bavec and F. Bavec 2015]. Moreover, agricultural production that promotes greenhouse gas emissions tends to develop on deforested land, so the total cumulative contribution of deforestation to global warming is estimated to be as high as 40% [Pearce 2018].

The decline in yields due to the transition to organic production systems may be of relatively minor importance for regions with poor conditions for agricultural production (where yields are already low). Still, its significance for highly productive agriculture areas may seriously affect aggregate production levels and food security. This could concern Europe, which is already, for example, one of the world's major importers of vegetable oils and soy protein [Qaim et al. 2020, Kuepper and Stravens 2022].

The plant nutrition regime is also problematic - in organic agriculture, nutrients are assumed to be maximally mobilised from soil resources [Kibblewhite et al. 2007], which, with insufficient mineral fertiliser resources, can lead to depletion of the productive potential of soils; moreover, the very process of nutrient release requires mineralisation accompanied by carbon release. Likely, previous analyses of the contribution of agriculture to greenhouse gas (GHG) emissions underestimate the significance of the conversion of natural land to agricultural land (loss of carbon storage potential), so the actual contribution of agriculture to GHG emissions may be as high as 20-25%, about twice as high as indicated by official statistics [Searchinger et al. 2018].

Other potentially positive impacts of organic farming are also quite debatable, as the effect of most of them turns out to be small if the level of environmental burden generated by the farm (production system) is related to the unit of production and not the unit of area. Organic farming often generates lower emissions per hectare, but at the same time, the volume of production achieved is also lower. A meta-analysis of 164 studies using *life cycle assessment* (LCA) by Michael Clark and David Tilman [2017] showed that the environmental impact of organic and conventional agriculture differs depending on the category of burden and the type of agricultural production. Most of the studies analysed showed the superiority of the organic system over the others only for energy consumption (except vegetable production). At the same time, the organic system proved to be more burdensome for the environment in the categories "eutrophication potential" and "acidification potential" (this is related to less control over the transformation processes of organic fertilisers introduced into the soil compared to synthetic fertilisers, which can be applied more precisely) and "soil use". However, it is worth emphasising that, irrespective of the production system, knowledge and the ability to apply inputs correctly play a massive role in reducing the negative impact of agriculture on the environment [Dahan et al. 2014].

There is also some doubt about the widespread belief in the health-promoting properties of organically produced food. Potential risks are associated with increased contamination of organic crops with fungal pathogens, leading to mycotoxin production and human consumption [Riches 2003, Snir et al. 2015]. However, it is emphasised that these issues require further study [Brodal et al. 2016].

In the context of emerging and documented uncertainties mainly related to the risk of expanding agricultural area, the question is increasingly being asked: 'Should we cultivate intensively on a smaller area (with the knowledge that there will be a serious impact on biodiversity in that area), or should we cultivate organically, affecting biodiversity (perhaps to a lesser extent) on a much larger area?' [Ramankutty and Rhemtulla 2012].

In addition to the aforementioned environmental dilemmas, attention should also be paid to the possible social consequences of a potential reduction in crop yields – a decrease in supply may not only reduce the availability of food in the physical sense but also in the economic sense (with the result that prices will rise – important especially for poorer sections of society).

SUSTAINABLE INTENSIFICATION AND ACHIEVING SUSTAINABLE DEVELOPMENT GOALS

The pinnacle form of agricultural evolution became industrial agriculture, which is defined as a system that makes extensive use of inputs of industrial origin [Barlett 1987]. The growing awareness of its negative consequences led to intensification being increasingly contrasted with the practice of extensification, of which organic farming became the primary form. Since the late 1990s, sustainable intensification has been considered an intermediate solution [Pretty 1997]. The critical assumption is the search for a balance between the ecological and economic dimensions in pursuing social (food and other) needs [Pretty 1997]. One of the hallmarks of this concept is the maximisation of eco-efficiency, understood as the ratio of the production effects obtained to the total consumption of material inputs and environmental resources [WBCSD 1995].

The term 'sustainable intensification' was probably originally used to highlight the need to change the nature of sub-Saharan agriculture (characterised by low inputs and low outputs) to show that agricultural intensification can be environmentally friendly to ensure food security [Struik and Kuyper 2017]. Nowadays, the concept can mean both "de-intensification" in high-input farming systems and intensification in the case of farming systems with a productivity gap [Struik and Kuyper 2017]. In the former case, it is a matter of strengthening the environmental dimension (by precisely dosing inputs). At the same time, in the latter, it is a matter of enhancing the economic dimension (avoiding the mistakes made in the process of classically understood intensification). "Agricultural intensification in the sense of sustainable intensification, especially in Europe, is therefore not about using more fertilisers, pesticides and machinery per hectare, but about knowledge-based development and the management of scarce resources to produce food with minimal environmental damage and greater environmental efficiency" [Buckwell et al. 2014, p. 7]. The very term sustainable intensification can evoke contradictory associations. Jules Pretty [1997], who popularised the term, writes, "Intensification became synonymous with agriculture, which inevitably caused great damage to the food production process, while "sustainable" was seen as a term that could be applied to environmentally friendly agriculture. The combination of these terms was an attempt to indicate that the desired goals (more food, better environment) could be achieved by different means".

The main objective of sustainable intensification is to improve resource efficiency in agriculture [Weltin et al. 2018]. In economic terms, an essential assumption of the concept is that agricultural production can be increased by increasing the involvement of the capital factor relative to the land factor but without increasing the negative environmental impact [Buckwell et al. 2014]. The concept has already been described in depth in the theoretical layer [Pretty 1997, Buckwell et al. 2014, Pretty and Bharucha 2014]. Still, there is a lack of empirical studies that provide evidence of the superiority of this approach over other systems. Relatively few studies attempting an in-depth analysis of the concept in the context of empirical data include the study by Jakub Staniszewski and Andrzej Czyżewski [2019] or analyses referring to the related idea of eco-efficiency [Sulewski et al. 2020]. Table 1 compares the basic assumptions of sustainable intensification against organic and conventional production systems.

Table 1. Dominant assumptions/motivations in key aspects

Aspect (dimension of the characteristic)	Production system		
	conventional	ecological	sustainable intensification
Economical	profit maximisation	maximisation of margins through higher prices, usually higher financial support	maximising eco-efficiency
Manufacturing	maximising yields to the limit of the economic optimum, large-scale production	minimisation of industrial inputs	maximising unit efficiency, minimising waste of all inputs (industrial and environmental)
Environmental	secondary importance in practice, high emissions (environmental costs)	crucial in assumptions, debatable in practice, and risk of increasing the agricultural area	conscious and precise use of resources, minimising emissions per unit of output
Social	high potential to meet world food needs, relatively low food prices, high food availability	less potential to meet food needs, high prices, risk of reduced access to food for poorer sections of society	production potential similar to conventional agriculture through more efficient use of inputs
Required competencies	small, low precision	high, low precision	high, high precision

Source: own elaboration based on the literature cited above

From a global point of view, agricultural intensification, understood as a better utilisation of the soils' potential, can contribute better to the social objectives of sustainable development (access to food as a basis for quality of life considerations) and the environmental objectives (lower unit emissions of greenhouse gases and pollutants, reduced deforestation, better utilisation of nutrients) than extensification of production. It is worth noting that the implementation of the concept of "sustainable intensification" is increasingly linked to the idea of "smart agriculture", which emphasises the importance of knowledge and modern technologies in meeting the environmental, social and economic challenges facing the food system [Tilman et al. 2011, Pretty and Bharucha 2014, 2021].

SIMULATING THE IMPACT OF PLANNED CHANGES IN THE SHARE OF ORGANIC PRODUCTION IN EUROPEAN UNION COUNTRIES

To illustrate the potential impact of increasing the share of organic production in EU countries to the level postulated in the EGD, a simulation of the changes in Utilised Agricultural Area (UAA) and animal stock required to keep agricultural production unchanged was carried out. At the same time, a simulation was carried out to illustrate the possible reduction in UAA area and animal stock as a result of abandoning organic farming. To estimate potential changes in the UAA, and animal stock, the existing share of organic farming in the different EU countries and the differences in productivity between organic and conventional farming were taken into account. Given the availability of statistical data, differences in productivity between conventional and organic farming were assumed to be estimated:

- for crop production based on the difference in wheat yields grown using both methods [Caldbeck and Sumption 2016, Eurostat 2023a],
- for livestock production based on the difference in milk yields of cows kept on conventional and organic farms across EU countries [Eurostat 2023b].

The approach used is undoubtedly a simplification, but in the absence of precise data indicating differences in production efficiency between systems, using approximants based on two essential products appears to be an approach that minimises the error of the estimates made. The underlying data adopted for the estimates are shown in Table 2.

Under the assumption of keeping the volume of total agricultural production unchanged, the potential changes in the UAA and animal stock that would result from increasing the share of organic production to 25% were determined (the share of UAA in plant activities and the share of animals in the stock expressed in LU (large livestock units) were used as a measure of the increase in organic production). In most countries, meeting the EU targets would require a significant increase in the area of UAA (Figure 1). The exception is Austria, where the share of organic production required by the EU has already been achieved.

Table 2. Share of organic production and adopted differences in production efficiency in EU countries in 2022

Countries	Percentage of organic farming [%] UR]	Wheat yield [tonnes/ha]		Percentage of organic animals [% DJP]	Cow milk yield [litres/year]	
		conventional	ecological		conventional	ecological
Austria	26.13	5.93	4.48	11.13	7,341	5,577
Belgium	7.24	8.95	6.76	2.54	8,354	5,582
Bulgaria	2.55	4.01	3.03	0.88	4,156	4,156
Croatia	7.21	5.87	4.43	2.28	5,564	3,701
Cyprus	4.41	2.67	2.02	0.61	8,797	8,211
Czech Republic	15.47	6.14	4.64	7.28	9,154	4,411
Denmark	11.41	8.10	6.12	6.75	10,028	9,235
Estonia	22.64	5.00	3.78	7.98	10,071	4,908
Finland	13.86	3.46	2.61	4.13	9,414	7,830
France	9.20	6.68	5.04	4.03	7,719	7,217
Germany	9.59	7.82	5.90	3.54	8,464	5,447
Greece	13.65	3.08	2.33	26.77	8,556	6,987
Hungary	6.12	5.47	4.13	0.91	8,187	4,184
Ireland	1.52	7.76	5.86	0.57	5,880	2,805
Italy	16.73	3.92	2.96	3.62	7,219	6,929
Latvia	14.79	5.34	4.03	10.96	7,278	4,991
Lithuania	8.08	5.39	4.07	3.93	6,405	5,425
Luxembourg	4.63	6.07	4.58	1.63	8,308	6,679
Netherlands	3.94	8.56	6.46	1.76	9,517	7,891
Poland	3.44	5.23	3.95	0.25	6,977	2,445
Portugal	8.06	2.77	2.09	2.62	9,019	6,022
Romania	3.67	2.97	2.24	0.42	3,888	2,815
Slovakia	11.97	5.52	4.17	6.60	7,616	4,157
Slovenia	10.30	5.80	4.38	4.17	6,382	3,701
Spain	10.19	4.25	3.21	1.47	10,714	6,022
Sweden	20.31	7.16	5.41	11.41	9,109	8,414

Source: own compilation based on Eurostat data [Eurostat 2023a,b]

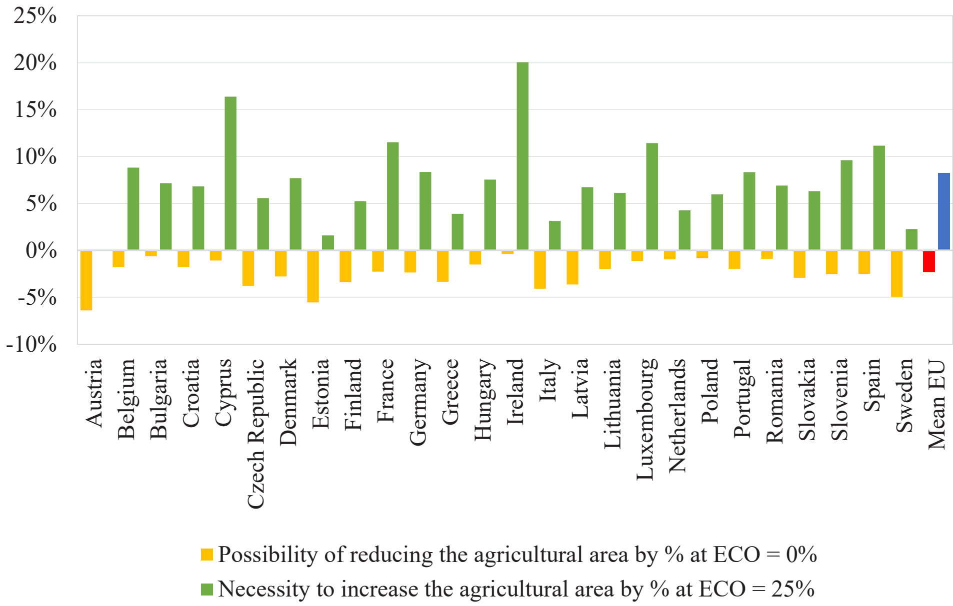

Figure 1. Changes in UAA demand if organic production is increased/discontinued in EU countries

Source: own elaboration

In the remaining countries, introducing the required share of organic crops would require an increase in the EU's UAA area of 8.2% on average. In comparison, analyses by Silvia-Elena Cristache et al. [2018] show that a 1% increase in organic area could result in a 0.278% decrease in production. Assuming an increase in this area to 25%, this could mean a reduction in production of around 7%. Therefore, the simulation results presented in the article are similar to the estimates of other authors. Increasing the area of UAA in European countries is highly debatable (the area of UAA has been decreasing in recent years), but implementing such a plan could only take place by reducing the area of non-agricultural areas and forests. On the other hand, abandoning the idea of organic farming and reverting to conventional agriculture would make it possible to increase production efficiency and thus possibly dedicate, on average, 2.3% of the UAA to environmental purposes while maintaining the same level of total agricultural production.

Keeping the volume of livestock production unchanged if the EU's assumed share of animals in the organic system is implemented would mean that the livestock population would have to be increased by a few to several percent (Figure 2). The possible effects of implementing changes in this respect depend on the existing share of animals in the organic production system and the differences in productivity between countries.

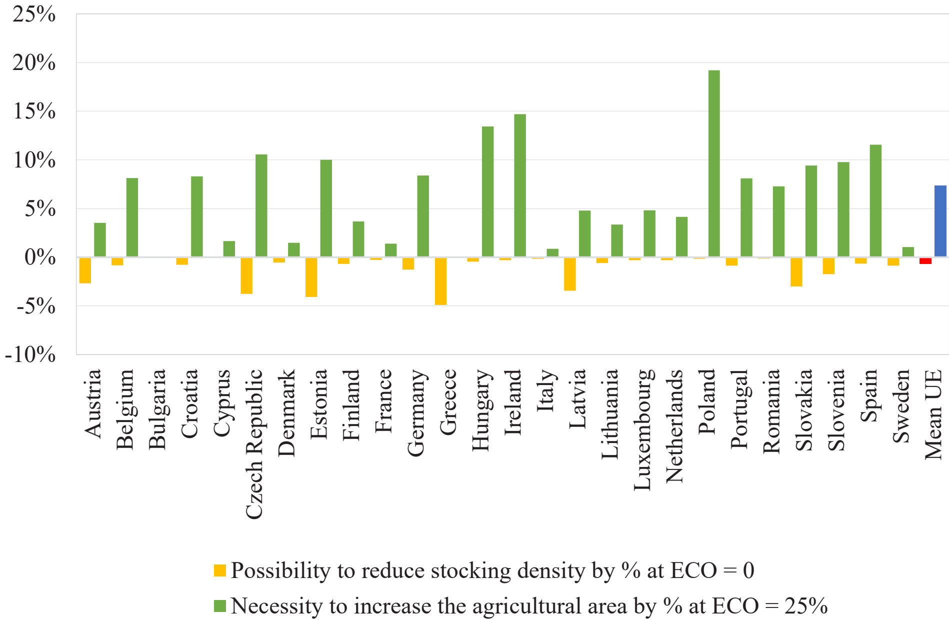

Figure 2. Changes in livestock numbers if organic production is increased/discontinued in EU countries

Source: own elaboration

Only Greece meets the 25% stocking rate requirement for animals kept in organic production. In most other countries, maintaining production at the current level would entail increasing livestock numbers. The exception is Bulgaria, where, due to the lack of differences in productivity, possible changes in the proportion of animals on organic farms do not necessitate an increase in animal stocking rates. In Poland, due to the low proportion of animals on organic farms, compensating for the lower productivity would require an increase in animal stock by nearly 20%. In the EU, an average increase in animal stock (expressed in LU) to compensate for lower productivity in the organic farming system would entail an increase of 7.4%. Abandoning organic methods in livestock production would allow an EU-wide reduction in livestock numbers of 0.7%. The issue of changes in livestock production was presented differently by the authors of a report prepared by IFOAM [Lampkin and Pade 2022]. Their analysis shows that an increase in the share of organic acreage to the extent assumed would result in a reduction in livestock numbers of around 11% (taking into account the share of organic farming from 2020), which, according to the authors of the report, would, however, reduce the demand for feed and increase the acreage available for the production of consumer crops, thereby limiting the decline in crop production.

CONCLUSIONS

The literature review has revealed that, regardless of the production system, agricultural activities involve interference with the natural environment, transforming natural ecosystems into agricultural ecosystems. According to available analyses, further deforestation would have catastrophic consequences for halting global climate change. It seems rational, therefore, to aim for the most efficient use of land that has already been incorporated into the agricultural landstock. Most studies indicate that organic farming means much lower production per unit area, which, given the globally growing demand for food, must generate pressure to find new cultivated areas. Even if food waste were significantly reduced, the estimated increase in food demand would be greater than the potential savings. Many analyses indicate that the scale of the positive impacts of organic farming is much smaller than is commonly believed. In this context, the drive to significantly increase the area of organic farming in the EU is questionable. While it is true that the direction of demographic change in the case of the EU (population decline) may justify such a move, it seems doubtful that this would serve the global goals of sustainable development. The contemporary agri-food market is in many respects global, which means that even if the EU is self-sufficient in most basic product categories, a local reduction in production volume may destabilise the situation on other markets (price increases, reduced availability, pressure to increase production).

The presented results of the simulation indicate that maintaining the current volume of agricultural production while increasing the share of the organic system to 25% of the agricultural land and livestock would require a simultaneous increase in the total agricultural area in the EU by over 8% and the livestock population by almost 7.5%. Considering that the total agricultural area in the EU is about 154.7 million ha, this would mean that an additional 12.6 million ha would have to be added (in comparison, the agricultural area in Poland needs to be about 2.2 million ha larger at 14.8 million ha).

Therefore, there are many uncertainties to bear in mind when discussing the role of organic farming in transforming the agricultural sector towards a more sustainable food production system. Some of the literature suggests that sustainable intensification (which is not a solution as well-known and supported as organic farming) is a more legitimate pathway to achieve this goal. According to this concept, intensive agricultural production based on scientific knowledge can be less harmful to the environment than a low-yielding extensive system. This approach's key premise is to maximise production efficiency while respecting existing environmental constraints. It is an alternative approach to organic farming, in which the dominant motive is to reduce inputs per unit area (extensification), which generates the risk of agriculture appropriating further areas of natural value.

An approach based on sustainable intensification appears to be the most appropriate for an integrated farming system, as it emphasises the possibilities of using different production techniques while aiming to improve "sustainbility". At the same time, the possibilities for its practical use are increasing as technological advances, expressed in the concept of "smart farming", become more widespread.

BIBLIOGRAPHY

Alexandratos Nikos, Jelle Bruinsma. 2012 *World Agriculture Towards 2030/2050: The 2012 Revision*. Rome: FAO.

Badgley Catherine, Ivette Perfecto, Kenneth Cassman, Jim Hendrix. 2007. Can organic agriculture feed the world? *Agriculture and Food Systems* 22 (2): 80-85.

Barlett Peggy F. 1987. Industrial agriculture in evolutionary perspective. *Cultural Anthropology* 2 (1): 137-154.

Bavec Martina, Franc Bavec. 2015 Impact of organic farming on biodiversity. [In] *Biodiversity in ecosystems – linking structure and function*, eds. Yueh-Hsin Lo, Juan A. Blanco and Shovonlal Roy. Licensee IntechOpen. DOI: 10.5772/58974.

Bellora Cecilia, Christophe Bureau. 2016. *How green is organic ? Indirect effects of making EU agriculture greener* (Presented at the 19th Annual Conference on Global Economic Analysis, Washington DC, USA). Purdue University, West Lafayette. Global Trade Analysis Project (GTAP), https://www.gtap.agecon.purdue.edu/resources/res_display.asp?RecordID=5003.

Bengtsson Janne, Johan Ahnström, Ann-Christin Weibull. 2005. The effects of organic agriculture on biodiversity and abundance: A meta-analysis. *Journal of Applied Ecology* 42: 261-269. DOI: 10.1111/j.1365-2664.2005.01005.

Brodal Guro, Ingerd S. Hofgaard, Gunnar S. Eriksen, Aksel Bernhoft, Leif Sundheim. 2016. Mycotoxins in organically versus conventionally produced cereal grains and some other crops in temperate regions. *World Mycotoxin Journal* 9 (5): 1-16. DOI: 10.3920/WMJ2016.2040.

Buckwel Allan, Andreas Nordang, Annabelle Williams, Jana Polakova, Winfried E.H. Blum, Jasmin Schiefer, Georg J. Lair, Alois Heissenhuber, Peter Schiepi, Christine Kramer, Wolfgang Haber. 2014. *Sustainable intensification of European agriculture*. A review sponsored by the RISE Foundation, https://ieep.eu/wp-content/uploads/2022/12/111120_BROCH_SUST_INTENS_DEF.pdf, access: 10.12.2023.

Caldbeck Janie, Phil Sumption. 2016. Mind the gap – exploring the yield gaps between conventional and organic arable and potato crops. *Organic Research Center Bulletin* 121: 1-4, https://orgprints.org/id/eprint/31232/1/Mind20the20gap20-20Bulletin2012120colour.pdf, access: 12.08.2023.

Clark Michael, David Tilman. 2017. Comparative analysis of environmental impacts of agricultural production systems, agricultural input efficiency, and food choice. *Environmental Research Letters* 12 (6): 1-11. DOI: 10.1088/1748-9326/aa6cd5.

Cristache Silvia-Elena, Mariana Vuta, Erika Marin, Sorin-Iulian Cioaca, and Mihai Vufa. 2018. Organic versus conventional farming – a paradigm for the sustainable development of the European countries. *Sustainability* 10 (11): 4279. DOI: 10.3390/su10114279.

Czyżewski Andrzej, Jakub Staniszewski. 2019. *Rolnictwo Unii Europejskiej w procesie zrównoważonego intensyfikacji* (European Union agriculture in the process of sustainable intensification). Warszawa: PWN.

Dahan Ofer, A. Babad, Naftali Lazarovitch, Efrat Eliani Russak, Daniel Kurtzman. 2014. Nitrate leaching from intensive organic farms to groundwater. *Hydrology and Earth System Sciences* 18: 333-341. DOI: 10.5194/hess-18-333-2014.

Dawkins Richard, Wong Yan. 2004. *The ancestor's tale: A pilgrimage to the dawn of life*. Boston: Houghton Mifflin Harcourt.

Diamond Jared. 1991. *The third chimpanzee: The evolution and future of the human animal.* United Kingdom: Hutchinson Radius.

EC (European Commission). 2019. Communication from the Commission to the European Parliament, the European Council, the Council, the European Economic and Social Committee and the Committee of the Regions. *The European Green Deal*. Brussels, 11.12.2019, COM(2019) 640 final, https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=COM3A20193A6403AFIN, access: 12.08.2023.

EC (European Commission). 2020a. *Towards a sustainable food system. Moving from food as a commodity to food as more of a common good.* Independent expert report. Luxembourg, https://op.europa.eu/en/publication-detail/-/publication/ca8ffeda-99bb-11ea-aac401aa75ed71a1/language-en, access: 12.08.2023.

EC (European Commission). 2020b. Communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions. *A Farm to Fork Strategy for a fair, healthy, environmentally-friendly food system.* Brussels, COM/2020/381 final, https://eur-lex.europa.eu/legal-content/PL/TXT/HTML/?uri=CELEX:52020DC0381, access: 12.08.2023.

EC (European Commission). 2020c. Communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions EU. *Biodiversity Strategy for 2030. Bringing nature back into our lives.* Brussels, COM/2020/380 final, https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=celex3A52020DC0380. access: 12.08.2023.

EEA (European Enviromental Agency). 2019. *The European environment – state and outlook 2020: Knowledge for transition to sustainable Europe*. Luxembourg: Publications Office of the European Union.

Eurostat. 2022a. *Eurostat statistics explained. Performance of the agricultural sector*, https://ec.europa.eu/eurostat/statistics-explained/index.php?title=Performance_of_the_agricultural_sector, access: 10.0.8.2023.

Eurostat. 2022b. *Organic farming statistics*, https://ec.europa.eu/eurostat/statistics-explained/index.php?title=Organic_farming_statistics#cite_note-3, access: 12.08.2023.

Eurostat. 2023a. *Crop production in EU standard humidity*, https://ec.europa.eu/eurostat/databrowser/view/apro_cpsh1__custom_9670284/default/table?lang=en, access: 12.08.2023.

Eurostat. 2023b. *Raw milk, total available* on farms, https://ec.europa.eu/eurostat/databrowser/view/apro_mk_farm/default/table?lang=en&category=agr.apro.apro_anip.apro_mk, access: 16.08.2023.

FAO (The Food and Agriculture Organization of the United Nations). 2021. *How to feed the world in times of pandemics and climate change? Opportunities for innovation in livestock systems*. Rome: FAO. DOI: 10.4060/cb2913en.

Follett Jennifer R., Ronald F. Follett, William C. Herz. 2010. Environmental and human impacts of reactive nitrogen. [In] *Advances in nitrogen management for water quality*, eds. Jorge A. Delgado, Ronald F. Follett. 1-37. Soil and Water Conservation Society.

Galloway James, Ellis B. Cowling. 2002. Reactive nitrogen and the world: 200 years of change. *Ambio* 31 (2): 64-71. DOI: 10.1579/0044-7447-31.2.64.

Galloway James, Frank. Dentener, D.G. Capone, Elizabeth W. Boyer, Robert W. Howarth, et al. 2004. Nitrogen cycles: Past, present, and future. *Biogeochemistry* 70: 153-226. DOI: 10.1007/s10533-004-0370-0.

Gowdy John Malcolm, Philippe Baveye. 2018. An evolutionary perspective on industrial and sustainable agriculture. [In] *Agroecosystem diversity: Reconciling contemporary agriculture and environmental quality*, ed. Gilles Lemaire. Amsterdam: Elsevier.

Gundala Raghava R., Anupam Singh. 2021. Wat motivates consumers to buy organic foods? Results of an empirical study in the United States. *PLoS One* 16 (9): e0257288. DOI: 10.1371/journal.pone.0257288.

Gustavsson Jenny, Christel Cederberg, Ulf Sonesson, Robert van Otterdijk, Alexandre Meybeck. 2011. *Global food losses and food waste – extent, causes and prevention*. Rome: FAO.

Hasell Joe. 2018: *Why do far fewer people die in famines today? Our World in data*, https://ourworldindata.org/why-do-far-fewer-people-die-in-famines-today, access: 12.08.2023.

Hirel Bertrand, Thierry Tetu, Peter J. Lea, Frederic Dubois. 2011. Improving nitrogen use efficiency in crops for sustainable agriculture. *Sustainability* 3: 1452-1485. DOI: 10.3390/su3091452.

Kibblewhite Mark, Karl Ritz, Mike J. Swift. 2007. Soil health in agricultural systems. *Philosophical Transactions of the Royal Society B, Biological Sciences* 363 (1492): 685-701. DOI: 10.1098/rstb.2007.2178.

Kuepper Barbara, Manon Stravens. 2022. *Mapping the European soy supply chain embedded soy in animal products consumed in the EU27+UK*. Amsterdam: Profundo.

Lampkin Nicolas, Katrin Pade. 2022. *Environmental impacts of achieving the EU's 25% organic land by 2030 target: A preliminary assessment*. Report for IFOAM Organics Europe. Brussels: IFOAM.

Loon Gary W., Atanu Sarkar. 2021. Feeding the world in a time of climate change. *Chemistry International* 43 (1): 14-20. DOI: 10.1515/ci-2021-0104.

Meemken Eva-Marie, Matin Qaim. 2018. Organic agriculture, food security, and the environment. *Annual Review of Resource Economics* 10: 39-63. DOI: 10.1146/annurev-resource-100517-023252.

Moonen Anna Camilla, Paolo Barberi. 2008. Functional biodiversity: An agroecosystem approach. *Agriculture, Ecosystems and Environment* 127 (1-2): 7-21. DOI: 10.1016/j.agee.2008.02.013.

Muller Adrian, Christian Schader, Nadia El-Hage Scialabba, Judith Bruggemann, Anne Isensee, et al. 2017. Strategies for feeding the world more sustainably with organic agriculture. *Nature Communications* 8 (1): 1290. DOI: 10.1038/s41467-017-01410-w.

Nerilie J. Abraham, Helen V. McGregor, Jessica E. Tierney, Michael N. Evans, Nicholas P. McKay, Darrell S. Kaufman. 2016. Early onset of industrial-era warming across the oceans and continents. *Nature* 536: 411-418. DOI: 10.1038/nature19082.

Oldfield Frank, John A. Dearing. 2003. The role of human activities in past environmental change. [In] *Paleoclimate, global change and the future. Global change. The IGBP Series*, ed. Keith D. Alverson, 143-168. Berlin: Springer.

Pearce Fred. 2018. Rivers in the sky: How deforestation is affecting global water cycles. *Yale Environment* 360, https://e360.yale.edu/features/how-deforestation-affecting-global-water-cycles-climate-change, access: 12.08.2023.

Pingali Prabhu L. 2017. The green revolution and crop biodiversity. [In] *Handbook of agricultural biodiversity*, eds. D. Hunter, L. Guarino, C. Spillane, P.C. Mckeown. New York: Routledge.

Pretty Jules. 1997. the sustainable intensification of agriculture. *Natural Resources Forum* 21 (4): 247-256. DOI: 10.1111/j.1477-8947.1997.tb00699.x.

Pretty Jules, Zareen Pervez Bharucha. 2014. Sustainable intensification in agricultural systems. *Annals of Botany* 114 (8): 1571-1596. DOI: 10.1093/aob/mcu205.

Qaim Matin, Kibrom T. Sibhatu, Hermanto Siregar, Ingo Grass. 2020. Environmental, economic, and social consequences of the oil palm boom. *Annual Review of Resource Economics* 12: 321-344. DOI: 10.1146/annurev-resource-110119-024922.

Ramankutty Navin, Jeanine M. Rhemtulla. 2012. Can intensive farming save nature? *Frontiers in Ecology and the Environment* 10 (9): 455-455. DOI: 10.2307/41811840.

Rana Jyoti, Justin Paul. 2017. Consumer behaviour and purchase intention for organic food: A review and research agenda. *Journal of Retailing and Consumer Services* 38: 157-165. DOI: 10.1016/j.jretconser.2017.06.004.

Raun William R., Gordon V. Johnson. 1999. Improving nitrogen use efficiency for cereal production. *Agronomy Journal* 91 (3): 357-363. DOI: 10.2134/agronj1999.00021962009100030001x.

Reganold John, Jonathan Wachter. 2016. Organic agriculture in the twenty-first century. *Nature Plants* 2: 15221. DOI: 10.1038/nplants.2015.221.

Reimer Marie, Myles Oelofse, Dorette Müller-Stöver, Kurt Moller, Else K. Bünemann, Silvia Bianchi, Airi Vetemaa, Dora Drexler, Bence Trugly, Ben Raskin, Hugh Blogg, Anton Rasmussen, Vincenzo Verrastro, Jakob Magid. 2023. Sustainable growth of organic farming in the EU requires a rethink of nutrient supply. *Nutrient Cycling in Agroecosystems.* Open access (2023). DOI: 10.1007/s10705-023-10297-7.

Reville William. 2022. *The big problem with organic farming is it cannot produce enough food to feed the world's population*, https://www.irishtimes.com/science/2022/09/01/the-big-problem-with-organic-farming-is-it-cannot-produce-enough-food-to-feed-the-worlds-population/, access 12.08.2023.

Riches Eleanor. 2003. *Organic food – the hazard of mycotoxins.* CABI News, https://www.cabidigitallibrary.org/do/10.5555/collection-news-11833/full/#Organic20Food20E2809320The20Hazard20of20Mycotoxins, access: 12.08.2023.

Ritchie Hannah. 2017. *Is organic really better for the environment than conventional agriculture?* https://ourworldindata.org/is-organic-agriculture-better-for-the-environment, access: 12.08.2023.

Ritchie Hannah. 2021. *Can we reduce fertilizer use without sacrificing food production?* https://ourworldindata.org/reducing-fertilizer-use, access: 12.08.2023.

Ritchie Hannah, Pablo Rosado, Max Roser. 2022. *Environmental impacts of food production*, https://ourworldindata.org/environmental-impacts-of-food, access: 12.08.2023.

Rodriguez-Bermudez Ruth, Ramiro Fouz, Marta Miranda, Inmaculada Oijales, Antonio Minervino, Marta Lopez-Alonso. 2019. organic or conventional dairy farming in northern Spain: Impacts on cow reproductive performance. *Reproduction in Domestic Animals* 54 (5): 902-911. DOI: 10.1111/rda.13446.

Searchinger Timothy D., Stefan Wirsenius, Tim Beringer, Patrice Dumas. 2018. Assessing the efficiency of changes in land use for mitigating climate change. *Nature* 564: 249-253.

Seufert Verena, Navin Ramankutty. 2017. Many shades of gray – the context-dependent performance of organic agriculture. *Science Advances* 3 (3): 1-14. DOI: 10.1126/sciadv.1602638.

Snir Ainit, Dani Nadel, Iris Groman-Yarolavski, Yoel Melamed, MArcelo Sternberg, Ofer Bar-Yosef, Ehud Weiss. 2015. The origin of cultivation and proto-weeds, long before neolithic farming. *PLoS ONE* 10 (7): e0131422. DOI: 10.1371/journal.pone.0131422.

Struik Paul, Thom Kuyper. 2017. Sustainable intensification in agriculture: the richer shade of green. A review. *Agronomy for Sustainable Development* 37: 39. DOI: 10.1007/s13593-017-0445-7.

Sulewski Piotr, Adam Wąs, Anna Kłoczko-Gajewska, Paweł Kobus, Kinga Pogodzińska, Marlena Gołas. 2020. *Ekoefektywność towarowych gospodarstw rolnych w Polsce* (Eco-efficiency of commercial farms in Poland). Warszawa: SGGW Publishing House.

Tilman David, Christian Balzer, Jason Hill, Belinda L. Befort. 2011. Global food demand and the sustainable intensification, of agriculture. *PNAS* 108 (50): 20260-20264. DOI: 10.1073/pnas.1116437108.

Tuomisto Hanna L., Ian D. Hodge, Philip Riordan, David W. Macdonald. 2012. Does organic farming reduce environmental impacts? A meta-analysis of European research. *Journal of Environmental Management* 112: 309-320. DOI: 10.1016/j.jenvman.2012.08.018.

United Nations (United Nations, UN). 2022. *World population prospects 2022. Summary of results*. New York: United Nations.

Van Dijk Michiel, Tom Morley, Marie Luise Rau, Yashar Saghai. 2021. A meta-analysis of projected global food demand and population at risk of hunger for the period 2010-2050. *Nature Food* 2: 494-501. DOI: 10.1038/s43016-021-00322-9.

WBCSD (World Business Council for Sustainable Development). 1995. *Eco-efficient leadership for improved economic and environmental performance*. WBCSD.

Weltin Meike, Silke Hüttel. 2022. Sustainable intensification farming as an enabler for farm eco-efciency? *Environmental and Resource Economics* 84: 315-342. DOI: 10.1007/s10640-022-00718-6.

Weltin Meike, Ingo Zasada, Annette Piorr, Marta Debolini, Ghislain Geniaux, Olga Moreno Perez, Laura Scherer, Lorena Tudela Marco, Catharina J.E. Schulp. 2018. Conceptualising fields of action for sustainable intensification – a systematic literature review and application to regional case studies. *Agriculture, Ecosystems & Environment* 257: 68-80. DOI: 10.1016/j.agee.2018.01.023.

Wik Mette, Prabhu Pingali, Sumiter Brocai. 2008. *Global agricultural performance: Past trends and future prospects*. Washington, DC: World Bank.

Wilks Jeremy. 2022. *Agriculture vs. climate change: can we feed the world with a warmer planet?* https://www.euronews.com/green/2022/07/01/agriculture-vs-climate-change-can-we-feed-the-world- with-a-warmer-planet, access: 12.08.2023.

Withers Paul J. A., Colin Neal, Helen P. Jarvie, Donnacha G. Doody. 2014. Agriculture and eutrophication: Where do we go from here? *Sustainability* 6 (9): 5853-5875. DOI: 10.3390/su6095853.

Ziętara Wojciech, Teresa Olko-Bagieńska. 1986. *Zadania z analizy dzialalnosci gospodarczej i planowania w gospodarstwie rolniczym* (Tasks related to business analysis and planning on a farm). Warszawa: PWRiL.

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DYLEMATY TRWAŁEGO ROLNICTWA – EKSTENSYFIKACJA PRODUKCJI CZY ZRÓWNOWAŻONA INTENSYFIKACJA

Słowa kluczowe: zrównoważona intensyfikacja, rolnictwo ekologiczne, trwałe rolnictwo, zrównoważony rozwój, Unia Europejska

ABSTRAKT. Głównym celem badań było określenie potencjalnego wzrostu zapotrzebowania na grunty rolne w krajach Unii Europejskiej w efekcie zwiększenia udziału produkcji ekologicznej do przeciętnie 25% (przy założeniu utrzymania wolumenu produkcji rolniczej na aktualnym poziomie). Analizę przeprowadzono na tle założeń koncepcji zrównoważonej intensyfikacji, jako alternatywnej opcji dla budowy bardziej zrównoważonego systemu produkcji rolnej. Na podstawie literatury dokonano weryfikacji utartych poglądów na temat zalet rolnictwa ekologicznego, konfrontując je z mniej znaną koncepcją zrównoważonej intensyfikacji. Wyniki przeprowadzonych symulacji wskazują, że wprowadzenie wymaganego udziału upraw ekologicznych wymagałoby przeciętnie w skali UE zwiększenia powierzchni użytków rolnych o 8,2%, a pogłowia zwierząt o 7,4%. Prowadzi to do wniosku, że bardziej uzasadnioną ścieżką w kierunku trwalszego (ang. *sustainable*) systemu produkcji żywności jest zrównoważona intensyfikacja, której istotą jest dążenie do maksymalizacji efektywności produkcji, przy poszanowaniu istniejących ograniczeń środowiskowych.

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