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Potential Changes in Land Use and Plant Production in Poland in the Context of Implementing the European Green Deal

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Abstract

The purpose of this paper is to identify the potential changes in agricultural land use in Poland as a consequence of implementing the European Green Deal, including its potential economic effects. The study covered crops of key importance to Polish agriculture, cultivated in a total area of 8.2 million ha, which accounts for more than 60% of land in good agricultural condition. The analyses were based on average values for 2016–2020 and used three scenarios for EGD implementation by 2030 (no EGD; partial implementation of the EGD; full implementation of the EGD). Each analysis took account of changes in the area of land under conventional, organic and precision farming systems. The study found that EGD requirements can be met by implementing the precision farming system, especially for intensive farming schemes like rape and sugar beet. Organic farming should be used either for extensively farmed cereals like oat or for fruits which are sold at higher prices when farmed organically. Another finding is that the full implementation of the EGD could decrease the production volume of key Polish crops by 13%, which can have important social impacts, such as increased prices of food products or a deterioration of food security.

Keywords: European Green Deal, Polish agriculture, land use, economic impacts, agricultural production efficiency

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Introduction

The European Green Deal (EGD) is the EU's new comprehensive strategy for sustainable development which spans all social, economic and environmental domains and is committed to making the Community climate-neutral by 2050.[1] Agricultural production, processing, food economics, eco-

1. See: 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. COM/2019/640 final.

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system services, and removals of greenhouse gases resulting from land use are some of the aspects that make nearly all parts of the EGD directly or indirectly related to agriculture. The following strategies will have the greatest impact on the agricultural sector:

- farm-to-fork (FtF): creating a fair, healthy and environmentally-friendly food system,[2] and
- protecting and restoring ecosystems and biodiversity.[3]

FtF attempts to solve the dilemmas that have long challenged agricultural production. Indeed, agriculture deals with a series of specific conditions, including contradictions unknown to industrial and service sectors (economic, environmental and social issues). First, agricultural production is necessary and non-postponable since it delivers basic and strategic products. Second, it requires large areas of land as it relies on biological growth processes. Third, the production volume depends on the current environmental condition and resource availability, whereas the demand for food is driven by population size and diet type. Fourth, the natural conditions of production vary across the world, which stimulates (if not requires) international trade. As a consequence of these aspects, agricultural production depends on environmental conditions (mainly on soil fertility and local climate) on the one hand, and has considerable (either positive or negative) impacts on the environment on the other.

From the point of view of the development potential of basic production units (i.e., farms, in the agricultural context), the interactions between agriculture and the environment need to be split into three essential groups. The first one includes cases where the farmers' microeconomic interest is consistent with the general social interest. This mostly relates to caring about soil quality and water resources which, as the basic productive input, should be delivered to the next generations in a condition no worse than when it was inherited by the current generation (Fayet et al. 2022; Montanarella and Panagos 2021). In this case, state intervention should first of all include creating and transferring knowledge on soil science, agricultural practices and agri-environmental practices. In turn, the second category includes areas where there is a contradiction between the producers' and the general social interests, for instance the adverse impacts of farming on the local or global ecosystem. Examples include the infiltration of natural and mineral fertilizer and pesticide residues into groundwater and surface water, as well as greenhouse gas emissions. This gives rise to externalities (Baum 2011; Nordhaus 2013; Sadowski 2021, 2022) — i.e., a situation where the activity of one party has an adverse effect on another (in this case, on the community of water users and on the human kind as a whole, respectively) otherwise than through the market mechanism. Since there is no microeconomic rationale for preventing this kind of impacts, state intervention must take place to internalize the externalities. The third group of impacts is a scenario where there is a conflict between the farmers' ongoing interests and the farms' long-term development opportunities. In such cases, reaping immediate benefits (mainly of an economic nature) is usually the preferred option. Examples include situations where crop rotation is a decision based solely on current profitability, without taking soil quality and phytosanitary aspects into account; even the awareness of the need to ensure long-term soil fertility gives way to ongoing interests. Bearing in mind that agriculture plays a role in ensuring long-term national security, prudent intervention from the government is justified in such cases. The problem is particularly important in the context of both the crucial role of soil in ensuring food security and its importance as a carbon sink (Montanarella and Panagos 2021). Soils also represent a significant reservoir of biological diversity that underpins a broad range of key processes and moderate ecosystem service provision (Nielsen, Wall, and Six 2015).

Nevertheless, even if adequate measures are taken by the state, and the producers embrace a sound long-run strategy, the conflict of interests between agriculture and the environment will persist. This is because the growing world population requires a continuous supply of adequate

2. See: 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 and environmentally-friendly food system. COM/2020/381 final.

3. See: 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. COM/2020/380 final.

amounts of food despite the ability to extend the area of agricultural land being very limited. In this case, the only option is to make land more productive, which usually involves greater pressure on the environment (Sadowski 2017; Sadowski and Baer-Nawrocka 2018). This, in turn, makes it necessary to look for technological and organizational solutions that enable sustainable intensification defined as the ability to produce an adequate amount of food without increasing environmental pressures (Boix-Fayos and de Vente 2023).

The European Green Deal makes an attempt to resolve this conflict by proposing measures designed to protect both the environment and the climate while also improving the quality of food products. Conversely, much less importance is given to maintaining the production volume, which is an understandable attitude from the perspective of the European Union as it is virtually not affected by any nutrition problems. Hence, the measures are focused on considerable preferences for organic farming where environmental goals have absolute priority over production objectives (Peeters et al. 2020).

Nevertheless, the assumptions of the program were created before the COVID-19 pandemic, the Russian invasion of Ukraine, and the related energy and food crisis (Labenko et al. 2022; Sadowski 2023; Strange et al. 2022).[4] Especially the latter event shows that, just like throughout history, the agricultural production's volume and alignment with demographic conditions are aspects of key importance to security. The reduction of the agricultural production capacity of Ukraine, a major importer of cereals and oilseeds (Eckert and Kovalevska 2021),[5] combined with the increasing prices of gas (the basic production cost for nitrogenous fertilizers) poses a threat to maintaining an adequate volume of agricultural production both globally and in Europe itself.

In this context, it becomes even more urgent and relevant to assess the ways and methods for solving major problems related to environmental impacts of agriculture. Should these solutions lead to a decline in production and land productivity or quite the opposite? Therefore, it becomes important to answer the question on a system — other than organic farming — which could mitigate the conflict between agriculture and the environment (Schiavo et al. 2021).[6] In the current technological and organizational reality, this question can be at least partly answered by precision farming which contributes to maintaining (or increasing) the existing production volume while making it possible to reduce the environmental and climate impacts of agriculture (Finger et al. 2019; Vecchio et al. 2020).[7]

In view of the above, the implementation of the assumptions behind the European Green Deal and other recent challenges facing agriculture (including the post-pandemic economic recovery and potential economic impacts of the war in Ukraine) can affect the restructuring of land uses. This primarily means large areas of land being brought under organic and precision farming, as well as the evolution of the structure of staple field and horticultural crops.

Hence, the purpose of this paper is to identify the potential changes in agricultural land use in Poland as a consequence of implementing the European Green Deal, and especially the structure of sown areas and particular agricultural systems, with its potential economic and social effects.

4. See also: "Promoting a Global Green Transition Following the Russian Invasion of Ukraine. The External Dimensions of the European Green Deal." ECDPM Discussion Paper no. 325 by Alfonso Medinilla, Koen Dekeyser, and Karim Karaki, June 2022, available at https://ecdpm.org/application/files/8016/5779/6051/Promoting-Global-Green-Transition-Russian-Invasion-Ukraine-External-Dimensions-European-Green-Deal-ECDPM-Discussion-Paper-325-2022.pdf.

5. See also: "The Breadbasket of the World? Agricultural Development in Ukraine." OSW Report by Sławomir Matuszak, Centre of Eastern Studies, Warsaw, December 2021, available at https://www.osw.waw.pl/sites/default/files/OSW-Report_The-breadbasket-of-the-world_net.pdf.

6. See also: "Sustainable Agricultural Soil Management: What's Stopping It? How Can It Be Enabled?" Report by Allan Buckwell, Elisabet Nadeu, and Annabelle Williams. Rural Investment Support for Europe (RISE) Foundation, 2022, Brussels, available at https://risefoundation.eu/wp-content/uploads/2022_SOIL_RISE_Foundation.pdf.

7. See also: "Just Transition in the EU Agriculture and Land Use Sector." Report by David Baldock, Allan Buckwell, Institute for European Environmental Policy (IEEP), 2021, available at https://ieep.eu/wp-content/uploads/2022/12/Just-transition-in-the-EU-agriculture-land-use-sector-IEEP-2022.pdf.

1 Purpose and methodology of the study

The investigation into potential production and economic impacts of implementing the European Green Deal was based on three scenarios (table 1), which were considered on the basis of the results of debates organized by Polityka Insight Sp. z o.o. as part of the project "Impact of the European Green Deal on Polish agriculture." Twenty-five experts from the most important scientific centers in Poland dealing with the above issues were invited to discuss the assessment of the impact of EGD on Polish agriculture. The discussion took place from June to December 2021.

Table 1. Assumptions behind the implementation scenarios of the European Green Deal

Scenario	Share of organic farming	Percentage change against the 2016–2019 average value			
		N fertilizers	P_2O_5 fertilizers	K_2O fertilizers	Pesticide consumption
I. Without the European Green Deal	6%	5% increase	0.8% increase	0.8% increase	24% increase
II. Partial implementation of the European Green Deal	13%	11% decline	3.4% decline	2.1% decline	5% decline
III. Full implementation of the European Green Deal	25%	20% decline	20.0% decline	20.0% decline	50% decline

The scenarios were based on three basic parameters, derived directly from the principles of the European Green Deal. These were the share of crops in the organic farming system and the increase or decrease in nitrogen, phosphorus and potassium fertilization, as well as pesticide use. Scenarios of changes in mineral fertilizer consumption were based, among other things, on Fertilizers Europe forecasts published before and after the announcement of the EGD assumptions.[8]

- Scenario I assumes a continuation of the current trend in the development of Polish agriculture — i.e., an increase in the use of industrial means of production and a relatively small increase in the area of organic farming (Kopiński 2018a, c). Trends of change were based on current trends.
- Scenario II assumes partial implementation of the assumptions of the European Green Deal. With regard to the area of organic crops, it was based on the determined linear trends of change in the area of organic farmland in 2004–2013 — i.e., the period of their most dynamic growth after Poland's accession to the EU. The decrease in sales of pesticides in scenario II (partial implementation of EGD) to 20 percent relative to its trend from 1991–2019 was calculated on the basis of statistical data.
- Scenario III is the full implementation of the principles of the European Green Deal, so that 25% of agricultural land is covered by the organic farming system, reducing the use of plant protection products by 50% and mineral fertilizers such as nitrogen (N) by 23%, phosphorus (P) by 13%, and potassium (K) by 12%.

During the study, the following production systems were identified for each scenario:

- Conventional (**conv**): a farming method mostly focused on maximizing incomes (Kuś and Stalenga 2006) in highly efficient specialized farms which rely on production technologies based on a large consumption of productive inputs and relatively small labor inputs.

8. See: "Forecast of Food, Farming and Fertilizer Use in the European Union 2018-2028," available at https://www.fertilizerseurope.com/wp-content/uploads/2019/08/Forecast_2018_Web.pdf; "Forecast of Food, Farming and Fertilizer Use in the European Union 2019-2029," available at https://www.fertilizerseurope.com/wp-content/uploads/2019/12/Forecast-of-food-farming-and-fertilizer-use-in-the-European-Union.pdf; "Forecast of Food, Farming and Fertilizer Use in the European Union 2020-2030," available at https://www.fertilizerseurope.com/wp-content/uploads/2021/03/Forecast-of-food-farming-and-fertilizer-use-2020-2030-Fertilizers-Europe.pdf; "Forecast of Food, Farming and Fertilizer Use in the European Union 2021-2031," available at https://www.fertilizerseurope.com/wp-content/uploads/2021/12/Forecast-2021-31-Studio-final-web.pdf; "Forecast of Food, Farming and Fertilizer Use in the European Union 2022-2032," available at https://www.fertilizerseurope.com/wp-content/uploads/2023/01/Forecast-2022-32.pdf.

- Organic (**eco**): a farming method with the highest possible sustainability of agricultural production, based on technologically unprocessed inputs of biological and mineral origin. It precludes the use of mineral fertilizers, chemical plant protection products, growth regulators, and synthetic feed additives. Conversely, it relies on natural processes taking place in the agri-ecosystem.
- Precision (**prec**): a system which essentially consists in using sophisticated navigation and computer technologies and methods for collecting and processing spatial data, including artificial intelligence (AI) and the Internet of Things (IoT), with a view to efficiently managing production processes. While the productive inputs of this system are similar to those found in the conventional system, they are used in smaller quantities and in a more precise manner. Precision farming enables agricultural management decisions to be tailored spatially and temporally. Site-specific sensing, sampling, and managing allow farmers to treat a field as a heterogeneous entity. Through targeted use of inputs, precision farming reduces waste, thereby cutting both private variable costs and the environmental costs such as those of agrichemical residuals. At present, large farms in developed countries are the main adopters of precision farming. Technological developments and big data advances continue to make precision farming tools more connected, accurate, efficient, and widely applicable (Blackmore 1994; Fantin Irudaya Raj, Appadurai, and Athiappan 2021; Finger et al. 2019; Munz and Schuele 2022).

The same forecasted area of agricultural land, of land in good agricultural condition, and of arable land, and the same forecasted sown areas and areas under specific crops are used in all the scenarios, based on the previous direction of plant production (Kopiński 2014).

Each scenario assumed that the levels of phosphorus and potassium fertilization will continue to follow the existing trends because their consumption and content in soils are relatively stable. Their total consumption will rather be impacted by the changing share of organic farming in Poland. According to the forecasts underpinning these scenarios, the latter will not use nitrate fertilizers and will consume 5% and 10%, respectively, of the volumes of phosphorous and potassium fertilizers used in conventional farming.[9] The total consumption of each product was calculated, based on the area of land under crops and on changes in production intensity in relation to the area of land in good agricultural condition, taking into account the differences in demand for fertilization between the crops.

Also, the scenarios take account of the applicable requirement to use 5% of agricultural land for non-production purposes (Ecological Focus Areas, EFA), which is part of the greening plan of the Common Agricultural Policy. In the 2023–2027 CAP perspective, all beneficiaries applying for direct payments will be required to comply with that condition (at a level similar to what was seen in previous years). An additional assumption was made that changes related to implementing the EGD would not affect the expenditure on seeds, and therefore the current levels are used in the cost analysis.

The study takes account of the share of sown areas under crops of key importance to Polish agriculture in the conventional system, in the organic system, and in the system which makes some use of precision farming. In all the scenarios, the structure of land under specific organic crops was estimated, based on the levels recorded in 2017-2019. Currently, permanent pasture and arable land under fodder plants account for circa 60% of agricultural land in organic farms. Hence, in scenario III in 2030, based on ongoing trends, it was assumed that the area sown with plant species covered by this analysis will be only 569,000 ha of agricultural land out of 3,432,000 ha of agricultural land in the organic system (i.e., 17%, see table 2 on next page) This will largely be the consequence of greater agri-technical requirements, which are difficult to be met in organic farming. The above means that other organic crops (2,863,000 ha) will still be cultivated on arable land not used in the production of the species covered by this analysis, and on permanent pasture.

Due to its costs and efficient use of available technical and IT solutions, precision farming can only be implemented in farms larger than 50 ha of agricultural land, located on soils of medium or higher quality. The current condition and the forecasted changes to that production system in the scenarios covered by this analysis are based on available literature (Bondyra 2021) and on data from the Central Statistical Office in Poland (Statistics Poland).

9. See footnote 8 on previous page.

Table 2. Reference data (average values for 2017–2019) and general assumptions for each scenario

Specification	2017–2019	Scenarios for 2030 I	II	III
Share of organic farming in the area of agricultural land	3.40%	6.20%	13.00%	25.00%
Area of land under organic farming (thousand ha of land in good agricultural condition)	496	851	1,783	3,432
Area of land under precision farming (thousand ha of land in good agricultural condition)	317	633	1,267	3,097
Area of agricultural land (thousand ha)	14,660	13,800	13,800	13,800
Area of agricultural land in good agricultural condition (thousand ha)	14,526	13,730	13,730	13,730
Area of arable land (thousand ha)	10,990	10,230	10,230	10,230
Sown area (thousand ha)	10,828	9,885	9,885	9,885

Source: Own study based on data published by Statistics Poland.

The calculations of forecasted production volumes assume that when it comes to conventional and precision farming products, the prices remain at the level presented in research projects by the Institute of Agricultural and Food Economics — National Research Institute[10] and data published *Agricultural Statistical Yearbooks* by the Statistics Poland (Domaszewicz and Łączyński 2018, 2020; Łączyński 2020). In turn, the information on prices of organic products was sourced from the Online Agricultural Stock Exchange.[11] The assumption was made that sugar beet would not be farmed organically, and therefore its price was not determined (table 3).

The prices of fertilizer components and active substances of plant protection products were determined, based on available market quotations (table 4).

Table 3. Price assumptions for agricultural products (PLN/t)

Specification	Conventional and precision farming (2018–2020)[a]	Organic farming (2020)[b]
Winter wheat	731.5	1,000.0
Spring wheat[c]	731.5	1,000.0
Triticale	645.2	800.0
Rye	679.3	790.0
Barley	663.2	880.0
Oat	590.5	800.0
Rape	1,594.4	3,050.0
Grain maize	658.7	1,200.0
Sugar beet[d]	104.0	–
Potatoes	652.0	1,400.0
Apple trees	772.0	1,200.0
Strawberries	3,000.0	4,000.0
Blackcurrants	1,388.0	3,200.0

[a] Average values for 2018–2020 based on data published by Institute of Agricultural and Food Economics — the National Research Institute and the *Agricultural Statistical Yearbooks* by Statistics Poland.
[b] Based on the Online Agricultural Stock Exchange (IGRIT) and interviews with producers.
[c] Based on winter wheat prices.
[d] Currently, sugar beet is not farmed organically and no price can be specified for it.

10. See: "Raporty rynkowe — stan i perspektywy" [Market reports — state and prospects] of the year 2020, published by The Institute of Agricultural and Food Economics — National Research Institute at http://www.ierigz.waw.pl/.

11. See: Internetowa Giełda Rolnicza i Towarowa (IGRIT), available at https://igrit.pl/.

Table 4. Price assumptions for productive inputs (PLN/kg)

Specification	Price
Active substance of plant protection products	366.87
N	3.62
P_2O_5	3.97
K_2O	2.53

Source: Own compilation based on analyses of market quotations

Table 5. Seed costs for all the scenarios considered (PLN/ha)

Specification	Eco	Conv	Prec
Winter wheat [a]	260.0	260.0	260.0
Spring wheat [b]	190.0	190.0	190.0
Triticale [b]	134.0	134.0	134.0
Rye [a]	180.5	180.5	180.5
Barley [a]	200.5	200.5	200.5
Oat [b]	127.0	127.0	127.0
Rape [a]	208.0	208.0	208.0
Grain maize [a]	560.5	560.5	560.5
Sugar beet [a]	731.5	731.5	731.5
Potatoes [a]	3,047.5	3,047.5	3,047.5
Apple trees [c]	×	×	×
Strawberries [d]	2,820.0	2,820.0	2,820.0
Blackcurrants [d]	×	×	×

[a] Agrokoszty, Institute of Agricultural and Food Economics—the National Research Institute, Warsaw.
[b] Calculations of the Agricultural Consultancy Center of the Mazowieckie Region in Warsaw.
[c] Expenses on reproductive materials are investment costs.
[d] Calculations of the Agricultural Consultancy Center of the Mazowieckie Region (1/4 of the area).

The prices of seed and reproductive materials (table 5) are based on research carried out in the Agrokoszty system.[12] Missing data was supplemented with calculations performed by the Agricultural Advisory Center of the Mazowieckie Region in Warsaw.[13]

The study covered:

- the area of land under specific crops,
- production value, defined as the physical quantity multiplied by price, and
- land productivity.

The study focused on marketable crops of key importance to Polish agriculture, as listed in table 3.

2 Results and discussion

2.1 Sown area

The importance of the crops covered by this analysis to Polish agriculture is reflected in that they had a total area of 8.2 million ha (i.e., over 60% of land in good agricultural condition) in 2016–2020. The area under most of these cereals (except for barley and grain maize) is expected to decline by 2030 (Kopiński 2018b) (see table 6 on next page). However, wheat will continue to be the main cereal cultivated in Poland, and is forecasted to be sown on an area of 1,700,000 ha

12. See: System Zbierania Danych o Produktach Rolniczych AGROKOSZTY [Agricultural Products Data Collection System AGROKOSZTY], available at https://agrokoszty.pl/.

13. See: https://modr.mazowsze.pl/.

Table 6. Area of land under the crops covered by this analysis, grouped by main production systems for the defined scenarios (thousand ha)

				2030											
	2017–2019			Scenario I				Scenario II				Scenario III			
Specification	**Eco**	**Conv**	**Total**	**Eco**	**Conv**	**Prec**	**Total**	**Eco**	**Conv**	**Prec**	**Total**	**Eco**	**Conv**	**Prec**	**Total**
Winter wheat	6	1,967	1,973	9	1,546	145	1,700	19	1,392	289	1,700	38	956	706	1,700
Spring wheat	2	465	467	3	367	30	400	7	334	59	400	14	241	145	400
Triticale	8	1,310	1,318	12	1,012	76	1,100	26	923	151	1,100	50	681	369	1,100
Rye	30	860	890	46	657	37	740	96	570	74	740	185	374	181	740
Barley	3	887	890	6	883	61	950	13	816	121	950	25	629	296	950
Oat	24	471	495	36	364	10	410	75	315	20	410	144	217	49	410
Rape	1	877	878	2	783	165	950	5	616	329	950	10	137	803	950
Grain maize	3	622	624	5	693	52	750	11	635	104	750	22	475	253	750
Sugar beet	0	237	237	0	202	28	230	0	174	56	230	0	94	136	230
Potatoes	1	311	312	1	267	12	280	3	253	24	280	6	215	59	280
Apple trees	6	170	176	12	181	4	197	26	163	8	197	49	129	19	197
Strawberries	2	48	50	3	51	2	56	7	45	4	56	14	31	11	56
Blackcurrants	1	42	44	3	44	2	49	6	40	3	49	12	29	8	49
Total	87	8,267	8,354	138	7,050	624	7,812	294	6,276	1,242	7,812	569	4,208	3,035	7,812

Source: Own study based on data published by Statistics Poland.

in 2030. The difference between the scenarios in the area of land under specific crops in defined farming systems is the consequence of the expected growth in the share of organic farming and of areas partly covered by precision farming systems (at the expense of reducing the area of land under conventional farming).

The assumptions behind the medium-term forecast take account of the continued decline in the importance of potatoes, which will translate into a decrease in the area of land under potatoes at an annual rate of 2,600 ha. In turn, the area sown with sugar beet will drop at a rate of 1,000 ha per year; it should also be noted that sugar beet is increasingly planted by physically larger high-yield farms, and its cultivation becomes increasingly regionally concentrated. The area of land under rape is expected to grow by 9.7% in relation to the average level recorded in 2016–2019, which is supposed to ensure a balanced response to national demand (Kopiński 2018b).

It is also forecasted that the area of land under apple orchards will grow by ca. 12%, and the area of strawberry cultivation will increase to reach 56,000 ha by 2030. In turn, the area under blackcurrants is estimated to grow to 49,000 ha.

Only the production of grain maize is forecasted to grow significantly. The production of the other plants covered by this analysis will not change considerably and is supposed to address the national demand for feed and food.

2.2 Land productivity

Scenario I

Scenario I assumes that yields will continue to follow the growth trend. In the case of most crops, this will contribute to an increase in production value per hectare by 2030 (table 7), and the greatest growth will be recorded for winter wheat. A slight (one-percent) decline in productivity, caused by an important increase in the area under lower-yield organic crops, will only be recorded for barley, potatoes, strawberries, and blackcurrants.

Scenario II

This scenario means a partial implementation of EGD assumptions (and the related need to reduce the use of chemical yield boosters), as well as an increase in the area under organic crops. Therefore,

Table 7. Total production volume of the crops covered by this analysis, grouped by main production systems for the defined scenarios (2016–2020 = 100)

	Scenario I		Scenario II		Scenario III	
Specification	**Per ha**	**Total**	**Per ha**	**Total**	**Per ha**	**Total**
Winter wheat	109	94	103	89	94	81
Spring wheat	113	97	107	92	98	84
Triticale	105	88	101	84	91	76
Rye	100	83	96	80	87	72
Barley	99	106	95	101	86	92
Oat	105	87	102	85	95	79
Rape	107	116	102	111	93	101
Grain maize	115	139	111	133	100	121
Sugar beet	106	103	100	97	91	88
Potatoes	103	92	98	88	89	80
Apple trees	99	111	92	103	81	90
Strawberries	99	111	91	102	78	88
Blackcurrants	101	112	97	108	88	98
Total	–	102	–	97	–	87

Source: Own study based on data published by Statistics Poland.

land productivity will either grow or decline for certain crops by 2030. Growth will be recorded for winter and spring wheat, triticale, oat, rape, and maize. Conversely, rye, barley, potatoes, apples, strawberries, and blackcurrants will follow a downward trend. Hence, productivity will drop for those crops which can be produced in a considerably more extensive scheme (rye), are highly sensitive to a reduced use of fertilizers and plant protection products, and are forecasted to be produced in much larger volumes in the organic farming scheme. In the vast majority of cases, the area under crops will grow or decline by several percent. However, at the aggregate level, this will translate into quite important changes in the production volume (table 7).

Scenario III

In the scenario of a full implementation of EGD assumptions, the drop in productivity is expected to be particularly sharp in cases with the greatest reduction in the use of yield boosters, and the greatest increase is likely to be observed in the area under organic crops. According to a study by Barreiro-Hurle et al. (2021), in the countries of the Central Europe North region[14] (which includes Poland), yields in organic crops are 42.9% lower than conventionally system for cereals, 56.7% for oilseeds, and 51.3% for vegetables. In these conditions, the highest decline in productivity (22.0%) will be recorded for strawberries, whereas the productivity of rye, barley, potatoes, apple trees, and blackberries is likely to drop by more than 10.0% (table 7). Such a strong decline in the productivity of nearly all crops (except for maize) will have a significant impact on the total volume of plant production while also affecting the levels of livestock and total agricultural production.

2.3 Total production

Scenario I

Scenario I expects growth in the production volume of barley, rape, grain maize, sugar beet, apples, strawberries, and blackcurrants. Conversely, a decline is supposed to be recorded for wheat, triticale, rye, oat, and potato (table 7). The reduction in the production value of potatoes and cereals (other than barley) is usually related to an increase in the area under organic crops (the greatest increments are expected for oat, blackcurrants, rye, apple trees, and strawberries, see table 6). At the aggregate level for all the crops covered by this study, production value is forecasted to grow by 2% over the analysis period.

Scenario II

In the scenario of partial implementation of the EGD, total production will depend on the assumed reduction in the use of yield boosters and on the assumed area of land under crops (including organic crops). Production growth will be recorded for crops such as barley, rape, grain maize, apple trees, strawberries, and currants (table 7). This will be mostly true for maize (with a growth rate of 33%, mainly due to it being planted on a larger area) and rape (a growth rate of 11%). Conversely, there will be a decline in the production of other crops (wheat, triticale, rye, oat, sugar beet, and potato). In scenario II, the aggregate production of all the crops covered by the analysis will drop by 3% (table 8 on next page).

Scenario III

The full EGD implementation scenario will involve a strong drop in total production. The above is true for all the crops covered by this analysis, except for maize and (to a smaller extent) rape, mainly because of an increase in their cultivation area (table 7). As regards other plants, this can

14. Barreiro-Hurle at al. aggregate EU countries into five regional groups: Central Europe North (BE, DE, LU, NL, PL); Central Europe South (AT, CZ, FR, HU, RO, SK); Northern Europe (DK, EE, FI, LT, LV, SE); Southern Europe (BG, CY, ES, GR, HR, IT, MT, PT, SI); Ireland (IE); see: “Modelling Environmental and Climate Ambition in the Agricultural Sector with the CAPRI Model.” JRC Technical Report by Jesus Barreiro-Hurle, Mariia Bogonos, Mihaly Himics, Jordan Hristov, Ignacio Pérez- Domínguez, Amar Sahoo, Guna Salputra, Franz Weiss, Edoardo Baldoni, and Christian Elleby. Publications Office of the European Union, Luxembourg, 2021, doi:10.2760/98160, available at https://publications.jrc.ec.europa.eu/repository/handle/JRC121368.

Table 8. Share of organic, conventional and precision production schemes for the crops covered by this analysis, grouped by main production systems for the defined scenarios (eco + conv + prec = 100)

			2030								
	2017–2019		Scenario I			Scenario II			Scenario III		
Specification	**Eco**	**Conv**	**Eco**	**Conv**	**Prec**	**Eco**	**Conv**	**Prec**	**Eco**	**Conv**	**Prec**
Winter wheat	0.3	99.7	0.5	91.0	8.5	0.9	82.1	17.0	1.4	56.7	41.9
Spring wheat	0.5	99.5	0.9	91.6	7.5	1.6	83.6	14.8	2.6	60.8	36.6
Triticale	0.6	99.4	1.1	92.0	6.9	1.9	84.3	13.8	3.0	62.9	34.1
Rye	3.0	97.0	5.5	89.5	5.0	10.0	79.7	10.3	16.9	56.0	27.1
Barley	0.4	99.7	0.6	93.0	6.4	1.2	86.1	12.8	1.8	66.8	31.4
Oat	4.9	95.1	8.8	88.7	2.4	16.2	78.8	5.0	27.9	58.8	13.3
Winter and spring rape	0.1	99.9	0.2	82.4	17.4	0.4	64.9	34.7	0.7	14.5	84.8
Grain maize	0.6	99.4	0.8	92.3	6.9	1.6	84.6	13.9	2.5	63.7	33.9
Sugar beet	0.0	100.0	0.0	87.8	12.2	0.0	75.7	24.4	0.0	40.9	59.1
Potatoes	0.4	99.6	0.5	95.2	4.3	1.3	90.2	8.6	2.1	76.9	21.1
Apple trees	2.7	97.3	4.9	93.0	2.1	10.4	85.4	4.2	20.6	69.2	10.2
Strawberries and wild strawberries	2.1	97.9	4.4	92.0	3.6	8.9	83.7	7.4	18.3	60.3	21.4
Blackcurrants	3.0	97.0	6.6	89.3	4.1	15.2	78.9	5.9	27.4	56.9	15.7
Total	0.8	99.2	1.5	90.8	7.8	2.9	81.5	15.6	5.1	56.4	38.6

Source: Own study based on data published by Statistics Poland.

be explained more by the growing share of organic farming than by a reduction in yields in conventional farming schemes. The drop is supposed to be particularly sharp in the case of crops of key importance to the economy and to food security, such as cereals, primarily including wheat (of which Poland is a major producer in the EU). Production may decline by nearly 20% for winter wheat and by circa 1/4 for triticale and rye. In the case of other crops, it could drop by several (or over a dozen) percent.

In scenario III, the total production value of the crops covered by this analysis is likely to decline by 13% (table 7). The possible drop in production as a consequence of implementing the EGD is also highlighted by Hening and Witzke[15], and Baldock and Buckwell[16], who note that the production of cereals and oilseeds in EU countries could decline by circa 20% mostly due to a reduction in the use of nitrate fertilizers. The above findings are similar to those derived from analyses carried out by Bremmer et al.,[17] who showed that implementing the goals of the Farm-to-Fork and Biodiversity strategies would entail a 10% to 20% decrease (on average) in the production volume of crops considered across the EU (depending on the scenario). Also, evaluations conducted by Wesseler (2022) indicate a decline in EU agricultural production in quantitative terms. The F2F strategy negatively affects aggregate consumer surplus and — depending on the assumption made — a net increase or decrease in producer surplus, thereby inducing an overall net welfare loss. The production volume could decline by up to 30% for some crops, such as apples, while others (such as sugar beet) would hardly be affected by the implementation of the FtF strategy. The production volume of perennial crops will decline more than that of annual crops. This will have a significant impact on international trade: the EU will see its exports decrease and its imports increase. In addition, the scale of the EGD compliance challenge will depend on the dominant type of products on the farm. According to Prandecki, Wrzaszcz and Zieliński (2021), strategic goals can be a serious challenge for specific farm groups: farms specializing in permanent crops (pesticide limitation), farms with intensive crop production (fertilizer management), and farms with a large-scale production of livestock production (antibiotics).

Full implementation of the EGD will result in a drop in production by just under 13%. Henning and Witzke,[18] too, indicate that the FtF strategy would lead to a significant decline in production with a related increase in prices within the EU. In turn, Beckman et al. forecast that the decline in agricultural production in the EU would range from 7% (if the strategy is adopted globally) to 12% (in the EU-only scenario).[19] Impacts on production would be smaller worldwide, except in the case of global adoption, when production would decline by 11percent. Barreiro-Hurle et al.[20] also show a decline in EU production and variations in prices and income for selected agricultural products, albeit to varying degrees. They additionally emphasize that implementing the objectives of the Farm-to-Fork and Biodiversity strategies would result in significant environmental benefits.

The drop in production identified in the studies is especially worrying as the analysis focuses on crops of key national importance. Therefore, this situation could have a detrimental effect on food security. Conversely, price volatility would not have any impacts because prices were assumed to remain at their current (fixed) level. However, if there was a price increase due to a drop in production volume (which is highly likely to happen), it would adversely affect the financial resources of consumers, especially of socially disadvantaged groups whose food expenditure represents an

15. See: "Economic and Environmental impacts of the Green Deal on the Agricultural Economy: A Simulation Study of the Impact of the F2F-Strategy on Production, Trade, Welfare and the Environment based on the CAPRI-Model." Executive Summary by Christian Henning and Peter Witzke. 9 September 2021, available at https://grain-club.de/fileadmin/user_upload/Dokumente/Farm_to_fork_Studie_Executive_Summary_EN.pdf.

16. See: "Just Transition in the EU Agriculture and Land Use Sector...," op. cit.

17. See: "Impact Assessment of EC 2030 Green Deal Targets for Sustainable Crop Production." Report by Johan Bremmer, Ana Gonzalez-Martinez, Roel Jongeneel, Hilfred Huiting, Rob Stokkers, and Marc Ruijs. Wageningen Economic Research, 2021, Report 2021-150, available at https://edepot.wur.nl/558517.

18. See: "Economic and Environmental impacts of the Green Deal on the Agricultural Economy...," op. cit.

19. See: "Economic and Food Security Impacts of Agricultural Input Reduction Under the European Union Green Deal's Farm to Fork and Biodiversity Strategies." Economic Brief by Jayson Beckman, Maros Ivanic, Jeremy L. Jelliffe, Felix G. Baquedano, and Sara G. Scott. United States Department of Agriculture, EB-30, November 2020, available at https://www.ers.usda.gov/publications/pub-details/?pubid=99740.

20. See: "Modelling Environmental and Climate Ambition in the Agricultural Sector...," op. cit.

important part of their household budgets. The above is all the more probable since the food and energy crisis triggered by the conflict in Ukraine has an effect on the prices of both the basic yield boosters and agricultural products themselves (including cereals which are a staple food for most societies). Because these developments have worldwide effects, prices will increase not only in Poland but in most countries around the globe, which can be reasonably expected to have the strongest impact on the population of less wealthy countries, especially those which depend on imports of agricultural raw materials.

In the analysis of scenario III, the large share of precision farming is an assumption of extreme importance (table 8). It is supposed to account for nearly 40% of the crops covered by this analysis, including over 80% of rape, nearly 60% of sugar beet and over 40% of wheat. Without such an important share of precision farming, the drop in production caused by a reduction in the use of mineral fertilizers and plant protection products would be much sharper than what is envisaged (13%) in Scenario III. Precision farming is one of the key solutions capable of maintaining, if not increasing, the production volume of food with a reduced use of industrial productive inputs (Beluhova-Uzunova and Dunchev 2019). This requires significant public funding for R&D directed at specific elements of precision agriculture, including IT solutions and satellite techniques (Wolf et al. 2021). In a broader sense, the simultaneous achievement of environmental and economic-production goals requires the interaction of private and public stakeholders (Rapsikevicius et al. 2021).

Hence, the above analysis should be viewed as a warning and an important signal for agricultural policymakers. It also proves that without support for the development of precision farming and farms relying on it, there is a risk of a major collapse of agricultural production with all its adverse consequences, including compromising food security in its economic dimension (limited availability of food due to it being expensive in relation to the population's incomes) or even market shortages of certain products. The possible significant increase in food prices in EU countries as a consequence of EGD implementation is also highlighted by Henning and Witzke.[21] This scenario indicates the need for a major reorientation of the agricultural policy. It should be focused on supporting not only small farms but mainly relatively large operators; in the Polish reality, it mostly means family farms larger than 50 ha, capable of implementing technical solutions that ensure keeping the production volume at a stable level while pursuing ambitious environmental and climate goals set out in the European Green Deal. In this context, Wojtyło and Musiałek highlight the problem of the fragmentation of Polish agriculture, which significantly limits the possibility of applying precise production methods.[22] Besides, these authors also note that the agricultural policy directed at supporting mainly small and medium-sized entities makes it difficult to simultaneously achieve environmental and production goals.

Conclusion

The implementation of the European Green Deal involves a reduction in the use of chemical yield boosters while giving greater importance to organic farming. In addition, it also includes a reduction in the sale of antimicrobials in animal production. The scenarios used in this analysis assume certain changes in the intensity of using yield-boosting inputs, which translate into changing production volumes. The adjustments will result in changes to land productivity and to the area under crops in different farming systems.

The analysis of the results shows that the opportunities and threats faced by Polish agriculture will largely depend on production systems. The developments provided for in the EGD include an increase in the area of land under organic crops. Administrative support provided for this farming system is very likely to encourage the producers to align their activity with its requirements. In doing so, they will take the utmost account of economic aspects — i.e. the income derived from

21. See: "Economic and Environmental impacts of the Green Deal on the Agricultural Economy...," op. cit.

22. See: "Europejski Zielony Ład. Stan realizacji, wyzwania, nadzieje" [The European Green Deal. Status of implementation, challenges, hopes]. Report by Michał Wojtyło Paweł Musiałek (eds.), Centrum Analiz Klubu Jagiellońskiego, Kraków 2022, available at https://klubjagiellonski.pl/wp-content/uploads/2022/06/europejski-zielony-lad-xxx-online.pdf.

subsidies. Already today, the functioning of organic farming in Poland largely relies on public support (Sadowski, Wojcieszak-Zbierska, and Zmyślona 2021).

Conventional farming continues to prevail in each of the scenarios used in this analysis. Due to market mechanisms and the fact that most of the crops covered by the analysis generally need to be farmed intensively, organic farming is not expected to play a major role either. Its development will not be considerably impacted by the political rent in the form of organic area payments. Most crops expected to be grown organically are not covered by this analysis, and have a smaller impact on Polish agriculture (such as permanent pasture or fodder plants grown on arable land). According to the assumptions made in this study, relatively extensive crops (rye, oat) and fruit and vegetables (apple trees, strawberries and currants) account for the largest share of organic farmland. As regards these cereals, discontinuing the use of chemical productive inputs would entail small economic losses because rye and oat (as examples of the crops covered by this analysis) are usually grown on poor soils, which demonstrate low productivity anyway. When it comes to fruit and vegetables, the prices of high-quality organic products intended for direct consumption can be expected to grow. In turn, it is reasonable to believe that the organic system will not be used for less intensive crops or plants grown on fertile soils.

Implementing the organic farming system to the degree stipulated in the EGD would entail a considerable drop in agricultural production, especially with respect to the crops covered by this analysis. However, the farmers could pursue such a scenario with adverse consequences if the benefits derived from the political rent they receive for organic production activities (organic farming subsidies) prevail over the incomes earned in the conventional system. The above shows that organic farming support should be rationally programmed by making it depend more on marketable organic production than on the area of organic farmland. This is because it seeks two potentially separate yet overlapping goals: delivering public goods in the form of soil, water, and biodiversity protection while also providing private goods (defined as high-quality market products). In the latter case, supply should be regulated by customer demand. Indeed, it needs to be assumed that a heterogeneous food market will witness an increase in demand for organic products, especially in wealthy countries (which is actually taking place). While public support (e.g., in the form of promoting organic products) is obviously acceptable, organic farming — just like any other agricultural system — should first of all deliver agricultural goods to a free market. When focused solely on the delivery of public goods, it no longer demonstrates the characteristics of agriculture as an economic activity.

The simulated drop in production will affect crops of key national importance, and can therefore have a detrimental effect on food security, including a reduction in the physical availability of certain products. The decline in production is highly likely to trigger an increase in food prices, which are already growing today (July 2023) due to greater production costs of chemical productive inputs. This will adversely affect the financial resources of consumers, especially of socially disadvantaged groups whose food expenditure represents an important part of their household budgets. In pursuing the commitment to reduce the use of plant protection products by 50% and fertilization levels by 20%, efforts need to be made to have the farmers accept these changes. Without their consent, the introduction of technological and economical alternatives (such as natural fertilizers or biological and mechanical methods for plant protection) can lead to lack of effective protection and adequate fertilization. This, in turn, may translate into an increase in the occurrence of diseases and pests while also perturbing the balanced flow of nutrients between the soil and plants. As a consequence, it can not only compromise food security but also pose a threat to food safety. There is a risk that in the absence of proper preparation, the EGD may — contrary to what its initiators intended — result in both a reduction in yields and a deterioration in their quality (including the quality of healthy food). Therefore, key to meeting the moderately unfavorable scenario (III) is the shift of organic production outside of major commodity crops and the possibility of implementing precision agriculture. The former is highly likely to happen as it should be the consequence of the farmers' rational behavior. However, excessive and easily available support for organic production (as it is currently provided — i.e., support which is allocated based on the area of organic farmland rather than on the market value of organic production) can also encourage the farmers of the crops covered by this analysis to go organic. In turn, the latter proves that without support for the development of precision farming and for farms that implement it, agricultural production could decline at an even sharper rate than the 13% assumed in this study.

The above is substantiated by the analyses carried out in this paper, with precision farming having an extremely significant share in scenario III (the assumption was made that nearly 40% of the crops covered by this analysis would be precision-farmed: over 80% of rape, almost 60% of sugar beet and ca. 40% of wheat). Due to economic and technological reasons, precision farming can be implemented in farms larger than 50 ha of agricultural land and on good (if not excellent) soils. Under the assumption that all farms larger than 50 ha shift to precision farming, nearly 70% of their land would be precision-farmed. This is a feasible scenario, but if the implementation of the EGD is supposed to be rational and consistent with the requirement of a balanced environmental, economic, and social approach, there is need for public support in implementing precision farming techniques and technologies.

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