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A "Teal" Deal for European agriculture

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Abstract

The European Union (EU) has been actively combating climate change for decades, and in 2019 it introduced its most ambitious project to date, the European Green Deal (EGD). EGD includes a variety of policies and strategies aimed at mitigating the adverse effects of climate change, foster an economic growth, and promote social equity. Recently, the European Commission has been contemplating the development of the European Blue Deal (EBD), which aims to address the growing water crises and water insecurity issues within the EU. Similar to the EGD, the EBD would encompass all sectors of the European economy, seeking integrated solutions to these pressing environmental problems. This review aims to assess the progress of the EGD, evaluate the objectives of the EBD, and provide insights into the factors that could either catalyze or hinder their effective and harmonious implementation. The concept of a "Teal Deal" (a combination of the blue and green color) which combines elements of both the EGD and the EBD, is explored, with particular emphasis on its implications for the agrifood sector. Here we argue on the necessity for a holistic approach to agricultural sustainability, rapid advancements in renewable energy, the adoption of crop diversification strategies, and the development of effective international policies to ensure global cooperation and support for these transformative initiatives. By addressing these key areas, the EU can make significant strides towards achieving its environmental and economic goals.

Keywords: agricultural sustainability; European Green Deal; European Blue Deal

Introduction

Ever since the industrial revolution, humanity has been spiraling into an exponential techno-economic growth at the steep cost of environmental degradation (Destek *et al*., 2024). Studies suggest that the extensive loss of biodiversity could constitute the sixth largest extension event in earth's history (Ceballos *et al*., 2015). Climate change is regarded as arguably the greatest threat to our collective prosperity (UN, 2021). Due to the anthropogenic climate crisis, food insecurity is constantly rising, especially in the developing world (Editorial, 2022). To put the severity of the status quo in perspective, in a study by Richardson *et al*. (2023), the authors estimated that Earth is currently beyond six of nine planetary boundaries (biochemical flows, freshwater

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change, land system change, biosphere integrity, climate change, and novel entities). These extraordinary changes on Earth in the Anthropocene are not newly discovered (Ohara, 2022). As early as the beginning of the 20th century, scholars and researchers foreshadowed Global Warming due to the rising carbon dioxide levels in the atmosphere (Wulff, 2020). Following the Second World War, the newly-formed green movements raised awareness on soil health and agriculture's dependence on chemical inputs (Paull, 2023). By the late 1980s members of the scientific community had already acknowledged the severity of climate change's consequences, some even comparing them to a "global nuclear war" (Kemp *et al*., 2022). Entering the new millennium, as the evidence of mankind's negative impact on the biosphere grew stronger, the first international climate change agreements were proposed (Maslin *et al*., 2023). Currently, most nations worldwide have agreed on adopting measures to tackle climate crisis and restore the environment to its original state (UN, 2015), though admittedly the efficiency of governments in addressing the environmental crisis varies vastly across the globe (Averchenkova *et al*., 2022).

One of the pioneers in mitigating environmental degradation is the European Union (EU). From its early days, the EU recognized the human impact on the environment (Hey, 2007). Through a series of initiatives and strategies, the EU prioritized agri-environmental sustainability and set a series of objectives related to environmental amelioration, food security, social equity, and many more (Hey, 2007). Under this scope, the EU reached a milestone in 2019 with the presentation of the European Green Deal (EGD) (ESDN, 2020). The EGD is a collection of strategies that aims to improve the well-being of people, make Europe climate-neutral, and protect and restore its natural habitats (European Commission, 2019a). Presented in December of 2019, EGD aspires to addresses issues of the energy, agricultural, and industrial sector, as well as social equity and inclusivity, by 2030 (ESDN, 2020). Recently, the Commission has been considering the lunching of an additional set of policies related to water use, safety, and security under the development of a European Blue Deal (EBD) (EESC, 2023a).

The aim of the present review is to concisely assess the progress of EGD, evaluate the objectives of EBD and, and provide insights to the factors that could catalyze or hinder their harmonious implementation, with emphasis on the aspects related to the agrifood sector.

The EGD at a glance

Prior to the EGD, the EU had already worked on and implemented environmental policies. Case in point, the 2005 Emission Trading System that aimed to reduce emissions via a carbon market (Soliman and Nasir, 2019) and the reform of the Common Agricultural Policy for 2014-2020 that promoted the preservation of the environment and the mitigation of climate change (Nazzaro and Marotta, 2016), just to name a few. Consequently, the Commission possessed the essential political tools and instruments to develop and initiate the EGD (van der Sluis, 2023). When Ursula von der Leyen presented the EGD, it was clear from the start that it would be a challenging policy programme (Alberti *et al*., 2021). As she stated "*…this is Europe's 'man on the moon' moment. The European Green Deal is very ambitious, but it will also be very careful in assessing the impact and every single step we are taking…*" (European Commission, 2019b). Following its presentation, the EGD incorporated several strategies, action plans, and packages (Figure 1), constantly progressing towards the "green transition" it embodies (European Commission, 2024a).

Broadly speaking, the EGD's key-policy areas are i) climate change mitigation and environmental restoration, ii) providing clean, affordable and secure energy for all, iii) promoting competitiveness and expanding the industrial sector whilst adopting the principles of circular economy, iv) establishing sustainable and smart mobility, v) equity and inclusivity for all EU citizens, and vi) fortify the agrifood sector and maintain food security (European Commission, 2024a).

Event	R	Date	Event	R
Presentation of the European Green Deal		21.02.2023	Package of measures on the aquaculture sector	
First COVID-19 case in EU		10.03.2023	Rules to boost energy efficiency	
Brexit		14.03.2023	Reform of the EU electricity market	
Proposal for a European climate law		16.03.2023	Critical Raw Materials Act	
European Industrial Strategy		16.03.2023	Net-Zero Industry Act	
Circular Economy Action Plan		16.03.2023	New European Bauhaus regarding Ukraine	
EU Biodiversity Strategy		22.03.2023	Consumer protection against greenwashing	
Farm to fork strategy		23.03.2023	Agreement on maritime transport emissions	
EU strategies for energy system integration		28.03.2023	Alternative Fuels Infrastructure Regulation	
2030 Climate Target Plan		21.04.2023	Marketing standards of agri-food products	
Chemicals strategy for sustainability		25.04.2023	Fit for 55 presentation	
Methane Strategy		25.04.2023	EU Energy Platform	
Renovation wave		26.04.2023	ReFuelEU Aviation proposal	
Offshore renewable energy		16.06.2023	Revision of the Energy Labelling Regulation	
European Climate Pact		05.07.2023	Sustainable use of key natural resources package	
European Battery Alliance		01.10.2023	Carbon Border Adjustment Mechanism	
New European Bauhaus		09.10.2023	Fit for 55 package of measures	
Strategy on adaptation to climate change		24.10.2023	European Wind Power Action Plan	
Zero pollution Action Plan		22.11.2023	New forest monitoring law	
Sustainable blue economy		28.11.2023	Acceleration of the roll-out of electricity grids	
New European Bauhaus		29.11.2023	Modernizing management of industrial emissions	
Proposals for more sustainable travel		02.12.2023	Pledge on Renewables and Energy Efficiency	
Decarbonise gas markets, promote hydrogen		05.12.2023	Agreement on hazardous chemicals	
Escalation of the Russo-Ukrainian conflict		07.12.2023	Rules on the energy performance of buildings	
REPowerEU		08.12.2023	Update on the gas market decarbonization	
Commission joins the European Climate Pact		14.12.2023	Reform of the EU's electricity market design	
Nature protection package		19.12.2023	Trans-European transport network agreement	
'Save gas for a safe winter' proposal		18.01.2024	Trucks and urban buses emissions agreement	
Reduction of energy bills for Europeans		25.01.2024	Strategic dialogue on the future of EU agriculture	
Measures against wildlife trafficking		29.01.2024	Cost-effective urban wastewater management	
Proposal for new Euro 7 standards		06.02.2024	Net-Zero Industry Act	
EU Algae Initiative		06.02.2024	2040 emissions reduction target	
Circular Economy for Packaging Regulation		06.02.2024	EU Industrial Carbon Management Strategy	
Law on global deforestation		08.02.2024	Banning of uses of toxic mercury in the EU	
A New Deal for Pollinators		20.02.2024	New air quality standards in the EU	
Green Deal Industrial Plan		11.03.2024	Regulation on fluorinated greenhouse gases	
Rules for renewable hydrogen		27.03.2024	Directive on green transition for consumers	
2030 zero-emissions target for new city buses				

Figure 1. A brief timeline of EGD. Significant events for the progress of EGD are enlisted in the "Event" columns, alongside their corresponding date. R columns dictate the relevance of each event: environmental policies, green; policies related to the industrial sector, blue; agricultural policies, brown; energy policies, yellow; infrastructure and urban environment policies, grey; historic events, red

The later was initially addressed in the "Farm to Fork" strategy, followed by additional initiatives (European Commission, 2024a). The EGD pursues a worldwide shift towards competitive sustainability across the entire food supply chain, and to diminish the environmental and climate impact of the EU's agrifood system

whilst enhancing its resilience to external shocks and ensuring food security amidst geopolitical uncertainties (European Commission, 2023a). In particular, by 2030, it aims to i) halve the utilization and risk associated with chemical pesticides by 50%, as well as decreasing the use of more hazardous pesticides by 50%, ii) decrease nutrient losses by a minimum of 50% (while ensuring soil fertility does not decline), and reduce fertilizer usage by at least 20%, iii) cut the sales of antimicrobials for farm animals and aquaculture by 50%, iv) achieve 25% of total farmland under organic farming, v) allocate 10% of farmland to high-diversity landscape features, and vi) diminish per capita food waste at the retail and consumer levels by half, all while reducing greenhouse gas emissions by at least 55% (compared to 1990) (Guyomard *et al*., 2023). Admittedly, distinguishing which strategies of the EGD affect European agriculture is complicated. For instance, agriculture is both a major cause and a casualty of environmental degradation (FAO, 2022a).

In the EU, approximately 10% of the annual GHGs emissions are attributed to the agricultural sector (OECD, 2023). These emissions contribute to climate change that has heavily affected the production of agrifood commodities (European Commission, 2024b). Therefore, every policy that aims to tackle climate change or any other form of environmental degradation could significantly impact the agri-food sector. Overall, when assessing its impact on a single sector, EGD should be evaluated on its hole and not broken down to separate strategies.

Criticism, limitations, and challenges

Ever since its conceptualization, many expressed their concerns regarding the consequences and the feasibility of the EGD's ambitions. When it was communicated to the EU Parliament, parliamentarians of The Left withheld their support due to the reliance of its carbon policies on market mechanisms and conversely, the European Conservatives and Reformists Group coalition opposed it due to their concerns over its potential impacts on employment and businesses (Almeida *et al*., 2023). According to Bogoslov *et al*. (2022), it could have a negative impact on entrepreneurship and competition within EU. Moreover, despite of having social equity amongst its central axes (European Commission, 2024a), it has been noted that EGD might not sufficiently address the gender gap in the EU policies (EEB, 2021). Authors have argued that the EGD actually averts and reallocates EU's climate responsibility (Fuchs *et al*., 2020), or even accused it of promoting "green colonialism" (Claar, 2022). The EU has also been criticized on its international agri-food trading relations with third countries in the post-EGD era, that in some cases result in higher prices for consumers (Sandri et al., 2023).

In the span of 2020-2022 the EU faced two unpredictable challenges: the outbreak of the COVID-19 pandemic and the escalation of the Russo-Ukrainian conflict (Rybski, 2023). Few months after the presentation of EGD the pandemic reached the EU. In the months that followed the strict travel restrictions, quarantines, and lockdowns resulted to a severe economic destabilization (Ehnts and Paetz, 2021). During this time carbon prices and energy demand plumbed (Dudău and Cătuți, 2020). Some expressed their concerns that this could have adverse effects on the implementation of EGD and the energy transition discourse, especially in European countries that heavily rely on fossil fuels (Dudău and Cătuți, 2020). Even though the Commission initially admitted that the EGD would delay as they would have to prioritize the management of the COVID-19 crisis (ECEEE, 2020), they quickly revised and adopted the EGD as a recovery strategy that would address the impact of the pandemic on the economy of EU (Crnčec *et al*., 2023). Similarly, two years later when the Russo-Ukrainian conflict was escalated the EGD was regarded as the mechanism that would reduce EU's dependency on fossil fuels and mitigate the energy crisis that the war caused (ETTG, 2022; Rybski, 2023). In both cases the EGD was adapted to the needs of the EU, and proposed solutions to the raising challenges whilst maintaining its original goals (ETTG, 2022).

The aforementioned price oscillations in fossil fuels had their toll in the European agricultural sector. The Russo-Ukrainian conflict elevated significantly the cost of not only fuels, but also pesticides, fertilizers, and energy altogether (FAO, 2022b). This was one of the major reasons that resulted in extensive farmers protests in many Member States (including Belgium, France, Germany, the Netherlands, Romania, and Poland) in the December of 2023 (Reuters, 2024a). In these protest European farmers demanded fair revenue, denouncing the EGD (Reuters, 2024b). The backlash put pressure on the Commission to take action, but also reraised questions on the efficiency of the European "green policies", including the EGD (Euronews, 2024a).

In 2023, the European Environment Agency (EEA) published a report on the progress of the 8th Environment Action Programme (EAP), with heavy implications on the advancement of the EGD (EEA, 2023). Based on the findings of the report, the EGD could be progressing alarmingly slow (Figure 2).

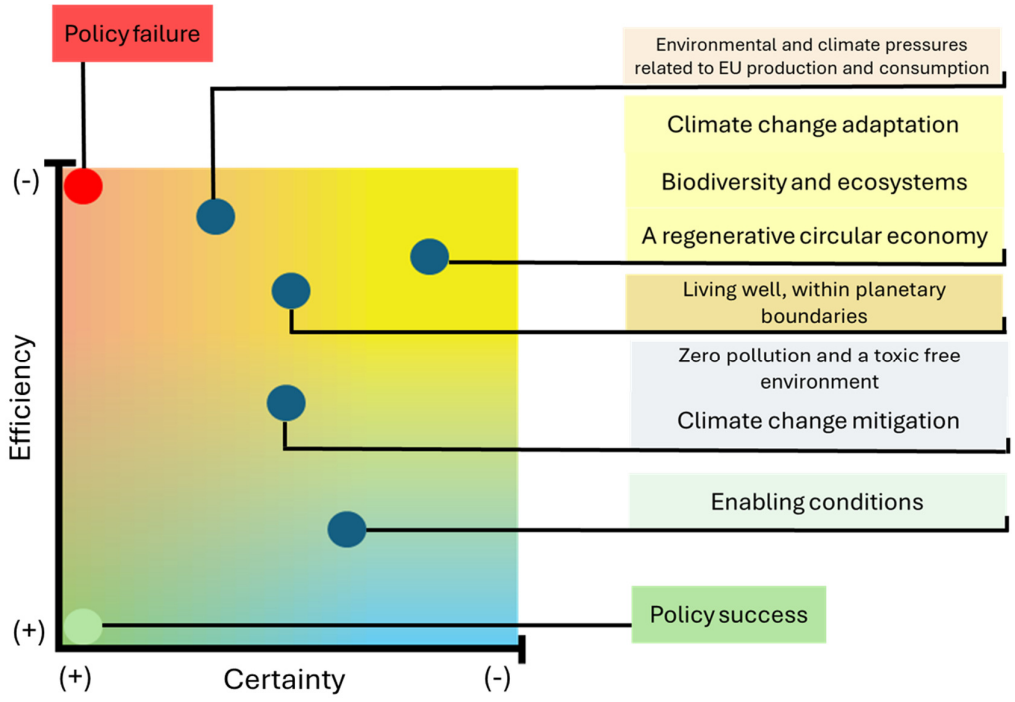

Figure 2. Indicative visualization of the 8th Environment Action Programme progress. The targets are placed on a color scale based on the probability of meeting them by 2030. The blue points in the graph correspond to the 8 targets of the Programme. Distance from the x axis indicates the probability to fail in meeting the targets, and distance from the y axis dictates the certainty of the prediction.

In their assessment, the EEA utilized 28 indicators relevant to the 8 targets (climate change mitigation, climate change adaptation, biodiversity and ecosystems, enabling conditions, a regenerative circular economy, zero pollution and a toxic free environment, living well within planetary boundaries, and environmental and climate pressures related to EU production and consumption) of the EAP. In some cases, the indicators suggest that in order to meet the 2023 targets the corresponding effort should be amplified by twofold-ninefold (EEA, 2023). In particular, the EEA report concluded that the current net emission, climate change adaptation, material footprint and waste management, nutrient losses into groundwater, biodiversity and ecosystem, and the energy efficiency related policies are probably insufficient and many objectives of the EGD could fail (EEA, 2023). Especially the GHGs removals by carbon sinks from the land use, land-use change and forestry (LULUCF) sector, the reduction of energy consumption and the overall consumption footprint, and the increment of circular material use and area under organic farming targets are very unlikely to be met by 2030 (EEA, 2023), indicating limitations in the energy and climate change related policies (Figure 3).

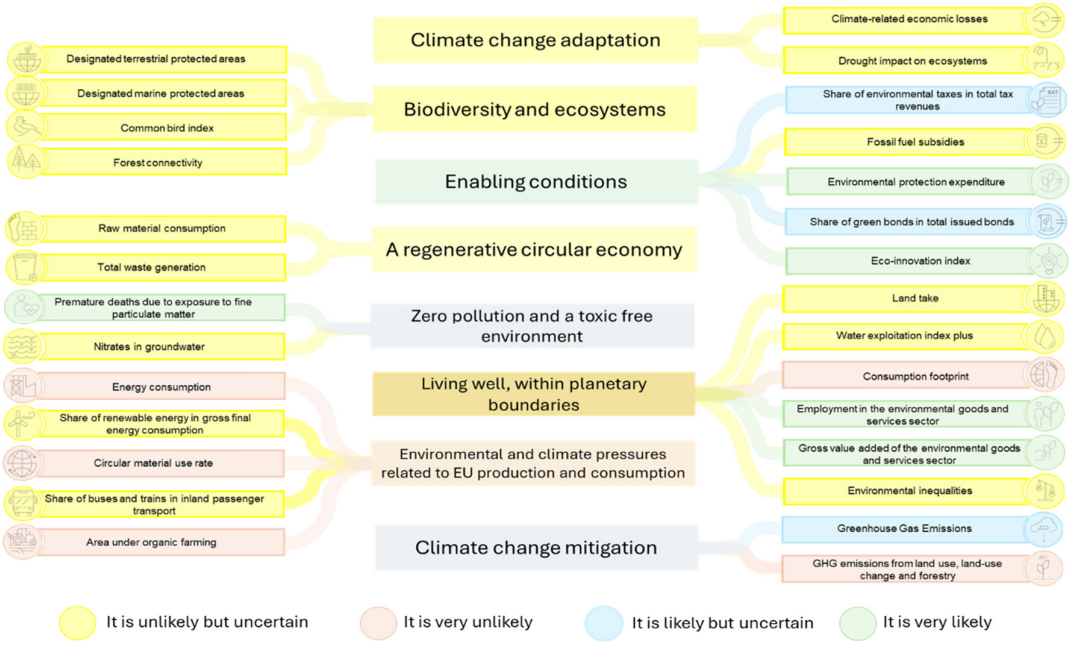

Figure 3. Progress of the 8th Environment Action Programme. The 8 Programme targets are depicted in the middle of the figure. The relevant indicators are connected with each target. Different colors represent the progress: yellow, unlikely but uncertain; red, very unlikely; blue, likely but uncertain; green; very likely (EEA, 2023)

A European Blue Deal

In the October of 2023 the European Economic and Social Committee (EESC) published a declaration where it calls for an EBD (EESC, 2023a). According to the EESC, EU should "*consider water as a priority and to adopt an EBD as a standalone strategic policy, on an equal footing with the EGD*" (EESC, 2023a). The theory behind the conceptualization of EBD is that water constitutes a vital resource for human welfare and the access to safe drinking water and sanitation is a human right (IUCN, 2004), therefore water crisis management should divert from the EGD umbrella and act as an independent, high-priority policy (EESC, 2023a). Afterall, approximately 20% of Europe and 30% of its population are estimated to suffer by water scarcity (with most models predicting that climate change will further boost these percentages) (EEA, 2021; ECA, 2021). Additionally, despite of the notable progress in sanitation during the last decade, in some Member States significant portions of the population still do not have access to basic sanitary facilities (Eurostat, 2023a).

Even though the conceptualization of EBD is still at an early stage, the declaration and a series of published EBD related opinions indicate the axes upon which it could be built. According to the EESC, the EBD should follow 15 basic principles (Table 1) (EESC, 2023a). These principles are related to the preservation of ecosystems and biodiversity, the agricultural and industrial sector, EU and international policies, and social aspects. Moreover, the EESC provided 21 actions that should be implemented in the near future, in accordance with the 15 principles (EESC, 2023a). The call for an EBD wishes to address the lackluster progress on the water-related objectives set by other initiatives of the EU, in accordance with the Sustainable Development Goals of the UN (Joó et al., 2023). Similar to the EGD, the EBD spans across societal (Angelova and Vardakastanis, 2024), environmental (Schwartz, 2023), and economic (Marin, 2023) aspects of water use and availability.

Table 1. The basic principles and some of the suggested actions for immediate implementation according to the call for a European Blue Deal (EESC, 2023a)

Principles		**Possible related actions to be implemented according to the EBD declaration**	
No.	Description	No.	Description
1	The new European water policy must be aligned with all other EU policies and based on up-to-date, accurate, transparent, comparable, easily accessible and reliable data	11	Create a Knowledge Innovation Community and step up the "five missions" approach.
2	The restoration and protection of ecosystems, wetlands and biodiversity	18	The recently agreed UN High Seas Treaty should be swiftly implemented.
3	The adoption of a human right-based approach to water and to a healthy environment in order to tackle water poverty	1	Develop common guidelines to monitor access to quality and affordable water and sanitation services (WASH) as well as to map the state of play and to regularly follow developments.
4	WASH services must be sustainable, equitable, of high quality and affordable for all	5	Finance WASH infrastructure, particularly in socially disadvantaged areas
5	All water users should be encouraged to adopt solutions and practices supporting the sustainable use and consumption of water	7	Awareness-raising campaigns and specific actions to promote understanding of the value of water and change long-term behavior must be launched in all Member States.
6	Support of the development of technologies enabling water efficiency, recycling and pollution reduction as well as their incremental uptake by agriculture, industry and households	15	A Blue Transition Fund (BTF) must be set up at EU level as a single EU access point for water investments and combining public investment with innovative financing.
7	Water losses due to leaks in networks and waste of water by agriculture, industry, households and all other users need to be significantly reduced	4	Each Member State's water infrastructure and water resources need to be immediately and thoroughly assessed in order to identify urgent investment needs. Consistent legislation should be put in place across all Member States to establish a sustainable water storage mechanism during wet periods.
8	Ensure access to sufficient quality water and its sustainable management in agriculture to enable adequate and sustainable food production in the EU	2	An EU advisory stakeholder platform should be established to share best practices, develop specific standards on water quality and use in agriculture and industry
9	Water should be seen as a fundamental element of the EU's industrial strategy	10	EU's industrial strategy needs to be reviewed to include water-related industrial challenges and opportunities
10	The no-harm principle has to be combined with a right for economic activities to consume water	20	A European Water Centre with an international dimension should be set up to support Member States to address water-related issues
11	The availability of skilled and specialized workers must be ensured, and the competitiveness of European companies must be preserved.	13	EU agricultural and industrial policies must integrate measures and promote the adoption of good practices, training and new technological solutions
12	Water prices, costs and taxes must be fair and transparent, and prices must be based on the principle of full cost recovery	6	Prices must take account of long-term water security, incorporate the 'polluter pays' principle and ensure universal access and affordable prices, particularly for vulnerable groups.
13	The EU should increase its efforts on blue diplomacy and water should be integrated into the EU's foreign policy and external relations, including neighborhood, trade and development policies	19	The EU should facilitate sustainable water and wastewater management through cooperation in the fields of infrastructure, technologies and expertise as part of economic partnerships and development cooperation. The Global Gateway is an excellent tool in that respect.
14	Develop international policies to promote the sparing and efficient use of water in all sectors of the economy and society, to reduce the pollution of ground waters and surface waters, as well as to restore polluted and degraded waters		
15	The adequate governance of freshwater resources, including groundwater	21	A dedicated EU Commissioner should be in charge of the water portfolio.

Of course, the EBD is expected to have a significant impact on European agriculture. In the EESC declaration, 3 out of the 15 principles (namely principles no. 6-8) are associated with the sustainable use of water in agriculture (EESC, 2023a). Among the urgent actions under the EBD, the EESC proposes *i) the formation of an EU advisory stakeholder platform to share best practices, develop specific standards on water quality and use in agriculture, ii) the systematic collection of transparent, comparable, easily accessible and reliable data on current state-of-play and long-term trends at EU level with regard to water use in the agricultural processes, iii) the integration of measures fostering the reduction, reuse and recycling of water and the reduction of water pollution,*

through the adoption of good practices, training and new technological solutions in agriculture, and iv) the integration of indicators in each Member State to facilitate the monitoring of the progress in water management in order to ensure a substantiable transition in the agri-food sector and its adaptation to climate change (EESC, 2023a). Rocamora and Comer (2023) suggested that under the context of EBD and the sustainable use of water in agriculture, the EU should focus on i) maintaining agricultural production, ii) ensuring the availability of sufficient (both in quantity and in quality) water for agriculture, iii) reducing the sector's water footprint, iv) promoting sustainable farming practices (e.g. precision agriculture, utilization of genetic resources and variation, sustainable soil management for increasing soil's water retention capacity), v) reducing food waste, vi) modernizing the irrigation infrastructures to minimize water losses, vii) promoting urban and peri-urban agriculture, viii) developing and integrating novel technologies for water management, and ix) promoting the principles of Circular Economy in water use (via water recycling). The latter should be accompanied by the decarbonization of agriculture, the use of renewable energy, and the aforementioned new technologies.

European agriculture in the era of "Teal" Deal

At present, EU's internal policies and strategies are conflicting. The EGD promises to "leave no man behind" but the Commission openly discuss seed law reforms that would counter farmers' right to seeds (Arche Noah, 2023). The EGD aspires to address environmental degradation, yet Commissioners oppose the restriction of chemical pesticides (Euronews, 2024b). EU's agri-environmental policies might have coherence issues in a crucial point for the Union's history. Once the EBD will be officially announced, the EU will enter the era of the "Teal Deal", defined by the simultaneous implementation of both the EGD and the EBD. Based on the literature, the progress of the EGD, and the published EBD related pieces, we argue that in this era EU should focus on the:

Holistic approach of agricultural "sustainability"

To better understand this paradigm, one could refer to the prominence of organic farming in the EGD. One of the EGD targets is for organic production to reach 25% of the EU's agricultural land use by 2030 (European Commission, 2020a). This objective coincides with the reduction of chemical inputs in agriculture and the enhancement of food safety that it vouches for (European Commission, 2020a). However organic farming is not the only sustainable-agriculture narrative that enables the minimization of inputs (e.g. agroecology, permaculture, regenerative agriculture etc.) (FAO, 2018; Krebs and Bach, 2018; Al-Kaisi and Lal, 2020). In fact, several studies suggest that other environmental-friendly farming approaches could address limitations of organic farming in an efficient manner (Tscharntke *et al*., 2021; Calabro and Vieri, 2024). For instance, the international literature heavily implies that despite of its benefits on the preservation of biodiversity (IFOAM, 2020), and the adaptation to climate change (IFOAM, 2012), the widespread adoption of organic agriculture could notably reduce the yields (Reimer *et al*., 2023). Under these circumstances, maintaining agricultural production often requires the expansion of cultivated land at the expense of natural habitats (Meemken and Qaim, 2018). Additionally, recent studies indicate that when factoring in the land use in third-party importers that will compensate for the domestic yield reduction, organic farming could in some cases increase GHGs net emissions (Smith *et al*., 2019). Studies also report that GHGs emissions can increase due to the use of organic fertilizers and soil amendments (Shakoor *et al*., 2021; He *et al*., 2023). On the contrary, integrated fertilization and pest management strategies could significantly reduce the use of agrochemicals (within the boundaries of EGD) and maintain the yields, without compromising neither the environment, nor consumers' safety (Pretty and Pervez Bharucha, 2015; Tang *et al*., 2022; Weltin and Hüttel, 2023). On a similar note, urban farming and precision agriculture have been included among the potential strategies that EBD could promote (Rocamora and Comer, 2023). However, urban agriculture could have a higher carbon

footprint (compared to conventional) (Hawes *et al*., 2024), and the equipment cost in precision agriculture is in some cases unacceptable for European farmers (Petrović *et al*., 2024).

Of course, the aforementioned findings are neither conclusive, nor demote the potential and the benefits of the strategies proposed in the EGD and the EBD. They only highlight the fact that sustainability is a flexible concept (Heal, 1998), defined by its outcome (Kuhlman and Farrington, 2010). The most prominent definition of sustainability is the one provided by the UN (1987), that regards it as "meeting the needs of the present without compromising the ability of future generations to meet their own needs". Given the heterogeneity of EU's Member States (GNP, infrastructure, agricultural productivity, rate of new technologies integration etc.) (Auray and Eyquem, 2021; Reimer *et al*., 2023; Triantafyllidis *et al*., 2023; Petrović *et al*., 2024), the heterogeneity of agricultural structures across the Union (Kryszak and Herzfeld, 2021), and the farmers' heterogeneous attitudes towards sustainability related policies (Niskanen et al., 2021) the Commission should provide a wide range of alternatives that lead to that desired outcome. In an effort to address the farmers protests across the EU and de-escalate the rising tension, von der Leyen announced in 2024 the withdrawal of the Sustainable Use Regulation (Euronews, 2024b). Instead of losing the focus on the original goal of halving pesticide use by 2030, EU must invest in developing more versatile strategies that comply with farmer needs. The development of proper-practices knowledge hubs and the investment in research to optimize them in specific contexts (addressed in both EGD and EBD) will be pivotal.

Sources of "green energy"

In a study by Zappa *et al*. (2019), the authors estimated that enabling a completely renewable European power system by 2050 could cost up to 530 billion € per annum. Likewise, a 2023 report by Aquila Capital concluded that a 100% self-sustainable energy sector in Europe by 2030 could cost up to 2 trillion €, though the 42.5% target of the Commission is theoretically much more feasible (Göke *et al*., 2023). Nonetheless, providing safe and accessible renewable energy sources (RES) can be crucial for agriculture (Majeed *et al*., 2023). From the recycling of black water or urban wastewater for irrigation that requires significant energy inputs (EBD) (Rocamora and Comer, 2023), to the decarbonization of agriculture (EGD) (European Commission, 2021b), European farmers could benefit immensely from RES.

Alarmingly, the 2023 EAP report found it highly unlikely for the 42.5% RES and the energy consumption targets to be met by 2030, unless fast and decisive actions are to be implemented (EEA, 2023). Concurrently, studies suggest that there is a notable spatial variability in RES development progress within the EU (Miłek *et al*., 2022), and a correlation among the national saturation level of some RES growth curves and the respective national GDP (Madsen and Hansen, 2019). The heterogeneity of the EU affects national RES development differently (e.g. weaker EU economies mainly face administrative challenges) (Gajdzik et al., 2023). This variability could hinder the EGD targets (Miłek *et al*., 2022). Even though it is soon to draw safe conclusions on the energy policies of the EGD (EEA, 2023), provided that they are falling short the EBD could step-up and deliver complementary strategies for the optimization of ocean and hydroelectric energy harvesting, both of which are much promising (European Commission, 2022; Fry *et al*., 2022). Additionally, the EU could invest in the promising bioethanol production from wasted crops and crop residues (e.g. wheat straw), without aggravating the "food vs. fuel" debate (Kim and Dale, 2004). An important aspect of energy security in the EU is the diversity in sources. The lesson learned from the recent crisis is that energy import dependency affects all sectors of EU's economy, including agriculture (EESC, 2023b). In a study by De Rosa *et al*. (2022) the authors estimated that reliance in energy imports reduces EU's energy security by 30%, yet effective RES policies (adaptable to the heterogeneity of the Member States) could address this challenge.

Even though the agricultural sector in the EU contributes to a relatively small percentage of energy consumption (3% in 2021) (Eurostat, 2023b), disruptions in the fuel market chain can skyrocket the prices of agrifood commodities (European Commission, 2023b). According to Paris *et al*. (2022) fertilizer and pesticide production, and irrigation account for more than half of the energy inputs in open-field agriculture within the

EU, thereby the rational management of these inputs would significantly reduce energy consumption. The development of RES could (in theory) contribute to preventing acute price oscillations in food commodities (Taghizadeh-Hesary *et al*., 2019).

Crop diversification and crop choices

As mentioned above, diversification in the EU energy sector could increase resilience to external shocks. Similarly, we emphasized on the significance of diverse "sustainability approaches". The same goes for agricultural practices and management strategies (Egli *et al*., 2021), and it should also be applied in crop choices. Crop diversification (CD) within an agricultural system can be defined in 5 levels: the cropping and grassland level (crop choices, crop management, adopted practices etc.), the farming system level (conventional, organic, agroecology, etc.), the landscape system level (land use, field arrangement, wildlife, etc.), the governance system level (policies, cooperations, certifications, labeling, etc.), and the food system level (consumption choices, diets, trade, etc.) (Reckling et al., 2023). CD has been suggested to enhance stability, increase profitability, and facilitate the transformation of the agrifood system towards a sustainable direction (Egli *et al*., 2021). Even though CD practices are not widely adopted across EU (Brannan *et al*., 2023), Zabala *et al*. (2023) highlighted the correlation between crop choices and CD whenever relative strategies are adopted.

The incorporation of alternative varieties and crops (whether minor, or neglected, underutilized, orphan, novel, etc.) is a promising strategy as they comply with the objectives of the EGD and the EBD. A relevant example is quinoa's integration in European agriculture. Quinoa (*Chenopodium quinoa* Willd.) is a pseudocereal that originates from the Andes (Pathan and Siddiqui, 2022). It has a high nutritional value (Pathan and Siddiqui, 2022), it requires relatively low inputs (compared to major cereals) (Afzal *et al*., 2023), it is adaptable to marginalized environments, drought tolerant and it can withstand salinity (it can also perform adequately when irrigated with saline water) (Yazar *et al*., 2015; Hinojosa *et al*., 2018), and its residues can be used for biofuel production (Bermejo *et al*., 2020; Martín *et al*., 2022). The successful campaigns that promoted its nutritiousness in the mid-2010's quickly established a dynamic market in the EU and nowadays, farmers in France, Spain, and the Netherlands have adopted the crop (CBI, 2020). Several alternative crops could follow quinoa's success story and be incorporated in EU's agri-food system under the context of EGD, whilst facilitating the reduction of agriculture's water footprint under the context of EBD (Kakabouki *et al*., 2021).

It should also be noted that the successful adoption of CD practices in the EU has often been proven to be dependent on the behavior and choices of consumers (Cornu *et al*., 2023). While studying the relationships between actors involved in crop diversification in 11 European countries, Cornu *et al*. (2023) concluded that market demand driven by consumers could had a significant positive impact on crop diversification, and that farmers adjust their production methods to meet consumer preferences. Consumer's behavior is a key element of both the EGD and the EBD, particularly in the form of achieving zero food waste (European Commission, 2020a; Rocamora and Comer, 2023). Maintaining a multi-actor approach in developing agricultural policies will instigate consumers' involvement and allow information to flow both bottom-up and top-down, hence increasing the efficiency of initiatives via the demand-supply equilibrium and promote proper consumer behavior

International policy and its effects on other parties

The Commission pledged that EU will become the first climate neutral continent, yet we should bear in mind that climate change, the degradation of the environment, and food insecurity are global challenges. In the case of GHGs, the cooperative mitigation policies of EU, China, and the USA would have a global impact as these three parties account for nearly 50% of the global emissions (Bown and Clausing, 2023). China in particular is estimated to produce close to 30% of them (IEA, 2024b). Studies demonstrate the mutual benefits of the Chinese and European emissions trading market integration, as well as its potential for global emissions mitigation (Li *et al*., 2021; Winkler *et al*., 2021). Yet, despite of the efforts for an effective multilateralism

engagement with regard to climate change mitigation (European Commission, 2019c) and the 2020 EU-China joint statements on climate (European Commission, 2021c), China's climate governance could be failing (Wu, 2023). Case in point, during the last decade (2013-2023), EU has reduced its total CO_2 emissions by approximately 17% and China has increased its corresponding total emissions by the same percentage (IEA, 2024a). EGD's ambition to lead a global agroecological transformation is improbable without the involvement of the countries that are major contributors of climate change. The development of blue diplomacy in the context of EBD (EESC, 2023a) could be an excellent opportunity to bridge the gaps in international policy, especially with China that currently faces a water crisis (Ma *et al*., 2020).

EU has been criticized several times for the contradiction among the positive impact of its international policies and the spillovers of its market demands on the Global South. For instance, the EGD was founded upon environmental amelioration, yet some major agricultural commodity imports of EU (e.g. palm oil, beef, soy, cocoa, and coffee) contribute significantly to deforestation and biodiversity loss in the countries they are produced (Koch and Keijzer, 2021). Additionally, the investment in RES and the increasing demand for raw materials in the EU have been associated with elevated GHGs emissions, work accidents, and forced labor in the developing countries (Malik *et al*., 2022). EU food demand might also have a significant impact on overseas water security (e.g. Ghana) (Malik *et al*., 2022). Teal Deal' s impact will gradually fade if the Commission does not address and prevent such instances.

Conclusions

EU wishes to establish itself as a global leader in environmental policy and transform the agrifood system. Despite of its undisputed progress, there is still a long road ahead. Throughout the implementation of the EGD the Commission has possibly overestimated its efficacy, yet the EBD could be a viable opportunity to address some of EGD's weaknesses. Even though the EESC has already called for a synergetic framework among the EGD and the EBD, policy makers should approach cautiously the interplays between these two strategies. Here, and based on the progress of EGD and the literature, we argue on the significance of diverse and holistic approaches on agricultural systems, crop diversity, and energy sources, as vital points of transforming the agrifood system in the EU. Additionally, we should also bear in mind the significance of EU's international policies as a means to fortify its efforts and pave the way towards agricultural sustainability.

Authors' Contributions

Conceptualization I.K., A.M., D.B.; Data curation P.S., I.R., A.F.; Investigation A.M., P.S.; Methodology I.K., D.B.; Project administration I.K., D.B.; Supervision I.K.; Validation P.S., I.R., A.F.; Visualization I.K.; Writing - original draft I.K, A.M., D.B; Writing - review and editing I.K, A.M., D.B. All authors read and approved the final manuscript.

Ethical approval (for researches involving animals or humans)

Not applicable.

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Conflict of Interests

The authors declare that there are no conflicts of interest related to this article.

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