Agricultural Decarbonization for a Better Future

Best Practices Manual for Decarbonization in the Agricultural Sector

Agricultural Innovation • Sustainability • Energy Transition • Circular Economy

Funded by:

Iceland Liechtenstein Norway grants

Promoter:

mountains of research

Partner:

BOGSDALEN GÅRD ANNO 2021

Authors:
Déborah Bozz
Alberto Teixeira
Luís Silva
Sara Rodrigues
Johanna Johansson

Translation:
Sónia Rio

Edition:
1st Edition

Editor:

MORE – Mountains of Research Collaborative Laboratory – Association.

DOI: https://doi.org/10.5281/zenodo.14267865

Table of contentes

1. Contextualization

Agriculture is constantly developing, and with this development and investment in the sector, we can observe significant technological innovations, such as chemical fertilizers, pesticides, tractors, and genetically modified seeds. However, these innovations have had major consequences, mainly related to the environment (De Lima & Martins, 2022). Currently, people are becoming more informed and learning about their environmental responsibility, meaning they are increasingly interested as consumers in green agricultural products. Although there are not many varieties available, this could be an area for investment to help the sector grow (Xin, Xu & Zheng, 2024).

According to Assad & Almeida (2004), five challenges are posed for farmers who want to manage for sustainable agriculture. Since agricultural activity is essential for everyone, these challenges include: (1) environmental challenges, (2) economic challenges, (3) social challenges, (4) territorial challenges, and (5) technological challenges. Overcoming them requires knowledge about each challenge in a way that is specific to the location of the activity, as well as other components and human aspects. Likewise, Adisa et al. (2024) adds that the agricultural sector is empirically linked to environmental degradation, resource depletion, and, primarily, promoting socio-economic inequality.

Organic agriculture, combined with innovation and technology, has become an alternative for achieving sustainable development in the agricultural system. Organic farming avoids using chemical fertilizers, pesticides, and other additives that harm the environment. However, the practice has its limitations, which is where technology and innovation come into play to minimize these challenges (Gamage et al., 2023).

Chataut et al. (2023) notes that another significant demand emerging in the agricultural sector is the intensive use of energy and greenhouse gas (GHG) emissions, highlighting the importance of further research on agricultural energy efficiency, especially focusing on the physical, chemical, and biological factors of crops. Data shows that there are differences in the level of GHG emissions

between the industry and agriculture in countries within the European Union. This demonstrates that the agricultural system is very complex, and efficient management to reduce GHG emissions will depend on specific research related to crops, regions, countries, and other conditions (Murawska & Goryńska-Goldmann, 2023). Just like organic farming, precision agriculture is emerging as an alternative to improve agricultural management. By gathering detailed information about the conditions of the area, strategies will be created to optimize the management of these crops, increasing operational efficiency (Chataut et al., 2023).

According to the FAO (2019), the management of water resources, soil management, carbon footprint, and energy efficiency can affect the agricultural system in different ways depending on the stage of the food chain. Water and soil are more utilized in the primary phase, energy is more relevant in the processing phase, while GHGs can accumulate throughout the entire supply chain. In this way, the circular economy arises with the premise of proposing cultural and behavioral changes to reduce the environmental impact of the agricultural supply chain, promoting the sustainable use of resources and the reuse of materials, moving away from linear extraction and disposal practices (Lopes, 2022).

According to Haque, Fan & Lee (2023), the relevance of the circular economy in the agricultural system should be strengthened, as it can generate new opportunities and business markets, contributing to environmental, sustainable, and efficient strategies, fostering the economic sector while addressing the needs of producers and services. One of the major challenges is reconciling food production with the environment. Driven by the Green Revolution, the modern agricultural system has focused on using fewer chemicals and a more circular system (Selvan et al., 2023).

In summary, modern agricultural systems are facing significant environmental and socio-economic challenges. This creates the need for a shift toward a sustainable system that already foresees changes in the sectors that require transformation. Efforts by farmers in this shift are essential, but governments, companies, and stakeholders in this sector must collaborate, as a successful transition requires public policies, collaborations, and, most importantly, investments.

2. Agri-food Sector

The agri-food sector is one of the most important in the economy, playing a key role in food security, environmental sustainability, and the economies of countries. It encompasses a wide range of activities, from production to processing, distribution, and regulation of food. This sector is essential for ensuring the supply of food to the population, while directly influencing environmental and economic issues at both national and global levels.

Torrens (2020) describes that the systematization of the agri-food sector occurred in the 20th century through industrialization, as well as the control of production chains in this sector. This led to significant impacts, particularly on the economy, but not only—there were also cultural, environmental, and social impacts. The most efficient agri-food system would be one that integrates a productive system with natural resource management, ensuring food production and consumption, with the goal of guaranteeing the sustainability of the agri-food system (Fraga et al., 2022).

According to De Fraga et al. (2022), the changes in the agri-food system today primarily focus on the financial aspect of the sector, neglecting essential issues such as environmental changes, population growth, the land market, and especially food distribution. Antunes (2018), on the other hand, addresses how the agri-food system is a sector that causes food contamination, environmental pollution, poisoning of rural workers, excessive processing and preservatives in food. In summary, the sector is a major cause of diseases, inequalities, and environmental injustice.

The conventional agri-food system must be revised, as it has hindered access to food, worsening the situation of food and nutritional insecurity, and, more importantly, causing other major problems, such as rural exodus and environmental degradation (Mussoi et al., 2015). Currently, due to the significant impacts of the SARS-CoV2 pandemic, the agri-food sector is under pressure to make changes in its processes in order to ensure food and nutritional sovereignty, addressing structural and multidimensional changes, promoting life, as well as the fundamental right to food (Torrens, 2020).

However, Esposito, Sessa & Malandrino (2020) describe that in recent years, the agri-food sector has been paying more attention to issues that are not directly linked to its system, such as environmental respect and human resources. This highlights the significant challenges the sector will face, as society and the market are demanding more environmentally responsible approaches and the combination of socio-economic actions to reduce food waste and loss. The authors Caiazza & Bigliardi (2020), in turn, explain how the agri-food sector needs to improve its communication strategy, as consumers are becoming increasingly demanding. In other words, the sector must adapt to the new market, marketing strategies, and emerging technologies.

Agri-food systems are interconnected with environmental impacts. Therefore, Chandrakumar et al. (2019) highlight the importance of using methodologies that can measure environmental impacts, such as GHG emissions, as well as evaluate the entire system. This approach can propose improvements in techniques and technologies, seeking to gather information from the product level, through processing, company data, and global sector data. Meanwhile, Ijassi, Rejeb & Zwolski (2021) discuss the multifunctionality of the agri-food sector, explaining how it becomes difficult to understand all the processes and, especially, to identify the impacts of this sector. As a result, they emphasize the importance of developing reference methods and techniques that can be used to evaluate these impacts. While the most frequently cited impacts are environmental, attention should also be given to the social and economic impacts of this sector.

Therefore, approaching the agri-food sector in a more holistic way, linking it with themes such as sustainability, management, and the implementation of innovations, is an increasingly necessary strategy for the sector. Only this interdisciplinary collaboration can create a path toward a better future (Ababou, Chech & Elhiri, 2023). In summary, while the agri-food sector is of great importance, it is facing increasing pressure for changes in its system. Thus, it must develop and invest in innovation and technologies to promote positive and sustainable changes in this fundamental sector of the global economy.

3. History

3.1. 1st Agricultural revolution

The first agricultural revolution, known as the Neolithic Revolution, marked the transition of human societies from hunter-gatherers to sedentary agricultural communities. According to Whayne (2024), the Neolithic revolution brought about the beginning of a change in human lifestyle, moving from solely hunting and gathering to practicing rudimentary agriculture, which also promoted the development of communities. During this phase, agriculture 1.0 had very small agricultural production and relied on rudimentary tools such as sticks, stones, and minimal equipment (Ahmed et al., 2024).

During this period, there was heavy reliance on human and animal labor, with production being significantly low and focused solely on subsistence (Petrović et al., 2024). Humans began cultivating plants and domesticating animals, establishing the first permanent settlements. This development enabled the creation of food surpluses, which in turn facilitated population growth and the rise of complex civilizations. The end of the last Ice Age resulted in population growth due to a warmer and more humid climate, which increased soil fertility. This shift marked the end of mobile foraging, as people settled in one place, investing in making poor lands more productive by clearing forests, irrigating when necessary, and planting wild seeds (Allen, 2024).

3.2. 2nd Agricultural revolution

Industry 2.0 is characterized by the use of machines, fertilizers, and improved seeds with the aim of helping farmers produce more, and it is known as agribusiness or industrial agriculture (Polymeni et al., 2023). The second agricultural revolution occurred during the Industrial Revolution and was characterized by mechanization and the adoption of new technologies in agriculture. Machines such as the iron plow and, later, the tractor, allowed for a significant increase in agricultural productivity. Furthermore, the introduction of new farming methods, such as crop rotation, helped improve the efficiency and sustainability of agricultural production.

An era in which the energy sources were oil and gas also brought many innovations to the transportation industry, allowing agricultural products to be transported, significantly improving efficiency and productivity (Liu et al., 2021). During this period, farmers operated agricultural machinery manually, and many chemicals were used. This period saw a significant increase in the efficiency and productivity of agricultural work. However, it also led to several problems, such as chemical contamination, environmental destruction, excessive energy consumption, and the waste of natural resources (Zhai et al., 2020).

3.3. 3rd Agricultural revolution

The third agricultural revolution, known as the Green Revolution, was marked by the introduction of high-yielding varieties of grains, intensive use of fertilizers and pesticides, and the expansion of irrigation. During this period, the transformation of agricultural management began, meaning the use of software and value chain systems to improve management (Haloui et al., 2024). Driven by scientific and technological advances, it resulted in significant increases in food production, especially in developing countries. However, it also brought challenges, such as environmental degradation and dependence on chemical inputs.

The idea of precision agriculture also became popular, where agricultural systems aimed to increase resource efficiency and operational performance by utilizing advances in computing and electronics (Bazargani & Deemyad, 2024). As a result, this period became a major response to societal issues as well as environmental and health problems, as it introduced the concept of reducing agricultural inputs and sparked discussions on these topics (Fountas et al., 2024).

3.4. 4th Agricultural revolution

The fourth agricultural revolution, or Agriculture 4.0, is characterized by the integration of digital and automated technologies in the agricultural sector, such as the Internet of Things (IoT), artificial intelligence (AI), big data, among others (Fountas et al., 2024). These innovations enable real-time monitoring and

management of agricultural operations, optimizing resource use, reducing waste, and increasing efficiency and sustainability.

This brings the shift to digital, evolving in parallel with the industrial sector, advancing further with new technologies and equivalent capabilities, envisioning the future of manufacturing (Haloui et al., 2024). Precision agriculture, combined with agricultural Internet of Things (IoT), leads to this revolution that interconnects different technologies. However, it still faces challenges with theoretical concepts. The goal, nevertheless, was to improve productivity and sustainability of crops, enhance working conditions, and improve the quality of production and processing (Zambom et al., 2019).

3.5. 5th Agricultural revolution

Agriculture 5.0 represents an important milestone for investors who prioritize environmental, social, and governance aspects. This new revolutionary era integrates innovative technologies with the goal of increasing efficiency and promoting sustainability, adapting to the specific demands of agri-food systems. The convergence of robotics, augmented reality, and 6G technologies marks a significant advancement, enabling real-time monitoring and the automation of agricultural practices (Haloui et al., 2024). It aims to provide farmers with precision tools tailored to the specific needs of their sectors, but also to create transformative strategies that encourage behavioural changes and increase the adoption of these technologies. However, it must also address social challenges, such as technological barriers and the need for behavioural changes (Fountas et al., 2024).

It is important that at this stage, new ways of producing healthy and affordable food are discussed, as well as the need to address the care and non-degradation of ecosystems through policies and programs that explicitly bring an environmental and social justice dimension to the discussions on food systems (Fraser & Campbell, 2019). The fifth agricultural revolution emerges with the premise of smart solutions. That is, in addition to integrating technologies and artificial intelligence as in the fourth revolution, it will also focus on sustainability and the autonomy of agri-food processes, seeking to redefine the way food is

produced by placing technology at the center of modern agriculture. A future is envisioned where digital technologies are seamlessly integrated into the complexities of agriculture, optimizing resources, increasing productivity, and promoting sustainable practices (Fountas et al., 2024).

4. Legislation

This topic will address the current legislation related to (1) the European Union, (2) Portugal, and (3) Norway, concerning the promotion of sustainability, reduction of the carbon footprint, and conservation of biodiversity.

4.1. European Union Legislation

The European Union is currently an example when it comes to legislation, guidelines, and regulations, particularly in environmental matters. The EU's legislations aim to harmonize the policies of Member States, ensuring a high standard of environmental protection across the region. As such, they cover a wide range of areas, including water management, air quality, biodiversity conservation, reduction of greenhouse gas emissions, and the transition to a circular and sustainable economy.

The Kyoto Protocol was celebrated in 1997 and is the first international legal treaty to limit the GHG emissions of developed countries. By signing it, the EU committed to reduce 8% of GHG by 2008-2012 and as a result, the European Climate Change Programme (ECCP) was created to identify and prepare the implementation of measures to combat climate change.

Then, the Paris Agreement, a groundbreaking achievement in climate policy, was signed in 2015, at the 21st COP, where almost all countries in the world agreed to make an ambitious effort for the combat of climate change and adaptation to its impacts, aiming at a sustainable low carbon economy.

From the Paris Agreement steamed the biggest efforts in environmental policy in the EU, as the Green Deal in 2019, the beacon that sets the agenda for actions towards sustainability, providing guiding principles for policy and strategies for its members to develop. The Green Deal underlines the objective of reaching carbon neutrality by 2025, while sustaining economic growth that is not resource depleting, in an inclusive, just manner. Also, an intermediate goal is set, to reach at least 55% reduction in GHG net emissions when comparing with the levels of 1990 by 2030.

In 2021, the Climate Law was adopted in the EU, as part of the Green Deal, legally binding the organization with the aim of reaching carbon neutrality until 2050, through regulation of GHG emissions and removals by its member states and promoting investment to foster the shift to a green economy.

The EU Emissions Trading System (EU ETS) is a cornerstone for climate policy that will likely play a big role in reaching carbon neutrality, as it was the world's first carbon market that remains one of the leading ones. The EU ETS applies in all EU Member States, the European Free Trade Association countries (Iceland, Liechtenstein and Norway) as well as Northern Ireland for several sectors, as electricity generation and aviation. When it comes to sectors not included, as is the case for agriculture, the Effort Sharing Regulation establishes for each EU Member State a national target for the reduction of greenhouse gas emission in each sector.

The CBAM - Carbon Border Adjustment Mechanism (Regulation (EU) 2023/956 of the European Parliament and of the Council of 10 May 2023) is another european regulation that aims to impose a carbon price on certain products imported into the EU, ensuring that the same price for carbon is imposed in imported products as the ones imposed inside the EU. This prevents companies from placing production in countries with fewer environmental policies to evade and then exporting them into the EU for a smaller price and for a higher carbon footprint. There is a transition period in place until the end of 2025.

Other important laws and regulations can be consulted on Table 1.

Table 1: European Union laws and regulations concerning sustainable food production and decarbonization.

Legislation		Year	Description
Official Journal of the European Union L 110, 25 April 2023	Greenhouse gas emissions permits.	2023	It establishes a change regarding the number of emissions permits to be placed in the market stability reserve for the European Union's greenhouse gas emissions trading system until 2030.
Official Journal of the European Union C 243, 27 June 2022	Just transition to climate neutrality.	2022	It establishes recommendations for the Union's transition to a climate-neutral and environmentally sustainable economy by 2050, ensuring that it is fair and leaves no one behind, in line with the principles of the European Green Deal and the European Pillar of Social Rights.

Official Journal of the European Union L 328, 21 December 2018	Regulation on the governance of the Energy Union and Climate Action.	2018	It establishes a governance mechanism to implement strategies and measures aimed at achieving the objectives and targets of the Energy Union and the European Union's long-term commitments on greenhouse gas emissions, in accordance with the Paris Agreement, for the first ten-year period from 2021 to 2030 for energy and climate.
Official Journal of the European Union L 243, 9 July 2021	European Climate Law.	2021	It establishes the regulation aimed at achieving net-zero greenhouse gas emissions for the Member States as a whole by 2050, mainly through the regulation of greenhouse gas emissions and removals at the Union level, investment in green technologies, and the protection of the natural environment.
Official Journal of the European Union L 172, 17 May 2021	Program for the Environment and Climate Action (LIFE).	2021	It establishes the LIFE Program, the Environment and Climate Action Program for the period 2021-2027, which aims to contribute to a fair transition to a sustainable, circular, energy-efficient economy based on renewable energy and climate neutrality.
Official Journal of the European Union L 156, 19 June 2018	Regulation on binding annual reductions of greenhouse gas emissions from 2021 to 2030.	2018	It establishes obligations for Member States regarding minimum contributions for the period 2021 to 2030, to meet the reduction of their greenhouse gas emissions by 30% below 2005 levels by 2030.
Official Journal of the European Union L 140, 5 June 2009	Regulation on reducing greenhouse gas emissions to meet the Community's commitments by 2020.	2009	It establishes provisions governing the minimum contribution of the European Union Member States to meet the European Community's greenhouse gas emissions reduction commitment for the period 2013 to 2020.
Official Journal of the European Union L 328, 21 December 2018	Energy from renewable sources.	2018	It establishes a common framework for the promotion of energy from renewable sources, where Member States must adopt support schemes for energy from renewable sources.
Official Journal of the European Union L 114, 12 April 2022	General Union Environment Action Program for 2030.	2022	It establishes an environmental agenda aimed at accelerating the green transition to a circular, neutral, sustainable, non-toxic, resource-efficient, renewable energy-based, resilient, and competitive economy in a fair, equitable, and inclusive manner, and to protect, restore, and

			improve the state of the environment, reversing and halting biodiversity loss.
Farm to Fork Strategy	Strategy for a fair, healthy, and eco-friendly food system.	2020	It establishes strategies aimed at ensuring access to sufficient, nutritious, sustainable, and healthy food for all Europeans at all times through the transition to sustainable food systems.
European Green Deal	European Green Deal	2019	It establishes a new growth strategy aimed at transforming the EU into a fair and prosperous society, with a modern, resource-efficient, and competitive economy, where there are no net greenhouse gas emissions by 2050 and in which economic growth is decoupled from resource use.
Bioeconomy Strategy	Bioeconomy Strategy.	2018	It establishes a policy that addresses all Member States with a multisectoral approach, including food and nutritional security, sustainable management of natural resources, reduction of dependence on non-renewable and unsustainable resources, climate change adaptation and mitigation, strengthening European competitiveness, and increasing employment opportunities.
Horizon Europe Strategic Plan 2021-2024	Horizon Europe Strategic Plan 2021-2024.	2021	It establishes a policy to promote open strategic autonomy, leading the development of digital, enabling, and emerging technologies, sectors, and value chains to accelerate and steer digital and green transitions through human-centered technologies and innovations.
Circular Economy Action Plan	Circular Economy Action Plan	2020	It establishes a policy aimed at increasing the circular economy of key economic players in order to make a decisive contribution towards achieving climate neutrality by 2050 and decoupling economic growth from resource use.

4.2. Portuguese legislation

Portuguese legislation on this topic is comprehensive and multidisciplinary, reflecting the country's commitment to environmental, social, and economic issues. It includes measures for adaptation to climate change, promotion of energy efficiency, and reduction of greenhouse gas emissions. Additionally, the legislation aims to combat food waste, protect biodiversity, and sustainably manage water resources and waste. Strategies are also in place to ensure food and nutritional security, promote sustainable agriculture, and

implement rural development policies. These initiatives demonstrate a continuous effort to balance economic development with environmental preservation and social well-being.

The National Strategy for Climate Change Adaptation (NSCCA) defines the aims and instruments to compensate the effects of climate change and improve the efforts towards decreasing climate change. It considers several scenarios, national and regional goals and actions tailored to each sector. The NSCCA that is in place until the end of 2025 considers 10 sectors, one of them agriculture and 6 theme areas related to different instruments, including research and innovation. Since the approval of the Basic Climate Law in 2021, the government must present a new Strategy every 10 years. Portugal got his first NSCCA approved in 2010, which was a great effort since many EU members had not done it yet.

The AdaPT program was also an important response to the needs identified in the NSCCA and constitutes the first integrated approach in terms of adaptation actions towards CC in Portugal, allowing for structuring projects to take place. This was financially supported through the European Economic Area (EEA) Agreement (EEA Grants).

The Portuguese National Adaptation Plan for Climate Change (P-3AC) was adopted in 2019, to systematize and complement the ENAAC 2020, focusing on achieving one of its objectives: to implement direct and relevant measures in the territory for CC adaptation, across several sectors of society.

Focusing on the long term, the National Roadmap for Adaptation 2010 will continue the efforts of the NSCCA and evaluate the vulnerabilities, impacts and trajectories of the Portuguese territory, to define the priorities and focal sectors. It will aim at supporting the activities of the National Strategy, focusing on the implementation and monitoring of the P-3AC and other tools of adaptation to CC.

Considering the mitigation of CC, the most important instruments are the National Energy and Climate Plans 2030 (NECP 2030) and the Roadmap for Carbon Neutrality 2050.

The Roadmap for Carbon Neutrality 2050 (Resolution of the Council of Ministers no. 107/2019) establishes the trajectories for reaching carbon neutrality by 2050, based on an economically and technically viable vision, reducing the level of emissions between 85% and 90% when comparing to the levels of 2005, with a contribution of all sectors by improving efficiency, efficacy and fostering innovation.

The NECP 2030 was developed according to obligations established by the Regulation on the Governance of the Energy Union, that sets common rules for planning, reporting and monitoring on EU climate and energy targets for 2030, that are in line with the Paris Agreement. The national goals for 2030 are the reduction of GHG emissions by 45 to 55% compared to 2005 a 47% incorporation of renewable energy in national energy consumption, amongst others. The renewable energy efforts are also supported by the Industrial Strategy and Action Plan for Ocean Renewable Energy (Resolution of the Council of Ministers no. 174/2017).

One of the eight strategic objectives defined by the NECP 2030 is to "Promote sustainable agriculture and forestry and foster carbon sequestration", pinpointing the essential role agriculture is expected to play in national goals towards decarbonization, through sustainable management practices that promote carbon sequestration, reduction of emissions related to resource consumption (e.g. fertilizers), bioeconomy promotion, wildfire prevention and improvement in animal effluent management. Agriculture-derived GHG emissions are expected to be decreased by 11% to achieve the national decarbonization goals.

Below, table 2 presents additional key laws and regulations.

Table 2: Portuguese laws and regulations concerning sustainable food production and decarbonization.

Legislation		Year	Description
Decree-Law No. 99/93	Statute of the Institution for Plant, Animal, and Food Protection	1993	It aims to establish the composition, duties, and responsibilities of these plant, animal, and food institutions, with the right to promote, research, manage, and control plant, animal, and food protection within the territory of Portugal.

Resolution of the Council of Ministers No. 113/2005	National Program for Efficient Water Use	2005	It aims to provide general guidelines for the efficient use of water resources in Portugal, especially in the urban, agricultural, and industrial sectors.
Resolution of the Council of Ministers No. 59/2005	Program for Monitoring and Evaluation of the National Plan for Climate Change.	2005	It aims to detail the components of the climate change monitoring system as well as the concept of indicators.
Decree-Law No. 142/2008	Wildlife and Biodiversity Preservation	2008	It aims to define the legislation produced on nature and biodiversity conservation and repeals Decree-Laws No. 264/79 and No. 19/93.
Decree-Law No. 194/2012	Authority for Economic and Food Safety	2012	It aims to control and ensure compliance with the legislation regulating economic activities in both the food and non-food sectors, as well as assess and communicate risks within the food chain.
Decree-Law No. 39/2013	National renewable energy targets	2013	It aims to establish the first amendments to Decree-Law No. 1141/2010, which sets the national renewable energy targets.
Ordinance No. 187-A/2014.	Strategic Plan for Urban Waste (PERSU 2020)	2014	It aims to be a reference document in the area of urban waste, facilitating the implementation of a set of key actions in waste management.
Law no. 92/2015	Agricultural development	2015	Aims to amend the administrative and legal procedures related to expropriated and nationalized areas under the laws that regulate the resizing of operations.
Decree-Law No. 76/2016	National Water Plan	2016	Aims to protect the aquatic environment from the damage caused by pollutant discharges, restore the functioning of natural systems, and combat biodiversity loss.
Decree-Law No. 42-A/2016	Fund for Nature and Biodiversity Conservation	2016	Aims to contribute through financing to the achievement of goals related to climate change, water resources, waste, and the conservation of nature and biodiversity.
Council of Ministers Resolution No. 174/2017	Industrial Strategy and the Action Plan for Ocean Renewable Energies	2017	Aims to identify measures for the sustainable financing of ocean renewable energies and an integrated vision of the development of value

			chains that support ocean renewable energies.
Council of Ministers Resolution No. 46/2018	National Strategy and its Action Plan for Combating Food Waste	2018	Aims to promote the reduction of food waste through an integrated and multidisciplinary approach, as well as carry out diagnosis, assessment, and monitoring.
Council of Ministers Resolution No. 55/2018	National Strategy for Nature Conservation and Biodiversity 2030	2018	Aims to be a key instrument in the pursuit of environmental policies and to respond to national and international responsibilities to reduce biodiversity loss.
Decree-Law No. 64/2018	Family Farming Statute	2018	Aims to recognize and distinguish the specificity of Family Farming in its various dimensions and promote appropriate public policies.
Council of Ministers Resolution No. 103/2018	National Council on Food Security and Nutrition	2018	Aims to contribute to the realization of the human right to adequate food and to support an integrated vision of issues related to food and nutritional security.
Council of Ministers Resolution No. 107/2019	Roadmap for Carbon Neutrality 2050	2019	Aims to identify decarbonization pathways across all sectors of the economy, seeking to reduce emissions, increase efficiency and innovation, and promote improvements.
Council of Ministers Resolution No. 130/2019	Action Program for Climate Change Adaptation	2019	Aims to implement adaptation measures through the identification of physical interventions with a direct impact on the territory.
Council of Ministers Resolution No. 45-A/2020	National Plan for Integrated Management of Rural Fires	2020	Aims to establish principles and guidelines for fire management as part of an integrated strategy, in order to minimize damage and maximize the benefits of fire.
Council of Ministers Resolution No. 52-A/2020	Healthy Neighborhoods Program	2020	Aims to promote partnerships and local interventions for the health and quality of life of territorial communities, by supporting projects.
Council of Ministers Resolution No. 53/2020	National Energy and Climate Plan 2030 (PNEC 2030)	2020	Aims to establish measures related to decarbonization, greenhouse gas emissions, renewable energy, energy efficiency, energy security, the internal

			market, and research, innovation, and competitiveness.
Council of Ministers Resolution No. 132/2021	National Strategy for Food and Nutrition Security	2021	Aims to contribute to an integrated vision of issues related to food and nutrition security, supporting the implementation of the human right to adequate food and a sustainable and healthy food system.
Decree-Law No. 12/2023	Strategic Plan for the Common Agricultural Policy of Portugal	2023	Aims to ensure food supply, contribute to environmental and climate performance, and support the socioeconomic development of rural areas.
Council of Ministers Resolution No. 31/2023	National Waste Management Plan 2030	2023	Aims to establish the strategy for waste prevention and management, along with guiding rules covering other types of waste.
Ordinance No. 108/2024/1	National Network of the Common Agricultural Policy (NNCAP)	2024	It aims to define the governance structure and functioning of the National Network of the Common Agricultural Policy, within the scope of the Common Agricultural Policy Strategic Plan.
Ordinance No. 125/2024/1	Specific Regulation of the Thematic Area Climate Action and Sustainability	2024	It aims to establish the rules applicable to operations within the scope of the thematic area of climate action and sustainability.

4.3. Norwegian legislation

In this section, Norwegian legislation related to the environment, climate change, and biodiversity will be discussed, aiming to provide a comprehensive overview of the main laws, plans, programs, and strategies implemented in the country.

In Norway, climate adaptation for municipalities is already being subsidized, as regulated by the “Regulation on grants for climate adaptation” (*Forskrift om tilskudd til klimatilpasning*) that enables research needed to understand the impacts of climate change, to develop climate change adaptation plans for county municipalities and municipalities and develop human resources knowledge and capacity. Support to non-profit organizations for promoting

activities and engagement with climate change and environmental issues is also being regulated by the 2021 “Regulations on grants to voluntary climate and environmental organizations as well as climate and environmental foundations” (*Forskrift om tilskudd til frivillige klima- og miljøorganisasjoner samt klima- og miljøstiftelser*).

The “Climate Targets Act” from 2017 (*Lov om klimamål*) is the most important national climate regulation in Norway as it establishes guidelines and implementation of Norway’s climate targets, as well as greenhouse gas emissions and removals as part of a transition to a low-emissions society by 2050. It constitutes the transposition of the Paris Act on national law and establishes a goal for reducing the GHG emission level by at least 55% by 2030 and 90 to 95% by 2050, considering the reference year of 1990. These efforts are being implemented in a collaborative manner between Norway and the EU.

As only 3% of Norway constitutes arable land and of that only 30% is suitable for grain and vegetable production, land is a valuable resource in the country and efficient effective management is essential for national food security and self-sufficiency, a goal that has been a focus of the political efforts and consequent national legislation.

The Land Act (land law) of 1995 established that the land resources of the country should be managed in the most useful for society and people who depend on the agrifood sector. These rules include the forms of use and exploitation of land resources, as well as property division and possession, ensuring an appropriate, varied system with a focus on the development of the local community, settlement and employment.

The country has strict rules of possession in the sense that people who own arable land to farm it or otherwise lease it for others to farm. Also, wood production is very important for the country, with small-scale farms combining agriculture and forestry. Sustainable management of forests with an aim for local and national economic development as well as conservation of biological diversity, is regulated under the “Forestry Act” (*Lov om skogbruk-skogbrukslova*).

Below is Table 3, presenting the legislations and a brief description of each one, to provide a better context for the topic.

Table 3: Norwegian laws and regulations concerning sustainable food production and decarbonization.

Legislation		Year	Description
Wildlife law	*Lov om jakt og fangst av vilt (viltloven)*	1981	It aims to protect wildlife habitats, as well as species that can be hunted and hunting seasons, the killing of animals without considering protective measures, hunting of deer and beavers; criteria regarding reasons and rights to shooting, hunting, and trapping animals, as well as the rights related to hunted animals.
Land Law	*Lov om jord (jordlova)*	1995	It establishes guidelines to create conditions for the land of the country, including forests and mountains and all their resources, to be used in a way that is most beneficial to society and agriculture.
Food law	*Lov om matproduksjon og mattrygghet mv. (matloven)*	2003	It aims to ensure food safety and promote health, quality, and consumer interests throughout the value chain, as well as ensure environmentally friendly production.
Waste regulation	*Forskrift om gjenvinning og behandling av avfall (avfallsforskriften)*	2004	It establishes the regulation governing waste management in Norway, focusing on recycling, treatment, and handling. It applies to all types of waste, including urban and industrial waste.
Pollution control regulation	*Forskrift om begrensning av forurensning (forurensningsforskriften)*	2004	It establishes measures to limit and manage pollution to protect the environment and public health. It includes provisions on waste management, air and water emissions, noise control, and soil contamination.
Forest law	*Lov om skogbruk (skogbrukslova)*	2005	It establishes the management and conservation of forests to promote the sustainable management of forest resources for local and national economic development and to ensure biodiversity.

Biodiversity Management Law	*Lov om forvaltning av naturens mangfold (naturmangfoldloven)*	2009	It aims to manage biological and geological diversity and ecological processes through sustainable use and nature conservation, in order to preserve it as the foundation for human activity, culture, health, and well-being, as well as the foundation for Sami culture.
Nature diversity law	*Lov om forvaltning av naturens mangfold (naturmangfoldloven)*	2009	It establishes the guarantee that nature, with its biological, landscape, and geological diversity, and its ecological processes, are preserved through sustainable use and conservation.
Strategy for an Environmentally Sustainable Norwegian Aquaculture Industry	*Strategy for an Environmentally Sustainable Norwegian Aquaculture Industry*	2009	It establishes a strategy for an environmentally sustainable aquaculture industry in Norway. It is a national strategy that focuses on the environmental aspects of sustainable agriculture, future goals, and the government's proposals for new measures.
Climate Change Law	*Lov om klimamål (klimaloven)*	2017	It establishes guidelines and implementation of climate goals, as well as emissions and removals of greenhouse gases as part of a transition to a low-emission society by 2050.
Norway's Climate Strategy for 2030	*Klimastrategi for 2030 – norsk omstilling i europeisk samarbeid - Meld. St. 41 (2016–2017)*	2017	It establishes the Norwegian Government's strategies to achieve the 2030 reduction targets under the Paris Agreement, mainly focusing on domestic emission reductions and the use of the EU's flexibility mechanisms.
Regulation on Climate Adaptation Grants	*Forskrift om tilskudd til klimatilpasning*	2018	It establishes a subsidy scheme aimed at promoting climate adaptation efforts in municipal and regional authorities.
Food, People, and the Environment: The government's action plan on sustainable food systems in the context of norwegian foreign and development policy	*Mat, mennesker og miljø: Regjeringens handlingsplan for bærekraftige matsystemer i norsk utenriks- og utviklingspolitikk 2019–2023*	2019	It establishes an action plan that provides a framework to intensify Norway's efforts to increase sustainable food production, improve nutrition, enhance employment and value creation, and promote capacity building and good governance in foreign and development policy.

Pollution Law	*Lov om vern mot forurensninger og om avfall*	2019	It establishes rules for the prevention of environmental pollution, such as general provisions regarding pollution, licenses for activities that may cause pollution, special rules regarding water discharge facilities, and provisions related to waste.
Norwegian Government's Hydrogen Strategy: Towards a Low-Emission Society	*Regjeringens hydrogenstrategi: på vei mot lavutslippssamfunnet*	2020	It establishes strategies for the necessary technological developments, competitive production of clean hydrogen, emissions-free transport, eco-friendly public contracts, safety and standards, national research, and international collaboration and research.
Regulation on Subsidies for Non-Profit Climate and Environmental Organizations and Climate and Environmental Foundations.	*Forskrift om tilskudd til frivillige klima- og miljøorganisasjoner samt klima- og miljøstiftelser*	2021	It establishes the provision of financial support to non-profit organizations and foundations that contribute to promoting engagement with climate and environmental issues and stimulate environmental activities at the local, regional, and national levels.
Global Food Nation by 2030	*Matnasjonen Norge*	2021	It establishes strategies that prioritize four areas of action, such as the production and supply of sustainable, safe, and healthy high-quality food, creating a foundation for growth and value creation across the country, innovation and diversity, and building competencies, recruitment, and reputation.
Climate, Hunger, and Vulnerability: Strategy for Climate Adaptation, Climate-Related Disaster Prevention, and the Fight Against Hunger	*Klima, sult og sårbarhet: Strategi for klimatilpasning, forebygging av klimarelaterte katastrofer og sultbekjempelse*	2021	It establishes strategies to contribute to achieving sustainability goals, strengthening developing countries to adapt to climate change, climate risks, and natural disasters prevention.
Norwegian Parliament Book (2022-2023):	*Meld. St. 26 (2022-2023) – Klima i endring:*	2022	It establishes measures to prepare and adapt nature and society to climate

Changing the Climate - Together for a Climate-Resilient Society	*sammen for et klimarobust samfunn*		change, creating a climate-resilient society.
Regulation on Ffunding for investment in sustainable food production	*Forskrift om midler til satsing p-rekraftig matproksjon og verdiskaping i nord*	2023	It establishes initiatives to strengthen vulnerable producer communities, enhancing the specialization of the agricultural sector and the food value chain, and leveraging regional advantages and opportunities in Arctic agriculture.

5. Partner Regions and Organizations of the 'Agricultural Decarbonization for a Better Future' Project

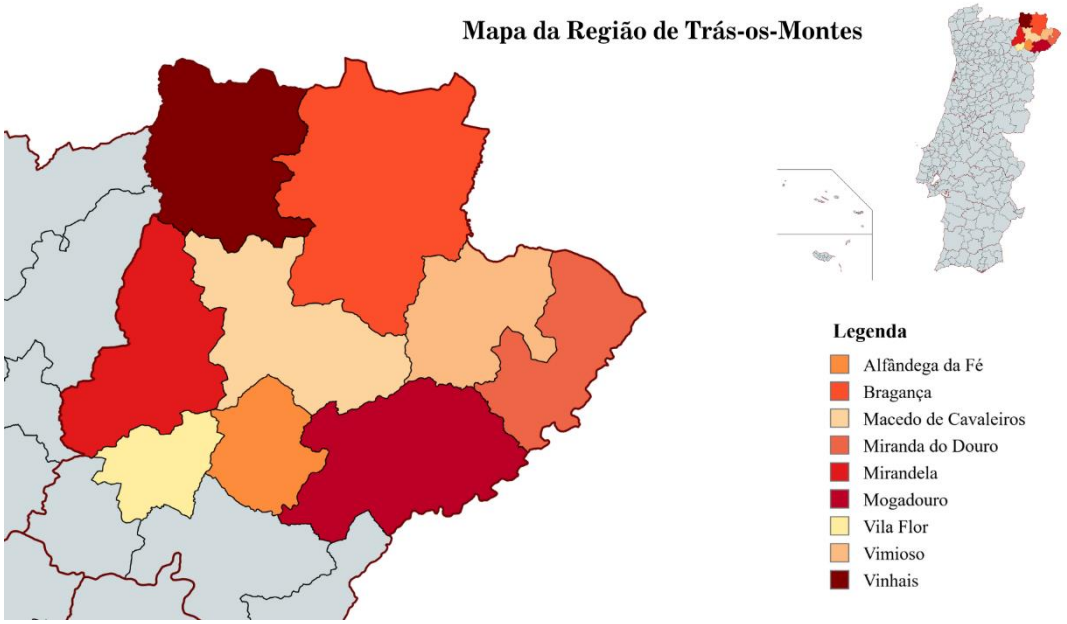
The identification and selection of the research object was based on the 'Agricultural Decarbonization for a Better Future' project established by the Mountains of Research Collaborative Laboratory (MORE) - Association, in cooperation with the company Bogsdalen Gård, establishing partnerships between Portuguese and Norwegian entities aimed at accelerating the transition to a more sustainable agri-food sector. This topic clearly describes the regions where the project focuses (Trás-os-Montes in Portugal and Stavanger in Norway).

5.1. Trás-os-Montes, Portugal

The land of Trás-os-Montes, Figure 1, is a sub-region located in the northeast of the country, belonging to the Northern region. It covers an area of 5,544 km² and had a population of 107,293 inhabitants according to the 2021 census. It is composed of 9 municipalities and 175 parishes, with the city of Bragança as the administrative center of the sub-region. It is bordered to the north and east by the Spanish provinces of Galicia and Castile and León, respectively, to the south by the municipalities that are part of the Douro Intermunicipal Community, and to the west by those of the Alto do Tâmega Intermunicipal Community. Regarding the climate, the Terra Fria and Terra Quente Transmontana regions have distinct morphological and climatic characteristics. Terra Fria has a high relief, cold and humid climate, while Terra Quente has lower relief and a hot and dry climate. The local economy is heavily based on the agri-industrial sector, with emphasis on the production of vegetables, fruits such as chestnuts, almonds, cherries, mushrooms, olive oil, and wines, as well as livestock such as cattle, sheep, goats, and pigs, and the growing transformation

and commercialization of endogenous products (Terra de Trás-os-Montes, 2024).

Figure 1. Map of Trás-os-Montes.

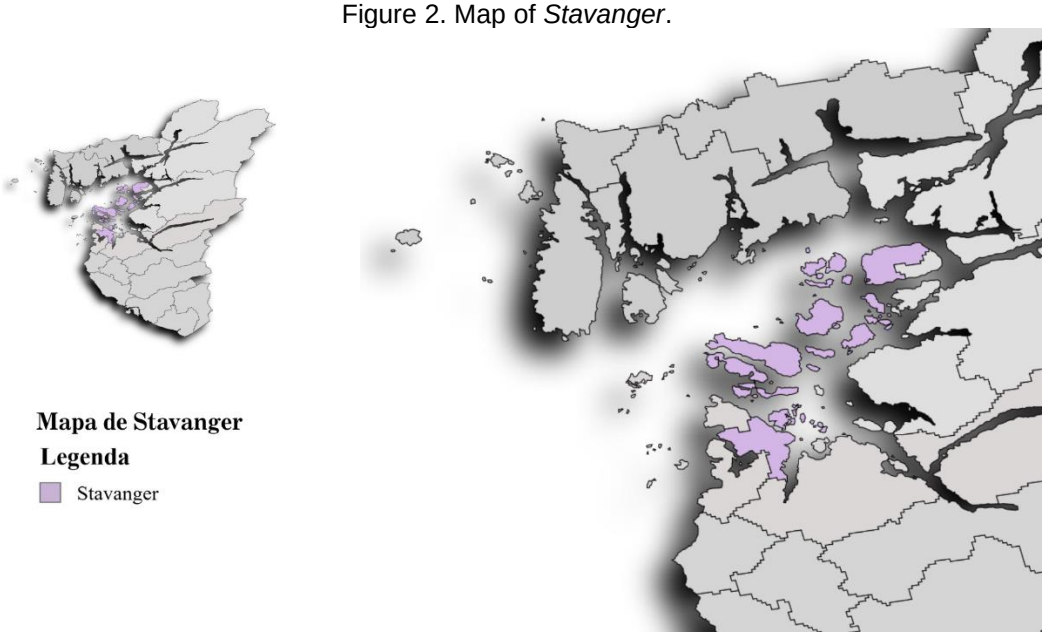


5.2. Stavanger, Norway

Stavanger, Figure 2, located in the county of Rogaland, is a city considered the third-largest urban area in Norway, covering 71 km² and with a population of 133,209 inhabitants according to the 2021 census. It includes the continental part on the western side of *Gandsfjorden/Byfjorden*, between *Dusavik* to the north and Forus to the south, with the city center at the mouth of *Gandsfjorden*. Additionally, Stavanger includes the islands to the north and east of the mouth of *Gandsfjorden*. In 2020, it was merged with *Rennesøy* and *Finnøy*, while the southeast part of the island of *Ombo*, which before 2020 belonged to *Hjelmeland*, borders *Sandnes* to the south, *Sola* to the southwest, and *Randaberg* to the west. At sea, the municipality borders *Kvitsøy* in *Håsteinfjorden*/*Kvitsøyfjorden* to the west, *Bokn* and *Tysvær* in *Boknafjorden*/*Nedstrandsfjorden* to the northwest, *Suldal* in *Boknafjorden* to the north, *Hjelmeland* in *Ombofjorden/ /Gardsundsfjorden* to the northeast, Strand in *Fisterfjorden/Høgsfjorden* to the east, and Sandnes in *Gandsfjorden* to the southeast.

Regarding its economic activities, the city is an important maritime center, being the third most important city in Norway in this sector, but the extraction of oil and natural gas is the main industry. It also has a modest hydroelectric energy production, with the largest plant being *Rørheim*. With the merger with *Finnøy* and *Rennesøy*, the agricultural area increased to 36% of the municipal territory. The service sector, including commerce, hospitality, transportation, and storage, represents smaller proportions of employment compared to the county (*Thorsnæs* & De Amoriza, 2024). Figure 2 presents the map of the city of *Stavanger*.

Figure 2. Map of *Stavanger*.



5.3. Project case studies

5.3.1. Bogsdalen Gård

Bogsdalen Gård is a farm focused on implementing holistic and regenerative agriculture principles, with an emphasis on soil improvement. It is located in Sirevåg, a village in the municipality of Hå in Rogaland County, Norway. The farm's location was previously a property that sold pine trees, primarily for Christmas, so the soil remains poor and low in organic matter, even after the trees were harvested, due to the type of pine species that grew there.

The farm began to be managed by Aleksander and Johanna in 2022, with the aim of offering the local community experiences on the farm, as well as providing meat, eggs, and vegetables, with a focus on animal welfare and production in harmony with nature. The idea is to focus on sustainable livestock farming in an extensive system, selling meat, vegetables, fruits, and value-added products directly to consumers, either at the farm itself or through local markets, applying a short food supply chain business model.

In the future, they plan to expand the business by renting out the upper part of the barn as a venue for events and accommodations in the midst of nature, as well as offering courses and workshops for farmers and hosting volunteers. Thus, this project and business model goes beyond food production, becoming an economically and socially diversified and holistic enterprise.

5.3.2. Elenovations

Elenovations, based in Stavanger, is a GreenTech company that offers innovative technology focused on enhancing plant growth and quality while using fewer resources. In other words, they aim to bring a new sustainable solution for plant cultivation on farms, with the lowest possible energy consumption.~

The company is working to be a pioneer in the development of technology for the application of magnetic fields in plant growth and yield, aiming to assist agriculture while reducing the use of natural resources. LifePot is an innovation with a validated patented technology (patent pending) that treats plants to grow healthier, with better root development, stronger stems, and more robust leaves, maintaining their quality for much longer.

Elenovations has already conducted tests on over 30 crops, including tomatoes, basil, lettuce, potatoes, saffron, and others. The results have shown that their technology has the potential to control production time, accelerate growth speed, produce high-quality plants, control crop size, reduce energy, water, and fertilizer consumption, manage germination induction, increase yield, improve root development, extend preservation time during storage, and control dormancy.

5.3.3. Røysland Gaard

The company Røysland Gaard is in Bjerkreim, Rogaland, with the goal of producing meat while prioritizing animal welfare, as this directly impacts the quality of the meat produced.

The farm covers an area of 240 hectares and is dedicated to livestock production, specifically beef and pork. The animals are raised freely throughout the year, even in winter, mainly roaming flat grazing areas and pine forests in the mountains, with access to a barn where they can take shelter if they wish.

The product line includes a variety of sausages and cured meats, as well as fresh meat. The company also has a retail store where it prepares gourmet meals, characterized by the high quality of the products.

5.3.4. Sortegel – Frozen Products, SA

Sortegel is a company specializing in frozen products and is currently a leading European unit for the processing and export of chestnuts. Founded in 1988, it is in Sortes, Bragança, Portugal. Of its annual chestnut production, approximately 25% is sold fresh, while the remaining 75% is used for peeling and IQF freezing. In addition to chestnuts, the company also markets other IQF products, including strawberries, cherries, raspberries, blueberries, blackberries, and figs.

The chestnut is classified with a Protected Designation of Origin (PDO) and has a reddish color. It is harvested exclusively from the ground, without using any mechanical processes to force the chestnuts to fall from the tree. The company operates with an annual production of around 10,000 tons, with approximately 400 hectares of its own production.

5.3.5. Acushla, SA

Acushla is a company located in Quinta do Prado, Vila Flor, in the Trás-os-Montes and Alto Douro region of Portugal, and is managed by Joaquim Moreira. The site consists of 14 hectares of century-old olive groves and 200 hectares of new olive groves, with approximately 70,000 olive trees. Once fully matured, these trees will produce around 250,000 liters of olive oil, with the production area following an organic farming system.

The company produces a variety of olive oil extracted from olive trees typical of the Trás-os-Montes region, such as Cobrançosa, Madural, Verdeal, and Cordovil. In its production, the use of pesticides and other chemicals is strictly excluded, fully respecting the conditions defined by the organic farming method, as outlined in the sector's legislation.

Being a Protected Designation of Origin (PDO) product from Trás-os-Montes, it is a high-quality extra virgin olive oil with a low acidity level. The olive grove is cultivated using techniques that respect natural life cycles and minimize environmental impact. The oil has a balanced, medium fruity flavor with subtle bitterness and spiciness, and its color is a greenish-yellow.

5.3.6. Trás-os-Montes Prime - House of Santo Amaro

Trás-os-Montes Prime - Casa de Santo Amaro is a family-run farm that has been in operation for eight generations, dedicated to producing high-quality olive oil in Sucçães, Mirandela. Currently, 80% of its production is organic, with plans to expand to 100% next year. The farm offers various olive oil brands, although only one is exclusively organic.

In addition to its own olive oil, Casa de Santo Amaro provides services for around 20 Douro wine producers, such as Sogrape, Vale Meão, and Quinta do Crasto, processing olives from their estates. Another area of the farm's activity is the production of nursery seedlings, particularly of the Cobrançosa and Madural varieties, with an annual output of approximately 200,000 plants for sale. In the organic olive groves, the grass is manually cut multiple times, a more expensive process compared to conventional fields where glyphosate (2L per hectare, once a year) is used, and the olive groves are not irrigated, receiving copper sulfate treatment to prevent diseases.

The Casa de Santo Amaro mill, which has adopted modern methods since 1894, produces 300,000 litters of olive oil per year, of which 60,000 liters are bottled. It operates 24 hours a day, and production is organized by variety and

stored in small tanks to segment the quality. Olive oil from the oldest olive trees is processed together. The different brands reflect the varied olive groves, in line with the Portuguese tradition of blends, and follow the PDO Azeite de Trás-os-Montes certification, which does not allow monovarietal oils. The plants are kept in the nursery for one year, in a non-climate-controlled greenhouse that protects from rain and accumulates heat, before being sold to producers.

5.3.7. Agromontesinho - Agricultural Estate of Vinhais

The company Agromontesinho - Casa Agrícola de Vinhais was built in 2019 and began its operations in 2020. However, last year the factory remained inactive due to low economic viability, as much of the production was compromised by fungi. At that time, the decision was made to directly export the chestnuts to Italy, where they have a partnership with an Italian company that provides the technology for chestnut processing, with which they maintain a commercial agreement.

The company receives 40 to 50 tons of chestnuts daily. However, the production line has a daily processing capacity of 25 tons of chestnuts, and it also has a scale that supports up to 60 tons. The process begins with the weighing of the chestnuts, which are then transported by a conveyor belt to an automatic calibrator, where they are sorted by size.

During processing, the chestnuts first go through a water tank, where impurities are removed through flotation. They are then dried in "burners" and peeled in two stages: one machine removes the pericarp (outer shell), and another vaporizes the inner shell (integument), resulting in whole, peeled chestnuts with no burns or cooking. After that, they are cooled and frozen at -55ºC. The broken chestnuts are separated for other uses, while the whole ones

are stored at 1ºC in four warehouses with a total capacity of 1,200 tons, where they can be preserved for up to a month.

6. Methods, Practices and Techniques for the Agri-food Sector

Based on the research conducted and the project development, it was observed that simple, yet effective practices are not widely adopted in the agri-food sector. These practices can make a significant difference in outcomes, both environmentally and in terms of financial and social impacts. Therefore, easy, medium, and difficult-to-apply techniques were selected, with their advantages and disadvantages characterized and presented.

It is essential that, initially, simple techniques that will yield positive results be implemented. This will allow for gradual investments and the application of more robust techniques, with the necessary focus for each sector. This approach ensures a smooth and efficient transition, maximizing benefits in terms of sustainability and productivity. Furthermore, the gradual adoption of these practices allows for continuous monitoring of results, enabling adjustments and optimizations as needed.

Engaging all stakeholders, from farmers to end consumers, is crucial to ensure the acceptance and success of these initiatives. Awareness campaigns and training programs are also key to empowering farmers and promoting the adoption of best practices.

Therefore, the strategic and gradual implementation of these techniques not only improves productivity but also contributes to environmental sustainability and social well-being, creating a more resilient and responsible agri-food sector.

6.1. Organic agriculture

***Description*:** Organic farming, which avoids the use of synthetic fertilizers and pesticides, is an approach that contributes to decarbonization. Although the yield of organic crops may be slightly lower, soil health and biodiversity benefit,

resulting in greater carbon sequestration capacity and a reduced need for external agents (Gliessman, 2015).

***Level of application*:** Easy.

***Advantages*:** Organic farming aims to promote better soil quality in food production by avoiding synthetic fertilizers and pesticides, reducing environmental impact, and improving biodiversity. It also supports sustainable agricultural practices that increase the soil's ability to sequester carbon, contributing to climate change mitigation.

***Disadvantages*:** Organic farming has lower and slower productivity compared to conventional farming, requiring more labor and more intensive management practices, which makes organic products more expensive for consumers.

6.2. Precision agriculture

***Description*:** Precision agriculture is one of the main approaches to reduce the use of chemical agents such as fertilizers and pesticides, while optimizing resource application, resulting in a lower environmental impact. Its implementation in farms across Europe has led to an average 20% reduction in fertilizer use and up to a 50% reduction in agricultural pesticides. This, in turn, has significantly reduced nitrous oxide (N_2O) emissions, a potent greenhouse gas. Soil sensors, drones, and GPS systems enable the monitoring of crop conditions and the application of only the necessary amount of resources, which not only increases efficiency but also reduces emissions associated with the production and application of these products (European Environment Agency, 2020; Rosati et al., 2021).

Level of application: Medium.

***Advantages*:** Precision agriculture seeks more efficient resource management and increased productivity, aiming to reduce operational costs and environmental impact.

***Disadvantages*:** The adoption of precision agriculture requires significant investments and advanced technologies such as sensors, drones, and GPS systems, in addition to the need for specialized training.

6.3. Life cycle analysis

Description: Life Cycle Analysis (LCA) is a methodology that seeks to assess the environmental performance of a specific product by detailing its flows and analyzing the system. It can be inherently complex and time-consuming, using process analysis that typically involves collecting data from individual processes to quantify these flows and their effects (Claudino & Talamini, 2013; Stephan, Crawford & Bontinck, 2019).

Level of application: Difficult.

***Advantages*:** Life Cycle Analysis (LCA) can evaluate the full environmental impacts of a product, identifying opportunities for recycling and reuse, optimizing processes, and reducing greenhouse gas emissions. It is also capable of considering real impacts on biodiversity, helping to minimize them.

Disadvantages: LCA requires specific software and extensive data collection, making the process time-consuming and complex. Additionally, it can involve significant financial investment, particularly for smaller companies or projects with limited resources.

6.4. Biofertilizers

Description: Liquid biofertilizers are organic compounds of animal or plant origin, used to fertilize the soil and promote plant growth through nutrient absorption and/or the production of growth hormones. In addition to their nutritional benefits, these biofertilizers have demonstrated fungistatic, bacteriostatic, and insect-repellent properties, proving effective in controlling plant diseases and pests as well (de Medeiros & Lopes, 2006; Brahmaprakash & Sahu, 2012).

Level of application: Medium.

Advantages: Improves soil health and biodiversity by reducing the need for chemical fertilizers. It benefits beneficial microorganisms, utilizes organic waste, and promotes a more sustainable agricultural system.

Disadvantages: Requires specific methodologies for each type of crop, demanding technical knowledge for formulation and application. It may have lower efficiency compared to chemical fertilizers, requiring more time to show results.

6.5. Rainwater harveting for irrigation

Description: The installation of rainwater harvesting tanks for collecting and storing rainwater for non-potable uses represents a significant saving in the use of drinking water. This system is suitable for a variety of uses, such as flushing toilets, garden irrigation, and laundry washing (Fewkes, 2000; Villarreal & Dixon, 2005).

Level of application: Easy.

***Disadvantages*:** Reduces the consumption of potable water leading to savings on water bills Simple installation maintenance and use

Disadvantages: Requires investment in collection and storage infrastructure. Dependent on the availability of rainwater which varies by season and region. Requires ongoing maintenance.

6.6. Composting

Description: Composting is a process of decomposition of organic waste by various microorganisms, transforming it into stable products suitable for various applications, with the most common being as fertilizers (Pan et al., 2024; Wu et al., 2024).

Level of application: Easy.

Disadvantages: Reduces the need for chemical fertilizers, increases the soil's ability to retain water, and improves aeration, which can promote healthy

plant growth. Additionally, it helps reduce the amount of solid waste sent to landfills and incinerators.

Disadvantages: Requires adequate space for installation and storage of compostable materials. The process also demands significant maintenance time, such as turning the compost, and technical knowledge to monitor the conditions of the compost.

6.7. Cover crops

Description: The use of cover crops is an agroecological strategy for field crop production, soil fertility management, water quality improvement, climate change mitigation, and increased microbial activity, through the use of one or more types of crops to cover the soil, interspersed with permanent crops (Chapagain, Lee & Raizada, 2020; Launay et al., 2022).

Level of application: Easy.

Disadvantages: Planting cover crops can reduce soil erosion by protecting the surface. The decomposition of cover crops adds organic matter to the soil, improving microbial biodiversity, fertility, and water retention capacity.

Disadvantages: Growing cover crops requires investment in seeds, as well as planting and management, which can increase costs and labor for the farmer. It also requires specialized knowledge about which crops to choose and how to manage and integrate them effectively.

6.8. Cultivation of native species

***Description*:** Native species are varieties that occur naturally in a specific region or ecosystem, having adapted over time to the specific environmental conditions of an area, including climate, soil, and interactions with other species. They play key roles in reducing environmental impacts (Lazaridi et al., 2024).

***Application level*:** Easy.

***Advantages*:** Native species are adapted to local conditions and are highly likely to thrive in their natural habitat. They are more resistant to local diseases and climate changes and contribute to the maintenance of biodiversity.

***Disadvantages*:** Native species may face challenges when confronted with invasive species that compete for resources or introduce new diseases. Invasive species can also have higher production yields.

6.9. Environmental education

***Description*:** Environmental education is a set of learning strategies aimed at helping individuals understand and raise awareness about the challenges posed by the environment. These challenges are shaped by learning resources, time available for learning, learning space, curriculum design, and the characteristics of the learners (Fang, Hassan & LePage, 2023; Uralovich et al., 2023).

***Application Level*:** Medium.

Advantages: Environmental education raises awareness and sensitivity about environmental issues such as climate change, pollution, and biodiversity loss, fostering more sustainable behaviors.

Disadvantages: Environmental education can be time-consuming due to slow behavioral changes that are difficult to measure. Its effectiveness varies depending on the quality of teaching, the participants' interest, and requires adequate resources, teacher training, educational materials, and infrastructure, which can limit its overall impact.

6.10. Green financing and carbon markets

Description: Green financing programs, such as the Green Climate Fund, are being implemented globally to support projects that contribute to climate change mitigation in agriculture. These funds encourage the adoption of low-carbon technologies and the transition to more sustainable practices. Additionally, carbon markets offer opportunities for farmers to sell carbon credits

by adopting practices that sequester CO_2, creating an additional source of income while promoting financial sustainability (Gardner, 2021).

***Application Level*:** Medium

***Advantages*:** Green financing programs and carbon markets enable the sale of carbon credits for CO_2 sequestration practices and also provide incentives to finance the transition to low-carbon technologies, accelerating the adoption of sustainable practices.

***Disadvantages*:** There are significant uncertainties and price volatility in the carbon market. Additionally, the certification and monitoring processes required to participate in these markets are complex and may require technical expertise and resources.

6.11. Photovoltaic Panels

***Description*:** Photovoltaic panels are devices that convert sunlight into electricity through the photovoltaic effect, capturing solar radiation and transforming it into electricity. They contribute to the diversification of energy sources and the reduction of greenhouse gas emissions (Meribout et al., 2023; Umar, Qureshi & Nawaz, 2024).

***Application Level*:** Medium.

***Advantages*:** Solar panels generate electricity from sunlight, reducing dependence on fossil fuels and greenhouse gas emissions. They offer an effective and sustainable solution for electricity production, with significant environmental benefits and energy cost savings.

***Disadvantages*:** Solar panels have intermittent production and depend on sunlight availability. The initial installation cost can be high, and the return on investment may take several years to recover. Additionally, regular maintenance is required.

6.12. Integrated agricultural systems

Description: Integrated agricultural systems refer to farming operations that incorporate trees, grain crops, ground species, or livestock, leading to a better optimization of land use with sustainable management practices and technologies aimed at mitigating the environmental impacts of agricultural activities (Borges, Calonego & Rosolem, 2019; da Silva et al., 2021).

***Application Level*:** Difficult

***Advantages*:** Integration can improve the use of available resources, such as light, water, and nutrients, resulting in higher productivity efficiency. It also promotes soil health, reduces environmental degradation, and limits economic risk by diversifying income sources through the combination of crops and livestock.

***Disadvantages*:** Integrating various practices can be complex, requiring specific knowledge of the different components, along with higher investment, time, and effort demands.

7. Challenges and opportunities in the agri-food sector

The challenges and opportunities in the agri-food sector are strongly linked to key aspects such as the transition to renewable energy sources, the adoption of new soil and crop management practices, the development of regulations and public policies that can support and monitor these transformations, as well as the dissemination of knowledge and the promotion of responsibility for conscious consumption.

During the COVID-19 pandemic, we observed that food demand remained stable; however, in terms of food security and supply chain management, most countries faced difficulties, with less developed nations experiencing even greater challenges in resolving these issues (Hamid & Mir, 2021). Despite still having major problems to address in the agri-food sector, technological revolution has brought significant advances, such as remote sensing and precision agriculture, among others (Webb & Buratini, 2016).

Innovation in the agri-food sector arises from various needs, driven by new technologies, such as high labor costs and the demand for increased productivity to improve the economy. In addition, facilitators like governance, data security, new business models, political changes, and innovative ecosystems also play a crucial role in this process (van Hilten & Wolfert, 2022). According to Chaparro-Banegas et al. (2024), the agri-food sector faces challenges related to innovation, which are also linked to research and development, highlighting that to promote innovation in the sector, companies need to invest in training and investment.

Still within the context of changes in the sector, automation and mechanization stand out as key topics, bringing discussions about transformations that can optimize processes and promote sustainable use of resources. However, concerns about agricultural labour arise, as many farms and farmers face difficulties in adapting (Christiaensen, Rutledge & Taylor, 2021). Another frequently discussed point is technology in the agri-food sector and how it has improved and added value through tools like Big Data and IoT, ensuring more sustainable resource use and optimizing processes (Kosior, 2018).

At the same time, new issues arise, such as the high costs for implementing these technologies, as well as scalability, intangible security and privacy aspects, interoperability issues, and the lack of standardization—some of the barriers to their implementation (Shoomal et al., 2024). Knowledge about some technologies and methodologies that can be applied in this sector needs to be significantly expanded. That is, research and education are crucial for improving the sector, as the lack of awareness and understanding among farmers and stakeholders also hinders adoption (Podder et al., 2024).

One point to note is the management of waste generated in the agri-food sector, where the circular economy emerges with the premise of managing the entire process, reducing waste, and bringing a new form of production that can be applied to traditional systems (Pomoni et al., 2024). This includes the substitution of mineral and synthetic fertilizers with biological fertilizers, as well as products that use circular economy processes with potential applications in agriculture, horticulture, or soil regeneration, representing a strategic interest for more sustainable agriculture (Hénault-Ethier et al., 2024).

Finally, Ukoba et al. (2024) provide an interesting perspective on the role of governments and how public policies can play a supportive, incentivizing role and clarify and regulate activities, showing how these can be leveraged by individuals, communities, and societies. In line with this topic, Abbate, Cenobelli & Cerchione (2023) present the idea that policies and governments working on sustainable agriculture initiatives should support a cultural shift to promote and implement digital technologies in the agri-food sector.

It is observed that the agri-food sector faces complex and interconnected challenges, ranging from the transition to sustainable practices to adapting to new technologies, highlighting several weaknesses and difficulties of the sector in the face of the new reality. This same sector still has significant advantages and opportunities to increase productivity and promote sustainability, provided there is continued investment in research, innovation, and training for it to evolve effectively. Furthermore, building a sustainable future for the agri-food sector depends on an integrated and proactive approach that considers economic, environmental, and social needs.

8. Conclusion

The agri-food sector is vast and has a direct impact on the environment, and the global concerns related to this sector, addressed at international events, are justified, as issues such as food security, social well-being, environmental preservation, and food production are closely linked to it, directly influencing the quality of life and the future of society.

Regarding decarbonization in the agri-food sector, the complexity of the topic becomes evident as each aspect within this sector, whether production processes, types of products, or waste generated, requires a specific and differentiated approach. Due to the heterogeneous nature of agri-food activities, solutions to reduce impacts, whether environmental or social, need personalized strategies, adapted to the particularities of each area of operation.

When analyzing the cases of Portugal and Norway, countries involved as partners in this project, significant differences are identified regarding the production, import, and export of agri-food goods, reflecting the realities and challenges faced by each country, which vary substantially. It is essential to adapt guidelines according to the specific contexts of each nation.

Regarding the methods, techniques, and practices analyzed, there is a predominant trend focusing on the development of new technologies and innovations. However, it is crucial to recognize that many existing techniques, often underutilized, have great potential to contribute significantly. The efficient implementation of these simple and consolidated practices can represent an immediate and effective step forward in reducing environmental and social impacts, offering a viable alternative to technological innovations that, in some cases, still require development or adaptation.

Furthermore, from small producers to large industries, it is essential to raise awareness about the importance of decarbonization and the adoption of sustainable solutions. Efficient public policies, economic incentives, and environmental education programs play a key role in this process, ensuring that the recommended practices are not only known but also continuously and effectively applied.

Thus, collaboration between the public and private sectors, as well as the integration of different scientific and practical knowledge, is indispensable for the agri-food sector to contribute decisively to mitigating climate change and building a more sustainable future.

9. References

Rosati, A., & Muller-Lindenlauf, M. (2021). Agroforestry and Organic Agriculture: A Review of the Benefits and Challenges. Organic Agriculture, 11, 9-25. DOI: 10.1007/s13165-020-00329-w.

IPCC. (2021). AR6 Climate Change 2021: The Physical Science Basis. Cambridge University Press. DOI: 10.1017/9781009157896.

Gardner, J. (2021). Circular Economy & Decarbonisation: Lessons from Industry. Chatham House. Available at: **https://accelerator.chathamhouse.org**.

Gliessman, S. R. (2015). Agroecology: The Ecology of Sustainable Food Systems. CRC Press.

Ababou, M., Chelh, S., & Elhiri, M. (2023). A Bibliometric Analysis of the Literature on Food Industry Supply Chain Resilience: Investigating Key Contributors and Global Trends. ***Sustainability***. *15*(11), p. 1-19. https://doi.org/10.3390/su15118812

Abbate, S., Centobelli, P., & Cerchione, R. (2023). The digital and sustainable transition of the agri-food sector. ***Technological Forecasting and Social Change***, *187*, p. 1-14. https://doi.org/10.1016/j.techfore.2022.122222

Acushla. (s.d.). ***Sobre nós.*** Available at: https://www.acushla.pt/produtores-de-azeite-biologico-extra-virgem/. Accessed on: September 20th 2024.

Adisa, O., Ilugbusi, B. S., Adewunmi, O., Franca, O., & Ndubuisi, L. (2024). A comprehensive review of redefining agricultural economics for sustainable development: Overcoming challenges and seizing opportunities in a changing world. ***World Journal Of Advanced Research and Reviews***. *21*(1), p. 2329-2341. https://doi.org/10.30574/wjarr.2024.21.1.0322

Ahmed, A. A., Kumar, V., Patil, V., & Venkatesh, B. R. Smart Agriculture–Using IoT to Strengthen the Agriculture Sector and Overcoming the Challenges of Cybersecurity in the Context of Agriculture 5.0. ***Green Solutions A Handbook for Sustainable Business Strategies and Models.*** ISBN 978-81-971276-6-3. p.62-73.

Alfândega da Fé (2024). Município. ***Câmara Municipal de Alfândega da Fé.*** Available at: https://www.cm-alfandegadafe.pt. Accessed on: June 3rd 2024.

Allen, R. C. (2024). The Neolithic Revolution in the Middle East: A survey and speculation article for the Economic History Review. ***The Economic History Review.*** p. 1-43. https://doi.org/10.1111/ehr.13307

Angon, P. B., Mondal, S., Jahan, I., Datto, M., Antu, U. B., Ayshi, F. J., & Islam, M. S. (2023). Integrated pest management (IPM) in agriculture and its role in maintaining ecological balance and biodiversity. ***Advances in Agriculture.*** 2023(1), p. 1-19. https://doi.org/10.1155/2023/5546373

Antunes A. (2018). Sistema agroalimentar, produtor de doença e iniquidade. Saúde e Sustentabilidade. ***Centro de Estudos Estratégicos da Fiocruz (CEE-FIOCRUZ).*** Available at: https://cee.fiocruz.br/?q=node/873. Accessed on: June 14th 2024.

Assad, M. L. L., & Almeida, J. (2004). Agricultura e sustentabilidade: contexto, desafios e cenários. ***Ciência & Ambiente.*** *29, p. 15-30 https://www.researchgate.net/publication/228718155_Agricultura_e_sustentabilidade*

Bao, L., Kusadokoro, M., Chitose, A., & Chen, C. (2023). Development of socially sustainable transport research: A bibliometric and visualization analysis. ***Travel behaviour and society.*** *30*, p. 60-73. https://doi.org/10.1016/j.tbs.2022.08.012

Bazargani, K., & Deemyad, T. (2024). Automation's impact on agriculture: opportunities, challenges, and economic effects. ***Robotics.*** *13*(2), 33. https://doi.org/10.3390/robotics13020033

Bogsdalen Gård. (s.d.). ***Om oss.*** Available at: https://bogsdalengard.no/loe-prosjektet. Accessed on: 16 set. 2024.

Borges, W. L., Calonego, J. C., & Rosolem, C. A. (2019). Impact of crop-livestock-forest integration on soil quality. ***Agroforestry Systems.*** 93(6), p. 2111-2119. https://doi.org/10.1007/s10457-018-0329-0

Bragança (2024). Município. ***Câmara Municipal de Bragança.*** Available at: https://www.cm-braganca.pt. Accessed on: June 4th 2024.

Brahmaprakash, G. P., & Sahu, P. K. (2012). Biofertilizers for sustainability. ***Journal of the Indian Institute of Science***. *92*(1), p. 37-62. https://journal.iisc.ac.in/index.php/iisc/article/view/22/0

Caiazza, R., & Bigliardi, B. (2020). Web marketing in agri-food industry: Challenges and opportunities. ***Trends in Food Science & Technology*****.** *103*, p. 12-19. https://doi.org/10.1016/j.tifs.2020.04.024

Chandrakumar, C., McLaren, S. J., Jayamaha, N. P., & Ramilan, T. (2019). Absolute sustainability-based life cycle assessment (ASLCA): a benchmarking approach to operate agri-food systems within the 2 C global carbon budget. ***Journal of Industrial Ecology*****.** *23*(4), p. 906-917. https://doi.org/10.1111/jiec.12830

Chapagain, T., Lee, E. A., & Raizada, M. N. (2020). The potential of multi-species mixtures to diversify cover crop benefits. ***Sustainability.*** 12(5), p. 1-16. https://doi.org/10.3390/su12052058

Chaparro-Banegas, N., Sánchez-Garcia, M., Calafat-Marzal, C., & Roig-Tierno, N. (2024). Transforming the agri-food sector through eco-innovation: A path to sustainability and technological progress. ***Business Strategy and the Environment*****.** (Early View). https://doi.org/10.1002/bse.3968

Chataut, G., Bhatta, B., Joshi, D., Subedi, K., & Kafle, K. (2023). Greenhouse gases emission from agricultural soil: A review. ***Journal of Agriculture and Food Research*****.** *11*, p. 1-8. https://doi.org/10.1016/j.jafr.2023.100533

Christiaensen, L., Rutledge, Z., & Taylor, J. E. (2021). The future of work in agri-food. ***Food Policy*****.** *99*, p. 1-12. https://doi.org/10.1016/j.foodpol.2020.101963

Claudino, E. S., & Talamini, E. (2013). Análise do Ciclo de Vida (ACV) aplicada ao agronegócio: uma revisão de literatura. **Revista Brasileira de Engenharia Agrícola e Ambiental.** *17*, p. 77-85. https://doi.org/10.1590/S1415-43662013000100011

da Silva, H. A., Santos, L. A. C., Pacheco, A. R., Calil, F. N., Calil, F. N. & Silva-Neto, C. de M. e (2021). Crop-livestock-forest integration systems: a scientometric analysis. ***Ecologia e Nutrição Floresta.*** 9(3), p. 1-16. http://dx.doi.org/10.5902/2316980X68190

De Fraga, L. K., Gonçalves, L. M., Godoy, W. I., & Outeiro, M. T. (2022). Sistemas agroalimentares sustentáveis e saudáveis: reflexões a partir da perspectiva agroecológica. ***Revista do Desenvolvimento Regional*****.** *19*(1), p. 120-142. https://doi.org/10.26767/coloquio.v19iesp1.2437

De Lima, L. A., & Martins, K. (2022). O marco legal do pagamento por serviços ambientais para o avanço de iniciativas agrosustentáveis. ***Brazilian Journal of Development*****.** *8*(6), p. 45720-45738. https://doi.org/10.34117/bjdv8n6-204

de Medeiros, M. B., & Lopes, J. da S. (2006). Biofertilizantes líquidos e sustentabilidade agrícola. **Bahia Agrícola. Salvador.** *7*(3) p. 24-26. http://www.seagri.ba.gov.br/sites/default/files/comunicacao05_v7n3.pdf

Elenovations. (s.d.). ***About us.*** Disponível em: https://www.elenovations.com/lifepot. Accessed on: September 17th 2024.

Esmaeilian, B., Wang, B., Lewis, K., Duarte, F., Ratti, C., & Behdad, S. (2018). The future of waste management in smart and sustainable cities: A review and concept paper. ***Waste management.*** 81, p. 177-195. https://doi.org/10.1016/j.wasman.2018.09.047

Esposito, B., Sessa, M. R., Sica, D., & Malandrino, O. (2020). Towards circular economy in the agri-food sector. A systematic literature review. ***Sustainability*****.** *12*(18), p. 1-21. https://doi.org/10.3390/su12187401

Etukudoh, E. A., Adefemi, A., Ilojianya, V. I., Umoh, A. A., Ibekwe, K. I., & Nwokediegwu, Z. Q. S. (2024). A Review of sustainable transportation solutions: Innovations, challenges, and future directions. ***World Journal of Advanced Research and Reviews.*** 21(1), p. 1440-1452. https://doi.org/10.30574/wjarr.2024.21.1.0173

European Union (2004). Directive 2004/35/CE of the European Parliament and of the Council on environmental liability with regard to the prevention and remedying of environmental damage. ***Official Journal of the European Union.*** L 143, 30 April 2004, p. 56-75. Disponível em: https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=OJ%3AL%3A2004%3A143%3ATOC. Accessed on: August 16th 2024.

European Union (2009). Decision No. 406/2009/EC of the European Parliament and of the Council on the effort of Member States to reduce their greenhouse gas emissions to meet the Community's greenhouse gas emission reduction commitments up to 2020. ***Official Journal of the European Union.*** L 140, 5 June 2009, p. 136-148. Disponível em: https://eur-lex.europa.eu/eli/dec/2009/406/oj. Accessed on: August 14th 2024.

European Union (2014). Commission Directive 2014/80/EU of 20 June 2014 amending Annex II to Directive 2006/118/EC of the European Parliament and of the Council on the protection of groundwater against pollution and deterioration. ***Official Journal of the European Union.*** L 182, 21 June 2014, p. 52-55. Disponível em: https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=OJ%3AL%3A2014%3A182%3ATOC. Accessed on: August 12th 2024.

European Union (2014). Commission Regulation (EU) No. 668/2014 laying down rules for the application of Regulation (EU) No. 1151/2012 of the European Parliament and of the Council on quality schemes for agricultural products and foodstuffs. ***Official Journal of the European Union.*** L 179, 19 June 2014, p. 36. Disponível em: https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=OJ%3AL%3A2014%3A179%3ATOC. Accessed on: August 16th 2024.

European Union (2018). Bioeconomy Strategy. ***Directorate-General for Research and Innovation (European Commission).*** Disponível em: https://knowledge4policy.ec.europa.eu/publication/sustainable-bioeconomy-europe-strengthening-connection-between-economy-society_en. Accessed on: August 19th 2024.

European Union (2018). Directive (EU) 2018/2001 of the European Parliament and of the Council on the promotion of the use of energy from renewable sources. ***Official Journal of the European Union.*** L 328, 21 December 2018, p. 82-209. Available at: https://eur-lex.europa.eu/eli/dir/2018/2001/oj. Accessed on: August 16th 2024.

European Union (2018). Regulation (EU) 2018/1999 of the European Parliament and of the Council on the Governance of the Energy Union and Climate Action. ***Official Journal of the European Union.*** L 328, 21 December 2018, p. 1-77. Available at: https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=OJ%3AL%3A2018%3A328%3ATOC. Accessed on: August 13th 2024.

European Union (2018). Regulation (EU) 2018/842 of the European Parliament and of the Council on binding annual greenhouse gas emission reductions by Member States from 2021 to 2030 contributing to climate action to meet commitments under the Paris Agreement and amending Regulation (EU) No. 525/2013. ***Official Journal of the European Union.*** L 156, 19 June 2018, p. 26-42. Available at: https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=OJ%3AL%3A2018%3A156%3ATOC. Accessed on: August 14th 2024.

European Union (2019). European Green Deal. ***Directorate-General for Communication (European Commission).*** Available at: https://commission.europa.eu/strategy-and-policy/priorities-2019-2024/european-green-deal_en. Accessed on: August 19th 2024.

European Union (2020). Circular Economy Action Plan – For a cleaner and more competitive Europe. ***Directorate-General for Environment (European Commission).*** Available at: https://environment.ec.europa.eu/strategy/circular-economy-action-plan_en. Accessed on: August 19th 2024.

European Union (2020). Directive (EU) 2020/2184 of the european parliament and of the council of 16 December 2020 on the quality of water intended for human consumption. ***Official Journal of the European Union***. L 435, 23 December 2020, p. 1-62. Available at: https://eur-lex.europa.eu/legal-content/EN/ALL/?uri=OJ:L:2020:435:TOC. Accessed on: August 12th 2024.

European Union (2020). Farm to Fork Strategy – For a fair, healthy and environmentally-friendly food system. ***Directorate-General for Health and Food Safety (European Commission).*** Available at: https://food.ec.europa.eu/document/download/472acca8-7f7b-4171-98b0-ed76720d68d3_en?filename=f2f_action-plan_2020_strategy-info_en.pdf. Accessed on: August 19th 2024.

European Union (2020). Regulation (EU) 2020/741 of the european parliament and of the council of 25 May 2020 on minimum requirements for water reuse. ***Official Journal of the European Union.*** L 177, 5 June 2020, p. 32-55. Available at: https://eur-lex.europa.eu/eli/reg/2020/741/oj. Accessed on: August 12th 2024.

European Union (2021). EU biodiversity strategy for 2030 - Bringing nature back into our lives. ***Directorate-General for Environment (European Commission).*** 1st Editions, p. 1-36. https://doi.org/10.2779/677548

European Union (2021). Horizon Europe Strategic Plan 2021-2024. ***Directorate-General for Research and Innovation (European Commission).*** 1st Editions, p. 1-101. https://doi.org/10.2777/083753. Accessed on: August 19th 2024.

European Union (2021). Regulation (EU) 2021/1119 for achieving climate neutrality (European Climate Law). ***Official Journal of the European Union.*** L 243, 9 July 2021, p. 1-17. Available at: https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=OJ%3AL%3A2021%3A243%3ATOC. Accessed on: August 16th 2024.

European Union (2021). Regulation No. 2021/783 of the European Parliament and of the Council establishing a Programme for the Environment and Climate Action (LIFE), and repealing Regulation (EU) No. 1293/2013. ***Official Journal of the European Union.*** L 172, 17 May 2021, p. 53-78. Available at: https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=OJ%3AL%3A2021%3A172%3ATOC. Accessed on: August 14th 2024.

European Union (2022). Council Recommendation of 16 June 2022 on ensuring a fair transition towards climate neutrality 2022/C 243/04. ***Official Journal of the European Union.*** C 243, 27 June 2022, p. 35-51. Available at: https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX%3A32022H0627%2804%29. Accessed on: August 13th 2024.

European Union (2022). General Union Environment Action Programme to 2030. ***Official Journal of the European Union.*** L 114, 12 April 2022, p. 22-36. Available at: https://eur-lex.europa.eu/legal-content/PT/TXT/?uri=OJ:L:2022:114:TOC. Accessed on: August 19th 2024.

European Union (2023). Decision (EU) 2023/852 amending Decision (EU) 2015/1814 as regards the number of allowances to be placed in the market stability reserve for the Union greenhouse gas emission trading system until 2030. ***Official Journal of the European Union.*** L 110, 25 April 2023, p. 21-24. Available at: https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=OJ%3AL%3A2023%3A110%3ATOC. Accessed on: August 13th. 2024.

Fang, W. T., Hassan, A. A., & LePage, B. A. (2023). The living environmental education: Sound science toward a cleaner, safer, and healthier future. ***Springer Nature.*** p. 3-24 https://doi.org/10.1007/978-981-19-4234-1

FAO. (2019). The State of Food and Agriculture. Moving forward on food loss and waste reduction. ***Food and Agriculture Organization of the United Nations***, Rome. https://openknowledge.fao.org/server/api/core/bitstreams/11f9288f-dc78-4171-8d02-92235b8d7dc7/content

Fewkes, A. (2000). Modelling the performance of rainwater collection systems: towards a generalised approach. ***Urban water.*** 1(4), p. 323-333. https://doi.org/10.1016/S1462-0758(00)00026-1

Fountas, S., Espejo-García, B., Kasimati, A., Gemtou, M., Panoutsopoulos, H., & Anastasiou, E. (2024). Agriculture 5.0: Cutting-edge technologies, trends, and challenges. ***IT Professional***. *26*(1), p. 40-47. https://doi.org/10.1109/MITP.2024.3358972

Gamage, A., Gangahagedara, R., Gamage, J., Jayasinghe, N., Kodikara, N., Suraweera, P., & Merah, O. (2023). Role of organic farming for achieving sustainability in agriculture. ***Farming System.*** *1*(1), p. 1-14. https://doi.org/10.1016/j.farsys.2023.100005

Ghisellini, P., Quinto, I., Passaro, R., & Ulgiati, S. (2024). Exploring environmental and social performances of circular start-ups: An orientation and certification assessment. ***Business Strategy and the Environment.*** 33(4), p. 3222-3241. https://doi.org/10.1002/bse.3620

Gonçalves, R. F., (2023). Os fundamentos - Capítulo 1 - Introdução. Transformação Digital e Indústria 4.0: Produção e sociedade. ***Editora Blucher.*** ISBN 978-65-5506-732-3. p. 19-25. https://storage.blucher.com.br/book/pdf_preview/PDF_transformacao.pdf

Gullon, P., Gullon, B., Astray, G., Carpena, M., Fraga-Corral, M., Prieto, M. A., & Simal-Gandara, J. (2020). Valorization of by-products from olive oil industry and added-value applications for innovative functional foods. ***Food Research International.*** 137, p. 1-17. https://doi.org/10.1016/j.foodres.2020.109683

Haloui, D., Oufaska, K., Oudani, M., & El Yassini, K. (2024). Bridging Industry 5.0 and Agriculture 5.0: Historical Perspectives, Opportunities, and Future Perspectives. ***Sustainability*****.** *16*(9), 3507. https://doi.org/10.3390/su16093507

Hamid, S., & Mir, M. Y. (2021). Global Agri-food sector: challenges and opportunities in COVID-19 pandemic. ***Frontiers in sociology*****.** *6*, p. 1-11. https://doi.org/10.3389/fsoc.2021.647337

Haque, F., Fan, C., & Lee, Y. Y. (2023). From waste to value: Addressing the relevance of waste recovery to agricultural sector in line with circular economy. ***Journal of Cleaner Production*****.** 415, p. 1-12. https://doi.org/10.1016/j.jclepro.2023.137873

Hénault-Ethier, L., Quinche, M., Reid, B., Hotte, N., Fortin, A., Normandin, É., Renaud, G. de La R., Zadeh, A. R., Deschamps, M. H. & Vandenberg, G. (2024). Opportunities and challenges in upcycling agri-food byproducts to generate insect manure (frass): A literature review. ***Waste Management*****.** *176*, p. 169-191. https://doi.org/10.1016/j.wasman.2023.12.033

https://www.infoteca.cnptia.embrapa.br/infoteca/bitstream/doc/1149409/1/DOC47-final.pdf

Ijassi, W., Rejeb, H. B., & Zwolinski, P. (2021). Environmental impact allocation of agri-food co-products. ***Procedia CIRP*****.** *98*, p. 252-257. https://doi.org/10.1016/j.procir.2021.01.039

Kosior, K. (2018). Digital transformation in the agri-food sector–opportunities and challenges. ***Roczniki Naukowe.*** *2018*(2), p. 98-104. https://doi.org/105604/01.3001.0011.8122

Launay, C., Houot, S., Frédéric, S., Girault, R., Levavasseur, F., Marsac, S., & Constantin, J. (2022). Incorporating energy cover crops for biogas production into agricultural systems: benefits and environmental impacts. A review. ***Agronomy for Sustainable Development.*** 42(4), p.1-24. https://doi.org/10.1007/s13593-022-00790-8

Lazaridi, E., Kapazoglou, A., Gerakari, M., Kleftogianni, K., Passa, K., Sarri, E., Papasotiropoulos, V., Tani, E. & Bebeli, P. J. (2024). Crop landraces and indigenous varieties: A valuable source of genes for plant breeding. ***Plants.*** 13(6), p. 1-23. https://doi.org/10.3390/plants13060758

Leimona, B., Mithöfer, D., Wibawa, G., & van Noordwijk, M. (2024). Sustainability certification: multiple values of nature coexist in value chain transformations toward a common but differentiated responsibility. ***Current Opinion in Environmental Sustainability.*** 66, p. 1-10. https://doi.org/10.1016/j.cosust.2023.101393

Li, M., Guo, J., Ren, T., Luo, G., Shen, Q., Lu, J., Guo, S. & Ling, N. (2021). Crop rotation history constrains soil biodiversity and multifunctionality relationships. **Agriculture, Ecosystems & Environment.** *319*, p. 1-9. https://doi.org/10.1016/j.agee.2021.107550

Liu, Y., Ma, X., Shu, L., Hancke, G. P., & Abu-Mahfouz, A. M. (2020). From industry 4.0 to agriculture 4.0: Current status, enabling technologies, and research challenges. In ***IEEE transactions on industrial informatics.*** 17(6), p. 4322-4334. https://doi.org/10.1109/TII.2020.3003910

Lopes, M. (2022). Descarbonização e circularidade: respostas dos sistemas alimentar e agroindustrial aos Objetivos de Desenvolvimento Sustentável. ***Embrapa Agroenergia***. 1ª ed. Brasília, DF. ISSN 2177-4439.

Macedo De Cavaleiros (2024). Município. ***Câmara Municipal de Macedo Cavaleiros.*** Available at: https://www.cm-macedodecavaleiros.pt. Accessed on: June 5th 2024.

Malik, A., Sharma, S., Batra, I., Sharma, C., Kaswan, M. S., & Garza-Reyes, J. A. (2024). Industrial revolution and environmental sustainability: an analytical interpretation of research constituents in Industry 4.0. ***International Journal of Lean Six Sigma.*** 15(1), 22-49. http://dx.doi.org/10.1108/IJLSS-02-2023-0030

Meribout, M., Tiwari, V. K., Herrera, J. P. P., & Baobaid, A. N. M. A. (2023). Solar panel inspection techniques and prospects. ***Measurement***. 209, p. 1-17. https://doi.org/10.1016/j.measurement.2023.112466

Miranda do Douro(2024). Município. ***Câmara Municipal de Miranda do Douro***. Available at: https://www.cm-mdouro.pt. Accessed on: June 6th 2024.

Mirandela (2024). Município. ***Câmara Municipal de Mirandela.*** Available at: https://www.cm-mirandela.pt. Accessed on: June 7th 2024.

Mogadouro (2024). Município. ***Câmara Municipal de Mogadouro***. Available at: https://www.mogadouro.pt. Accessed on: June 10th 2024.

Murawska, A., & Goryńska-Goldmann, E. (2023). Greenhouse Gas Emissions in the Agricultural and Industrial Sectors—Change Trends, Economic Conditions, and Country Classification: Evidence from the European Union. ***Agriculture.*** *13*(7), p. 1-25. https://doi.org/10.3390/agriculture13071354

Musarat, M. A., Irfan, M., Alaloul, W. S., Maqsoom, A., & Ghufran, M. (2023). A review on the way forward in construction through industrial revolution 5.0. ***Sustainability.*** 15(18), p. 1-26. https://doi.org/10.3390/su151813862

Mussoi, M. R., Sirota, V. G. R., dos Anjos, M. de C. R., da Silva, A. C. G. F. da S. F. (2015). Agroindústrias familiares: resgate de saberes e práticas na promoção da soberania e segurança alimentar e nutricional. ***In III Jornadas Questão Agrária e Desenvolvimento.*** p. 1-9. http://www.jornadaquestaoagraria.ufpr.br

Norway (1981). Lov om jakt og fangst av vilt (viltloven). ***Klima- og miljødepartementet, Landbruks- og matdepartementet***. Dato: LOV-1981-05-29-38. Available at: https://lovdata.no/dokument/NL/lov/1981-05-29-38. Accessed on: August 9th 2024.

Norway (1995). Lov om jord (jordlova). ***Landbruks- og matdepartementet.*** Dato: LOV-1995-05-12-23. Available at: https://lovdata.no/dokument/NL/lov/1995-05-12-23. Accessed on: June 26t 2024.

Norway (2003). Lov om matproduksjon og mattrygghet mv. (matloven). ***Helsedepartementet.*** Dato: LOV-2003-12-19-124. Available at: https://lovdata.no/dokument/LTI/lov/2003-12-19-124. Accessed on: August 9 2024.

Norway (2004). Forskrift om begrensning av forurensning (forurensningsforskrifganten). ***Miljøverndepartementet.*** Dato: FOR-2004-06-01-931. Available at: https://lovdata.no/dokument/LTI/forskrift/2004-06-01-931. Accessed on: August 8th 2024.

Norway (2004). Forskrift om gjenvinning og behandling av avfall (avfallsforskriften). ***Klima- og miljødepartementet.*** Dato: FOR-2004-06-01-930. Available at: https://lovdata.no/dokument/SF/forskrift/2004-06-01-930. Accessed on August 9th 2024.

Norway (2005). Lov om skogbruk (skogbrukslova). ***Landbruks- og matdepartementet.*** Dato: LOV-2021-05-07-34. Available at: https://lovdata.no/dokument/LTI/lov/2021-05-07-34. Acessed on: June 25th 2024.

Norway (2009). Lov om forvaltning av naturens mangfold (naturmangfoldloven). ***Miljøverndepartementet.*** Dato: LOV-2009-06-19-100. Available at: https://lovdata.no/dokument/LTI/lov/2009-06-19-100. Accessed on: August 8th 2024.

Norway (2009). Lov om forvaltning av naturens mangfold (naturmangfoldloven). ***Miljøverndepartementet.*** Dato: LOV-2009-06-19-100. Available at: https://lovdata.no/dokument/LTI/lov/2009-06-19-100. Accessed on: June 25th 2024.

Norway (2009). Strategy for an Environmentally Sustainable Norwegian Aquaculture Industry. ***Nærings- og fiskeridepartementet.*** Available at:

https://www.regjeringen.no/no/dokumenter/strategy-for-an-environmentally-sustaina/id566395/. Accessed on: August 8th 2024.

Norway (2017). Klimastrategi for 2030 – norsk omstilling i europeisk samarbeid - Meld. St. 41 (2016–2017). ***Klima- og miljødepartementet.*** Available at: https://www.regjeringen.no/no/dokumenter/meld.-st.-41-20162017/id2557401/. Accessed on: August 7th 2024.

Norway (2017). Lov om klimamål (klimaloven). ***Klima- og miljødepartementet.*** Dato: LEX-FAOC178766. Available at: https://lovdata.no/dokument/LTI/lov/2017-06-16-60. Accessed on: June 25th 2024.

Norway (2018). Forskrift om tilskudd til klimatilpasning. ***Klima- og miljødepartementet.*** Dato: FOR-2018-06-25-1169. Available at: https://lovdata.no/dokument/LTI/forskrift/2018-06-25-1169. Accessed on: June 25th 2024.

Norway (2019). Lov om vern mot forurensninger og om avfall. ***Klima- og miljødepartementet.*** Dato: LOV-1981-03-13-6. Available at: https://lovdata.no/dokument/NL/lov/1981-03-13-6?q=Lov%20om%20vern%20mot%20forurensninger. Accessed on: August 7th 2024.

Norway (2019). Mat, mennesker og miljø: Regjeringens handlingsplan for bærekraftige matsystemer i norsk utenriks- og utviklingspolitikk 2019–2023. ***Utenriksdepartementet.*** Available at: https://www.norway.no/en/missions/un/news/123/news-on-development-and-humanitarian-efforts/new-action-plan-to-combat-hunger/. Accessed on: August 7th. 2024.

Norway (2020). Regjeringens hydrogenstrategi: på vei mot lavutslippssamfunnet. ***Klima- og miljødepartementet.*** Available at: https://www.regjeringen.no/no/dokumenter/regjeringens-hydrogenstrategi---pa-vei-mot-lavutslippssamfunnet/id2704860/. Accessed on: August 7th2024.

Norway (2021). Forskrift om tilskudd til frivillige klima- og miljøorganisasjoner samt klima- og miljøstiftelser. ***Klima- og miljødepartementet.*** Dato: FOR-2011-09-29-973. Available at: https://lovdata.no/dokument/LTI/forskrift/2021-06-11-1928. Accessed on: June 25th 2024.

Norway (2021). Klima, sult og s'rbarhet: Strategi para klimatilpasning, forebygging av klimarelaterte katastrofer og sultbekjempelse. ***Utenriksdepartementet.*** Available at: https://www.regjeringen.no/no/dokumenter/klimatilpasning_strategi/id2963175/. Accessed on: August 8th 2024.

Norway (2021). Matnasjonen Norge. ***Landbruks- og matdepartementet, Helse- og omsorgsdepartementet, Nærings- og fiskeridepartementet.*** Available at: https://www.regjeringen.no/no/dokumenter/matnasjonen-norge/id2834496/. Accessed on: August 7th 2024.

Norway (2022). Meld. St. 26 (2022-2023) – Klima i endring: sammen for et klimarobust samfunn. ***Klima- og miljødepartementet.*** Available at: https://www.regjeringen.no/no/dokumenter/meld.-st.-26-20222023/id2985027/. Accessed on: August 8th 2024.

Norway (2023). Forskrift om midler til satsing på bærekraftig matproduksjon og verdiskaping i nord. ***Landbruks- og matdepartementet.*** Dato: FOR-2023-08-08-1312. Available at: https://lovdata.no/dokument/LTI/forskrift/2023-08-08-1312. Accessed on: June 26th2024.

Norway (2024). Government.no. ***Kingdom of Norway***. Oslo, Norwegian Government Security and Service Organisation. Available at: https://www.regjeringen.no. Accessed on: June 14th2024.

Pan, C., Yang, H., Gao, W., Wei, Z., Song, C., & Mi, J. (2024). Optimization of organic solid waste composting process through iron-related additives: A systematic review. ***Journal of Environmental Management***. 351, p. 1-15. https://doi.org/10.1016/j.jenvman.2023.119952

Petrović, B., Bumbálek, R., Zoubek, T., Kuneš, R., Smutný, L., & Bartoš, P. (2024). Application of precision agriculture technologies in Central Europe-review. ***Journal of Agriculture and Food Research.*** 5, p. 1-10. https://doi.org/10.1016/j.jafr.2024.101048

Podder, A., Paul, S., Sen, A., Roy, K., & Chakraborty, A. (2024). Revolutionizing the Agriculture and Food Industry through Blockchain Technology: Challenges and Opportunities.

***Educational Administration: Theory and Practice*.** *30*(6), p. 209-214. https://doi.org/10.53555/kuey.v30i6.5148

Polymeni, S., Plastras, S., Skoutas, D. N., Kormentzas, G., & Skianis, C. (2023). The impact of 6G-IoT technologies on the development of agriculture 5.0: a review. ***Electronics.*** *12*(12), p. 1-24. https://doi.org/10.3390/electronics12122651

Pomoni, D. I., Koukou, M. K., Vrachopoulos, M. G., & Vasiliadis, L. (2024). Circular economy: A multilevel approach for natural resources and wastes under an agri-food perspective. ***Water-Energy Nexus***. 7, p. 103-123. https://doi.org/10.1016/j.wen.2023.12.003

Pongrácz, E., & Pohjola, V. J. (2004). Re-defining waste, the concept of ownership and the role of waste management. ***Resources, conservation and Recycling*.** *40*(2), p. 141-153. https://doi.org/10.1016/S0921-3449(03)00057-0

Portugal (1993). Estatuto da Instituição de Proteção Vegetal, Animal e Alimentar. ***Decreto-Lei n.º 99/93.*** Diário da República n.º 78/1993, Série I-A de 1993-04-02, p. 1681-1695. Available at: https://diariodarepublica.pt/dr/detalhe/decreto-lei/99-1993-680641. Accessed on: July 31st. 2024.

Portugal (2005). Programa de Monitorização e Avaliação do Plano Nacional para as Alterações Climáticas. ***Resolução do Conselho de Ministros n.º 59/2005.*** Diário da República n.º 47/2005, Série I-B de 2005-03-08, p. 1997-2012. Available at: https://diariodarepublica.pt/dr/detalhe/resolucao-conselho-ministros/59-2005-588831. Accessed on: July 30th 2024.

Portugal (2005). Programa Nacional para o Uso Eficiente da Água. ***Resolução do Conselho de Ministros n.º 113/2005.*** Diário da República n.º 124/2005, Série I-B de 2005-06-30, p. 4059-4062. Available at: https://diariodarepublica.pt/dr/detalhe/resolucao-conselho-ministros/113-2005-233732. Accessed on: July 31st 2024.

Portugal (2008). Preservação da Vida Selvagem e da Biodiversidade. ***Decreto-Lei n.º 142/2008.*** Diário da República n.º 142/2008, Série I de 2008-07-24, p. 4596-4611. Available at: https://diariodarepublica.pt/dr/detalhe/decreto-lei/142-2008-454502. Accessed on: July 31st 2024.

Portugal (2012). Autoridade para a Segurança Económica e Alimentar. ***Decreto-Lei n.º 194/2012.*** Diário da República n.º 163/2012, Série I de 2012-08-23, p. 4641-4646. Available at: https://diariodarepublica.pt/dr/detalhe/decreto-lei/194-2012-175336. Accessed on: July 31st 2024.

Portugal (2013). Metas nacionais de energia renovável. ***Decreto-Lei n.º 39/2013.*** Diário da República n.º 54/2013, Série I de 2013-03-18, p. 1691-1709. Available at: https://diariodarepublica.pt/dr/detalhe/decreto-lei/39-2013-259898. Accessed on: July 31st 2024.

Portugal (2014). Plano Estratégico para os Resíduos Urbanos (PERSU 2020) para Portugal Continental. ***Portaria n.º 187-A/2014.*** Diário da República n.º 179/2014, 1º Suplemento, Série I de 2014-09-17, p. 2-4. Available at: https://diariodarepublica.pt/dr/detalhe/portaria/187-a-2014-56928479. Accessed on: July 30th 2024.

Portugal (2015). Desenvolvimento agrícola. ***Lei n.º 92/2015.*** Diário da República n.º 156/2015, Série I de 2015-08-12, p. 5754-5754. Available at: https://diariodarepublica.pt/dr/detalhe/lei/92-2015-69992904. Accessed on: July 30th 2024.

Portugal (2016). Fundo para a Conservação da Natureza e da Biodiversidade. ***Decreto-Lei n.º 42-A/2016. Diário*** da República n.º 155/2016, 1º Suplemento, Série I de 2016-08-12, p. 3-11. Available at: https://diariodarepublica.pt/dr/detalhe/decreto-lei/42-a-2016-75150234. Accessed on: July 30th 2024.

Portugal (2016). Plano Nacional da Água. ***Decreto-Lei n.º 76/2016.*** Diário da República n.º 215/2016, Série I de 2016-11-09, p. 3951-4007. Available at: https://diariodarepublica.pt/dr/detalhe/decreto-lei/76-2016-75701996. Accessed on: July 25th 2024.

Portugal (2017). Estratégia Industrial e o Plano de Ação para as Energias Renováveis Oceânicas. ***Resolução do Conselho de Ministros n.º 174/2017.*** Diário da República n.º 227/2017, Série I de 2017-11-24, p. 6176-6188. Available at:

https://diariodarepublica.pt/dr/detalhe/resolucao-conselho-ministros/174-2017-114248654. Accessed on: July 26th 2024.

Portugal (2018). Conselho Nacional de Segurança Alimentar e Nutricional. ***Resolução do Conselho de Ministros n.º 103/2018.*** Diário da República n.º 143/2018, Série I de 2018-07-26, p. 3706-3708. Available at: https://diariodarepublica.pt/dr/detalhe/resolucao-conselho-ministros/103-2018-115777792. Accessed on: July 31st. 2024.

Portugal (2018). Estatuto da Agricultura Familiar. ***Decreto-Lei n.º 64/2018.*** Diário da República n.º 151/2018, Série I de 2018-08-07, p. 3946-3949. Available at: https://diariodarepublica.pt/dr/detalhe/decreto-lei/64-2018-115933868. Accessed on: July 30th 2024.

Portugal (2018). Estratégia Nacional de Conservação da Natureza e Biodiversidade 2030. ***Resolução do Conselho de Ministros n.º 55/2018.*** Diário da República n.º 87/2018, Série I de 2018-05-07, p. 1835-1880. Available at: https://diariodarepublica.pt/dr/detalhe/resolucao-conselho-ministros/55-2018-115226936. Accessed on: July 25th 2024.

Portugal (2018). Estratégia Nacional e o respetivo Plano de Ação de Combate ao Desperdício Alimentar. ***Resolução do Conselho de Ministros n.º 46/2018.*** Diário da República n.º 82/2018, Série I de 2018-04-27, p. 1708-1720. Available at: https://diariodarepublica.pt/dr/detalhe/resolucao-conselho-ministros/46-2018-115191272. Accessed at: July 24th 2024.

Portugal (2018). Roteiro para a Neutralidade Carbónica 2050. ***Resolução do Conselho de Ministros n. 107/2019.*** Diário da República n.º 123/2019, Série I de 2019-07-01, p. 3208-3299. Available at: https://diariodarepublica.pt/dr/detalhe/resolucao-conselho-ministros/107-2019-122777644. Accessed on: July 24th 2024.

Portugal (2019). Programa de Ação para a Adaptação às Alterações Climáticas. ***Resolução do Conselho de Ministros n.º 130/2019.*** Diário da República n.º 147/2019, Série I de 2019-08-02, p. 10-45. Available at: https://diariodarepublica.pt/dr/detalhe/resolucao-conselho-ministros/130-2019-123666112. Accessed on: July 24th 2024.

Portugal (2020). Plano Nacional de Gestão Integrada de Fogos Rurais. ***Resolução do Conselho de Ministros n.º 45-A/2020.*** Diário da República n.º 115/2020, 1º Suplemento, Série I de 2020-06-16, p. 2-145. Available at: https://diariodarepublica.pt/dr/detalhe/resolucao-conselho-ministros/45-a-2020-135843143. Accessed on: July 26th 2024.

Portugal (2020). Plano Nacional Energia e Clima 2030 (PNEC 2030). ***Resolução do Conselho de Ministros n.º 53/2020.*** Diário da República n.º 133/2020, Série I de 2020-07-10, p. 2-158. Available at: https://diariodarepublica.pt/dr/detalhe/resolucao-conselho-ministros/53-2020-137618093. Accessed on: July 26th 2024.

Portugal (2020). Programa Bairros Saudáveis. ***Resolução do Conselho de Ministros n.º 52-A/2020.*** Diário da República n.º 126/2020, 1º Suplemento, Série I de 2020-07-01, p. 2-5. Available at: https://diariodarepublica.pt/dr/detalhe/resolucao-conselho-ministros/52-a-2020-136997541. Accessed on: July 26th 2024.

Portugal (2021). Estratégia Nacional de Segurança Alimentar e Nutricional. ***Resolução do Conselho de Ministros n.º 132/2021.*** Diário da República n.º 178/2021, Série I de 2021-09-13, p. 10-46. Available at: https://diariodarepublica.pt/dr/detalhe/resolucao-conselho-ministros/132-2021-171183636. Accessed on: July 25th 2024.

Portugal (2023). Plano Estratégico da Política Agrícola Comum de Portugal. ***Decreto-Lei n.º 12/2023.*** Diário da República n.º 40/2023, Série I de 2023-02-24, p. 2-13. Available at: https://diariodarepublica.pt/dr/detalhe/decreto-lei/12-2023-207760041. Accessed on: July 25th 2024.

Portugal (2023). Plano Nacional de Gestão de Resíduos 2030. ***Resolução do Conselho de Ministros n.º 31/2023.*** Diário da República n.º 60/2023, Série I de 2023-03-24, p. 140-276. Available at: https://diariodarepublica.pt/dr/detalhe/resolucao-conselho-ministros/31-2023-210923319. Accessed on: July 25th 2024.

Portugal (2024). Portal Diplomático. ***República Portuguesa***. Lisboa, Ministério dos Negócios Estrageiros. Available at: https://portaldiplomatico.mne.gov.pt. Accessed on: June 13th 2024.

Portugal (2024). Rede Nacional da Política Agrícola Comum (RNPAC). ***Portaria n.º 108/2024/1.*** Diário da República n.º 54/2024, Série I de 2024-03-15. Available at: https://diariodarepublica.pt/dr/detalhe/portaria/108-2024-855593247. Accessed on: July 30th 2024.

Portugal (2024). Regulamento Específico da Área Temática Ação Climática e Sustentabilidade. ***Portaria n.º 125/2024/1.*** Diário da República n.º 64/2024, Série I de 2024-04-01. Available at: https://diariodarepublica.pt/dr/detalhe/portaria/125-2024-858167926. Accessed on: July 2024.

Rogaland (2024). Om oss. ***Rogaland fylkeskommune***. Available at: https://www.rogfk.no. Accessed on: June 17 2024.

Røysland Gård. (s.d.). ***Litt om oss.*** Available at: https://roylandgard.no/pages/om-oss. Accessed on: September 18th 2024.

Saiz-Rubio, V., & Rovira-Más, F. (2020). From smart farming towards agriculture 5.0: A review on crop data management. ***Agronomy.*** *10*(2), 207. http://dx.doi.org/10.3390/agronomy10020207

Selvan, T., Panmei, L., Murasing, K. K., Guleria, V., Ramesh, K. R., Bhardwaj, D. R., Thakur C. L., Kumar D., Sharma, P., Umedsinh, R. D., Kayalvizhi, D. & Deshmukh, H. K. (2023). Circular economy in agriculture: Unleashing the potential of integrated organic farming for food security and sustainable development. ***Frontiers in Sustainable Food Systems.*** *7*, p. 1-17. https://doi.org/10.3389/fsufs.2023.1170380

Shoomal, A., Jahanbakht, M., Componation, P. J., & Ozay, D. (2024). Enhancing Supply Chain Resilience and Efficiency through Internet of Things Integration: Challenges and Opportunities. ***Internet of Things.*** 27, p. 1-26. https://doi.org/10.1016/j.iot.2024.101324

Socas-Rodríguez, B., Álvarez-Rivera, G., Valdés, A., Ibáñez, E., & Cifuentes, A. (2021). Food by-products and food wastes: Are they safe enough for their valorization?. ***Trends in Food Science & Technology.*** 114, p. 133-147. https://doi.org/10.1016/j.tifs.2021.05.002

Sortegel. (s.d.). ***Empresa.*** Disponível em: https://www.sortegel.com/. Acesso em: 23 set. 2024.

Stephan, A., Crawford, R. H., & Bontinck, P. A. (2019). A model for streamlining and automating path exchange hybrid life cycle assessment. ***The International Journal of Life Cycle Assessment***. *24*, p. 237-252. https://doi.org/10.1007/s11367-018-1521-1

Terra de Trás-os-Montes (2024). Comunidade Intermunicipal. ***Comunidade Intermunicipal das Terras de Trás-os-Montes.*** Available at: https://www.cim-ttm.pt. Accessed on: June 12 2024.

Thorsnæs, G. & De Amoriza, S. E. (2024). Stavanger. ***Store Norske Leksikon***. Available at: https://snl.no/Stavanger. Accessed on: June 18 2024.

Thorsnæs, G. (2021a). Dalane. ***Store Norske Leksikon***. Available at: https://snl.no/Dalane. Accessed on: June 19th 2024.

Thorsnæs, G. (2021b). Haugalandet. ***Store Norske Leksikon***. Available at: https://snl.no/Haugalandet. Accessed on: June 20th 2024.

Thorsnæs, G. (2021c). Jæren. ***Store Norske Leksikon***. Available at: https://snl.no/J%C3%A6ren. Accessed on: June 21th 2024.

Thorsnæs, G. (2024). Ryfylke. ***Store Norske Leksikon***. Available at: https://snl.no/Ryfylke. Accessed on: June 21st 2024.

Tonle, F. B., Niassy, S., Ndadji, M. M., Tchendji, M. T., Nzeukou, A., Mudereri, B. T., Senagi, K. & Tonnang, H. E. (2024). A road map for developing novel decision support system (DSS) for disseminating integrated pest management (IPM) technologies. ***Computers and Electronics in Agriculture.*** 217, p. 1-19. https://doi.org/10.1016/j.compag.2023.108526

Torrens, J. C. S. (2020). Sistemas Agroalimentares: impactos e desafios num cenário post pandemia. ***P2P e Inovação.*** 7(1), p. 192-211. https://doi.org/10.21721/p2p.2020v7n1.p192-211

Ukoba, K., Yoro, K. O., Eterigho-Ikelegbe, O., Ibegbulam, C., & Jen, T. C. (2024). Adaptation of solar power in the Global south: Prospects, challenges and opportunities. ***Heliyon***. 10, p. 1-18. https://doi.org/10.1016/j.heliyon.2024.e28009

Umar, S., Qureshi, M. S., & Nawaz, M. U. (2024). Thermal Imaging and AI in Solar Panel Defect Identification. ***International Journal of Advanced Engineering Technologies and Innovations***. 1(3), 73-95. https://ijaeti.com/index.php/Journal/article/view/230

Uralovich, K. S., Toshmamatovich, T. U., Kubayevich, K. F., Sapaev, I. B., Saylaubaevna, S. S., Beknazarova, Z. F., & Khurramov, A. (2023). A primary factor in sustainable development and environmental sustainability is environmental education. ***Caspian Journal of Environmental Sciences***. 21(4), p. 965-975. https://doi.org/10.22124/CJES.2023.7155

Van Hilten, M., & Wolfert, S. (2022). 5G in agri-food-A review on current status, opportunities and challenges. ***Computers and Electronics in Agriculture*****.** *201*, p. 1-11. https://doi.org/10.1016/j.compag.2022.107291

Vila Flor (2024). Município. ***Câmara Municipal de Vila Flor.*** Disponível em: https://www.cm-vilaflor.pt. Acesso em: 11 jun. 2024.

Villarreal, E. L., & Dixon, A. (2005). Analysis of a rainwater collection system for domestic water supply in Ringdansen, Norrköping, Sweden. ***Building and Environment.*** 40(9), p. 1174-1184. https://doi.org/10.1016/j.buildenv.2004.10.018

Vimioso (2024). Município. ***Câmara Municipal de Vimioso.*** Available at: https://www.cm-vimioso.pt/. Accessed on: June 12th 2024.

Vinhais (2024). Município. ***Câmara Municipal de Vinhais.*** Available at: https://www.cm-vinhais.pt. Accessed on: June 12th 2024.

Webb, R., & Buratini, J. (2018). Global challenges for the 21st century: the role and strategy of the agri-food sector. ***Animal Reproduction (AR)*****.** *13*(3), p. 133-142. https://doi.org/10.21451/1984-3143-AR882

Whayne, J. (2024). Introduction: Agriculture from Pre-History to the Present. The Oxford Handbook of Agricultural History. ***Oxford Handbooks.*** p. 1-22. https://doi.org/10.1093/oxfordhb/9780190924164.002.0006

Wu, D., Gao, W., Zhao, Y., Wei, Z., Song, C., Qu, F., & Wang, F. (2024). Elaborating the microbial mechanism of humic substance formation during lignocellulosic biomass composting by inoculation with different functional microbes. ***Industrial Crops and Products.*** 208, p. 1-13. https://doi.org/10.1016/j.indcrop.2023.117838

Xin, Y., Xu, Y., & Zheng, Y. (2024). A Study on Green Agricultural Production Decision-Making by Agricultural Cooperatives under Government Subsidies. ***Sustainability*****.** *16*(3), p. 1-27. https://doi.org/10.3390/su16031219

Yu, T., Mahe, L., Li, Y., Wei, X., Deng, X., & Zhang, D. (2022). Benefits of crop rotation on climate resilience and its prospects in China. ***Agronomy.*** *12*(2), p. 1-18. https://doi.org/10.3390/agronomy12020436

Zambon, I., Cecchini, M., Egidi, G., Saporito, M. G., & Colantoni, A. (2019). Revolution 4.0: Industry vs. agriculture in a future development for SMEs. ***Processes*****.** *7*(1), 36. http://dx.doi.org/10.3390/pr7010036

Zhai, Z., Martínez, J. F., Beltran, V., & Martínez, N. L. (2020). Decision support systems for agriculture 4.0: Survey and challenges. ***Computers and Electronics in Agriculture.*** 170, p. 1-16. https://doi.org/10.1016/j.compag.2020.105256

Ziatdinov, R., Atteraya, M. S., & Nabiyev, R. (2024). The Fifth Industrial Revolution as a transformative step towards society 5.0. ***Societies.*** 14(2), p. 1-15. https://doi.org/10.3390/soc14020019

Working together for a green and competitive Europe.

Funded by:

Iceland Liechtenstein Norway grants

Promoter:

mountains of research

Partner:

BOGSDALEN GÅRD
ANNO. 2021