Received: 16 February 2024 | Accepted: 20 July 2024

DOI: 10.1002/aepp.13470

SUBMITTED ARTICLE

AAEA Agricultural & Applied Economics Association WILEY

The EU target for organic farming: Potential economic and environmental impacts of two alternative pathways

Dimitrios Kremmydas[1] | **Caetano Beber**[1] | **Edoardo Baldoni**[1] | **Pavel Ciaian**[1] | **Thomas Fellmann**[1] | **Alexander Gocht**[2] | **Jordan Hristov**[1] | **Davide Pignotti**[2] | **Dolores Rey Vicario**[1] | **Davit Stepanyan**[2] | **Pascal Tillie**[1]

[1]European Commission, Joint Research Center (JRC), Economics of the Food System (JRC.D.4), Seville, Spain

[2]Thünen Institute, Institute of Farm Economics, Braunschweig, Germany

Correspondence
Dimitrios Kremmydas, European Commission, Joint Research Center (JRC), Economics of the Food System (JRC.D.4), Seville, Spain.
Email: dimitrios.kremmydas@ec.europa.eu

Editor in charge: Jerome Dumortier

Abstract

The EU aims to reach 25% of the total agricultural area under organic farming by 2030. Interlinking a farm-level and agro-economic market model, we assess impacts of achieving the target either at Member State or aggregated EU level. Results show that flexible budget allocation across Member States would be more cost-efficient and less detrimental to EU production. Conversely, targeting at Member State level proves more effective in generating greater aggregated and more evenly distributed environmental benefits across EU regions. The results indicate the importance of leveraging tailored approaches to optimize organic farming outcomes across the EU.

KEYWORDS

CAPRI model, EU, European Green Deal, Farm to Fork strategy, IFM-CAP model, organic farming, organic target

JEL CLASSIFICATION

Q58, Q18

The authors are solely responsible for the content of the article. The views expressed are purely those of the authors and may not in any circumstances be regarded as stating an official position of the European Commission.

The Farm to Fork (F2F) strategy of the European Green Deal aims to stimulate the transition to a sustainable food system that is fair, healthy, and environmentally friendly. One proposed mean to achieve the transition is to expand the area under organic management to 25% of the EU's agricultural area by 2030 (European Commission, 2019, 2021). However, only 9.9% of the utilized agricultural area (UAA) is currently under organic farming in the EU.[1] Therefore, to achieve the 25% goal, a sizable agricultural area would need to convert from conventional to organic production methods in the next few years.

Organic farming methods have positive local environmental effects but also adverse impacts on production quantities when compared with conventional agricultural practices (Baker et al., 2019; Meemken & Qaim, 2018; Reganold & Wachter, 2016; Seufert & Ramankutty, 2017; Timsina, 2018). Thus, converting an additional 15% of the EU UAA to organic agriculture may have a significant effect on the EU farming sector and global agricultural food systems. Such ambitious target raise concerns about the impact on the overall supply of agricultural commodities, related market effects and global food security. These concerns gained further momentum considering trade interruptions and high food inflation in the context of Russia's war on Ukraine (European Commission, 2023).

In addition, the pathway to achieving the 25% target by 2030 is unclear. While the target is established at the EU level, the commitments at the Member States (MS) level are not predefined. In their national CAP strategic plans, MS have individually set organic area targets and allocated the financial resources they consider appropriate through Pillars 1 and 2. The considerable diversity of agricultural systems and the varying level of maturity of organic agriculture across MS justify them to allocate resources according to their specific circumstances and needs. However, due to the target not being legally binding, there is a risk that some MS may not fully embrace the ambition of the organic target and downplay their contribution to achieving the overall EU target of 25%.

Within this context, this article intends to answer the following question: What are the economic and environmental impacts of the 25% organic target in the EU, and how do these impacts differ between alternative pathways for implementing the target? To answer this question, we analyze two scenarios. The first scenario simulates that every MS individually reaches the 25% organic target (MS-Target), whereas in the second scenario the EU reaches the target with flexibility in budget allocation across MS (EU-Target). These two scenario settings likely represent bounds within which the actual implementation of the organic target may fall if the EU adheres to the target. The comparison of the scenarios will provide insights into the cost-effectiveness of reaching the target as well as differences in expected budgetary requirements, production and market impacts, and environmental outcomes.

The primary contribution of this article to the literature is in addressing the scarcity of analyses regarding the impacts of the 25% organic target at the EU level. Scientific papers that model conversion to organic farming either assume a 100% conversion (Barbieri et al., 2019; Jones & Crane, 2009; Lee et al., 2019; Muller et al., 2017; Smith et al., 2018), or focus on a single country (Kerselaers et al., 2007) or a few farms (Acs et al., 2009; Acs et al., 2007), or analyze disaggregated EU level impacts without taking into account all relevant behavioral effects (supply, market and/or environmental) (Calabro & Vieri, 2024; Kremmydas et al., 2023a). Furthermore, reports assessing the Green Deal either do not examine the organic target at all (Beckman et al., 2020), examine the organic target jointly with other F2F measures (Barreiro-Hurle et al., 2021; Henning et al., 2021), or focus on the target using only a limited number of crops and countries across the EU (Bremmer et al., 2021). This article extends the previous literature by interlinking farm-level behavior and market effects, examining both the economic and environmental impacts of the 25% organic target. Specifically, we employ an EU-wide farm model—Individual Farm Model for Common Agricultural Policy Analysis (IFM-CAP)—to analyze farms' organic conversion and the supply response to the organic target. Subsequently, we link the CAPRI market model to assess market effects of the target. To our knowledge, this is the first attempt at modeling the organic target at the EU level comprising all relevant dimensions: supply, market, and environment.

METHODOLOGY

Analyzing the impacts of the organic target requires the consideration of two critical aspects: (i) the supply response, which encompasses farms' conversion choices, and (ii) the market effects of the target. Given that organic conversion choices and associated production practices are inherently farm-specific, it is important to employ an individual farm-level approach. This approach allows a more accurate capture of the costs and benefits of organic conversion and technology (Buysse et al., 2007; Ciaian et al., 2013). Addressing market effects requires the use of a model capable of accounting for both intra-EU market dynamics and international trade changes in the global context. Therefore, we use the IFM-CAP farm-level supply model (Kremmydas et al., 2023a; Kremmydas et al., 2022) to capture the individual farm level response in supply and the CAPRI partial-equilibrium model (Britz & Witzke, 2014) to analyze market effects.

IFM-CAP: Modeling the supply response at farm level

The IFM-CAP model (Kremmydas et al., 2022) is a mathematical programming model designed to characterize the behavior and decision-making processes of individual farms. The model assumes that farmers maximize their expected utility subject to technical and policy constraints related to resource endowments, production relationships (feed requirements), and CAP policy obligations (including constraints related to organic farming). The policy constraints determine eligibility with different types of direct payments (coupled and decoupled) and control compliance with environmental obligations.

The parameterization of IFM-CAP is based on individual farm-level information (81,000 farms for 2017; the model's base year) across the 27 MS from the Farm Accountancy Data Network (FADN) database.[2] FADN data are complemented by other external EU-wide data sources such as the European Farm Structure Survey, the CAPRI model database, and Eurostat. The model calibrates to the observed base year data with a Positive Mathematical Programming (PMP) approach (Petsakos & Rozakis, 2015). The PMP approach recovers the unknown parameters of an implicit quadratic cost function, ensuring that (i) each farm replicates its base year activity levels, and (ii) when all farms are pooled together, the resulting aggregate (regional) price supply elasticity approximates a set of supply elasticity priors provided by the CAPRI model (Kremmydas et al., 2022; Petsakos et al., 2023).

Recently, the IFM-CAP model was modified to model the potential conversion of conventional farms to organic farming (Kremmydas et al., 2023a). This modeling is based on the assumption of economic rationality of farms. When faced with the decision of converting to organic farming or not, a conventional farm compares the expected utility of its maintaining the current conventional status with that of becoming organic. The expected utility of the potential organic status considers specific factors such as farming practices, prices, yields, and costs specific to organic production. Overall, a farm will opt for organic over conventional production if the expected utility of organic farming exceeds that of conventional.

Consequently, the IFM-CAP modification enriched the model's database with data on the organic practices (crop rotation, nitrogen management, maximum stocking density, feed self-sufficiency, and minimum share of fodder in the animals' diet) and yield gaps, price premiums, and costs differentials between organic and conventional production. Appendix C provides a summary of the model's database update, while detailed information is available in Kremmydas et al. (Kremmydas et al., 2023a). The modification also extended the calibration of the model to ensure that, for the conventional farms in the base year, the expected utility of a potential conversion to organic is lower than their expected utility as conventional farms. This condition implies that farms observed as conventional in the base year will only convert to organic if the organic payment is higher than in the base year.

In fact, the IFM-CAP enables the estimation of the payment threshold necessary to incentivize an FADN farm to convert to organic production (Kremmydas et al., 2023b). This allows to simulate scenarios of different levels of organic payments and estimate the number of farms likely to convert to organic production, for example, an increase of 1% of the current organic payments may result in a 0.5% increase in the number of farms transitioning to organic. Thus, to simulate the supply response to achieving the 25% organic target, we simulate a stepwise increase in the payment levels. As organic payments increases, more and more farms will convert. Eventually payment level will be reached where a sufficient number of farms convert to meet the area target.

CAPRI: Modeling the market effects

The Common Agricultural Regionalized Impact Analysis model (CAPRI) is a comparative static, partial equilibrium model for the agricultural sector designed for policy impact assessment of agricultural, environmental, climate change, and trade-related policies (CAPRI, 2022). CAPRI is composed of two different interlinked modules: the supply module and the market module. The supply module consists of a set of independent regional mathematical programming models for each of 280 NUTS2 regions of EU 27, Norway, Western Balkans and Turkey representing around 50 animal and crop activities. Each supply model maximizes the regional agricultural income subject to land constraints, nutrient balances and policy requirements. The market model is a comparative static, deterministic, spatial multi-commodity model depicting about 60 primary and secondary agricultural products, covering around 80 countries and trade blocks worldwide. In the market module supply, feed, processing and human consumption are simulated with behavioral equations that have flexible functional forms. The functions' coefficients are calibrated with the use of algorithms that make them consistent with micro-economic theory. International trade is modeled following the Armington assumption (Armington, 1969). Goods are differentiated by place of origin, which allows modeling bilateral trade flow between countries and establishing consumer preferences for imports based on historical trade patterns. Moreover, bilateral import prices are derived by accounting for trade policy measures at the border, such as tariffs, tariff-rate quotas, variable levies, and the entry-price system for fruits and vegetables. Where applicable, further market measures like public intervention and export subsidies are also implemented. This detailed modeling approach ensures a nuanced representation of international trade dynamics within the agricultural sector. In this article, we use only the market module of CAPRI.

The estimated supply effects resulting from the organic target, simulated in IFM-CAP, are subsequently implemented into CAPRI. In this integration process, the farm-level results from IFM-CAP are aggregated at NUTS2 level, which then serve to shift the crop-specific supply curves of each respective NUTS2 region within CAPRI. The simulations of the two models stop at this stage, that is, the market feedback effect is not further taken into account in IFM-CAP.

Scenarios

To assess the potential impacts of reaching the EU organic target, we analyze two scenarios:

- Scenario "MS-Target" simulates the imposition of a 25% organic target individually for each MS. This scenario represents a more stringent application of a shared effort across all MS, without allowing flexibility to select converting farms across MS.
- Scenario "EU-Target" simulates a flexible budget allocation across MS to reach the 25% organic target at the EU level. In this scenario, farms requiring a lower organic payment, irrespective of the MS they belong to, convert and receive payments until the 25% target is reached at EU level.

The main difference between the two scenarios lies in the pool from which the converting farms are drawn and in the corresponding level of organic payments.[3] This distinction is graphically depicted in Figure 1a, b. The *x*-axis represents farms ordered by the payment required to trigger conversion to organic farming, with those requiring less payment positioned at the beginning. The y-axis indicates the level of organic payment per hectare. The starting point of the curve on the y-axis represents the current level of organic payments (P_0 or $P_{MS1,0}$ or $P_{MS2,0}$). The curve illustrates the relationship between the organic payment level and the number of farms that will convert. The dotted vertical line shows where the converted area will equal the organic target, corresponding to the marginal farm ($F_{MS1,n}$ or $F_{MS2,m}$ or F_n), where the organic payment makes the farm indifferent between being conventional or organic. For farms below this threshold, the payment exceeds their conversion costs.

In Figure 1a, the selection of farms for the MS-Target scenario is illustrated for two Member States, MS1 and MS2. The varying levels of current payments ($P_{MS1,0}$ vs. $P_{MS2,0}$) and the relationship between payment levels and the number of farms (different curves) result in differing

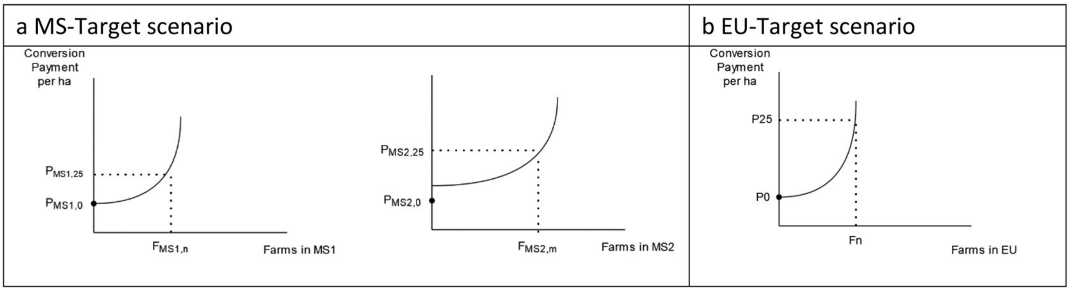


FIGURE 1 Selection of farms in the MS-Target and EU-Target scenarios.

numbers of farms and payment levels required to reach the 25% in each MS ($P_{MS1,25}$ vs. $P_{MS2,25}$ and $F_{MS1,n}$ vs. $F_{MS2,m}$). In Figure 1b illustrates the selection of farms in the EU-Target scenario. As the target and budget are defined at EU level, all farms and their corresponding conversion payment levels are pooled together. Hence, P_0 corresponds to the minimum of $P_{MS1,0}$ and $P_{MS2,0}$. The payment level P_{25} induces the conversion of enough farms to meet the 25% organic area target. While the selected farms may belong to both MS, if MS1 farms generally have lower conversion payments than MS2 farms, the majority of the chosen farms will likely be from MS1.

For each scenario, to calculate the new organic supplies (which will be implemented as supply shocks in CAPRI), we first determine the number of farms required to reach the corresponding area target (farms are arranged in ascending order of conversion payment, as depicted in Figures 1a and 1b). Then, the supply shock is computed as the supply changes resulting from these selected farms transitioning from conventional to organic production. The budgetary requirement corresponds to the payment level multiplied by the area of the converting farms (the rectangles formed by the dotted lines and the two axes in Figures 1a and 1b).

The supply shock is relative to a baseline that represents the European Commission's medium-term outlook for EU agricultural markets in 2030 (DG AGRI, 2020).[4] However, in the baseline, we assume no change in the number of organic farms compared to the current (2017) situation. We make this assumption because we are interested in simulating the effects of increasing the organic area from the current base year levels to the 25% target. We provide the organic area in baseline/current situation and under the MS-Target and EU-Target scenarios Tables A1, A2 and A3 in Appendix A. Finally, the baseline also assumes the continuation of the current CAP until 2030, including the environmental restrictions (e.g., restriction on grassland conversion).

RESULTS

Supply effects

The 25% organic target impacts agricultural supply through three primary factors: (i) the adoption of organic farming practices on converted farms, such as crop rotation, nitrogen management, stocking density, feed self-sufficiency, and minimum fodder share in the livestock diet, (ii) the lower yields associated with organic farming as a direct consequence of the management requirements and restrictions, and (iii) the price premiums for organic products (including the higher price of purchased feed on organic farms). All these factors (and their interaction) lead farms to adjust land allocation, animal numbers and production quantities. These adjustments, however, are heterogeneous across activities depending on which factor is a stronger driver for a particular activity.

Table 1 shows the impact of the organic target on land allocation and animal numbers in the EU. Notably, the organic target tends to influence the distribution of land use, with major crops experiencing reductions in area while smaller crops see increases, largely due to rotation and nitrogen management requirements specific to organic farms. Consequently, some primary crops like soft wheat, barley, and maize are often replaced by secondary crop activities such as oats and rye, and protein crops. Additionally, the number of animals decreases due to restrictions on the livestock density. This reduction of animal numbers is also reflected in a reduction in area dedicated to the production of animal feed, such as grassland or fodder crops. However,

TABLE 1 Change in crop areas and in animal numbers for main agricultural activities in the EU (absolute and relative change compared to the base year).

	EU-Target				MS-Target			
	Area (1000 ha)	(%)	Production (1000 ton)	(%)	Area (1000 ha)	(%)	Production (1000 ton)	(%)
Soft wheat	−348.1	(−2.0)	−5909.5	(−5.1)	−525.7	(−3.1)	−8954.5	(−7.7)
Barley	−179.2	(−1.6)	−3037.3	(−4.6)	−255.4	(−2.2)	−4472.2	(−6.7)
Maize	−66.6	(−1.0)	−1596.3	(−2.4)	−302.8	(−4.4)	−4560.6	(−6.8)
Oats	+19.5	(+1.0)	−163.0	(−2.3)	+42.5	(+2.2)	−227.6	(−3.2)
Potatoes	−7.8	(−0.7)	−863.6	(−2.2)	−30.0	(−2.8)	−2100.9	(−5.3)
Pulses	+30.4	(+1.2)	−71.7	(−0.9)	+21.2	(+0.8)	−249.1	(−3.1)
Soya	+18.6	(+3.3)	15.8	(+0.8)	+45.9	(+8.1)	44.4	(+2.3)
Rapeseed	+39.8	(+1.1)	−384.0	(−2.7)	−2.6	(−0.1)	−902.7	(−6.5)
Sunflower	−9.2	(−0.3)	−236.9	(−2.8)	−16.9	(−0.6)	−515.9	(−6.0)
Grassland	−394.3	(−1.5)	−27,247.5	(−3.8)	+68.5	(+0.3)	−9348.9	(−1.3)
Fodder Maize	−199.8	(−2.6)	−5795.6	(−2.3)	−307.5	(−3.9)	−11631.6	(−4.7)
Other fodder crops	−99.3	(−0.5)	−535.9	(−0.3)	+433.4	(+2.3)	1893.0	(+1.1)
Fallow land	+803.5	(+9.8)	—	—	+496.7	(+6.1)	—	—

	EU-Target				MS-Target			
	Animals (1000 heads)	(%)	Production (1000 ton)	(%)	Animals (1000 heads)	(%)	Production (1000 ton)	(%)
Bovine	−1913.6	(−2.3)			−1468.1	(−1.8)		
Meat			−341.6	(−4.3)			−217.0	(−2.7)
Cow milk			−12,375	(−0.5)			−2392.3	(−1.1)
Sheep and goats	−3080.6	(−3.3)			−2265.7	(−2.4)		
Meat			−17.4	(−1.3)			−18.5	(−1.4)
Pigs	−280.4	−3.3			−344.2	(−0.5)		
Pork			−38.4	(−0.3)			−42.2	(−0.3)
Poultry	−16,130.6	(−2.1)			−15,527.0	(−2.0)		
Eggs			−78.7	(−3.6)			−114.7	(−5.2)
Meat			−45.9	(−1.0)			−33.1	(−0.7)

Note: The breakdown of areas and animals into conventional and organic are in Table B1 in Appendix B.
Source: IFM-CAP simulations.

the grassland and fodder area per animal increases on farms that have converted to organic production because of the requirements for a greater feed self-sufficiency and a higher proportion of fodder in the animal diet. The grassland and fodder areas decrease because the reduced feed demand due to the organic farming restriction on livestock density, more than offsets the increased feed demand due to the requirement for greater feed self-sufficiency and a higher proportion of forage in the diet. Note that the effect of lower yields and price premiums on organic farms also affects land allocation and animal numbers but their effect is secondary relative to the impact of organic farming practices. This is because only the relative changes in yields and prices of organic farms have an impact on land allocation and animal numbers, and the two have offsetting effect on each other.[5]

The high increase in fallow land area (9.8% in the EU-Target and 6.1% in MS-Target) can be attributed to two primary factors. Firstly, the model assumes that grazing farms, which reduce the number of animals, convert grassland and fodder crops into fallow land. This is more pronounced in the EU-target scenario, where over 43% of the converting farms engage in grazing livestock, compared to 18% in the MS-Target scenario, thereby resulting in a more substantial increase in fallow land. Secondly, the adoption of organic management practices, notably crop rotation, requires a higher share of arable land to be fallow. Overall, however, the increase in fallow land may be an overestimation, as IFM-CAP does not capture the structural change that grazing farms might undergo.[6] In practice, grazing farms could opt to convert unused grazing areas into alternative arable activities, thereby mitigating the surge in fallow land.

The impact of the organic target on land allocation is greater in the MS-Target scenario than in the EU-Target scenario (Table 1). This outcome can be attributed to the differences in the farm selection process for conversion between the two scenarios: the EU-Target selects from a combined pool of all EU farms, whereas the MS-Target involves farm selection split by MS subpools. Essentially, the EU-Target facilitates a more profitable allocation of organic land, enabling countries in which organic farming is more profitable to surpass the 25% target, while other countries may remain below this threshold. Surprisingly, the impact of the organic target on animal numbers is smaller in the MS-Target scenario compared to the EU-Target scenario, which is primarily due to a larger share of livestock farms (especially grazing livestock) converting in the former scenario than in the latter.

The changes in land allocation and animal numbers, combined with yield reductions associated with organic farming, generally result in decreased production for most activities in the EU. Table 1 provides an overview of the changes in the production of main agricultural products. Both scenarios exhibit a reduction in production for most main products, ranging from −0.2% to −8%. The mostly negative changes in production quantities indicate that the yield reduction dominates the area changes. The exceptions are soya seed and other fodder crops, for which production increases in at least one scenario, implying that the area increase compensates for the yield reduction. With few exceptions, the EU-Target scenario results in lower production changes (between −0.3% and −5.1%) than the MS-Target scenario (between −1.3% and −7.7%).

For example, the −7.7% reduction in soft wheat production in the MS-Target scenario can be attribute to two causes. First, a reduction of soft wheat area by −3.1%, as farms that convert to organic farming need to use crop rotations with a greater variety of crops, causing soft wheat to be planted less frequently. Second, the further −4.6% reduction in wheat production is due to the lower organic yields compared to conventional wheat production. This dual influence explains why certain crops show both increases in areas and decreases in supply. For example, oats experience a +2.2% increase in area but a –3.2% decrease in production in the MS-Target scenario. That occurs because for converting farms oats become more prevalent in rotations, yet the expanded cultivation area does not compensate for the reduced organic yield compared to conventional agriculture.

To better explain the disparities in the supply response between the two scenarios, an examination of the difference in the farm types undergoing conversion is essential (Table 2). Notably, a significant difference between the EU-Target and the MS-Target scenarios is the number of converting farms. Approximately 0.65 million farms convert in the EU-Target scenario, whereas 1.26 million farms convert in the MS-Target scenario. This implies that, on average, the converting farms in the EU-Target are larger in terms of land use.

Another notable difference between the EU-Target and the MS-Target scenario results is the composition of farm specializations (Table 2). Livestock farms are more prevalent in the EU-Target scenario (55% livestock farms versus 38% crop farms), while crop farms have a greater representation in the MS-Target scenario (29% livestock farms versus 58% crop farms).[7] This is particularly notable in the "Other grazing livestock" farm specializations (cattle farms), which accounts for 18.2% of all organic farms in the MS-Target scenario and 43.9% in the EU-Target scenario. The rationale behind this difference are lower conversion costs (and hence lower minimum organic payment) associated with these farm specializations. Consequently, as the

TABLE 2 The distribution of organic farms by farm specialization in the EU (Number of farms; % in the total organic farms).

	Baseline[a]	EU-Target	MS-Target
Field crops (1)	55,392	138,844	329,224
	19.8%	20.5%	26.1%
Horticulture (2)	5087	5228	12,559
	1.8%	0.8%	1.0%
Wine (3)	19,852	34,975	96,065
	7.1%	5.2%	7.6%
Other permanent crops (4)	76,160	76,292	296,304
	27.2%	11.2%	23.5%
Milk (5)	30,434	65,789	128,161
	10.9%	9.7%	10.2%
Other grazing livestock (6)	58,739	297,692	229,051
	21.0%	43.9%	18.2%
Granivores (7)	3346	7840	11,022
	1.2%	1.2%	0.9%
Mixed (8)	30,964	51,644	157,600
	11.1%	7.6%	12.5%
All organic farms	279,975	678,304	1,259,985
	100.0%	100.00%	100.0%

Source: IFM-CAP.

[a]Regarding the number of organic farms and the organic area, the baseline scenario assumes the current situation in the base year and is not a projection to 2030. For more information, see Section 2.3.

EU-Target scenario pools all farms across the EU, these farm specializations are selected in greater numbers compared to the MS-Target scenario.

Both of the aforementioned factors contribute to the more adverse supply impact on crops in the MS-Target scenario, and conversely, the more negative supply impact on animal production in the EU-Target scenario.

Budgetary costs

Table 3 presents the budgetary costs in the baseline scenario and for achieving the 25% organic target under the two scenarios. The baseline budget for organic payments paid to exiting organic farms is around 1.6 billion EUR. In the EU-Target scenario, the simulated expenditure increases to 5.1 billion EUR, whereas in the MS-Target it rises to 8.6 billion. Thus, the budgetary costs for the organic target represent a 3.2-fold increase in the EU-Target scenario and 5.3-fold increase in the MS-Target scenario compared to the baseline organic budget.

For context, the total Pillar 1 CAP budget is approximately 40 billion EUR.[8] This means that in the MS-Target scenario, the organic budget needs to increase from the baseline level of 4%–21% of the Pillar 1 budget. In the case of EU-Target, the share in the Pillar 1 budget represents 13%. This information underscores the substantial budgetary adjustments required in both scenarios to achieve the 25% organic target.

Prices

Table 4 presents the simulated price changes associated with achieving the 25% organic target in the EU. The overall reduction in supply for most products is reflected in price increases in both scenarios. Following the production changes, prices for most products tend to increase more in the MS-Target scenario (ranging from 0.3% to 14%) than in the EU-Target scenario (ranging from 0.2% to 10.7%). This holds particularly for crop products, with the exceptions being soya seed in both scenarios and potatoes in the EU-Target scenario. The price of soya seed decreases due to the supply increase, although its production level in the EU remains minor

TABLE 3 Budgetary cost for reaching the 25% organic target in the EU (billion EUR).

Scenario	Budgetary expenditure (billion EUR)	Additional expenditure to CAP strategic plans (billion EUR)
Baseline[a] (*source*: see scenarios; 9.9%)	1.611	—
CAP strategic plans[b] (*source*: IFOAM; 15%)	2.278	—
EU-Target (*source*: own estimations; 25%)	5.132	2.854
MS-Target (*source*: own estimations; 25%)	8.576	6.298

[a]Baseline refers to the base year situation, where the organic area is 9.9% of total UAA (see scenario description).
[b]We take the projected CAP expenditure from the IFOAM report that corresponds to reaching 15% of the EU agricultural area under organic farming.

TABLE 4 Producer price changes for the aggregate organic and conventional production in the EU (% change relative to baseline).

	EU-Target	MS-Target
Cereals	6.4%	8.3%
Soft wheat	6.6%	8.5%
Barley	6.3%	7.5%
Oats	6.2%	9.6%
Grain maize	6.3%	8.4%
Oilseeds	5.3%	6.3%
Rapeseed	5.5%	8.2%
Sunflower seed	6.7%	5.0%
Soya seed	−0.2%	0.3%
Vegetables and permanent crops	1.7%	3.8%
Table grapes	0.2%	0.3%
Table olives	0.9%	14.5%
Wine	3.5%	8.7%
Pulses	4.2%	5.0%
Potatoes	−2.2%	1.2%
Meat	3.7%	3.1%
Beef	10.7%	6.7%
Pork meat	1.4%	1.5%
Poultry meat	3.2%	3.3%
Eggs	9.4%	9.0%

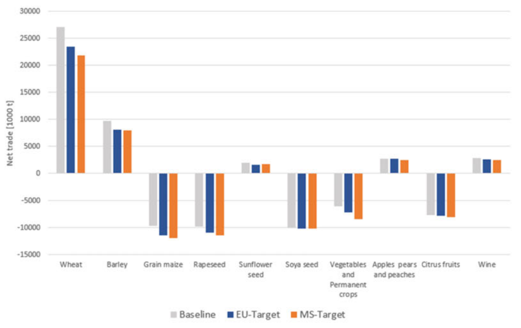
Source: CAPRI.

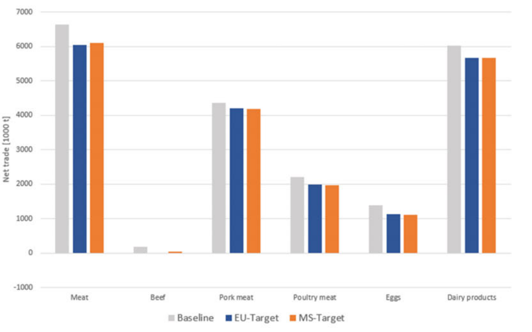
compared to other oilseeds, such as rapeseed and sunflower. The price of potatoes decreases in the EU-Target scenario due to their relative affordability compared to other more expensive alternatives, resulting in substitution effects that drive the demand for potatoes, despite the production decreases.

Trade

As the demand for food products in the EU is relatively inelastic, the price changes resulting from the introduction of the organic target have only a limited impact on total EU demand. The combination of the inelastic demand and reduced supply contributes to decreases in exports from the EU to the rest of the world and increases in imports of agricultural products to the EU to meet demand. This leads to an overall worsening of the EU net trade position, which is most pronounced for cereals and livestock products.

Figure 2 presents the changes in the EU net trade (i.e., exports–imports) positions, excluding intra-EU trade in the EU. In both scenarios, the introduction of the organic target leads to an increase in imports and decline in EU exports for all agricultural products, except soya seed. Differences between scenarios are primarily characterized by the EU-Target scenario's less





Source: CAPRI

FIGURE 2 Absolute difference in EU net trade quantities for main agricultural products (absolute change relative to baseline). *Source*: CAPRI.

TABLE 5 The impact of the organic target on key environmental indicators in EU (% change relative to baseline).

Indicator	EU-Target Aggregate change	EU-Target Per billion EUR of organic payments	MS-Target Aggregate change	MS-Target Per billion EUR of organic payments
GHG emissions	−3.7%	−0.88%	−3.8%	−0.49%
N surplus	−12.5%	−2.97%	−14.9%	−1.92%
Biodiversity	0.7%	0.17%	0.8%	0.10%
Soil erosion	−1.0%	−0.24%	−1.0%	−0.13%
Pesticide risk	−0.8%	−0.19%	−2.1%	−0.27%

Note: GHG emissions (N_2O, CH_4, and CO_2) from livestock and managed soils are estimated per farm using the IPCC Guidelines (IPCC, 2019a; IPCC, 2019b). (1) Nitrogen (N) surplus for each farm is estimated through a farm balance approach, accounting for all the N inputs to and outputs from the farm (Leip et al., 2011). (2) Biodiversity impact is quantified through calculation of the Shannon diversity index for both the entire farm, based on crop group shares. (3) Soil erosion effects are assessed by adaption the Revised Universal Soil Loss Equation (RUSLE). (4) Pesticide risk is approximated by using the expenditure on pesticides on farms (EUR) as a proxy for environmental impacts related to pesticide use.
Source: IFM-CAP.

pronounced effects on net trade, especially within the "vegetables and permanent crops" and "wheat" categories. This is largely due to the scenario's lower impact on exports.

Environment

To assess the environmental impacts of the organic target, we consider the following key indicators: GHG emissions, N surplus, biodiversity, soil erosion, and pesticide risk (Table 5). The results indicate that the organic target positively affects the environment by improving the environmental performance of converting farms. The MS-Target scenario leads to greater aggregate changes in environmental indicators, mainly attributed to a higher share of intensive farms converting to organic production compared to the EU-Target scenario.

The reduction in emissions (−3.7% in the EU-Target and −3.8% in the MS-Target) is mainly due to the elimination of synthetic fertilizer usage in farms converting to organic farming, leading to lower emissions from nitrogen (N) application to soils. Additionally, the decrease in animal numbers in newly converted organic farms contributes to reduced emissions from manure management and enteric fermentation in the case of ruminants.

The N surplus across Europe also diminishes (−12.5% and −14.9%), as organic farms generally have less N inputs (e.g., feed imports) compared to conventional farms, and they do not purchase synthetic fertilizers. We assume that new organic farms that used synthetic fertilizers in the baseline will increase their use of organic manure, but this increase is lower than the nitrogen content in the synthetic fertilizers they applied before the conversion. Similarly, the pesticide risk decreases (−0.8% and −2.1%), a result of the restrictions on the types of pesticides permitted in organic farming practices.

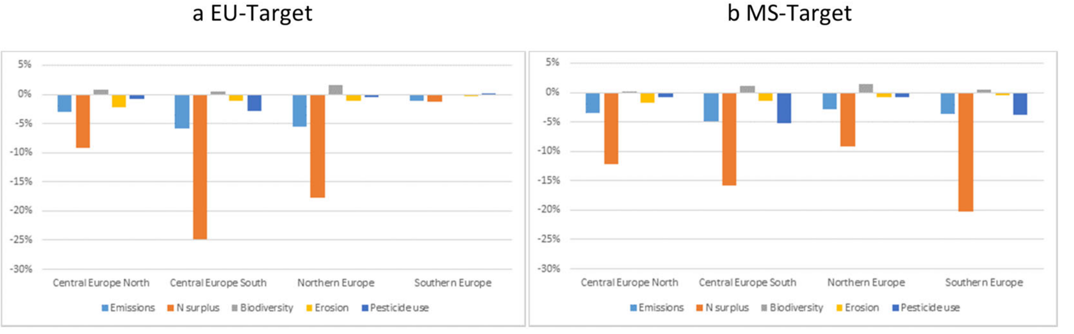
Biodiversity also improves (0.7% and 0.8%) because the farms converting to organic have a more diversified crop mix. The changes in the crop mix also reduce the risk of soil erosion (−1%), despite the increase in fallow land, as the area of crops with lower c-factor (crop-specific soil loss factor) expands under both scenarios.

While the MS-Target scenario demonstrates a more positive impact in absolute terms compared to the EU-Target scenario, this perspective shifts when considering the effect per billion EUR of public expenditure on organic subsidies. In this context, the MS-Target scenario is more effective (exhibiting a higher absolute effect) but less efficient (demonstrating a lower relative effect) than the EU-Target scenario. As shown in Table 5, most environmental indicators show a higher improvement per billion EUR of organic payments in the EU-Target scenario compared to the MS-Target scenario, while the reverse holds true for the aggregate effects. As suggested earlier, this outcome can be attributed to the fact that in the EU-Target scenario a greater proportion of extensive farms (e.g., those with a higher grassland share) convert to organic production compared to the MS-Target scenario. Additionally, the former scenario results in converting farms being less costly from a budgetary expenditure perspective. The exception is pesticides risk, which is both more effective and efficient in the MS-Target scenario.

Crucially, the two scenarios yield a very different distribution of the environmental benefits across EU regions (Figure 3). In the MS-Target scenario, environmental improvements are relatively evenly dispersed across different EU regions, whereas in the EU-Target scenario, the benefits are concentrated mainly in Central and Northern Europe. This discrepancy arises because the MS-Target scenario requires that farms from all MS reach the 25% organic target. This is not the case for the EU-Target, where some MS may over or under deliver the organic area relative to the set target. For example, more farms from Central and Northern Europe (mainly grazing livestock) undergo conversion in the EU-Target scenario, while fewer crop related farms convert in Southern Europe. This leads to significant disparities in environmental impacts between the two regions in the EU-Target scenario.

DISCUSSION AND CONCLUSIONS

In this article, we link the IFM-CAP farm-level model with the CAPRI agro-economic market model to analyze economic and environmental impacts of reaching the EU's 25% target for organic agriculture, as outlined in the Farm to Fork strategy. Given the lack of clear and established specifics regarding target implementation in the strategy, we explore two plausible alternative pathways. The first scenario (MS-Target) assumes that each MS must strictly achieve



Note: *- Central Europe North: BE, LU, NL, DE, PL*
- Central Europe South: AT, CZ, FR, HU, SK, RO
- Northern Europe: SE, FI, EE, LT, LV, DK,IE
- Southern Europe: BG, HR, CY, EL, IT, MT, PT, SI, ES

Source: IFM-CAP

FIGURE 3 Regional impacts of the organic target on key environmental indicators in the EU (% change relative to baseline). Central Europe North: BE, LU, NL, DE, PL. Central Europe South: AT, CZ, FR, HU, SK, RO. Northern Europe: SE, FI, EE, LT, LV, DK, IE. Southern Europe: BG, HR, CY, EL, IT, MT, PT, SI, ES. *Source*: IFM-CAP.

the 25% target, resembling the current situation where MS manage the organic budget individually. In contrast, the second scenario (EU-Target) assumes that the 25% target is set at the EU level, allowing some MS to underperform and others to over perform with respect to their share in organic agriculture. This scenario represents a hypothetical situation where the target implementation and organic budget allocation are managed at the EU level. The primary contribution of this article to the literature is the integration of farm-level behavior and market effects to examine the impact of the EU's organic target. Additionally, the article provides a more comprehensive analysis by focusing on both the economic and environmental impacts of the target.

The simulation results align with expectations, indicating that, on one hand, the introduction of the organic target would lead to some adverse economic impacts, while, on the other hand, the expansion of the organic area would result in various environmental benefits. From an economic perspective, we find a decrease in the supply of main agricultural products in the EU ranging from −0.3% to −7.7%, depending on the crop and animal type. Additionally, we estimate a price increase between 0.2% and 14.4% and a decrease in EU net trade position (exports minus imports), varying across products. Furthermore, our results underscore the necessity for a substantial increase in the organic budget to reach the 25% target, ranging from 5.1 to 8.6 billion EUR depending on the target implementation. From an environmental perspective, our simulations indicate positive environmental impacts, reducing agricultural GHG emissions by almost 4% and the nitrogen surplus by over 10%, with positive impacts on soil erosion, pesticide risks, and biodiversity.

The results reveal that significant differences exist in both economic and environmental impacts between the EU and MS implementation of the organic target. First, the EU-Target is substantially less costly than the MS-Target. This difference arises from the EU-Target selecting farms for conversion with the lowest costs from a combined pool of all EU farms, whereas the MS-Target involves farm selection split by MS sub-pools. Second, the number of farms converting in the EU-Target scenario (0.65 million) is only about half compared to the MS-Target scenario (1.26 million farms). Furthermore, converting farms in the EU-Target scenario are larger on average, with most specializing in livestock production. Conversely, in the MS-Target scenario, farms are smaller on average, and most are crop farms. Third, with some exceptions, the EU-Target scenario results in a lower production reduction, lower price increases and a less significant deterioration of the EU net trade position. Overall, from an economic perspective, the EU implementation appears to be more attractive, yielding fewer adverse economic consequences.

However, from an environmental perspective, the MS implementation of the organic target may offer advantages over the EU implementation in at least two respects. First, the MS-Target is more effective, generating higher absolute environmental benefits (e.g., for GHG emissions, N surplus, biodiversity, soil erosion) than the EU-Target. It is important to note here that although the MS-Target is more effective, it is less efficient when measuring the generated environmental benefits per euro of public money spent compared to the EU-Target. This result can be explained by a higher proportion of extensive farms converting to organic production in the EU-Target scenario. Moreover, the converting farms in the EU-Target scenario are less costly from a budgetary expenditure perspective. Second, another area where MS-Target outperforms the EU-Target is in the regional distribution of the environmental benefits. The MS-Target results in a relatively even distribution of environmental benefits across different EU regions, whereas in the EU-Target, they are concentrated in a few regions. This discrepancy arises because the MS-Target scenario requires that farms from all MS reach the 25% organic target, whereas under the EU-Target, some MS may over or under deliver the organic area relative to the set target.

When drawing conclusions from our findings, it is necessary to recognize the assumptions inherent in our modeling framework applied in this article. First, the modeling framework does not differentiate between conventional and organic products, hindering the consideration of substitution dynamics in simulations for both internal and external EU markets. Furthermore, it does not allow for the incorporation of potential changes in price premiums of organic products. Our results are contingent upon the assumption that organic price premiums over conventional products remain unchanged from the current (pre-target) level. However, an increased supply of organic products could potentially lead to a decrease in the price premiums, thereby influencing the simulation results. Second, environmental leakages to non-EU countries are not accounted for in our article. However, the simulated deterioration of the EU net trade position in the article can be expected to result in negative environmental outcomes being leaked to non-EU countries. This, for example, has been shown by other studies when investigating potential GHG emission leakage effects arising from GHG mitigation efforts in the EU (Fellmann et al., 2018; Himics et al., 2018; van Doorslaer et al., 2015). Third, our model assumes a fixed farm structure, that is, farms' production specialization and size remain unchanged following conversion to organic production. In reality, converted farms may make more significant adjustments in production structure and scale than our modeling framework estimates. Finally, the estimated supply shock will prompt market adjustments, but since we do not account for any market feedback effects on supply, we do not capture this aspect. Consequently, our results tend to overestimate the magnitude of positive supply shocks and underestimate negative ones.

Despite these limitations, our results indicate that a strategic decision might need to be taken by the MS and the EU on how to allocate the organic budget most efficiently in order to minimize adverse effects on production, while concurrently leveraging targeted approaches to maximize the generation of environmental benefits across EU regions. This may require more targeted and regionally customized policy frameworks. One aspect that merits further investigation in this respect is assessing how a targeted conversion to organic agriculture in environmental hotspot regions would affect economic and environmental indicators.

Overall, compared to exiting literature, our article establishes a basis for more comprehensive and differentiated analyses regarding economic and environmental impacts and different pathways for achieving the organic target in the EU. Future research should aim to extend the analysis by considering more disaggregated differentiation between conventional and organic products to be able to account more accurately for the market implications of the target. Other areas of future research could focus on issues such as the territorial heterogeneity of the organic target effects and changes in consumption habits with respect to organic products.

DISCLAIMER

The authors are solely responsible for the content of the paper. The views expressed are purely those of the authors and may not in any circumstances be regarded as stating an official position of the European Commission.

ENDNOTES

[1] Eurostat, Organic farming statistics, https://ec.europa.eu/eurostat/statistics-explained/index.php?title=Organic_farming_statistics.

[2] The FADN is a European system of annual farm surveys that collects structural and accountancy information on EU farms, such as output, land use, input costs, subsidies, and income. It is unique in the sense that it is the only source of EU-wide harmonized and representative farm-level microeconomic data.

[3] Under the CAP, organic farms can receive financial support through Pillar 1 and Pillar 2. In this paper, we do not differentiate the source of the payments.

[4] CAPRI calibrates the baseline to the European Commission's medium-term outlook for EU agricultural markets, considering the CAP 2014 policy reform. IFM-CAP uses CAPRI baseline projections (e.g., prices and yields) to construct the IFM-CAP baseline.

[5] Note that differences in yields and prices between conventional and organic farms have only an indirect effect on land allocation and animal numbers. They determine which farm converts to organic system because they determine the overall farm profitability of organic production (alongside organic farming practices). That is, the differences in yields and prices between conventional and organic farms determine for which farm specializations it is most profitable to convert to organic, while their relative changes in turn affect how converted farms allocate crop and animal activities within the farm.

[6] Note that IFM-CAP allows substitution of crops for alternative crop activities. For a given farm, these alternative crop activities are those previously observed on farms specializing in the same production activities in the same region. In line with this modeling assumption, for the farms specializing only in livestock and having only permanent grassland, there is no option to switch to alternative crops such as arable crops. Therefore, the only alternative for these farms is to leave the grassland fallow if it economically not profitable to use it in the production process.

[7] The rest of farms are mixed farms: 7.6% in the EU-Target scenario and 12.5% in the MSU-Target scenario.

[8] Regulation (EU) No 1307/2013, Annex I.

REFERENCES

Acs, S., P. Berentsen, R. Huirne, and M. van Asseldonk. 2009. “Effect of Yield and Price Risk on Conversion from Conventional to Organic Farming.” *Australian Journal of Agricultural and Resource Economics* 53(3): 393–411. https://doi.org/10.1111/j.1467-8489.2009.00458.x.

Acs, S., P. B. M. Berentsen, and R. B. M. Huirne. 2007. “Conversion to Organic Arable Farming in The Netherlands: A Dynamic Linear Programming Analysis.” *Agricultural Systems* 94(2): 405–415. https://doi.org/10.1016/j.agsy.2006.11.002.

Alvarez, R. 2021. “Comparing Productivity of Organic and Conventional Farming Systems: A Quantitative Review.” *Archives of Agronomy and Soil Science*: 1–12. https://doi.org/10.1080/03650340.2021.1946040.

Armington, P. S. 1969. "A Theory of Demand for Products Distinguished by Place of Production." *IMF Staff Papers* 16: 159–178.

Baker, B. P., T. A. Green, and A. J. Loker. 2019. "Biological Control and Integrated Pest Management in Organic and Conventional Systems." *Biological Control* 140: 104095. https://doi.org/10.1016/j.biocontrol.2019.104095.

Barbieri, P., S. Pellerin, V. Seufert, and T. Nesme. 2019. "Changes in Crop Rotations Would Impact Food Production in an Organically Farmed World." *Nature Sustainability* 2(5): 378–385. https://doi.org/10.1038/s41893-019-0259-5.

Barreiro-Hurle, J., M. Bogonos, M. Himics, J. Hristov, I. Pérez-Domiguez, A. Sahoo, G. Salputra, F. Weiss, E. Baldoni, and C. Elleby. 2021. *Modelling environmental and climate ambition in the agricultural sector with the CAPRI model, EUR 30317 EN*. Luxembourg: Publications Office of the European Union. https://doi.org/10.2760/98160.

Beckman, J., M. Ivanic, J. Jelliffe, F. Baquedano, and S. Scott. 2020. "Economic and Food Security Impacts of Agricultural Input Reduction Under the European Union Green Deal's Farm to Fork and Biodiversity Strategies." U.S. Department of Agriculture, Economic Research Service, EB-30. https://ageconsearch.umn.edu/record/307277.

Bremmer, J., A. Gonzalez-Martinez, R. Jongeneel, H. Huiting, R. Stokkers, and M. Ruijs. 2021. "Impact Assessment of EC 2030 Green Deal Targets for Sustainable Crop Production." *Wageningen Economic Research* 2021-150: 69. https://research.wur.nl/en/publications/impact-assessment-of-ec-2030-green-deal-targets-for-sustainable-c.

Britz, W., and P. Witzke. 2014. CAPRI Model Documentation. https://www.capri-model.org/lib/exe/fetch.php?media=docs:capri_documentation.pdf

Buysse, J., G. van Huylenbroeck, and L. Lauwers. 2007. "Normative, Positive and Econometric Mathematical Programming as Tools for Incorporation of Multi-Functionality in Agricultural Policy Modelling." *Agriculture, Ecosystems and Environment* 120(1): 70–81. https://doi.org/10.1016/j.agee.2006.03.035.

Calabro, G., and S. Vieri. 2024. "Limits and Potential of Organic Farming towards a more Sustainable European Agri-Food System." *British Food Journal* 126(1): 223–236. https://doi.org/10.1108/BFJ-12-2022-1067.

CAPRI. 2022. "CAPRI Model Documentation 2022." https://www.capri-model.org/doku.php?id=capri:docs.

Ciaian, P., E. G. Maria, S. Gomez, Y. Paloma, T. Heckelei, P. Sckokai, K. Elouhichi, A. Thomas, and T. Vard. 2013. "Farm Level Modelling of CAP: A Methodological Overview." In *JRC Scientific and Policy Reports*, edited by S. Langrell. Luxembourg: Publications Office of the European Union http://publications.jrc.ec.europa.eu/repository/handle/JRC79969.

de Ponti, T., B. Rijk, and M. K. van Ittersum. 2012. "The Crop Yield Gap between Organic and Conventional Agriculture." *Agricultural Systems* 108: 1–9. https://doi.org/10.1016/j.agsy.2011.12.004.

European Commission. 2023. "Drivers of Food Security." Commission Staff Working Document, SWD (2023) 4 Final, Brussels.

Fellmann, T., P. Witzke, F. Weiss, B. van Doorslaer, D. Drabik, I. Huck, G. Salputra, T. Jansson, and A. Leip. 2018. "Major Challenges of Integrating Agriculture Into Climate Change Mitigation Policy Frameworks." *Mitigation and Adaptation Strategies for Global Change* 23(3): 451–468. https://doi.org/10.1007/s11027-017-9743-2.

Gaudaré, U., S. Pellerin, M. Benoit, G. Durand, B. Dumont, P. Barbieri, and T. Nesme. 2021. "Comparing Productivity and Feed-Use Efficiency between Organic and Conventional Livestock Animals." *Environmental Research Letters* 16(2): 024012.

Henning, C., P. Witzke, L. Panknin, and M. Grunenberg. 2021. *Ökonomische und Ökologische Auswirkungen des Green Deals in der Agrarwirtschaft*. Kiel, Germany: Institut für Agrarökonomie, Abteilung Agrarpolitik, Christian-Albrechts-Universität https://www.bio-pop.agrarpol.uni-kiel.de/de/f2f-studie.

Himics, M., T. Fellmann, J. Barreiro-Hurle, I. Pérez-Domínguez, T. Jansson, H.-P. Witzke, and F. Weiss. 2018. "Does the Current Trade Liberalization Agenda Contribute to Greenhouse Gas Emission Mitigation in Agriculture?" *Food Policy* 76: 120–29. https://doi.org/10.1016/j.foodpol.2018.01.011.

IPCC. 2019a. "Chapter 10: Emissions From Livestock and Manure Management." In *Intergovernmental Panel on Climate Change*. Geneva: IPCC https://www.ipcc-nggip.iges.or.jp/public/2019rf/pdf/4_Volume4/19R_V4_Ch10_Livestock.pdf.

IPCC. 2019b. "Chapter 11: N_2O Emissions from Managed Soils and CO2 Emissions from Lime and Urea Application." In *Intergovernmental Panel on Climate Change*. Geneva: IPCC https://www.ipcc-nggip.iges.or.jp/public/2019rf/pdf/4_Volume4/19R_V4_Ch11_Soils_N2O_CO2.pdf.

Jones, P., and R. Crane. 2009. *England and Wales Under Organic Agriculture: How Much Food Could Be Produced*? Reading, UK: Centre for Agricultural Strategy, School of Agriculture, Policy and Development, University of Reading.

Kerselaers, E., L. de Cock, L. Lauwers, and G. van Huylenbroeck. 2007. "Modelling Farm-Level Economic Potential for Conversion to Organic Farming." *Agricultural Systems* 94(3): 671–682. https://doi.org/10.1016/j.agsy.2007.02.007.

Kremmydas, D., P. Ciaian, and E. Baldoni. 2023a. "Modeling Conversion to Organic Agriculture with an EU-Wide Farm Model." *Bio-Based and Applied Economics* 12(4): 261–304. https://doi.org/10.36253/bae-13925.

Kremmydas, D., P. Ciaian, E. Baldoni, P. Tillie, G. Diakoulakis, and A. Kampas. 2023b. "What Will Be the Budgetary Cost for Reaching Green Deal's Organic Target? A Farm Level Approach." *European Commission* JRC135783 https://publications.jrc.ec.europa.eu/repository/handle/JRC135783.

Kremmydas, D., A. Petsakos, P. Ciaian, E. Baldoni, and P. Tillie. 2022. "The EU-Wide Individual Farm Model for Common Agricultural Policy Analysis (IFM-CAP v.2)." http://doi.org/10.2760/248136.

Lee, J., M. Necpálová, and J. Six. 2019. "Biophysical Potential of Organic Cropping Practices as a Sustainable Alternative in Switzerland." *Agricultural Systems* 181: 102822. https://doi.org/10.1016/j.agsy.2020.102822.

Leip, A., W. Britz, F. Weiss, and W. de Vries. 2011. "Farm, Land and Soil Nitrogen Budgets for Agriculture Calculated with CAPRI." *Environmental Pollution* 159: 3243–53 https://www.sciencedirect.com/science/article/pii/S0269749111000625?via%3Dihub.

Meemken, E. M., and M. Qaim. 2018. "Organic Agriculture, Food Security, and the Environment." *Annual Review of Resource Economics* 10: 39–63. https://doi.org/10.1146/annurev-resource-100517-023252.

Muller, A., C. Schader, N. El-Hage Scialabba, J. Brüggemann, A. Isensee, K. H. Erb, P. Smith, et al. 2017. "Strategies for Feeding the World more Sustainably with Organic Agriculture." *Nature Communications* 8(1): 1–13. https://doi.org/10.1038/s41467-017-01410-w.

Offermann, F., and H. Nieberg. 2000. "Profitability of Organic Farming in Europe." In *IFOAM 2000-The World Grows Organic, Proceedings 13th International IFOAM Scientific Conference, Basel 28-31 August 2000* 666–69. VDF Hochschulverlag.

Petsakos, A., P. Ciaian, M. Espinosa, A. Perni, and D. Kremmydas. 2023. "Farm-Level Impacts of the CAP Post-2020 Reform: A Scenario-Based Analysis." *Applied Economic Perspectives and Policy* 45(2): 1168–88. https://doi.org/10.1002/aepp.13257.

Petsakos, A., and S. Rozakis. 2015. "Calibration of Agricultural Risk Programming Models." *European Journal of Operational Research* 242(2): 536–545.

Reganold, J. P., and J. M. Wachter. 2016. "Organic Agriculture in the Twenty-First Century." *Nature Plants* 2: 15221. https://doi.org/10.1038/nplants.2015.221.

Seufert, V., N. Ramankutty, and J. A. Foley. 2012. "Comparing the Yields of Organic and Conventional Agriculture." *Nature* 485(7397): 229–232.

Seufert, V., and N. Ramankutty. 2017. "Many Shades of Gray—The Context-Dependent Performance of Organic Agriculture." *Science Advances* 3(3): e1602638. https://doi.org/10.1126/sciadv.1602638.

Smith, L. G., P. J. Jones, G. J. D. Kirk, B. D. Pearce, and A. G. Williams. 2018. "Modelling the Production Impacts of a Widespread Conversion to Organic Agriculture in England and Wales." *Land Use Policy* 76: 391–404. https://doi.org/10.1016/j.landusepol.2018.02.035.

Timsina, J. 2018. "Can Organic Sources of Nutrients Increase Crop Yields to Meet Global Food Demand?" *Agronomy* 8(10): 1–20. https://doi.org/10.3390/agronomy8100214.

van Doorslaer, B., W. Peter, H. Ingo, et al. 2015. "An Economic Assessment of GHG Mitigation Policy Options for EU Agriculture (EcAMPA)." In *JRC Technical Reports, European Commission*. Luxembourg: Publications Office of the European Union. https://doi.org/10.2791/180800.

How to cite this article: Kremmydas, Dimitrios, Caetano Beber, Edoardo Baldoni, Pavel Ciaian, Thomas Fellmann, Alexander Gocht, Jordan Hristov, et al. 2025. "The EU Target for Organic Farming: Potential Economic and Environmental Impacts of Two Alternative Pathways." *Applied Economic Perspectives and Policy* 47(2): 602–623. https://doi.org/10.1002/aepp.13470

APPENDIX A

In Table A1 we provide the organic area in base year/baseline.

For the MS-Target scenario, each MS needs to reach at least to 25% of UAA with organics.

TABLE A1 Organic area in base year/baseline

Base year (2017) – Same as baseline							
	UAA (1000 ha)	Organic area (1000 ha)	Share of organic land		UAA (1000 ha)	Organic area (1000 ha)	Share of organic land
AT	2305.1	674.8	29.3%	IE	4401.6	124.5	2.8%
BE	1349.7	121.8	9.0%	IT	11600.3	2549.1	22.0%
BG	3502.7	159	4.5%	LT	2799.3	289.8	10.4%
CY	100.4	2.8	2.8%	LU	126	5.3	4.2%
CZ	2273.5	550.4	24.2%	LV	1518.2	380.8	25.1%
DE	13569.7	1266.8	9.3%	MT	7.3	0	0.0%
DK	2255.3	371	16.5%	NL	1628.2	164.1	10.1%
EE	826	179.7	21.8%	PL	13733.2	616.7	4.5%
EL	3289.5	213	6.5%	PT	2341.8	180.1	7.7%
ES	19940.9	2625.1	13.2%	RO	10,027	50.8	0.5%
FI	2217.4	325.2	14.7%	SE	2682.2	554.7	20.7%
FR	25533.6	1462.3	5.7%	SI	446.2	97.9	21.9%
HR	1035.6	116.6	11.3%	SK	1462.5	188.9	12.9%
HU	4448.9	116.4	2.6%	EU	135422.1	13387.6	9.9%

In Table A2 we show the additional organic area in 1000 ha and as a share of the base year UAA.

For the EU-Target scenario, the MS do not have national targets. The target is set at the EU level. For this, in Table A3, we present the area (1000 ha) and the share of the land that will convert only in EU level and not in MS level.

TABLE A2 Organic area in MS-Target scenario

	New organic area (1000 ha)	% of new organic area to UAA	% current and new organic area		New organic area (1000 ha)	% of new organic area to UAA	% current and new organic area
AT	0	0.0%	29.3%	IE	975.9	22.2%	25.0%
BE	215.7	16.0%	25.0%	IT	351	3.0%	25.0%
BG	716.7	20.5%	25.0%	LT	410	14.6%	25.0%
CY	22.3	22.2%	25.0%	LU	26.2	20.8%	25.0%
CZ	18	0.8%	25.0%	LV	0	0.0%	25.1%
DE	2125.6	15.7%	25.0%	MT	1.8	25.0%	25.0%
DK	192.8	8.5%	25.0%	NL	242.9	14.9%	25.0%
EE	26.8	3.2%	25.0%	PL	2816.6	20.5%	25.0%
EL	609.4	18.5%	25.0%	PT	405.3	17.3%	25.0%
ES	2360.1	11.8%	25.0%	RO	2456	24.5%	25.0%
FI	229.1	10.3%	25.0%	SE	115.8	4.3%	25.0%
FR	4921.1	19.3%	25.0%	SI	13.6	3.1%	25.0%
HR	142.3	13.7%	25.0%	SK	176.7	12.1%	25.0%
HU	995.8	22.4%	25.0%	EU	20567.5	15.2%	25.1%

TABLE A3 Organic area in EU-Target scenario

	New organic area (1000 ha)	% of new organic area to UAA	% current and new organic area
EU	20,567.7	15.2%	25.1%

APPENDIX B

TABLE B1 Breakdown of areas and animals into conventional and organic (1000 ha or 100 heads, % of area).

	Baseline			EU-Target			MS-Target		
	CONV	ORG	ORG %	CONV	ORG	ORG %	CONV	ORG	ORG %
Soft wheat	16400.9	626.4	3.7%	14820.1	1859.0	11.1%	13859.2	2642.4	16.0%
Barley	10880.0	557.2	4.9%	9760.4	1497.6	13.3%	9458.7	1723.0	15.4%
Maize	6769.4	152.3	2.2%	6234.7	620.4	9.0%	5516.0	1102.8	16.7%
Oats	1586.0	385.3	19.5%	1414.8	576.0	28.9%	1350.1	663.8	33.0%
Rye	1715.3	264.2	13.3%	1649.8	324.7	16.4%	1400.8	610.8	30.4%
Durum wheat	1706.2	237.7	12.2%	1473.0	525.1	26.3%	1447.6	546.0	27.4%
Other cereals	2244.6	272.7	10.8%	2087.2	447.9	17.7%	1819.1	772.4	29.8%
Potatoes	1019.3	55.9	5.2%	978.5	88.8	8.3%	899.1	146.0	14.0%
Pulses	2249.3	376.4	14.3%	2083.9	572.3	21.5%	1976.2	670.8	25.3%
Soya	522.2	41.9	7.4%	495.5	87.3	15.0%	460.9	149.2	24.5%
Rapeseed	3592.3	82.7	2.3%	3195.7	519.1	14.0%	2950.9	721.4	19.6%
Sunflower	2841.9	115.0	3.9%	2587.8	359.9	12.2%	2329.2	610.8	20.8%
Grassland	22544.4	4219.8	15.8%	14146.5	12223.3	46.4%	18723.1	8109.6	30.2%
Fodder maize	7668.8	155.1	2.0%	7276.1	347.8	4.6%	6946.6	569.7	7.6%
Other fodder	15508.0	2954.9	16.0%	12600.0	5962.2	32.1%	12405.3	6491.1	34.4%
Vegetables (open field)	908.6	84.3	8.5%	886.6	117.5	11.7%	686.6	334.8	32.8%
Fallow land	7480.9	719.7	8.8%	6698.3	2305.9	25.6%	6446.8	2250.6	25.9%
Bovine	75886.4	7894.2	9.4%	62039.5	19827.5	24.2%	67441.2	14871.3	18.1%
Sheep and goats	80496.7	12380.5	13.3%	58667.6	31129.0	34.7%	70800.7	19810.8	21.9%
Pigs	66203.2	1690.8	2.5%	64001.8	3611.8	5.3%	63441.4	4108.3	6.1%

Note: CONV refers conventional farms; ORG to organic farms.

APPENDIX C

C.1 | PERFORMANCE DIFFERENCE BETWEEN ORGANIC AND CONVENTIONAL FARMS

Economic and agronomic literature point to significant differences in the performance of organic farms when compared to conventional ones (Alvarez, 2021; De Ponti et al., 2012; Offermann & Nieberg, 2000; Seufert et al., 2012). To model the farm-level supply response in scenarios of increased agricultural area under organic farming, the current modeling approach applies performance differences and behavioral constraints to the farms selected to convert to organic farming.

Estimates of performance differences are extracted from the literature and are based on either econometric studies using FADN data (Kremmydas et al., 2023b) or on farm monitoring

TABLE C1 Performance differentials of organic farms with respect to conventional ones.

Type	Parameter	Activity	Range	Source
Output	Yields	Crops	−2% to −76%	(Kremmydas et al., 2023a)
		Animal products	−0.1% to −32%	(Kremmydas et al., 2023a); Gaudaré et al. (2021)
	Prices	Crops	+1% to +114%	(Kremmydas et al., 2023a)
		Animal products	+1% to +113%	(Kremmydas et al., 2023a); Gaudaré et al. (2021)
Input	Costs	Seeds	−1% to +78%	(Kremmydas et al., 2023a)
		Fertilizers	−3% to +25%	(Kremmydas et al., 2023a)
		Crop protection	−99% to +18%	(Kremmydas et al., 2023a)
		Other costs	−56% to +98%	(Kremmydas et al., 2023a)
		Feeds	+1% to +24%	Kremmydas et al., 2023a)
	Efficiency	Feeds	−13%	Gaudaré et al. (2021)

and field experiments (Gaudaré et al., 2021). These are then applied to the output (yields and prices) and to the inputs (costs and efficiency) of converted farms according to the type of activity and macro-region (Kremmydas et al., 2023a). Table C1 describes the sets of parameters used to model the performance difference between conventional and organic farming as well as respective data sources.

Yield decreases, changes in input costs and efficiency, and behavioral constraints influence the environmental performance of organic farms with respect to the conventional ones. To estimate the environmental implications of reaching the 25% organic farming target, we focus on: GHG emissions, N surplus, crop diversity, soil erosion, and pesticide risk. The GHG emissions (N_2O, CH_4, and CO_2) from livestock and managed soils are estimated per farm using the IPCC Guidelines (IPCC, 2019a; IPCC, 2019b), based on the crops and livestock activity levels and quantity of input use from FADN. Emission factors, volatilization and leaching fractions are mainly coming from National Inventory Reports or default IPCC values when national/regional ones are not available. Nitrogen (N) surplus for each farm is estimated through a farm balance approach, accounting for all the N inputs to and outputs from the farm (Leip et al., 2011). Throughputs, as the uptake of grass by animals, or the application of manure, are not part of the farm N budget. Crop diversity impacts are quantified through calculation of the Shannon diversity index for the farm, based on crop group shares. Soil erosion effects are assessed by adaption the Revised Universal Soil Loss Equation (RUSLE) (Kremmydas et al., 2022). Finally, the pesticide risk is approximated by using the expenditure on pesticides on farms (EUR) as a proxy for environmental impacts related to pesticide use.