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Towards a sustainable Agri-food System for Greece: Insights from the FABLE Calculator

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Towards a sustainable Agri-food System for Greece: Insights from the FABLE Calculator[1]

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Abstract

Agriculture is a fundamental sector for Greece, accounting for more than 4% of the GDP and representing almost 11% of total employment. However, it is characterized by stagnant productivity and subpar contribution to climate change mitigation efforts. This chapter explores the transformation of the Greek agri-food system toward sustainability, leveraging insights from the FABLE calculator. The analysis highlights the environmental and economic benefits of transitioning to a National Commitments pathway, which aligns with EU and national policies and declarations and is underpinned by a bold reform agenda across the agri-food value chain. Key findings indicate that implementing targeted policies and adopting sustainable agricultural practices could halve agricultural greenhouse gas emissions by 2050 while reducing production costs by nearly 50%. A central theme of the chapter is the double dividend of shifting to a Mediterranean diet, which not only enhances public health but also significantly reduces emissions, particularly methane, from livestock. Holding all other assumptions compatible with a business-as-usual scenario, shifting to a Mediterranean diet is associated with a curbing of GHG emissions from agriculture of 5% by 2030 and 46% by 2050 compared to 2020 levels. The findings underscore the importance of addressing structural challenges in the Greek agricultural sector, including fragmented landholdings, low productivity, and slow technological adoption. Policy recommendations emphasize increasing investment in precision agriculture, strengthening Agricultural Knowledge and Innovation Systems (AKIS), and promoting financial incentives to facilitate sustainable transitions. Moreover, integrating the Mediterranean diet into national health strategies and raising public

[1] The authors would like to thank Dr. Theodoros Benos for his insightful comments and overall contribution in this research.

awareness can drive demand-side shifts. Ultimately, this chapter provides a roadmap for Greece to achieve a resilient and low-emission agri-food system, aligning with broader sustainability goals while fostering economic and environmental benefits.

Introduction

Agriculture, forestry and other land use (AFOLU) systems are responsible for 13-21% of global greenhouse gas emissions (IPCC, 2023). In the EU, the agri-food sector accounts for 45% of total environmental impacts, 80% of which is from livestock cultivation (IPCC, 2023). Deforestation, intensive farming, population and economic growth, and dietary patterns have been the primary direct and indirect drivers of this trend. To reach net-zero emissions by 2050 for the sector, it's estimated that $260 billion per year needs to be invested in mitigation technologies and practices. This represents a large and mostly untapped potential, as this investment can lead to more than $44 trillion in benefits (IPCC, 2023).

A strong and sustainable agri-food system contributes to poverty reduction, human health, economic growth and environmental benefits, all of which fall under the Sustainable Development Goals (SDGs) for 2030 of zero hunger, climate action, life on land, and health and well-being. The carbon budget of a warming planet is rapidly shrinking, with agri-food systems required to reach net-zero to achieve emissions reduction targets (Mosnier et. al., 2023). A healthy environment depends on agri-food system transformation since meeting food requirements is directly linked to the challenges of halting biodiversity loss (FABLE, 2022). However, the paradigm of scaling agri-food systems to make cheaper and more abundant food has ignored the environmental and health consequences of the processes needed to scale. Therefore, a shift in the entire agri-food system is needed (Mosnier et al., 2023).

The technologies to transform and modernize the current system exist, with remote sensing platforms, in-ground sensors, targeted spray systems and automated machines offering the potential to increase resource efficiency, increase profits for farmers and reduce the environmental burden of farming (United States Government Accountability Office, 2024). Given the large potential climate and economic benefit of land and resource efficiency gains possible, the agri-food system provides a large opportunity to address the shortfalls so far in fighting climate change and achieving the SDGs.

Agriculture is a fundamental sector for Greece in particular, contributing approximately 4% to the GDP and representing almost 11% of total employment, the second highest share in EU-27 (World Bank, 2021). Greece is renowned for several high-value agricultural products that have significant market shares in domestic and international markets. The country is one of the top producers of olive oil, contributing significantly to the global supply. Additionally, Greece produces a variety of fruits and vegetables, such as tomatoes, peaches, and grapes, which are essential for both local consumption and export markets. These exports play a vital role in the country's economy, supporting the trade balance and generating income. In Greece, the agri-food system results in 7-9 MT of CO_2e per year while accounting for more than 80% of total water withdrawal (World Bank, 2021). While emissions in the sector are declining, albeit at a slower pace compared to the economy as a whole, there has been low adoption of new technologies and practices, while productivity remains low. In 2023 alone, the Gross Value Added (GVA) of the primary sector rose by 15%, reaching €7.5 billion, while the sector employed around 400,000 people—roughly 10% of the country's total workforce—maintaining Greece's position as 12th among EU-27 in agricultural GVA (Laura, 2024; Eurostat, 2023). Despite weak integration into global markets and continued reliance on low-value exports (Pissarides et al., 2020), agriculture remains a core pillar of the Greek economy.

This chapter aims to highlight the untapped potential for the sustainable transition of the Greek agri-food system by leveraging data-based scientific projections. To this end, we present results from the FABLE calculator, a potent modelling tool tailored to the Greek agricultural and food system context. The following section briefly describes the trends and stylized facts underpinning the Greek agri-food sector. Section 3 presents the results from the FABLE calculator. Section 4 offers policy recommendations stemming from the empirical findings. The last section is the conclusion.

Trends and Practices in the Greek Agri-food System

It is well recognized that the agri-food sector is facing serious and multidimensional challenges driven by demographic changes, the climate crisis, and evolving eating habits. Several studies project that by 2050, global agri-food consumption will increase by 40%, and the sector will be required to produce 70% more food, even though the availability of arable land is expected to grow by only 10% (FAO, 2018; Kirova et al., 2019; Popp et al., 2012; Randive et al., 2021; Pardey et al., 2014). Simultaneously, more than 68% of the world's population is expected to live in urban areas, while around 12% may continue to experience malnutrition (UN, 2019; Barth-Jaeggi et al., 2023). Moreover, the average amount of arable land per capita is forecast to decline from 0.23 hectares today to 0.15 hectares (Theys et al., 2016).

In Greece, the agri-food sector is not limited to primary agriculture; rather, it is part of a broader ecosystem that includes several upstream and downstream industries. These range from inputs like agricultural machinery, fertilizers, pesticides, and seeds to output-related industries such as food manufacturing, wholesale and retail trade, and catering. Collectively, these industries form the agri-food sector, which contributes 7.2% to Greece's total GVA and supports 15% of the national workforce (excluding catering) (EC, 2020; AB, 2020).

The food, beverage, and tobacco sector is particularly dominant within Greek manufacturing. With 16,263 firms, it accounts for nearly 39% of all personnel in domestic processing industries (EY, 2022). Greece also boasts a rich portfolio of products registered under the EU's Protected Designation of Origin (PDO) scheme, totalling 115 products. These include 33 wines, 15 spirit drinks, 20 kinds of cheese, 19 varieties of olive oil, 26 fruits, vegetables and pulses, two kinds of honey, as well as emblematic products such as Mesolongi's bottarga (*avgotaraho*), Kozani saffron, and Chios mastic (EC, 2025). Well-known regional specialities like Santorini wines, Kalamata olives, Cretan olive oil, feta cheese, Prespes giant beans, and Feneos fava are prime examples of the sector's cultural and economic value.

The agricultural sector's gross value distribution also demonstrates its economic significance. Around 42% of total production is directed to final household consumption, 23% is used as input for the domestic food and beverage industry, 19% supports internal agricultural and livestock production, 13% is exported, and 6% serves the catering sector. In comparison, the food and beverage sector channels 86.1% of its output to final consumption, 8.4% to catering and tourism, 4.4% to exports, 2.8% to self-consumption, and only 0.7% to livestock production (ELSTAT, 2022; Eurostat, 2023; EC, 2020).

In recent years, however, the Greek agri-food sector has struggled with competitiveness, sustainable growth, and modernization (Makantasi and Valentis, 2024). Despite its central role in the economy, the sector has low productivity levels and slow rates of technology adoption, while ties to the research and innovation ecosystem remain limited (Pissarides et al., 2020).

One persistent structural challenge is the small size and fragmented nature of land holdings, which limits economies of scale and impedes productivity growth. According to 2020 data, the average farm size in Greece is under 7 hectares[2], compared to 17.1 hectares in the EU (ELSTAT, 2020; Eurostat, 2022; Pissarides et al., 2020). As a result, output per hectare is significantly lower than in leading agricultural countries such as the Netherlands. Compounding this issue is the ageing farming population: nearly 65% of farm managers are aged 55 or older, with 37.1% aged over 65—the highest proportion in the EU (Li et al., 2023; Liu et al., 2023).

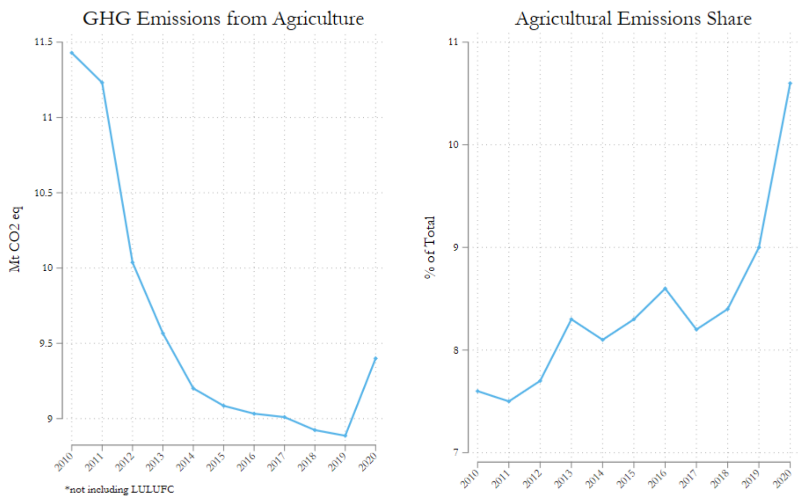
The sector also suffers from a lack of formal training. Only 0.7% of Greek farm managers have completed agricultural education, while 94.1% rely on informal or inherited knowledge (Eurostat, 2020). Outdated farming methods and underinvestment in modern technologies continue to hinder growth. Addressing these gaps requires renewed investment in precision agriculture, sustainable practices, and training.

The prolonged economic crisis in Greece had a deep impact on the sector, stalling investments and reducing domestic product, productivity, and wages (Christopoulou & Monastiriotis, 2015; Kontogeorgos et al., 2016). Infrastructure and innovation uptake stagnated for over a decade (Gashu et al., 2019). Global disruptions, including COVID-19 and geopolitical instability—such as the war in Ukraine and conflicts in the Middle East—have added new burdens by driving up input costs and disturbing supply chains (Farooq et al., 2021; Kozielec et al., 2024; Saâdaoui et al., 2022). At the same time, weak integration into global markets and continued reliance on low-value exports have further undermined competitiveness (Pissarides et al., 2020).

[2] Accurate data is not always easily accessible, primarily due to the periodic nature of studies that provide this type of information.

However, climate change is emerging as the most pressing long-term threat. Rising temperatures, reduced rainfall, and extreme weather events—such as the 2023 "Daniel" storm and widespread wildfires in Rhodes and Attica—are already having severe effects. Although emissions from agriculture have fallen by 18% over the past 25 years, the sector's share of total GHG emissions has risen from 7.6% in 2010 to 10.1% in 2021, reflecting its slower pace of decarbonization relative to other sectors, such as energy and manufacturing (see Figure 1). This further underlines the gap in adopting new technologies and production methods, especially the ones material for climate change mitigation.

Figure 1: Agricultural Emissions Greece



Source: Eurostat & FAO

The Farm to Fork and Biodiversity Strategies of the European Union offer a valuable opportunity for Greece to move toward a more eco-friendly and economically resilient agri-food sector (Boix-Fayos & De Vente, 2023). Such initiatives envision boosting innovation and productivity while reducing the environmental impact of the sector. In the Greek context, this could mean a reliance on more efficient agricultural methods, precision farming technologies, and techniques for sustainable food processing. Embracing these strategies would enable Greece to lower the ecological footprint of its agricultural sector as it pertains to greenhouse gas emissions, water consumption, food loss and waste, and soil erosion. The Common Agricultural Policy (CAP) plays a critical enabling role, aligning sectoral improvements with the broader environmental and climate objectives of the EU.

Moreover, these policy frameworks were generated to strengthen innovations in the agri-food industry in the EU. Through environmentally friendly varieties of crops developed, high-end pest control techniques developed, or principles of circular economy channelled through food production and distribution. These are capable of not only enhancing productivity but also improving the quality and nutritional content of Greek agricultural products. By applying these strategies and the funding opportunities opened up for it, Greece stands a chance to strengthen research and innovation towards sustainable agriculture to promote rural transformation and offer new employment opportunities in the agri-food sector.

Projections using the FABLE Calculator

The FABLE Approach

The FABLE Consortium[3] is a collaborative network bringing together researchers worldwide to create national strategies that align with global sustainability goals, including the Sustainable Development Goals (SDGs) and the Paris Agreement. By collaborating across countries, researchers and stakeholders design strategies that are both scientifically sound and politically practical. These strategies focus on critical areas such as improving agricultural productivity, conserving biodiversity, reducing greenhouse gas emissions, and advancing socio-economic development. The Consortium emphasizes data-driven approaches and facilitates the exchange of knowledge and best practices internationally. Through collaborative efforts and integrated modeling, FABLE supports policymakers in developing sustainable and resilient food systems that can adapt to emerging challenges.

[3] https://fableconsortium.org/

All results and projections within the FABLE approach are drawn with the FABLE Calculator, a powerful Excel-based tool designed to model and project sustainable pathways. The calculator includes 88 raw and processed indicators related to the agricultural sector, economy, and population (Mosnier, 2020). A FABLE Pathway represents a combination of scenarios based on assumptions about key economic, institutional, climatic, and social variables. In turn, the scenarios encompass all of the possible actions that determine the trajectory of the chosen pathway.[4] Key scenario components include:

- Population growth: Projections for demographic change over time.
- Dietary patterns: Assumptions about caloric intake and consumer shifts, such as increased plant-based diets.
- Agricultural productivity: Improvements in crop yields and livestock productivity, often reflecting technological advances.
- Land-use policies: Protection or conversion of natural ecosystems, expansion or reduction of agricultural land, and establishment of protected areas.
- Trade assumptions: Import and export scenarios for food and agricultural products to simulate self-sufficiency or global integration.
- Conservation measures: Inclusion of targets for biodiversity conservation and climate mitigation such as afforestation.
- Bioenergy demand: Scenarios regarding land use for biofuel production

The FABLE Calculator employs a sequential, interdependent approach to model food and land-use systems, where each calculation step builds upon variables computed in previous steps. This cascade methodology presented in Figure 2 ensures that human demand drives all changes in the system. The process begins by computing annual demand for food and non-food consumption, which serves as the foundation for all subsequent calculations. Human demand encompasses three components: food products, biofuels, and other non-food consumption. Historical demand data per capita is derived from FAOSTAT commodity balances,

[4] https://fableconsortium.org/content/pages/scenathon-2023/

establishing the baseline for future projections. Next, the calculator determines livestock sector production, which supplies animal food products while consuming agricultural products for feed. This step computes the evolution of livestock herds, which directly influences feed demand and pasture area requirements needed for subsequent calculations.

Using human and feed demand from previous steps, the calculator computes crop production requirements. Import quantities are calculated by multiplying total demand by the imported consumption share according to selected scenarios, while export quantities follow designated export scenarios. Harvested area is determined by dividing total targeted production by average annual yield per hectare, using FAOSTAT productivity data and selected productivity scenarios for 2015-2050. When targeted expansion of productive land (pasture, cropland, and urban areas) exceeds feasible expansion limits, the calculator applies proportional adjustments. The "excess expansion" is distributed by reducing pasture and cropland areas proportionally based on their share in total targeted agricultural land expansion.

Any discrepancies between targeted and feasible land areas trigger adjustments throughout the causality chain. Livestock numbers are recalculated based on feasible pasture area and ruminant density. Feed demand is adjusted using the cropland adjustment ratio, and crop production is recomputed using feasible planted areas and productivity parameters. The calculator concludes by computing key performance indicators using feasible variables from previous steps. These include daily per capita consumption of kilocalories, protein, and fat; production value and trade balance; greenhouse gas emissions from land-use change and agriculture; biodiversity conservation metrics; and water footprint from crop and livestock production.

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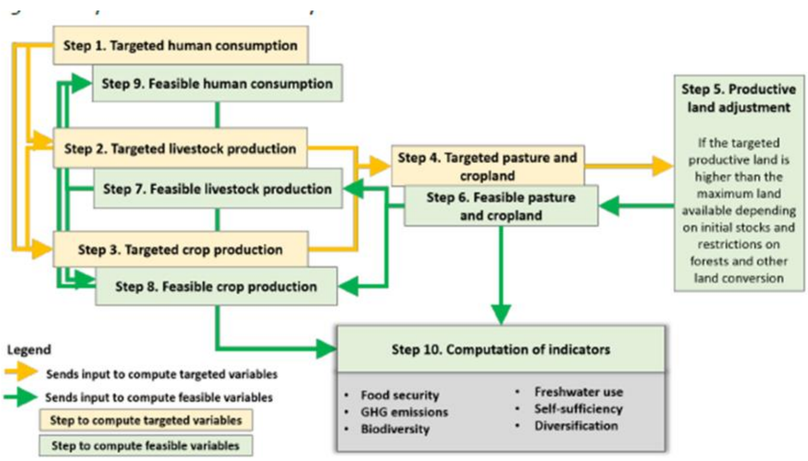
Figure 2: The FABLE Calculator



Source: Mosnier et al., 2020

Unlocking Agri-food Sustainability through National Commitments

As part of the 2023 Scenathon, the FABLE team evaluated 3 distinct pathways in FABLE and produced the respective country report, which was incorporated within the FABLE Consortium to assess the global implications of different pathways. Following the Scenathon procedures, the pathways projected were Current Trends (continuing business as usual based on historical trends), National Commitments (adherence to national and EU explicit and tacit commitments and regulations), and Global Sustainability (in line with national commitments but acknowledging the development status of the Greek economy in the global context). The pathways are described in detail in Koundouri et al. (2023; 2024). The Greek team leveraged the knowledge stock and expertise of the Global Climate Hub and created these pathways based on national and EU documents, pieces of legislation and official declarations.

An iterative process was then performed, updating FAO data with national sources and translated this into three distinct pathways for 2050.

Under the *National Commitments* pathway, the agricultural and food sector undergoes a systemic transformation capturing both the supply and the demand side[5]. Supply side effects include a sizable increase in crop and livestock productivity, stemming from the uptake and dissemination of advanced technologies in agricultural production, as well as a drastic reduction in post-harvest losses and a halt in urban expansion. One should not overlook the potent effect of demand shifts in aligning the performance of the agricultural sector with respect to environmental and sustainability targets. Contrary to the current dietary trends in Greece, the *National Commitments* pathway assumes a shift towards healthy food consumption, aligned with the EAT-LANCET recommendations[6]. This pathway also assumes reduced waste in food production and a drastic drop in post-harvest losses compared to the baseline assumptions. An overview of the components of the 3 pathways for Greece in the FABLE simulations is presented in Table 1 (some of the scenarios with no variation across pathways have been omitted).

PATHWAY	CurrentTrends	NationalCommitments	GlobalSustainability
GDP	Medium speed of economic growth	Medium high speed of economic growth	Low speed of economic growth for most advanced countries (allowing convergence)
Population	No Change	Medium Growth	Medium Growth
Diets	2010 FAO Diet	Lancet Recommendation	Lancet Recommendation
Share of food supply which is wasted	2010 Share	Reduced share compared to 2010	Reduced share compared to 2010

[5] All assumptions underpinning the different pathways are described in detail in Koundouri et al. (2024)

[6] https://www.thelancet.com/commissions/EAT

Share of consumption which is imported	stable imports	reduced imports	stable imports
Evolution of exports	exports* 1.5 by 2050	exports* 2 by 2050	exports* 2 by 2050
Livestock productivity	2000-10 Average	High Growth	High Growth
Crop productivity	No Growth	High Growth	High Growth
Land available for agricultural expansion	No deforestation beyond 2030	No deforestation beyond 2030	No deforestation beyond 2030
Ruminant density	2000-10 Average	2000-10 Average	No Growth
Level of activity of the population	Moderately active lifestyle that includes modest physical activity	Moderately active lifestyle that includes modest physical activity	Active lifestyle that includes elevated physical activity
Protected areas expansion	2010 Protected Areas	Expansion of Protected Areas	Expansion of Protected Areas
Post-harvest losses	2000-10 Average	Reduced Losses	Reduced Losses
Biofuel demand	2000-10 Average	OECD Projections	OECD Projections
Global warming potential coefficient	GWP from the AR6	GWP from the AR6	GWP from the AR6
Urban area expansion	Current Trend of urban land use change	2015 level of urban area	2015 level of urban area
Agroecological practices	Diversified	Organic	Mixed

Source: Authors' Elaborations

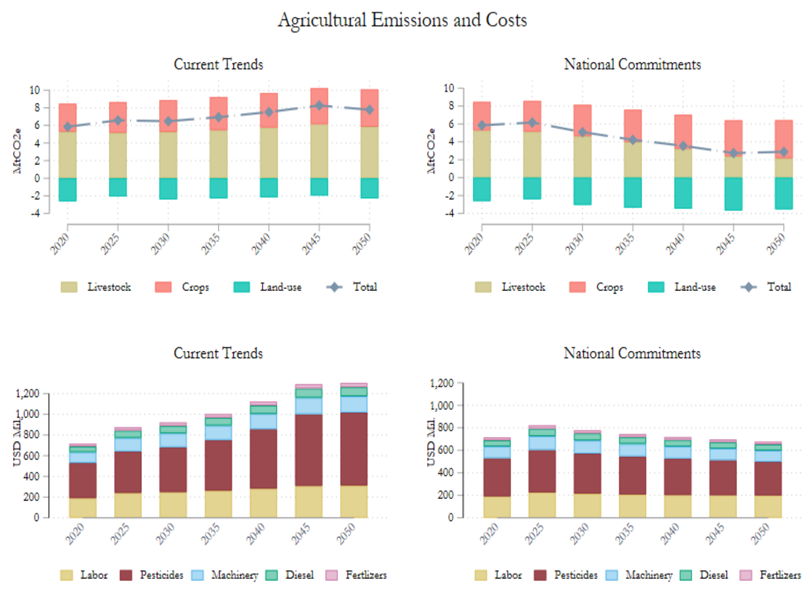
Figure 3 summarizes the results from the FABLE Calculator, showcasing the pronounced differences between the Current Trends and National Commitments pathways. In the top panel, we show the marked decrease in agricultural GHG emissions by 2050 should Greece implement all policies related to the commitments stemming from national and international legislation and initiatives. Under the

National Commitments pathway, total emissions are halved from 5.88 Mt of CO2eq. during the 2020-2050 period, compared to a sharp increase of 33% under the current trends pathway. Having said that, it is noteworthy that by 2030, total agricultural emissions in the National Commitments pathway are 21% lower than business as usual, which highlights the rapid progress to be made if the relevant policy initiatives are consolidated. The decline in livestock emissions is most pronounced, as the combination of enhanced productivity and a dietary shift away from red meat is associated with a 59% drop in total emissions by mid-century; under current trends, livestock emissions grow by 10%. Specifically, methane emissions fall by 44% contingent on national commitments.

Advancements in crop productivity and the proliferation of agricultural practices under national commitments contribute to a drop of crop emissions by a third, whereas maintaining business as usual would have the exact opposite effect by 2050. Furthermore, applying explicit afforestation targets, reducing the share of land for pasture as a result of dietary shifts, and halting urbanization explain the surge in emission absorption through LULUCF by 35% in the 2020-2050 timespan. Finally, the reforms in this pathway are associated with a substantial increase in the share of land where national procedures predominate by 10 percentage points (52-62%) compared to business as usual.

The lower panel of Figure 3 showcases the interesting results regarding the costs for the agricultural sector under the distinct pathways. The FABLE Calculator projects total and disaggregated costs, specifying labor, fertilizer, pesticide, machinery and energy (diesel) costs. Total costs for the agricultural sector rise to almost 1.3 billion USD in 2050 under current trends; however, they are almost half the volume if Greece follows a trajectory underpinned by national commitments. Given that the latter implies a modest 5% reduction compared to 2020 levels, it is evident that the difference stems from the immensely difficult task of catering to the needs of the food system under current practices. Fertilizer costs alone are projected to grow by more than 100% by 2050 if Greece maintains the trajectory implied by the first quintile of the 21st century. By mid-century, projected costs are 35-50% lower across all categories (labor, machinery, fertilizers and pesticides, diesel). A decisive factor is the 17% drop in production volume associated with the bold reforms both in the demand and supply side in the national commitments pathway, however, advancements in crop and livestock productivity tangibly reduce the input requirements per unit of output. Having said that, bolstering the spread of agroecological practices is associated with enhanced soil health, further attenuating the pesticide and fertilizer requirements.

Figure 3: Current Trends vs National Commitments



Source: FAO and Authors' Calculations

The results from the FABLE calculator underline the significant, yet untapped, potential for the sustainable transformation of the Greek agri-food system. Adherence to legislated and soft targets formulating the national commitments pathway brings the agricultural sector closer to net-zero emissions by 2050 whilst cutting total production costs in half and halting biodiversity loss. Our results are in line with the opportunities for the Greek agricultural sector identified by Skylakaki and Benos (2022), who underline the potential to be harnessed by adopting research outcomes from Greece and abroad, leveraging the global shifts towards healthy and nutritious food products and fostering openness for Greek agricultural exports. Overall, shifting to National Commitments produces tangible results globally in addressing pending issues in (inter alia) SDGs 13 and 15, contributing to emissions reduction and a halt in biodiversity loss (FABLE, 2024).

It is important to clarify that food demand in the FABLE Calculator is modeled primarily based on domestic population consumption. The projections incorporate demographic trends, including the anticipated population decline in Greece, which is expected to reduce overall food demand in the coming decades. This factor, combined with dietary shifts and productivity gains, contributes to the reduction in agricultural production volumes observed in the National Commitments pathway. While some static trade assumptions exist in the calculator, it does not dynamically account for potential increases in export demand. This represents a limitation of the current modeling framework. Future research may enhance these projections by integrating food trade dynamics and linking domestic supply to international market scenarios.

The double dividend of the shift to Mediterranean Diets

We further monitor the demand-side effects by examining the output of shifting to a Mediterranean diet that includes a high consumption of fruits, vegetables, whole grains, and legumes. This diet aligns with the Lancet Recommendation of a diet that emphasizes a plant-forward diet where meat and dairy constitute a small role. This is far from the current dietary behaviour in Greece, as the younger generations are distancing from the traditional dietary patterns (Matrimianaki et al., 2022). We impose a strong demand lever in the FABLE calculator, as we assume a shift towards a consumption aligned with the tenets of the Mediterranean diet in the Current Trends and National Commitments Pathways. The Mediterranean diet is based on pronounced fruit and vegetable consumption, combined with moderate red meat and a high share of non-refined cereals.

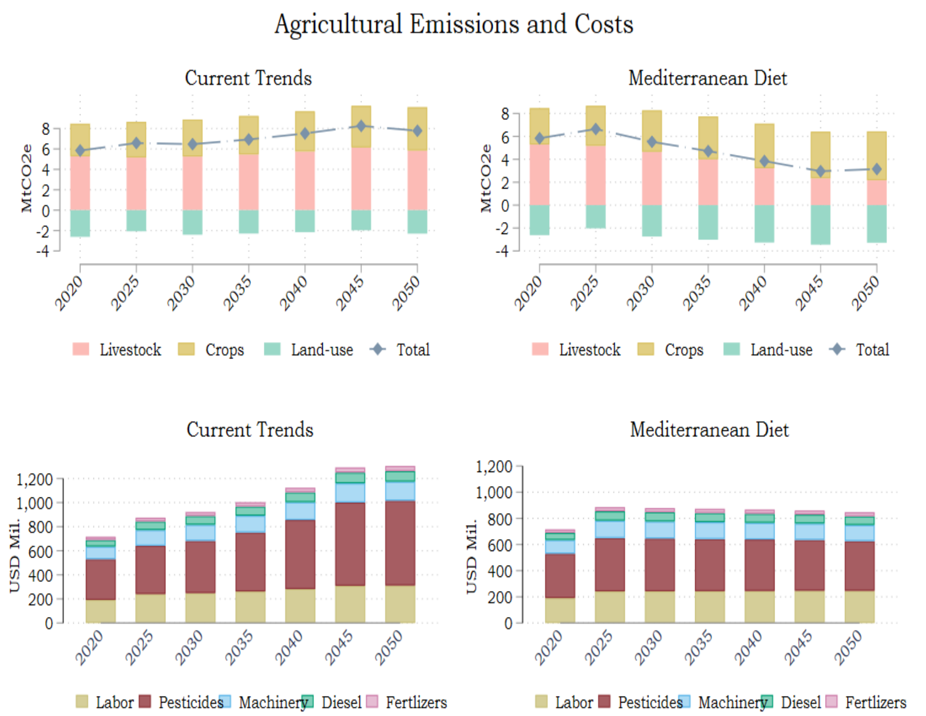
On top of the well-known benign effects on health and well-being (Trichopoulou et al., 2003; Tosti et al., 2018), the Mediterranean diet is associated with a reduction in GHG emissions from AFOLU (Popp et al., 2010; Aleksandrowicz et al., 2016; Poore and Nemecek, 2019; FAO, 2023). The main mechanism for the latter is the drop in livestock emissions (especially in CH4) due to the fall of red meat consumption and, hence, ruminant populations. Moreover, less land is required for livestock production, reducing deforestation and increasing natural carbon sequestration. In addition, the reduction in animal feed growing results in reigning in fertilizer and pesticide use with

GHG emissions mitigating effects. Finally, subdued meat consumption can lower food waste, indirectly reducing emissions associated with food production, transportation, and disposal.

Figure 3 shows the effects of shifting to a Mediterranean diet while keeping all other assumptions related to the *Current Trends* pathway unchanged. Total GHG emissions from agriculture are reduced 5% by 2030 and 46% by 2050 compared to 2020 levels. Compared to a business-as-usual scenario, these reductions increase to 15% and 60%, respectively. This is primarily due to reduced meat consumption leading to a significant decrease in pastureland and ruminant density. This development leads to a 40-60% drop in methane (CH_4) livestock emissions from enteric methane and a 35-55% drop in nitrous oxide (NO_2) from less fertilizer needed and improved manure management. Having said that, reducing meat consumption as part of a Mediterranean diet also reduces emissions through the reduction of food waste, resulting in the impressive effects yielded by the FABLE Calculator in this case (FABLE, 2024). Our results are in line with recent empirical studies quantifying the emission reduction effect of healthy diets. Aleksandrowicz (2016) uses data from 63 studies to conclude that there are plenty of healthy diet combinations to achieve a 60-70% reduction in GHG emissions. Halmstrom et al. (2015) use 14 recent empirical studies in their meta-analysis to underline that curtailing red meat consumption and moving towards more plant-based diets can result in a 10-45% GHG emission decrease compared to baseline scenarios in countries with affluent diets.

From a production cost perspective, the shift to a Mediterranean diet resulted in significant cost savings, as by 2050, costs associated with pesticide consumption are reduced 30-45%, whereas those related to fertilizer consumption are reduced by 25-30% (Figure 4). However, the Mediterranean diet also results in a 14.6% drop in agriculture production from 2025 to 2040, reducing jobs and incomes for the sector overall. This income drop can be mitigated through enhanced productivity, which is part of the National Commitments Pathway, as discussed in the section above. The reduced production in the livestock sector is justified by the shifting away from animal products and is accompanied by a smaller but non-negligible drop in crop production as it provides the products required for animal feed. The drop in production is mitigated once we enhance the Mediterranean diet pathway with the policy levers associated with *National Commitments.* Driven predominantly by the increase in crop and livestock productivity, the decline in agricultural production is mitigated and, most importantly, profitability is not severely affected as a result of an even greater reduction in costs. Having said that, these results highlight the pressing need to couple the dietary shift with supply-side measures and fiscal support for the agricultural sector, especially in a medium-low productivity context as in the case of Greece.

Figure 4: Effects of shift to Mediterranean Diet



Source: FAO and Authors' Calculations

Policy Recommendations

The productivity enhancement of Greece's agriculture sector hinges significantly on how to advance technology adoption and agroecological practices.

Farmers are increasingly reliant on subsidies, which primarily come from EU funds, and this is a structural weakness that must be addressed (Pissarides report). This is especially concerning considering the Common Agricultural Policy (CAP) specifies a decrease in subsidy per hectare for countries like Greece receiving higher per-hectare support (Pissarides et al., 2020). Under the CAP for 2021-2027, Greece should prioritize resiliency and productivity enhancements while subsidies are predictable. Additionally, the government should reconsider fiscal policy instruments compliant with national debt sustainability constraints and EU legislation, separate from subsidies, to not only support farmers' income but to allow them to implement the necessary solutions without additional financial burden. In addition, national authorities would benefit from developing and implementing a coherent plan or cooperatives to leverage their contribution to knowledge dissemination for small-scale member farmers. The plan could entail a robust institutional framework for the internal organisation of the cooperatives, a set of financial incentives aiming to lead to the merger of the (more than 1000) existing cooperatives in Greece and a capacity building program.

Considering the importance of productivity enhancement, underscored *inter alia* by the results presented in the previous section, we advocate that precision agriculture is of material importance. The adoption of precision agriculture in Greece can be accelerated through targeted policies and initiatives that address both technological and financial challenges. Central to this effort is the Agricultural Knowledge and Innovation Systems (AKIS), which creates vital connections between farmers, researchers, and the private sector (Makantasi and Valentis, 2024). Supported by CAP 2023-2027 funding, AKIS facilitates knowledge transfer and provides essential training for modern agricultural practices (Koundouri et al., forthcoming). Key initiatives include establishing a national registry of technical experts offering tailored precision agriculture advice and developing local sensor networks to address Greece's diverse geographical conditions. Regional digital hubs, earmarked as "knowledge reservoirs" in Greece's CAP Strategic Plan, can serve as centers of excellence, providing access to advanced technologies and training through demonstrations and pilot projects. These databases will have to be utilized by the advisors receiving support within the AKIS system (the official target is 6.790 advisors).

This vision aligns with the EU's Farm-to-Fork strategy, which aims to increase the sustainability of the sector while increasing resiliency. In practice, this aim is difficult to implement as sustainable practices may typically be more expensive, or at least more expensive to initially implement. Moreover, farmers' concerns regarding competition with non-EU countries that do not implement costly technology and practice measures discourage adoption. However, in Greece's most recently submitted National Energy and Climate Plan in 2025, these practices may be necessary for the survival of smallholder farms in the face of potential water shortages in the future. Irrigation practices, water management and localized support are emphasized heavily in the plan. This is another example of how smallholder farmers need to plan in aggregate to tackle common challenges.

Specific agriecological practices have already been demonstrated, with pilots on reduced tillage and cover crops demonstrating increased water retention and soil quality. These practices are especially important as the changing climate reduces soil quality and causes an increased frequency of wildfires. Agroecological practices inherently involve a reduction in the use of external inputs such as synthetic fertilisers and pesticides (van der Ploeg et al., 2019). Results from the FABLE calculator indicate that modest increases in the percentage of agricultural land in Greece implementing these practices decreases land use and emissions while maintaining productivity[7]. Educating farmers to implement sustainable practices and get the funding they need to transition to new technologies is paramount. Initiatives like the Agroecological Network of Greece[8] can help to bridge this gap and should take a larger role in coordination among farmers.

To harness the benign effects of the dietary shift toward a Mediterranean diet, a key step is the explicit integration of the Mediterranean diet into the National Health Strategy. This can be supported by scaling up existing initiatives that promote the social dissemination of healthy eating patterns. Public awareness campaigns should highlight the positive impacts of this dietary shift on both human health and the reduction of greenhouse gas emissions. These campaigns could draw inspiration from

[7] The results are not presented here and are available upon request from the authors.
[8] https://www.agroecology-europe.org/agroecological-network-greece-initiated/

successful international examples in Canada[9], Denmark[10], and Finland[11]. Incentivizing consumers is also material in promoting dietary shifts and in this case a comprehensive food labelling, especially in the form of mandatory front-of-pack labelling systems, can enhance consumers' understanding of the nutritional value of food products (Pineda et al., 2022) Community gardens and urban agriculture can also be supported as bottom-up approaches to ensure access to healthy, local produce, which in the Greek case can contribute to the shift towards a Mediterranean diet and reaping the emission-reducing benefits presented in the previous section (Cleveland et al., 2017).

Having said that, the concomitant reduction in agricultural production (mainly but not exclusively in the livestock sector) warrants supplementary measures to support the agricultural producers. These include the technological transformations mentioned in this section with the aim to increase productivity and yields, however, additional action is required, especially in the context of high input costs for farmers in Greece and the EU. The recent strategic dialogue on CAP at the EU level (Strohschneider, 2024) makes some points in the right direction, including the need to adjust payment schemes to favor low-income and young farmers and simplify the administrative procedures for farmers to adopt environmentally sound practices.

Other policy recommendations are aimed to not only increase efficiency and productivity in the supply of goods but to increase its value as well. Common branding for Greek food can help boost demand, as can integrating agriculture with key sectors of the economy, like tourism (Pissarides, 2020). Ultimately, this could also encourage smallholder farmers to share resources and transform cooperatives into something more than financial structures.

Conclusion

Transforming the food and agricultural systems is paramount for a climate-resilient future for Greece, which faces growing challenges due to water scarcity, soil

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[9] https://food-guide.canada.ca/en/

[10]https://national-policies.eacea.ec.europa.eu/youthwiki/chapters/denmark/74-healthy-lifestyles-and-healthy-nutrition

[11]Finland fuels children's future with financial literacy and food

degradation and extreme weather events. To accomplish this, transformations, primarily in the form of the adoption of new technological advances and innovative solutions, and dietary pattern change must be emphasized.

This chapter has demonstrated, using the FABLE calculator, the untapped potential for significant reductions in greenhouse gas (GHG) emissions and production costs in the 2025-2050 period should Greece adhere to its national commitments stemming from national and EU legislation and policy documents. Under the National Commitments pathway, which aligns with national and EU policies, agricultural GHG emissions could be halved by 2050 compared to business-as-usual scenarios By transitioning towards more sustainable practices, investing in the adoption of state-of-the-art technologies to enhance productivity and optimizing resource use, the Greek agricultural sector can maintain its viability while contributing meaningfully to climate mitigation.

Furthermore, we model the effects of a shift to the Mediterranean diet for the Greek population, contrary to the trends of the last 40 years, to find significant emission reduction effects through the reduction in pastureland and the sharp decline in fertilizer and pesticide use. Specifically, methane emissions from livestock could decline by 44%, and total agricultural emissions could decrease by 60% compared to current trends. The combined benign effects for human health and climate change mitigation from such a dietary shift, although far from current consumption patterns in Greece, warrant a succinct inclusion of the Mediterranean diet in the policy agenda. A concomitant set of supply and fiscal measures to support the livestock farmers is imperative to minimize trade-offs and ensure the economic (and political) viability of the transition.

However, realizing this transition to sustainability demands acute policy action and widespread dissemination of knowledge among stakeholders. Collaboration between policymakers, industry players, and local communities is essential to foster the rapid deployment of sustainable practices and technologies. The fostering of domestic innovation systems and enhanced linkages to international knowledge and technology sources is pivotal for unlocking productivity gains, which are of vital importance for the Greek agricultural sector. Key measures include expanding investment in precision agriculture, strengthening Agricultural Knowledge and Innovation Systems (AKIS), and supporting cooperatives to enhance economies of scale. The Common

Agricultural Policy (CAP) should prioritize financial mechanisms that facilitate sustainable transitions, such as targeted capital transfers and incentives for young farmers. Moreover, comprehensive educational initiatives are needed to empower farmers with the skills and tools necessary for this transition.

Ultimately, the path forward is clear: a concerted effort to embrace sustainability will not only address Greece's environmental challenges but also enhance its agricultural sector's resilience and competitiveness. By capitalizing on its unique natural and cultural heritage, Greece has the opportunity to emerge as a leader in sustainable agriculture, setting a powerful example for other nations navigating the complexities of climate-smart food systems.

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