INSTITUTO
UNIVERSITÁRIO
DE LISBOA

How Governance Innovations Encounter Regime Resistance: Exploring Decline of Fossil Fuels, Fertilisers and Pesticides in EU Nature Restoration Law

Dalia Alejandra Soto Ricardo

Master (MSc) in Political Economy

Supervisor:
Nuno Miguel da Costa Bento, Integrated Researcher,
DINÂMIA'CET-Iscte

July, 2025

iscte

CIÊNCIAS SOCIAIS
E HUMANAS

Department of Political Economy

How Governance Innovations Encounter Regime Resistance: Exploring Decline of Fossil Fuels, Fertilisers and Pesticides in EU Nature Restoration Law

Dalia Alejandra Soto Ricardo

Master (MSc) in Political Economy

Supervisor:
Nuno Miguel da Costa Bento, Integrated Researcher,
DINÂMIA'CET-Iscte

July, 2025

Dedicado a mi familia, que, a pesar de la distancia,
siempre me acompaña desde el corazón.

Acknowledgements

This thesis represents a long and challenging process of engaging with the complexities of sustainability and system transitions. With no prior background in agriculture, my journey began with a desire to understand these dynamics more closely, leading me to Úbeda, one of Spain's oldest towns. There, Juan and Rosa welcomed me onto their family farm, which was committed to sustainable practices. Unfortunately, mounting pressures forced them to cease operations and give way to a large-scale olive monoculture. The transformation of that landscape, once rich with biodiversity, left a lasting impression on me and became the initial spark for the ideas developed in this thesis.

I am grateful for their generosity and openness, and to the many individuals I've met along the way who are committed to transforming agriculture into a system that will sustain current and future generations while restoring the environment in which it unfolds.

I give my sincere thanks to my supervisor, Nuno, for his guidance and encouragement throughout this project. His thoughtful feedback helped me navigate both the theoretical and empirical complexities of the research.

I'm deeply thankful to my family for their constant support, and to my grandmother, Moraima, whose strength and kindness continue to inspire me.

To my friends in Lisbon—Paulo, Rosário, Tiago, Kian, Jonas, and Sara—thank you for the memories, the conversations, and the much-needed balance along the way. To Ashley, Julia, and Seoyoun, back in Canada, thank you for always being present, no matter the distance.

This thesis is as much about systems as it is about people, and without them, I wouldn't be where I am today.

Resumo

À medida que as transições para a sustentabilidade exigem cada vez mais o surgimento de tecnologias limpas e o declínio ativo das tecnologias insustentáveis, torna-se necessária uma maior clareza conceptual sobre como os sistemas incumbentes resistem à sua própria desestabilização. Esta dissertação aborda essa lacuna ao questionar de que forma os fatores de resistência ao nível do regime influenciam a dinâmica do declínio sociotécnico. Com base em desenvolvimentos recentes na literatura sobre as funções de declínio nas transições sociotécnicas, o estudo centra-se na *Nature Restoration Law* (NRL) da União Europeia, uma inovação em termos de governação que introduz metas juridicamente vinculativas para a restauração de ecossistemas. Através de um estudo de caso comparativo de três sistemas tecnológicos centrais, combustíveis fósseis, fertilizantes sintéticos e pesticidas, esta investigação explora como as formas políticas, económicas e discursivas de resistência moldam e interferem com quatro funções centrais do declínio: deslegitimação, orientação para a saída, declínio de mercado e desmobilização de recursos. A NRL é analisada ao longo do seu desenvolvimento, desde a proposta inicial ao Conselho Europeu em 22 de junho de 2022, passando por várias revisões, até à sua adoção em 24 de junho de 2024. Em todos os quatro casos, a resistência a estas funções de declínio é examinada através da análise de documentos e meios de comunicação, incluindo projetos de lei, relatórios de stakeholders e discursos públicos.

Os resultados demonstram que os mecanismos de resistência influenciam de forma desigual as funções de declínio: os interesses económicos dificultam sobretudo a desmobilização de recursos, enquanto o lobbying político e a construção de narrativas retardam os processos de deslegitimação e orientação para a saída. Este estudo fornece pistas sobre como inovações de governação, como a NRL, interagem com sistemas enraizados, oferecendo um quadro analítico para identificar formas de resistência e conceber estratégias de eliminação mais eficazes. Ao aprofundar a compreensão dos processos de declínio, este trabalho contribui para o avanço da teoria das transições sociotécnicas e apoia os decisores políticos na gestão de um terreno de transição marcado por tensões e conflitos.

Abstract

As sustainability transitions increasingly demand the emergence of clean technologies and the active decline of unsustainable ones, greater conceptual clarity is needed on how incumbent systems resist destabilisation. This thesis addresses that gap by asking how regime-level resistance factors influence the dynamics of socio-technical decline. Building on recent developments in the literature on decline functions in relation to socio-technical transitions, this study centres on the European Union's Nature Restoration Law (NRL), a governance innovation that introduces legally binding ecosystem restoration targets. Through a comparative case study of three key technological systems , fossil fuels, synthetic fertilisers, and pesticides, it examines how political, economic, and discursive forms of resistance shape and interfere with four decline functions: delegitimation, guidance toward the exit, market decline, and resource demobilisation. The NRL is examined throughout its development, from its initial proposal to the European Council on June 22, 2022, including various revisions, to its adoption on June 24, 2024. Across all four cases, resistance to the four decline functions is examined using documents and media analysis of policy drafts, stakeholder reports, and public discourse.

Findings show that resistance mechanisms influence decline functions to different degrees, with economic interests primarily hindering resource demobilisation, while political lobbying and narrative framing slow down delegitimation and guidance toward exit. This study provides insights into how governance innovations, such as the NRL, interact with entrenched systems, offering a framework for identifying resistance and designing more effective phase-out strategies. By deepening the understanding of decline processes, this work expands socio-technical transitions theory and supports policymakers in managing the contested terrain of system transitions.

Keywords: socio-technical decline, regime resistance, sustainability transitions, Nature Restoration Law, governance innovation, TIS, agricultural systems

JEL Classification: O33; Q55, Q16

Index

CHAPTER 1

Introduction

1.1. Urgency for Change in Agricultural Socio-technical Systems

The agricultural sector contributes to a total of 10% of greenhouse gas (GHG) emissions across European Union (EU) member states (Directorate-General for Climate Action, 2023). These emissions largely stem from the release of nitrous oxide (N_2O) and methane (CH_4). The natural cycle of nitrogen is disturbed by the excessive use of synthetic fertilisers, which affects soil health and the surrounding environment due to fertiliser run-off, often ending up in water reserves and contributing to algae buildup (Staletovich, 2018).

Beyond direct contamination of water systems, intensive fertiliser use accelerates topsoil degradation, an increasingly urgent concern for global agriculture. Topsoil, the uppermost layer of soil where nutrients, organic matter, and microbial life interact to sustain crops, is eroding at alarming rates. Estimates indicate that over 24 billion tons of fertile soil are lost annually due to unsustainable agricultural practices (FAO, 2022). Within the EU, more than 60% of arable land, which refers to land suitable for growing crops, is affected by erosion, with only 30% remaining in relatively stable condition (European Commission, 2023). The loss of topsoil not only reduces agricultural productivity but also weakens the resilience of ecosystems, further exacerbating the challenges posed by climate change and land degradation.

Over 80% of ecosystems across member states are in poor condition, which are further exacerbated by the intensive use of synthetic fertilisers, declining pollinator population, water scarcity, and droughts (Haahr, 2024). The excessive consumption of available water sources due to inadequate water management and increasing climate pressures heightens drought conditions, with over half of EU member states recently exposed to warning drought levels (Euronews, 2022). Pollinators are fundamental to agriculture, contributing €5 – 15 billion euros annually to the EU economy through the pollination of crops, of which 84% depend on insect pollination (European Environmental Agency, 2025). However, wild insect populations in the EU have declined by 75% in recent decades since 2000, with wild pollinators continuing to be significantly affected (Directorate-General for Environment and European Commission, 2020; see Figure A1 in Appendix, adapted from Sánchez-Bayo & Wyckhuys, 2019).

Increasing climate pressures and environmental degradation adversely impact human health and well-being. Global temperatures have risen approximately 26% faster than in any prior period since the 1970s, with forecasts indicating a 1.5°C increase by 2050 (Hausfather, 2024). The significant rise in temperatures creates conditions conducive to the spread of diseases through insects that thrive in warmer climates. Since 2016, malaria fatalities have steadily increased, and other mosquito-borne infections, such as dengue, have spread to previously unaffected countries, for instance, France (European Centre for Disease Prevention and Control, 2024).

Recurrent environmental pressures have led to the large-scale displacement of residents in severely impacted regions. For example, the growing incidence of droughts contributes to desertification, where fertile land degrades due to inadequate management and external climate pressures. These lands account for 40% of the world's terrestrial surface, and a United Nations (UN) report indicates that land degradation is occurring at a rate 35 times higher than historical averages, resulting in the loss of approximately 100 million hectares of productive land annually (United Nations, 2024; United Nations Statistics Division, 2024).

Because desertification affects food production, residents have migrated in search of more hospitable locations with access to basic needs and amenities. In Kenya and Somalia, for example, over one million people have been displaced due to the failure of crops to germinate and livestock dying at unprecedented rates (World Weather Attributor, 2023). Similarly, heavy rainfalls, causing floods and overflowing dams, displace millions of people across East Africa, resulting in fatalities and creating a surging demand for refugee complexes. While natural climate cycles such as the Indian Ocean Dipole contribute to heavy rainfalls, they alone do not account for their increased occurrences (Erdenesanaa, 2023).

The growing incidence of climate pressures, driven by rising temperatures, and the consequent impacts they have on the environment, people, and the economy is not solely due to intensive agricultural practices. However, certain conventional approaches to farming contribute to the continued degradation of the environment because of inadequate management of resources and disposal of waste produced as a byproduct of the process. For instance, poultry farming for meat, eggs, and feathers in low-impact backyard rearing methods is one of the most efficient approaches to providing nutritional security for people across the world (Vaarst, Steenfeldt, and Horsted, 2015).

However, *industrial* poultry production, the largest compared to other meats, reached 142.7 million tons in 2023, with imports from China, Saudi Arabia, the EU, the Philippines, Canada, and the Democratic Republic of the Congo (DRC) projected to rise due to tight domestic budgets, supplies, and affordability concerns (Food and Agriculture Organisation of the United Nations, 2023). Moreover, uncertainty in supply has disrupted global chains, as demonstrated by the US egg crisis, caused by the bird flu outbreak, which intensified in early 2025. This situation led to increased sourcing from other regions, resulting in a 53% rise in US egg prices from January 2024 to January 2025 (USA Today, 2025).

Despite its potent nutritional value and adaptability, intensive poultry farming produces significant emissions that impact its surrounding environment, extending from soil, air, and water systems. When poultry litter (manure) exceeds the capacity of the soil to absorb it as fertiliser, the excess often damages soil health and leaches onto surrounding water systems, contaminating both the water and proving detrimental to human health (Augère-Granier, 2019). Additionally, when poultry waste is not managed adequately, it releases significant amounts of greenhouse gasses (GHG), such as nitrous oxide (N_2O), methane (CH_4), and ammonium gas (NH_3) (Dróżdż et al., 2020).

GHG emissions can result from both natural processes and human activity. For example, when atmospheric nitrogen (N_2) enters the soil, it goes through a process of *fixation*, transforming into ammonium (NH_4+). Ammonium then undergoes successive *nitrification* processes, converting first into nitrite (NO_2-) and then into nitrate (NO_3-). Plants have the capability to absorb atmospheric nitrogen during their various stages of transformation once it enters the soil, although nitrate is generally preferred for uptake (Don, 2025).

The process of fixation and nitrification is facilitated by thousands of bacteria that live in the soil. Plants that host these bacteria are commonly known as *nitrogen fixers*, and most notably, these plants include peas, beans, and clover. As they grow, nitrogen-fixing plants release NH4+ into the soil, which helps prepare the soil for future crop growth (Wagner, 2011).

However, not all atmospheric nitrogen that enters the soil is absorbed by plants. It can escape back into the atmosphere through *volatilisation*, which occurs when ammonium converts into ammonium gas. Nitrate can be washed out into bodies of water during heavy rainfalls through a process called *leaching*, impacting the water's ecosystem and surrounding environment (Singh et al., 2022). There are also other bacteria in the soil that perform a process called *denitrification*, which converts ammonium gas to atmospheric nitrogen, releasing it back into the atmosphere.

While nitrogen (N) naturally tends to escape the soil, the majority of it is retained because of the nitrogen-fixing bacteria. When synthetic N is used in agriculture as a fertiliser, it is more prone to volatilisation, thus contributing to the increasing levels of nitrous oxide (N_2O) in the atmosphere, a potent GHG. Moreover, the excessive use of N and inadequate application, where 50-70 per cent of the applied fertiliser ends up in the surrounding environment, causes significant environmental problems, contributing to soil acidification and water eutrophication (Guo et al., 2010). Used in large quantities, N also affects the concentration of hydrogen in the soil, causing microorganisms, such as worms, to depart. Worms play an essential role in the nitrogen cycle by decomposing dead plants, and their excrement provides rich nutrients for nitrogen-fixing bacteria.

According to a 2023 report from Fertilizer Europe (2023), the total fertiliser consumption of the EU amounted to 16 million tonnes in 2022, applied to 123.8 million hectares of land, with imported fertilisers accounting for a significant share. Within the EU, wheat and fertilised grasslands were the largest fertiliser consumers in 2021/2022, each accounting for 26% of consumption. The most commonly used nitrogen fertiliser products were nitrates (49%), followed by urea (12%), compound fertiliser (19%), and other types (15%). Although fertiliser consumption in the EU has fluctuated over time with a recent decline, a slight increase in the consumption of phosphate fertilisers is projected by 2032 (Fertilizer Europe, 2023; see Figure A2 in Appendix).

Another potent GHG is CH4 (methane), released by various livestock during digestion, which accounted for approximately 400 million tonnes among EU member states alone in 2020 (Our World in Data, 2023). Ruminant animals, such as cows, camels, and giraffes, acquire their nutrients through fermentation. When breaking down sugars, ruminants go through a process called *enteric fermentation*, and this process also produces methane. Methane is primarily expelled through belching, although some methane is also produced in the larger intestine. This is a natural process for animals. However, in large quantities, methane is a GHG that traps heat in the atmosphere. It is approximately 84 times more potent than carbon dioxide (UNEP, 2021).

In an effort to mitigate the impacts of agriculture and restore ecosystems, the EU has proposed various measures and regulations. However, it failed to achieve key goals under its previous EU Biodiversity Strategy to 2030, such as the voluntary target of restoring 15% of degraded ecosystems by 2020 (Domingo et al., 2022). In response to these shortcomings, the European Commission proposed the Nature Restoration Law (NRL) in 2022, demonstrating a concerted effort towards safeguarding and restoring vital ecosystems. This proposal aims to address those failures by making the restoration of certain species and habitats mandatory through legally binding targets and goals at the EU level. However, despite EU and international efforts, biodiversity loss and ecosystem degradation continue to accelerate at unprecedented rates (Bilyard, 2023).

The NRL represents an intersection between regulatory shifts, institutional pressures, and socio-political contestation. Its trajectory illustrates the mechanisms driving a technological innovative systems (TIS) toward decline, particularly in the context of agricultural transformations where environmental policies challenge established industrial practices. From a governance standpoint, the NRL is innovative not only because of its binding legal framework, but also due to its objective of fostering cross-sectoral coordination across environmental, agricultural, and economic domains. *Governance innovations refer to novel approaches, instruments, or institutional arrangements aimed at reshaping how collective decisions are made and implemented within a system (Loorbach et al., 2017).* In this lens, the NRL seeks to influence the existing system by redefining the rules, responsibilities, and relationships that structure land use and restoration across the EU. This distinguishes it from other innovation types by targeting the enabling conditions under which technological and behavioral changes may occur.

Alongside the development of large-scale policy frameworks across political levels, the 21st century has witnessed the significant surge in new technologies and innovations that aim to reduce the environmental impact of agriculture. For instance, one such method involves using photovoltaic solar panels to desalinate seawater and supply energy to hydroponic greenhouses, allowing crops, such as tomatoes, to be grown in arid, resource-scarce environments (Dash et al., 2024).

Hydroponic farming is a method for cultivating plants without the need for soil. This is done by using water pumps that create a flow of water between the ‘towers’ or ‘water beds’ on which the plants ‘float.’ Because they are not rooted in the soil, they require their nutrients to be cycled into the water that is continuously pumping through their system; these include nitrogen (N), phosphorus (P), potassium (K), calcium (Ca), Magnesium (Mg) and sulfur (S) primarily, with some plants requiring more nutrients than others (Ohler, 2023).

Although hydroponics does reduce water consumption significantly, reportedly by as much as 70-80% compared to soil-based systems (Kannan et al., 2022), it relies on solar panels to motorise the water pumps, thus proving to be a costly start-up investment if it is to be implemented for commercial distribution. Moreover, there are growing concerns about the high costs related to the disposal of solar panels once they reach the full cycle of their use. According to projections from the International Renewable Energy Agency (IRENA), solar panel waste could reach large volumes by early 2030s and total approximately 78 million tonnes globally by 2050 (International Renewable Energy Agency, 2016). Waste is expected to surpass new instalments by 2031, highlighting an impending challenge for disposal and recycling efforts (Atasu, Duran, and Wassenhove, 2021).

Beyond high costs, the maintenance of a hydroponic facility requires intensive monitoring and specialisation as its equipment and water systems need to be properly managed to reduce any potential costs related to a malfunction (McCray, 2023). Further losses can occur if the nutritional components of the water are not properly implemented, resulting in yield losses and potential waterborne diseases. This can occur because the water continuously circulating through the plants increases the risk of outbreak, as the solution in the water supply carries the pathogens from one plant to another. Moreover, it is extremely important to dispose of the water in an appropriate manner as it can highly contaminate the surrounding environment. Treating the water to remove nutrients and contaminants is a complex and costly process, requiring advanced purification technologies and substantial investments (Richa et al., 2020).

Despite offering alternatives to intensive practices, hydroponics does not directly contribute to the restoration of surrounding fauna and, at a broader level, the restoration of desertified lands. On a more fundamental level, these evolving technologies, do not directly address the underlying drivers of soil degradation and pollution, such as nutrient depletion, overconsumption of chemicals, and poor land management, which are central to the broader environmental impact of fertilisers on soil, air, and water systems (FAO, 2022). Moreover, while hydroponics can be beneficial in arid regions, countries experiencing severe and prolonged drought may have more difficulty incorporating these systems due to limited infrastructure that facilitates access to water and energy.

The field concerned with socio-technical transitions is relatively new, with agriculture receiving less attention compared to other sectors such as energy and transportation (Sutherland et al., 2014). This approach conceptualises production-consumption systems as socio-technical systems, that is, dynamic configurations of institutions, actors, and technologies that collectively fulfill societal functions such as providing food, mobility, and energy (Geels & Turnheim, 2022). Within these systems, transitions refer to the long-term reconfiguration of these interrelated elements, where technological innovations both shape and are shaped by political, economic, and cultural dynamics (Geels 2024). As the relationships between actors, practices, and structures shifts, whether through changes in regulation, user preferences, or economic models, the system begins to transition. When these shifts fundamentally alter the dominant rules, norms, and structures, a transition to a new socio-technical system develops.

The urgency to protect the environment and adopt sustainable agricultural practices entails a shift in the productive and social dimensions of these paradigms (Sutherland et al., 2014, p. 9). To provide a deeper understanding of the forces that lead to these shifts, this dissertation will adopt the framework of socio-technical transitions literature. Socio-technical transitions research focuses on the structural changes that occur in socio-technical systems which fulfil fundamental societal functions (Geels, 2024).

While socio-technical transitions literature has largely focused on the adoption and diffusion of new innovations, there remains a significant gap in the study of the decline of embedded technologies (Markard et al., 2020, p. 2). Much of the current research investigates how new technologies spread across different sectors, structures, and socio-political contexts. Yet comparatively little attention has been given to how the previously dominant technologies have been driven into decline or entirely replaced, resulting in the emergence of a new socio-technical configuration, a transition (Bento et al. 2025). This is relevant for the development of this dissertation as the decline of dominant agricultural technologies, such as fertilisers and pesticides derived from petrochemicals, are central to the case studies in Chapter 4.

The long-term transformation of the agricultural system will undoubtedly be challenging. It can be characterised as multidimensional, multi-actor, and inherently conflictual, involving various stakeholders with diverging interests (Geels & Turnheim, 2022). Moreover, it can be a lengthy and open-ended process, requiring sustained efforts, resources, and adaptability. Because of this, attention to the political dimensions of sustainability is crucial, as it also involves cultural and discursive struggles over the framing of problems and solutions. The media exerts significant influence that further complicates these dynamics, shaping public perceptions and policy discourse on agricultural issues (Meadowcroft, 2007).

To gain a deeper understanding of socio-technical system transitions, the Multi-level Perspective (MLP) offers a valuable analytical framework that integrates insights from sociology, evolutionary economics, and institutional theory (Geels, 2002). This model outlines how innovations emerge, evolve, and integrate through interactions across three distinct levels: niches, socio-technical regimes, and landscapes. Each level is associated with a set of characteristics that shape the development and diffusion of new technologies and practices (see Figure A3 in the appendix). At the center of each system is a socio-technical regime, defined by Geels (2002) and further developed by Fuenfschilling and Truffer (2014), as a complex alignment of institution rules, both formal and informal, that structure behavior and sustain current systems. These regimes represent established configurations and are supported by actors whose actions and expectations reinforce these guidelines.

In contrast, technological niches are protected spaced where radical innovation can develop free from the immediate pressures of dominant regimes. Niches offer alternatives to existing configurations but may face resistance from actors invested in maintaining the regime's stability (Geels, 2020). The socio-technical landscape, the third level, consists of broader, slower-changing elements such as cultural norms, political systems, demographics, and societal values. These landscape-level forces exert long-term influence and create systemic pressures that can destabilise regimes, prompting transitions. The interaction across these levels is crucial; niches can challenge regimes, and regimes are continuously shaped by pressures from both landscapes and niches. As Köhler et al. (2019) note, socio-technical transitions are inherently multi-dimensional, co-evolutionary, actor-driven, long-term, and conflictual, with outcomes that are uncertain, novel, and often goal-oriented. The MLP thus provides a dynamic lens through which the evolution of complex systems can be analysed.

The escalating pressures of climate change and environmental degradation demand a transformative shift towards sustainable agricultural practices. However, the adoption and diffusion of such innovations are not merely a matter of technological advancement. They are intrinsically tied to the complex dynamics of socio-technical transitions, encompassing the interplay of technological, social, economic, and political factors. There is an urgency to accelerate the diffusion of innovations, as climate pressures and demand for food increase in the coming decade. Understanding how agricultural transitions unfold is crucial to ensuring a just and feasible transition.

Diffusion is the social process through which an innovation is communicated, adopted, and integrated into the practices of a community over time (Rogers, 2003). An innovation refers to an idea, practice, or object that is perceived as new by an individual or social group. The perceived 'newness' of an innovation is not defined by when it was first developed, but by how novel it appears to the adopting entity (Rogers, 1983). Various factors influence this perception, which in turn can impact the rate of diffusion. For example, the Dvorak keyboard, despite offering improved performance, accuracy, and reduced fatigue compared to the widely used QWERTY layout, has not seen widespread adoption (Lessley, 1978). This failure can be attributed to factors such as vested interests, high switching costs, lack of awareness, and the deeply ingrained habits of QWERTY users. While an innovation may offer significant advantages, its adoption depends on how those advantages are perceived, shaped by five specific attributes.

The first of these is *relative advantage*, referring to the degree to which an innovation is seen as superior to current practices (Rogers, 1983, 2003). The greater the perceived benefit, the more rapidly the innovation tends to diffuse (Ali et al., 2019; Greenhalgh et al., 2004). *Compatibility* is the second attribute, describing how well an innovation aligns with existing values, experiences, and needs. Innovations that contradict established norms may face resistance, particularly when these norms are deeply embedded (Scott et al., 2008). The third attribute, *complexity*, refers to how difficult the innovation is to understand and use. If it demands significant effort to learn or does not align with existing views, adoption may be slow, as seen in Wellin's (1955) study of Los Molinas villagers who rejected boiling water due to a lack of understanding about germs. *Triability*, the fourth attribute, involves the extent to which an innovation can be tested on a limited basis, greater trialability often encourages faster adoption (Sartipi, 2020). Closely linked is *observability*, which refers to how visible the results of an innovation are; the more observable the benefits, the more likely others to adopt it.

The diffusion process also involves four key elements. The first is the innovation itself, inclusive of the five attributes outlined above. The second concerns communication channels, the means by which information about the innovation is transmitted (Rogers, 2003). While mass media is effective at spreading awareness, interpersonal communication plays a more influential role in adoption decisions, through this can be hindered by high levels of heterophily, or dissimilarity, between individuals. The third element is *time,* encompassing the stages an individual undergoes from first hearing about the innovation to forming an opinion, deciding to adopt or reject it, implementing it, and confirming that decision. Lastly, the *social system*, structured network of relationships and norms within a community, can either facilitate or obstruct the diffusion of innovations (Rogers & Bhowmik, 1970), as it provides the behavioral stability within which adoption decisions are made.

Positioning Within Theoretical Frameworks

Much of the transition literature has focused on the development and diffusion of sustainable technologies, while less attention has been given to how unsustainable systems are phased out. Although concepts such as the MLP and TIS have been central to understanding systemic change, they have tended to emphasise innovation and niche development, leaving the decline of incumbent regimes comparatively underexplored.

Recent works, such as the decline functions framework proposed by Bento et al. (2025), offer an important step toward filling this gap. By outlining key processes, namely delegitimation, guidance toward exit, market decline, and resource demobilisation, this framework provides a structured way to understand the dynamics of decline. However, it does not yet fully address how specific forms of regime resistance, such as lobbying, media strategies, or economic entrenchment, interact with these functions.

This thesis contributes to the emerging research on decline by placing the focus on resistance factors within regimes, and how they shape or block decline functions in practice. Through the case studies of fossil fuels, synthetic fertilisers, and chemical pesticides, it becomes possible to compare how different types of resistance, economic, political, or cultural, interact with specific decline functions. For example, economic dependence on fertilisers may slow market decline, while lobbying by industry actors may interfere with guidance towards exit. These dynamics play out in different ways across sectors, but all help to explain how resistance mechanisms affect the overall pace and direction of phase-out processes.

By examining these relationships through the lens of a governance innovation, the NRL, this thesis explores how policy instruments can be designed to respond to and reshape resistance. The NRL is not only a legislative intervention but also an attempt to shift how environmental targets are structured, monitored, and enforced. This makes it a useful case for studying how governance tools can actively intervene in socio-technical systems to support decline. This thesis contributes to transition studies by analysing how regime resistance can be understood through the lens of governance innovation. Particularly in how institutional mechanisms are mobilised to manage destabilisation and challenge entrenched, lock-in dynamics within unsustainable agricultural practices. In doing so, this thesis aims to address a clear theoretical gap: how regime resistance and policy design interact in shaping the decline of established socio-technical agricultural regimes.

Understanding how decline processes unfold in practice, and how they might be steered more effectively, requires close attention to the role of governance in shaping resistance dynamics. Governance innovations are increasingly recognised as important components of sustainability transitions, particularly in contexts where existing institutional arrangements hinder the phase-out of environmentally harmful practices. While the framework of decline functions (Bento et al., 2025) helps identify the structural and institutional mechanisms that support or hinder technological phase-out, it does not in itself explain how policy innovations may intervene in these dynamics. Resistance mechanisms, particularly those embedded in political, market, or institutional configurations, can either block or redirect decline trajectories. This makes governance interventions a critical focal point for empirical analysis.

1.3. Structure of Thesis

This thesis is structured as follows. Chapter 2 outlines the theoretical foundations, focusing on socio-technical transitions, technological innovation systems in decline, regime resistance, and governance innovations in agriculture. Chapter 3 presents the methodological approach and introduces the Nature Restoration Law (NRL) as the entry point for empirical analysis. Chapter 4 delivers the main findings, examining media framings of the NRL and three comparative case studies on fossil fuels, fertilisers, and pesticides, each analysed in relation to key actors, historical context, and resistance to decline. Chapter 5 discusses the findings, offers policy implications, and concludes with directions for future research.

CHAPTER 2

Decline in Governance Innovations

2.1. Socio-technical Transitions

Socio-technical transitions research focuses on the structural changes that occur in socio-technical systems, which fulfil fundamental societal functions, such as mobility, heating, energy, and food, bringing about progress. Socio-technical systems are heterogeneous combinations of various elements that interact, react, and adapt to each other. They include technologies, industry knowledge, markets, consumer behaviour, infrastructure, and cultural beliefs among other components.

2.1.1. Conceptualising Socio-technical Transitions Research

Literature concerning socio-technical transitions is relatively emergent, with various publications referencing the contributions of Frank Geels, a key author in this network.

As inferred by Köhler et al. (2019), there are seven distinctive features in socio-technical transitions:

First, transitions are multi-dimensional and co-evolutionary because they consist of the ongoing changes of multiple elements at different levels. These elements consist of a combination of technologies, markets, cultural delineations, user preferences, infrastructures, policies, industrial capabilities, and supply and distribution chains. Transitions are co-evolutionary because they are composed of multiple interdependent changes that occur simultaneously across different dimensions.

Second, transitions are multi-actor processes because they are enacted by a combination of actors and social groups across multiple domains in society, politics, and academia. These groups have diverging interests that are shaped by their beliefs and strengthened by their capabilities to dialogue and access to resources. Because various social actors are involved, transitions are bound to be inherently conflictual.

The third characteristic emphasises how transitions are long-term processes that can unfold across a series of decades. This occurs because innovations and practices undergo development through different phases from which they then evolve and begin to diffuse at a wider scale. However, there are other factors that are 'locked-in' the current production paradigm that make it difficult to shift the existing system. Likewise, the resistance of incumbent actors can curtail the diffusion of innovations.

The fourth characteristic focuses on the inherently conflictual nature of transitions. Because sustainable transitions entail deep changes to current systems, the structures, particularly industries, that dominate given sectors are threatened by the possibility of a new distribution of resources and power. Thus, transitions are also characterised by resistance and struggles from actors with vested interests whose economic positions are threatened. Moreover, it is conflictual because it is difficult to agree on what the most desirable pathway towards innovation and sustainability is due to the diverse players that are involved.

The fifth characteristic focuses on the open-endedness and uncertainty aspect of sustainability transitions. Because there is an overwhelmingly vast number of pathways that can be pursued across different domains, it is not possible to pick with certainty which one will prevail. Consequently, what the future entails is relatively open-ended. Because innovation processes are not linear, often shaped by failure, disruption, and shifting priorities, uncertainty becomes an inherent feature of transition dynamics.

A sixth characteristic, related to the previous one, involves the notions of stability and change. It refers to more novel actions that divert from the regular practices that are deeply nested in current and dominating modes of production and consumption. These include adopting certain 'green' initiatives that aim to reduce their impact on the environment, such as commuting to work in a shared vehicle, installing solar-PV systems, opting for heat pumps, and changing diets towards ones with less meat.

However, there are production and consumption patterns that are deeply embedded in systems that revolve around the high consumption of coal-fired plants, petrol vehicles, intensive agricultural programs, and retail chains that create stable and familiar behaviours. These patterns overpower novel initiatives because they have established mechanisms that 'lock in' these intensive development trajectories, and it is precisely how these trajectories are altered through change that socio-technical transitions research aims to understand by drawing from a multitude of disciplines.

The seventh characteristic is normative directionality. Because sustainability is perceived as a public good, private actors do not have a sufficiently strong incentive to direct their resources towards this objective. Therefore, public policy is instrumental in transitions by shaping environmental regulations and standards through policy tools such as taxes and subsidies. Normative statements are essential for shaping principles and decision-making mechanisms by providing a clear vision of the objectives and desired outcomes of these transitions. Because low-carbon transitions aim not only to improve technological performance, but also to align innovation with broader environmental goals. A clear sense of direction is therefor required to navigate policy towards more ambitious measures aimed at reducing carbon emissions (Geels, 2020).

Based on the above characteristics, socio-technical system transitions are brought about due to the interconnected nature of the different dimensions that build the foundations of development, societies, culture, politics, and economics (Geels & Turnheim, 2022). Although relatively new, Geels (2002, 2005, 2020) and Köhler et al. (2019) aim to incorporate socio-technical transitions research into a more mainstream level when discussing the paradigm of climate change and environmental sustainability. These ambitions align with the recent acknowledgements by the European Commission for the necessity to 'rethink policies for clean energy' supply as 'conventional approaches will not be sufficient' to address the objectives of the European Green Deal (EC, 2019).

2.1.2. Overview of Socio-technical Transitions Literature in Agriculture

The following section will explore various works that have been conducted in the sector of agriculture, particularly in relation towards sustainable transitions. Two notable authors in the field are Ika Darnhofer and L.A. Sutherland, who combine the findings of socio-technical transitions research with case studies across Europe. Their work explores topics such as just transitions in the food system, the introduction of organic foods, and the role of collaboration, among other themes central to ongoing research on sustainable transitions in agriculture.

In a book chapter, Darnhofer (2014) provides an in-depth overview of the core characteristics of socio-technical systems in relation to sustainable agriculture in Europe. She highlights the interconnected nature of agriculture with other sectors, sighting Geels and Verhees (2011) publication, which suggests that for niches to grow, they should interact with two or more sectors. This is a significant observation as the agricultural regime is deeply connected with other sectors such as transport, energy, heating, marketing, and health and nutrition, etc.

Succeeding chapters in the same book to which Darnhofer (2014) contributes to, *Transition Pathways Towards Sustainability in Agriculture: Case Studies from Europe* (Sutherland, 2014), explore various case studies of agricultural innovations across European countries. These include, for instance, high nature value farming in Bulgaria, France, and Portugal (Peneva et al., 2014), countryside consumption and lifestyle farming in Bulgaria, Scotland, and Portugal (Pinto-Correira et al., 2014), and independent studies outside the book, such as grassland conservation efforts in Austria, France, and Norway (Darnhofer, 2017). In doing so, they bring forward key lessons pertaining to niches and innovations within the sector. In relation to the success of niches, Darnhofer (2014) highlights seven key lessons and circumstances under which niches stabilise. These findings are further affirmed in the succeeding case studies presented in the following paragraphs:

1. Fostering and maintaining a learning environment.
2. Exploring and comprehending diversity.
3. Establishing new and effective connections.
4. Continuously aligning strategies and expectations.
5. Ensuring all stakeholders enhance their situations.
6. Acknowledging the significance of a change agent in initiating the process.
7. Recognising the value of unexpected outcomes.

Despite sighting these observations, it is not yet clear under which conditions a 'breakthrough' occurs and induces a transition (Darnhofer, 2014). The following paragraphs highlight key findings from distinct studies conducted about agricultural transitions and resistance by various authors.

Building on key point number 3, “Establishing new and effective connections,” highlighted by Darnhofer (2014), Schiller et al. (2014) emphasise how collaboration among stakeholders further drives agricultural transitions toward regional sustainability. They stress that successful collaboration among stakeholders is influenced by factors such as actor relationships, objectives, and technical means.

Concerning actor relations, trust, commitment, and leadership are crucial for establishing effective partnerships, particularly in creating shared visions and managing local networks (Schiller et al., 2014). The authors discuss how management structures facilitate collaboration between businesses and broader regime actors for initiatives such as machinery rings. In terms of objectives, they find that innovative collaborations often emerge in response to the immediate needs of stakeholders, helping alleviate feelings of isolation and providing unforeseen benefits, reiterating key lesson number seven, recognising the value of unexpected outcomes. Lastly, the technical means supporting collaboration can evolve over time, often shaped by the learning process itself, contributing to the success of these initiatives.

Building on the theme of cooperation, the following study demonstrates how actor relations are essential for establishing connections during the introduction of an alternative method of farming. Peneva et al. (2014) highlight the potential of alternative pathways towards sustainable agriculture, particularly through the concept of 'high nature value farming' and its implications for European agriculture. The authors outline six indicators of post-productivity, with those being: (1) policy change, (2) organic farming, (3) counter-urbanisation, (4) inclusion of environmental NGOs, (5) consumption of the countryside, and (6) on-farm diversification activities. Through case studies in Bulgaria, France, and Portugal, they observe how farmers challenge homogenisation in production structures and products, emphasising diversification and multifunctional approaches, which is in line with key point number 2, exploring and comprehending diversity. Networking processes facilitate connections between niche and regime actors, fostering local knowledge exchange. Learning primarily occurs through training, while partnerships between actors with diverse interests enable collective action.

Pinto-Correira et al. (2014) explore the role of "countryside consumption" as a catalyst for change in agricultural and land-based activities across Europe. Coining countryside consumption as a driver of change aligns with key point six, acknowledging the significance of a change agent in initiating the process. They note that many transitions are rooted in biophysical space and emphasise the lack of support for lifestyle farmers by policy actors, as observed in case studies from Bulgaria, Portugal, and Scotland. The authors characterise countryside consumption as a driver of land and farmland management, fueled by desires for a rural lifestyle, healthy food, and leisure, sometimes independent of production. They conceptualise it as a socio-technical niche, introducing novel land uses without a collective intention for radical regime-level change.

Individuals involved in countryside consumption often pursue lifestyle interests, including lifestyle production, through rural residence. This phenomenon exists outside of the commercial agricultural sector, making it a distinct landscape feature separate from the agricultural regime. Overall, lifestyle farming represents a socio-technical transition primarily driven by social aspects, such as new perceptions of the countryside and associated values.

The above studies further reiterate the key points of successful niches within socio-technical system transitions in agriculture, as posited by Darnhofer (2014). With those key points at the forefront of understanding niche development and success in sustainable transitions, the following section is a selection of works from Darnhofer and Sutherland that further explore the idea of introducing new approaches and innovations in agriculture. These studies highlight how the more integrated structures of the agricultural sector and regime make sustainable transitions challenging, looking beyond the niche and observing the fundamental structures onto which they anchor and develop. This also includes insights into the policy paradigms and the "socio" aspect of socio-technical transitions, particularly farmer behaviour and identity, which are often overlooked (Diaz et al., 2013, p. 73).

This first study, *Preserving Permanent Grasslands in Western Europe: Why Are Promising Approaches Not Implemented More Widely* (Darnhofer et al., 2017), demonstrates how some policies designed to protect ecological diversity and preserve landscapes may inadvertently create tensions by limiting regional actors from participating in and contributing to the management of these areas, thereby affecting conservation efforts. This is most observable when considering the conservation efforts of permanent grasslands in Western Europe, which face challenges despite the introduction of agri-environmental measures aimed at sustaining extensive grazing. According to Darnhofer (2017), key barriers include limited involvement of regional actors and lack of flexibility for farmers in managing these landscapes. Findings from a Delphi inquiry with experts from Austria, France, and Norway underscore the need for both agricultural and environmental administrations to adopt a more inclusive and participatory process, which could enhance the design and implementation of conservation measures.

The above study highlights that single-loop learning, which entails minor adjustments to existing practices, is dominant but insufficient, whereas double-loop learning, where underlying assumptions are re-evaluated, could drive transformative change. However, existing administrative structures, with their emphasis on efficiency, predictability, and control, resist such fundamental shifts. To foster double-loop learning, a reconceptualisation of roles is necessary, positioning farmers as active participants and researchers in the role of facilitators of adaptive inquiry. This transformation, though critical for the resilience of grassland ecosystems amidst climate change and economic pressures, is challenging due to the prevailing power dynamics and the primary identity of farmers as food producers, which often conflicts with exclusive biodiversity goals.

This second study, *Farmer Intentional Pathways for Net Zero Carbon: Exploring the Lock-In Effects of Forestry and Renewables* (Barnes et al., 2022), focuses on how path dependency, in which previous decisions limit adaptability to new environmental goals, challenges the implementation of new approaches towards sustainability. This is especially evident in efforts to achieve net-zero carbon emissions in agriculture, which remain significantly high because conventional farming systems are embedded in structures which depend on fossil fuels and other components that significantly increase emission levels.

While forestry and renewable energy hold potential for offsetting greenhouse gas emissions, entrenched pathways and conventional practices in farming, such as risk aversion and specialisation, restrict the sector's capacity to embrace these options at scale. Financial risks, high opportunity costs, and the need for peer-to-peer knowledge sharing further inhibit the transition toward renewables and forestry. Moreover, decisions over farming are composed of a complex web of decision makers and actors, all of whom have distinct motivations for land use and production. These findings suggest that achieving net-zero targets requires interventions that reduce the economic and social costs of shifting away from conventional practices.

Investment in agricultural knowledge and innovation systems in Europe significantly depends on diverse advice sources, particularly in the implementation phase, to avoid unnecessary abandonment. Sutherland et al. (2022) observe in their study, *What Can We Learn from Droppers and Non-adopters About the Role of Advice in Agricultural Innovation?,* of factors that influence investment decisions, that peer-to-peer networks and social relationships among farmers are pivotal to both adoption and continued use. Through structured interviews with 1,080 farmers across 13 European countries, findings reveal that adopters of innovations, such as digital technologies, biological pest control, and soil-enhancing practices, often access varied sources of advice during the early stages of awareness and evaluation. These include not only formal channels but also informal interactions with neighbours, technicians, and peer groups, reinforcing the significant of social ties and learning in the adoption process.

The study identifies three primary reasons for discontinuing innovations: overly pushy sales tactics, insufficient support for ongoing implementation, and partial adoption, where farmers selectively retain parts of an innovation. Some "droppers" express willingness to revisit the innovation once technology or advisory services improve. Additionally, the study finds that innovations related to direct marketing or new on-farm activities require more community-based support mechanisms, including involvement from NGOs, to persist over time. These insights emphasise that a multifaceted advisory approach, especially one that fosters peer support and integrates both formal and informal knowledge exchange, can enhance the resilience and stability of agricultural innovations.

The final study in this section, *Green Tides in Brittany: What Can we Learn About Niche–Regime Interactions?* by Diaz et al. (2013), emphasises how socio-technical transitions in agriculture influence environmental outcomes through an exploration of niche-regime interactions within the context of the "green tides" in Brittany. Focusing on the niche of extensive, grassland-based dairying, the research utilises an abductive approach combining interviews and secondary sources to illustrate how mature niches interact with established regimes. Findings underscore that niche success depends on creating "common ground" with regime practices, facilitating the integration of niche innovations without significantly disrupting the systems.

In the case of the green tides in Brittany, the primary ecological challenge, eutrophication from nutrient overflow, demonstrates the critical role of reducing nitrate leakage from intensive agricultural land to restore marine balance. However, as Diaz et al. (2013) reveal, niche-regime integration is complex and requires attention to both material and semiotic factors, as posited by Actor-Network Theory (ANT). Successful transitions necessitate adaptive, opportunistic interactions rather than rigid strategic plans, suggesting that niche actors must navigate and respond to the fluid interests and selective adaptations of regime actors. As a result, the findings suggest that a deeper incorporation of social elements within socio-technical frameworks is essential for understanding how niches not only influence but are reshaped by the regimes they aim to transform.

2.2. Technological Systems in Decline

Technological Innovation Systems (TIS) provide a useful lens for understanding how specific technologies emerge, diffuse, and influence broader patterns of sectoral transformation (Bergek et al., 2008). In the agricultural sector, TIS shape the development, adoption, and scaling of technologies that fundamentally alter how agricultural production is organised, managed, and sustained. A TIS is comprised of networks of actors, institutions, and infrastructures that interact to support the generation and deployment of a specific technological field. These systems are not merely technical in nature but are embedded within political, economic, and regulatory environments that condition their growth and stability (Bergek et al., 2015).

At its core, a TIS can be understood as a dynamic network of agent and institutions that collectively influence the generation, diffusion, and utilisation of a specific technology. The structure of a TIS comprises four key elements: (i) actors, such as firms, universities, and government bodies involved in the development and deployment of the technology; (ii) networks that connect these actors through formal partnerships or informal collaboration; (iii) institutions, including both formal rules (e.g., regulations, standards) and informal rules (e.g., cultural beliefs or professional expectations); and (iv) the technological artefacts and infrastructures themselves (Bergek et al., 2008; Markard & Truffer, 2008). These structural components form the basis of a system in which innovation is not solely the product of technical advancement, but also of the co-evolving relationships among diverse actors embedded within specific institutional settings.

In addition to its structure, the TIS framework places strong emphasis on a set of key functions, which describe the essential innovation activities that occur when systems evolve effectively. These include knowledge development and diffusion; entrepreneurial experimentation; guidance of the search (i.e., shared visions or expectations); market formation; resource mobilisation, and legitimation (Hekkert et al., 2007). Each function serves a distinct role in shaping the development of the system, and imbalances or failures in one or more of these areas, commonly referred to as system weaknesses, can hinder technological progress or adoption. The interplay between structural elements and system functions is critical for understanding how emerging technologies gain momentum, become institutionalised, or conversely, enter a phase of decline.

Understanding both the structural and functional dimensions of TIS is essential, particularly as they form the conceptual foundation for decline functions. Decline in a TIS does not simply reflect technological redundancy but emerges from complex shifts in actors relations, institutional support, and weakening of key functions such as legitimation or resource mobilisation. As such, analysing transitions through the TIS lens enables a nuanced understanding of not only how technologies emerge and diffuse, but also how they erode and are eventually phased out.

One illustrative example is the TIS surrounding agricultural chemicals, particularly synthetic fertilisers and pesticides, which have profoundly shaped modern agricultural practices over the past century. These chemical technologies have been central to intensifying productivity and enabling the expansion of industrial-scale farming. As environmental concerns such as biodiversity loss, water pollution, and soil degradation have gained prominence, there is growing interest in understanding not only how these technological systems are built and stabilised but also how they decline.

A TIS in decline experiences diminishing investments, weakening legitimacy, and institutional retraction, resulting in reduced development, deployment, and use of its associated technologies (Smith & Raven, 2012). In the agricultural sector, this is increasingly relevant as certain entrenched technologies, such as synthetic pesticides or fertilisers, face mounting pressures from regulators, civil society, and shifting market dynamics.

2.2.1. Processes of Functions of Decline

Recent research in sustainability transitions highlights the importance of analysing how TIS decline occurs. Decline is not only about phasing out a technology but also involves deeper systemic transformations, including shifts in actor networks, policy frameworks, market conditions, and resource allocations. In particular, Bento, Nuñez-Jimenez, and Kittner (2025) propose an analytical framework that identifies four decline functions to fill a theoretical gap in understanding the processes that contribute to the decline of dominant technologies.

The authors propose delegitimation, guidance toward exit, market decline, and resource mobilisation as four decline functions. Each function captures distinct, yet interrelated, aspects of technological decline and is organised into two main categories. The first category includes delegitimation and guidance toward exit, which focus on sociopolitical pressures such as unfavourable changes in public discourse, social norms, and policy narratives. These elements work together to erode a technology's legitimacy and shift investment strategies. The second category consists of market decline and resource demobilisation, which address economic and structural pressures stemming from intensified competition and the emergence of alternative technologies that threaten the market viability and resource flow to the incumbent system.

Delegitimation refers to the gradual decline in social acceptance of a particular TIS. This phenomenon occurs when a technology diverges from established norms, values, and rules or becomes linked with negative perceptions and public concerns. As these associations develop, the technology's appropriateness and desirability may diminish, leading to challenges for stakeholders in justifying their continued engagement with it (Bento, Nuñez-Jimenez, and Kittner, 2025).

The process of guidance toward exit involves redirecting the focus and investments of stakeholders away from a waning system. Various factors, including changing expectations regarding future market conditions, a reduction in perceived technological opportunities, or the loss of political and institutional support can influence this shift. Consequently, these elements prompt stakeholders to reassess their commitments and gradually allocate resources to alternative innovation systems.

Market decline refers to a decrease in the commercial opportunities associated with a particular technology. This decline can stem from various factors, such as heightened competition from alternative technologies, shifts in policy frameworks, or saturated market demand. Consequently, the TIS experiences diminished demand and faces challenges in achieving growth or profitability.

Resource demobilisation plays a critical role in this process, characterised by a reduction in the availability of essential resources. These resources may include financial capital, skilled labour, and necessary infrastructure for stakeholders within the TIS. As firms and institutions shift their focus to other systems, access to these vital resources becomes more limited, complicating the ability of the TIS to sustain its operations.

2.2.2. Regime Resistance to Decline Functions

The decline functions proposed by Bento, Nuñez-Jimenez, and Kittner (2025) provide valuable insights into how dominant technological systems transition into phases of decline. It is important to note that these decline functions do not occur in a vacuum, they are heavily influenced by the surrounding institutional, economic, and societal contexts. The manifestation of a decline function can be significantly shaped, delayed, or redirected by various resistance mechanisms.

According to Geels (2024), resistance from incumbent actors is not only a frequent occurrence but is often strategically organised due to their access to political influence, economic resources, and cultural legitimacy. This resistance does not manifest uniformly, rather, it varies depending on the specific decline function it interacts with. The following section will explore the ways in which these resistance mechanisms, namely economic, political, and social, affect each decline function.

Delegitimation, which highlights the gradual decline in societal and institutional support for a TIS, is met with resistance from various fronts. Politically, incumbents often influence the definition and discussion of issues within policy-making arenas, employing discursive strategies to postpone regulatory changes or minimise the urgency of necessary transitions (Geels, 2024). To complement these efforts, firms may engage in public relations campaigns or align themselves with sustainability goals to reduce potential damage to their reputation.

Additionally, societal resistance, often stemming from established user practices or deep-rooted cultural attachments, can hinder the emergence and persistence of negative perceptions regarding these transitions. This creates a complex legitimacy landscape where conflicting narratives can slow the complete acknowledgement of decline.

When stakeholders begin to experience uncertainty about the future direction of a TIS, they may resort to defensive investments and other strategic measures to maintain their support. From a political perspective, resistance may manifest in the way transitions are framed and discussed, often depicting them as premature or fraught with economic risk (Geels, 2024). Such strategies can dilute or postpone clear transition signals that might otherwise lead actors toward withdrawal. Furthermore, factors such as sunk investments and path dependency often incentivise firms to postpone exit. On a social level, efforts to guide stakeholders toward exit may be resisted by labour groups and communities that depend on established technologies for employment and identity.

In the context of market decline, incumbent actors often implement strategies to maintain their market positions. Economically, these strategies may include offering financial incentives to create a buffer against diminishing commercial opportunities. Politically, resistance can manifest through lobbying for trade protections or seeking regulatory exemptions, which help incumbents mitigate competitive pressures (Geels, 2024). Additionally, from a societal standpoint, the adoption of alternative innovations may be impeded by factors such as familiarity bias, affordability issues, and uncertainty around new options (Ozer & Tang, 2019). Consequently, this interplay of mechanisms can lead to a disparate experience of market decline, where some sectors or regions face significant demand erosion while others remain supportive of existing systems.

Similarly, resource demobilisation can be countered through political manoeuvring, such as securing public investment or favourable regulatory conditions that prolong the viability of an outdated system (Geels, 2024). On an economic front, firms may reallocate internal funding or attract private capital to sustain operations, particularly when alternative investments seem uncertain. At the societal level, resistance can be reflected in education and labour systems that continue to prepare and support individuals for declining technologies, thereby reinforcing a skilled workforce that prolongs the viability of these systems. Such mechanisms effectively delay demobilisation, allowing for the continued existence of systems that are otherwise in a state of structural decline.

The interplay between technological decline and regime resistance can be meaningfully visualised by mapping the key decline functions proposed by Bento, Nuñez-Jimenez, and Kittner (2025) against the corresponding economic, political, and societal resistance mechanisms outlined by Geels (2024). The table below offers a conceptual synthesis that illustrates how each decline function is potentially delayed, redirected, or contested by specific regime responses. This format helps highlight the complexity of transition processes, where socio-political and economic structures actively shape the pace and direction of decline.

Decline Function	Description	Political Resistance	Economic Resistance	Societal Resistance
Delegitimation	Loss of public and institutional support for a TIS	Discursive framing in policy arenas to delay regulation; lobbying to reframe narratives	Strategic PR campaigns to align with sustainability discourse	Cultural attachment to technology; entrenched user practices
Guidance Toward Exit	Stakeholders begin to question future viability of a TIS and withdraw support	Transitions framed as premature, too risky, or economically harmful	Path dependency, sunk costs, and risk-aversion inhibit strategic exit	Job losses and identity threats provoke resistance from labor groups and communities
Market Decline	Shrinking demand and diminishing commercial relevance	Advocacy for trade protections or regulatory exemptions to buffer decline	Incentives to maintain operations, including subsidies or pricing strategies	Reluctance to adopt alternatives due to cost, trust, or familiarity
Resource Demobilisation	Withdrawal of capital, labor, and other key resources from the system	Securing public investment or support to maintain operations	Reallocation of internal funding; private capital retention	Persistence of training and education pipelines supporting obsolete technologies

Table 1. Mapping Decline Functions and Regime Resistance Mechanisms
This table outlines the conceptual relationship between four decline functions, delegitimation, guidance toward exit, market decline, and resource demobilisation, and various forms of regime resistance. It serves as a visual map for analysing systemic resistance to sustainability transitions, particularly in mature socio-technical systems.

2.3. Governance Innovations

Governance innovations involve changes to institutional arrangements, decision-making procedures, and policy instruments. Different to technological innovations, which typically focus on physical artefacts or processes, or social innovations which centre around new practices or norms among groups, governance innovations directly intervene in the rules, procedures, and actor relationships that structure decision-making and policy implementation.

They often emerge in complex, multi-level challenges, such as climate change or resource degradation, that require adaptive participatory, and cross-sectoral coordination. What makes governance innovations distinct is that they alter how problems are framed, who is included in decision-making, and what kinds of outcomes are prioritised, thereby influencing the broader system conditions in which other innovations unfold (Borrás & Edquist, 2013; Voß & Bornemann, 2011).

While technological and infrastructural change often targets material components of a regime, governance innovations intervene in the institutional logics and decision-making frameworks that sustain it. They operate by modifying how rules are created, how authority is distributed, and how legitimacy is granted, thereby creating opportunities to expose contradictions, redistribute power, and challenge incumbent control (Voß et al., 2009). For instance, the introduction of more inclusive, deliberative, or reflexive policy processes can erode existing policy monopolies, weaken the coherence of dominant narratives, and introduce alternative problem framings into policy agendas (Meadowcroft, 2009). These institutional shifts may not directly dismantle technologies, but they undermine the governance structures that protect them, enabling reallocation of resources, regulatory change, and eventually, phase-out.

In this context, governance innovations, particularly those that reconfigure institutional responsibilities, establish new legal mandates, or mobilise civil society, represent potential levers for disrupting regime stability and enabling deliberate phase-out. It is within this theoretical space that the Nature Restoration Law (NRL) emerges as a salient example of how policy design can influence resistance factors and reshape the institutional foundations of agricultural socio-technical regimes. Through its binding restoration targets, the NRL reduces the discretionary space available to Member States, making compliance a legal obligation rather than a voluntary commitment. Through its binding restoration targets, the NRL narrows the discretionary space typically afforded to Member States, thereby limiting the extent to which national governments can interpret restoration efforts as voluntary or optional. In parallel, it introduces procedural requirements, such as regular reporting, cross-sectoral coordination, and stakeholder consultation, that potentially shift the dynamics of influence within the policy process. These mechanisms offer expanded roles for environmental NGOs, scientific advisory bodies, and sub-national authorities, actors that have often operated at the margins of formal land-use governance.

Rather than eliminating resistance, governance innovations such as the NRL may displace or reconfigure it. Incumbent actors may adapt their strategies, from opposing legislation outright to reframing its implications, seeking exemptions, or delaying implementations. The NRL introduces new arenas of legitimacy and accountability, where dominant narratives can be challenged and alternative problem framings can gain visibility. While these institutional shifts do not dismantle incumbent regimes directly, they modify the procedural and discursive conditions under which resistance plays out. These dynamics illustrate that regime destabilisation is not a linear process, but a negotiated one, where governance innovation can recalibrate the balance of power and gradually erode the protective architecture surrounding incumbent systems. By embedding sustainability objectives into legal and institutional frameworks, innovations such as the NRL enable the broader conditions for decline functions, such as delegitimation or guidance toward exit, to gain traction within contested socio-political environments.

The NRL marks a significant evolution in the governance of environmental restoration and climate pressures across the EU by consolidating various environmental objectives into a single legislative framework. This approach elevates the expectations for implementation and establishes a legally binding commitment, setting it apart from earlier strategies. As a result, member states are mandated to adapt their domestic laws and policy instruments to align with the targets established at the EU level, thereby making compliance a legal requirement.

Framing the NRL as a governance innovation highlights its role in addressing societal challenges through improved coordination, regulation, and policy design. According to Driessen et al. (2012) and Voß et al. (2006), governance innovations often lead to a reconfiguration of the roles of various actors, the introduction of new mechanisms for enforcement or monitoring, and the broadening of policy objectives across different sectors and governance levels.

The NRL embodies several of these aspects, unifying multiple policy streams within a cohesive legislative framework, for example, by bringing together biodiversity protection, agricultural land use, and water management under a single regulation. It establishes legally binding obligations that enhance vertical integration between the European Union and national governance levels, such as requiring member states to regularly report on progress toward restoration targets. Additionally, the NRL extends the scope of environmental governance into new social and economic areas, for instance, by introducing restoration measures for drained peatlands used in farming and setting urban greening targets, linking ecological goals with land-use and planning strategies. This approach modifies the specifics of sustainability policy and transforms the institutional structures through which these policies are implemented and enforced.

The NRL represents a significant advancement in governance by actively shaping how sustainability targets are defined, monitored, and enforced. By viewing it as a governance innovation, we can better analyse its effects within the larger system it aims to transform. Although the policy is primarily developed at the EU policy level, its repercussions extend to national, regional, and local levels, influencing environmental governance practices across various contexts.

Moreover, the NRL interacts with broader social and cultural aspects related to environmental issues. It addresses challenges that impact sectors involved in resource distribution and material exchange, which can have considerable ecological impacts. Consequently, the NRL influences those directly engaged in these sectors through labour, ownership, or investment, as well as communities and civil society organisations dedicated to environmental restoration. While some stakeholders may be directly involved in economic activities, others contribute through activism, knowledge sharing, or local partnerships. For instance, grassroot organisations and coalitions, such as the WeMove Europe campaign, which mobilised citizens in support of the NRL during legislative debates, gathering over 70,000+ signatures, play an important role in shaping public discourse and pressuring policymakers (WeMove Europe, 2023). Therefore, the influence of the NRL reaches beyond formal governance frameworks, engaging with the social dynamics that facilitate and are influenced by sustainability transitions.

2.4. Decline, Resistance, and Governance: A Conceptual Framework

Building on the preceding overview of Technological Innovation Systems (TIS), this section presents a conceptual framework that combines insights from technological decline (Bento et al., 2025) with theories of regime resistance (Geels, 2024). This framework serves two purposes: (i) to clarify the relationships between different forms of system decline, and (2) to highlight the specific mechanisms through which incumbent regimes delay or obstruct these processes. This structure also functions as a bridge between the conceptual foundations and the case study of the NRL, helping to illustrate how policy interventions interact with entrenched socio-technical agricultural systems.

This framework rests on the understanding that regime decline is not a linear process, but a contested and uneven dynamic, shaped by actors seeking either to sustain or reconfigure their positions. The empirical analysis applies the decline functions, delegitimation, guidance toward exit, market decline, and resource demobilisation, to three TIS systems related to agriculture: fossil fuels, synthetic fertilisers, and pesticides. Within each case, the framework is used to assess how these decline functions evolve, and how incumbent actors respond, whether through discursive, political, or institutional forms of resistance.

Before analysing the case studies, the empirical analysis begins by tracing the NRL's legislative trajectory, identifying turning points, actor coalitions, and resistance strategies that surfaced during its development. The conceptual lens developed supports this analysis by helping to map how regime actors position themselves in relation to the targets of law, and how their responses reflect broader patters of resistance to decline.

The decline functions are operationalised in each of the three TIS to evaluate how efforts to reconfigure or scale down environmentally harmful systems encounter pushback. By structuring the analysis around this conceptual framework, this thesis seeks to uncover how resistance against decline is organised, sustained, and potentially challenged in EU agriculture. This allows for a comparative view of how regime incumbents react to perceived threats under a shared policy agenda, offering insights into the political dynamics that condition the feasibility of environmental policies.

CHAPTER 3

Methodology

3.1. Research Approach

This thesis investigates the impact of regime-level resistance on the decline of unsustainable agricultural technologies and practices in the European Union (EU). It focuses on three core domains central to industrial agriculture: synthetic fertilisers, chemical pesticides, and fossil fuel use. These domains are not only technological systems but also embedded practices and behaviours shaped by policy frameworks, economic incentives, and institutional cultures. The study situates these within the broader context of the EU's Nature Restoration Law (NRL), which serves as a governance innovation intended to reverse ecosystem degradation by prompting systemic changes in land management and agricultural inputs.

The research is grounded in the Technological Innovation Systems (TIS) framework, with particular attention to the concept of decline functions, delegitimation, guidance toward exit, market decline, and resource demobilisation, as developed by Bento, Nuñez-Jimenez, and Kittner (2025). These functions offer a structured lens for analysing how unsustainable systems are actively destabilised or maintained. Complementing this, the Multi-Level Perspective (MLP) on socio-technical transitions (Geels, 2002; 2011) supports the identification of broader regime dynamics, particularly the interaction between established systems and external pressures. While MLP has traditionally focused on niche innovation and regime emergence, here it is used to trace the structural and discursive roots of regime resistance, building on insights from Turnheim and Geels (2012) and recent literature on system decline.

Regime resistance is analysed through three interrelated dimensions: political resistance, economic resistance, and cultural resistance. These categories are derived from the socio-technical transitions literature (notably Turnheim & Geels, 2012) and operationalised to examine how actors and institutions resist or reshape decline trajectories. Political resistance includes lobbying, policy capture, and discursive framing by influential stakeholders; economic resistance captures subsidy structures, market dependencies, and cost-related arguments; while cultural resistance refers to identity, tradition, and knowledge practices that normalise high-input agriculture. These forms of resistance are mapped onto the four decline functions to understand how and why transitions away from unsustainable practices are delayed or redirected.

The NRL provides an empirical anchor for this analysis. As a governance innovation, it seeks to institutionalise ecological restoration across member states by introducing legally binding targets. These include rewetting peatlands, restoring pollinator habitats, and reversing soil and biodiversity degradation. Each of these targets implies a form of systemic agricultural change, particularly in relation to the reduction of fossil fuel dependency, synthetic fertiliser use, and chemical pesticide applications. These three domains were selected as they represent key pillars of the industrial-agricultural model that the NRL implicitly challenges. For example, restoring peatlands requires reducing diesel-fuelled drainage systems; reversing nutrient pollution involves limits on fertiliser use; and pollinator protection necessitates pesticide reductions. Each sub-case thus explores how regime resistance interacts with policy-induced pressures for decline.

This thesis research adopts a comparative qualitative case study design. It conducts a historical event analysis of the governance process surrounding the NRL and the associated resistance dynamics within each technological domain. The analysis draws on a combination of literature reviews, document analysis, and narrative tracing across institutional, political, and discursive developments. This systematically assembles publicly available evidence and secondary resources to map out key actors, events, and oppositional strategies.

Data collection involved an iterative snowball technique to identify relevant sources, beginning with high-profile media articles and expanding to include blogs, industry statements, union communications, NGO campaigns, policy documents, and academic literature. A total of 3,268 articles were reviewed to gather data on the frequency, timing, and distribution of media coverage related to the NRL, such as identifying when articles were published, by whom, and in which political or discursive contexts. These were reviewed and cross-referenced to construct a chronological timeline of the NRL's development, capturing how its objectives were reframed, contested, or supported over time.

This empirical material underpins a dynamic understanding of how resistance to sustainability transitions manifests across different domains. It highlights how narratives around food security, sovereignty, and economic viability were deployed to counter ecological imperatives. The analysis contributes to the growing field of transition decline studies by showing how governance innovations such as the NRL encounter friction when confronting entrenched socio-technical regimes. Future research could expand on this foundation through interviews or policy network analysis to deepen understanding of actor motivations and institutional learning processes.

3.2. Case Study: The Nature Restoration Law

By analysing the policy debates, actor networks, and media representation surrounding the NRL, this section provides an empirical foundation for understanding the role of resistance mechanisms in response to decline functions.

3.2.1. EU-Level Policy Analysis

The NRL is one of the most significant recent EU policies aimed at addressing biodiversity loss and environmental degradation. As an EU legislative initiative, it aims to reverse biodiversity loss and restore ecosystems.

The NRL was submitted to the European Commission on June 22, 2022, as part of the European Green Deal and supports commitments under the EU Biodiversity Strategy for 2030. Moreover, the proposal seeks to establish a broader directive to ensure that at least 20% of the EU's land and sea areas are restored by 2030, with a long-term commitment of restoring all ecosystems in need by 2050 (Proposal for a Regulation of the European Parliament and of the Council on Nature Restoration, 2022). Setting mandatory restoration targets reflects a shift towards a more structured and enforceable approach, ensuring greater accountability among member states.

Despite its environmental ambitions, the NRL faced immediate resistance from key agricultural stakeholders, including major farming unions, agribusiness lobbies, and political actors aligned with intensive agricultural production. The European People's Party (EPP) emerged as a primary opponent, framing the legislation as a threat to food security, economic stability, and rural livelihoods. Conversely, environmental organisations, scientific institutions, and progressive political groups advocated for its adoption, emphasising its role in addressing biodiversity collapse and mitigating climate change.

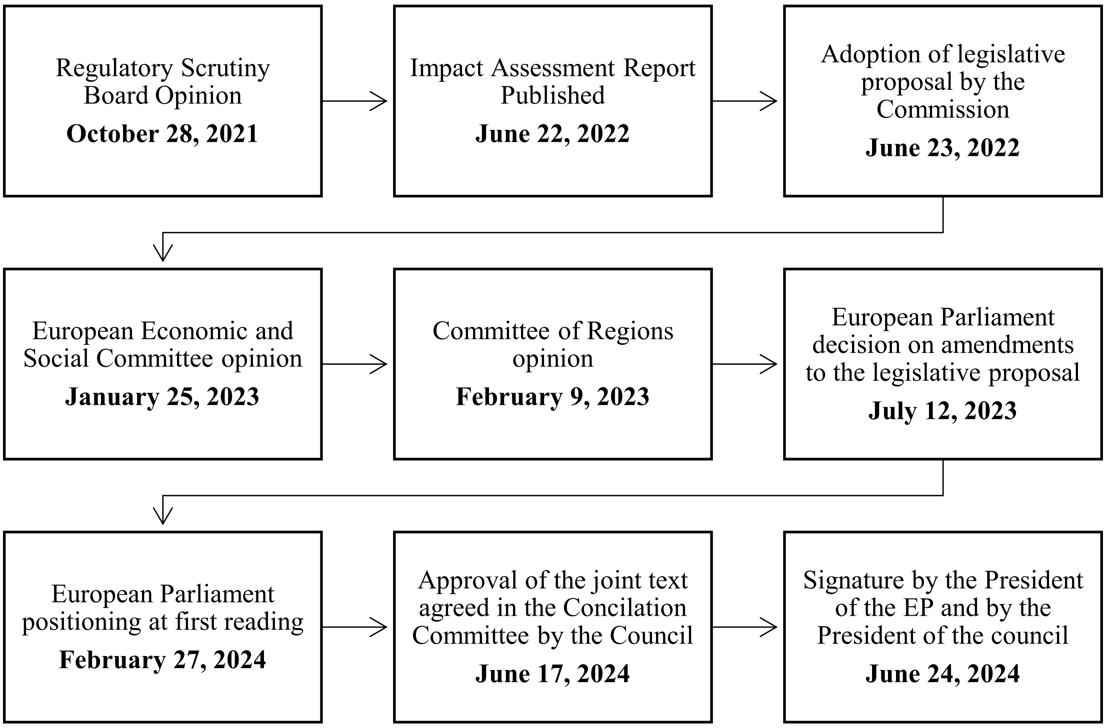

Figure 1. Key Legislative Milestones in the Adoption of the EU Nature Restoration Law (2021-2024)
This timeline outlines major institutional steps in the legislative process of the Nature Restoration Law, from the issuance of the Regulatory Scrutiny Board Opinion in October 2021 to the final signatures by the Presidents of the European Parliament and the Council in June 2024. It includes formal procedures such as the Commission's proposal, assessments by advisory bodies, parliamentary deliberations, and the conciliation process, highlighting the complexity and duration of EU environmental lawmaking.

A debate took place on July 11th, 2023, about the NRL, with rapporteur César Luena (Spain, S&D). An initial vote on July 12th referred the matter back to the committee. Subsequently, a motion to reject the Commission proposal and a request for amendments by the ECR (European Conservatives and Reformists) Group were both rejected, and the provisional agreement was adopted, closing Parliament's first reading.

The debate on the NRL revealed stark divisions in how different actors framed the issue. Supporters primarily from environmental and left-leaning groups (S&D, Greens/EFA), framed the law as a necessary response to ecological collapse, arguing that agriculture must undergo structural changes to reduce its environmental footprint. In contrast, opposition groups (EPP, NI, Renew) framed the NRL as a threat to food security and economic stability, emphasising that mandatory land restoration would reduce arable land, increase reliance on food imports, and harm farmers' livelihoods (EPP, 2023).

Opposition to the NRL largely centred on concerns about economic impacts, national sovereignty, and agricultural competitiveness. Critics such as Christine Schneider (Germany, EPP) rejected mandatory restoration targets, arguing that sustainability policies should rely on incentives rather than legal obligations. This framing positioned the NRL as a top-down imposition from the EU, reinforcing concerns about overregulation and loss of member state control over agricultural policy.

Another key point of contention was the proposal requiring member states to reduce arable land use by up to 10%, a figure that combines the Common Agricultural Policy (CAP) requirements of 3% with an additional 7% mandates under enhanced eco schemes. Critics, such as Anne Sander (France, EPP) and Edina Tóth (Hungary, NI), argue that these measures would force Europe to increase food imports from countries with lower environmental standards, ultimately undermining the EU's own sustainability goals.

Beyond food security, critics raised concerns about the broader economic fallout of forced transitions. Some MPs argued that the NRL's restoration targets would increase unemployment by forcing farmers out of production, while others suggested that companies could relocate to non-EU countries, such as China, to avoid stricter regulations. This economic framing, which prioritises short-term financial stability over long-term environmental restoration, illustrates the structural resistance to discontinuation policies across different sectors.

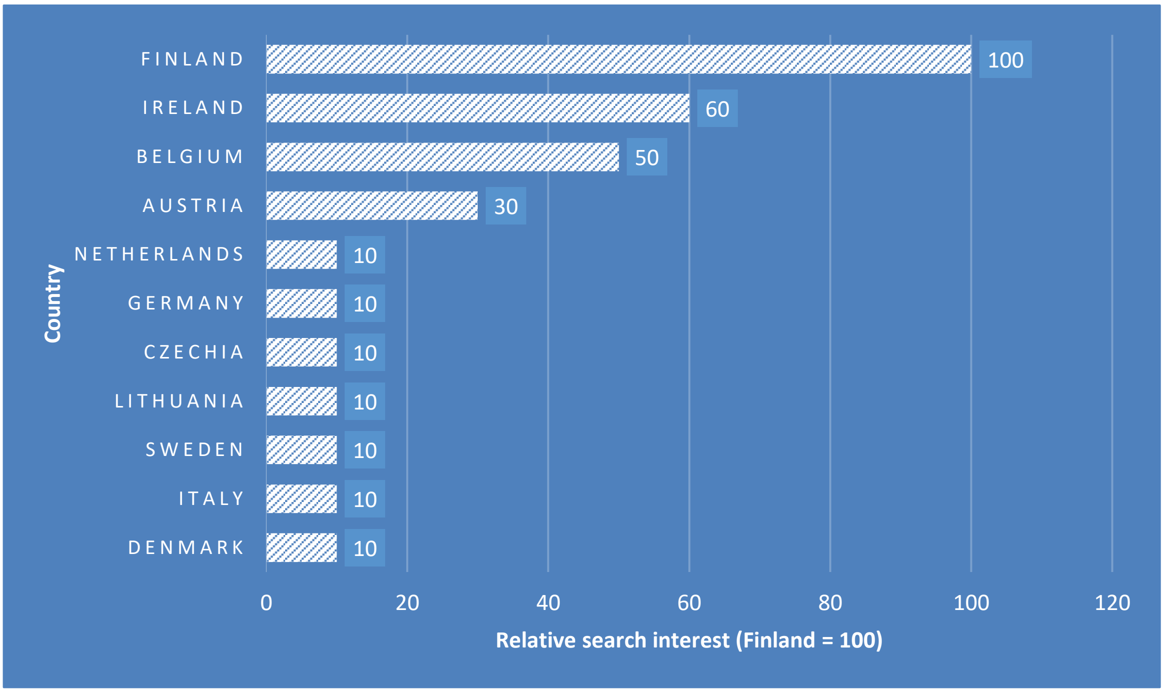

Figure 2. Relative Search Interest in the EU Nature Restoration Law by Country (Google Trends, 2022-2025)
Based on normalised Google Trends data, where Finland is indexed at 100 as the country with the highest relative search interest. Values represent the proportion of searches related to the "EU Nature Restoration Law"

relative to overall Google activity in each country. Data does not reflect absolute volume but interest level adjusted for population and search behavior.

From a TIS perspective, the NRL reflects how delegitimation processes and political struggles shape the decline of incumbent systems. As the proposal developed, biodiversity was increasingly framed as a cross-sectoral and long-term governance objective. This framing contributed to tensions within the legislative process, particularly as stakeholders linked to agricultural and rural interests questioned the implications for existing land-use practices. The policy sought to institutionalise restoration and mitigation efforts, yet its final version underscores the resilience of the technological system underpinning conventional farming.

3.2.2. NRL and Media Discourse

To effectively analyse the NRL as a governance innovation, it is important to investigate how changing public narratives and the formation of actor coalitions have influenced the policy within its political and social contexts. Drawing insights from over 800 news and blog reports, including contributions from EU member states and international observers, this section highlights key moments that have altered the discursive frameworks surrounding the NRL, shaping its development.

The role of media in shaping public and political perceptions of the NRL is crucial to understanding its contested trajectory. The following figure presents a quantitative analysis of media coverage surrounding the NRL debate, highlighting fluctuations in reporting intensity over time.

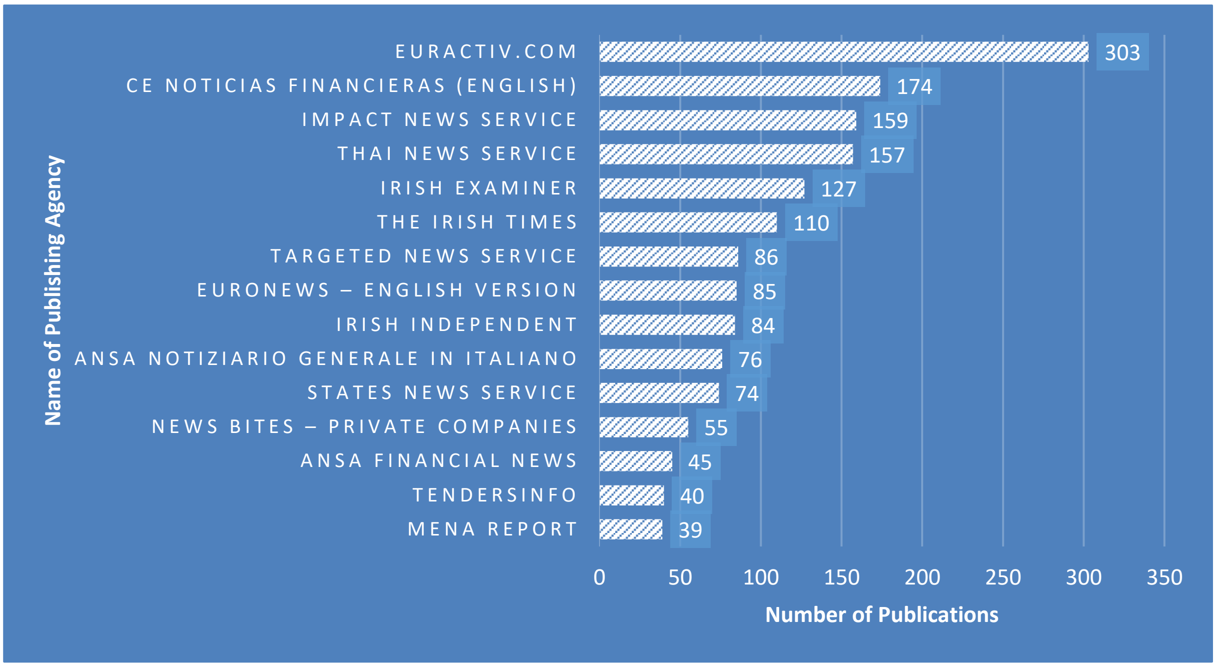

Figure 3. Number of Publications by News Agency

Based on 3,268 search results retrieved from Nexis Uni (2025) using keyword filters related to the EU Nature Restoration Law. Includes the top 15 most frequently publishing news agencies between 2022 and 2025. Titles were analysed for frequency; duplicates and syndicates entries were excluded.

Initially, the NRL was embraced by various stakeholders as an ambitious ecological initiative; however, it quickly became a central point of political contention at local, national, and international levels. This situation underscores the difficulties of integrating systemic restoration objectives within multilevel governance structures.

This analysis begins by examining early interpretations of the NRL, focusing on the developments that took place between 2023 and 2024, a timeframe characterised by significant shifts in discourse. This section is structured chronologically, outlining key dates and events to illustrate how stakeholders' sentiments evolved and influenced the progression of the NRL.

In early 2023, discussions about the NRL gained prominence within the EU's legislative framework, particularly concerning measures aimed at ecosystem restoration and climate resilience. Prominent EU-focused publications, such as Euractiv, highlighted the views of Frans Timmermans, from the EU Socialist Party, who was serving as the Executive Vice President of the European Commission at that time. He characterised the NRL as a significant component of the European Green Deal and the EU Biodiversity Strategy for 2030, emphasising the importance of ecosystem restoration not only as an environmental objective but also as a key factor in achieving overarching climate and economic goals (Foote, 2023).

This growing institutional attention was also reflected in international media responses to the NRL. As shown in Figure 4 below, monthly news coverage of the legislation increased significantly between mid-2023 and mid-2024, aligning with critical evaluations during the NRL's legislative trajectory and policy contestation.

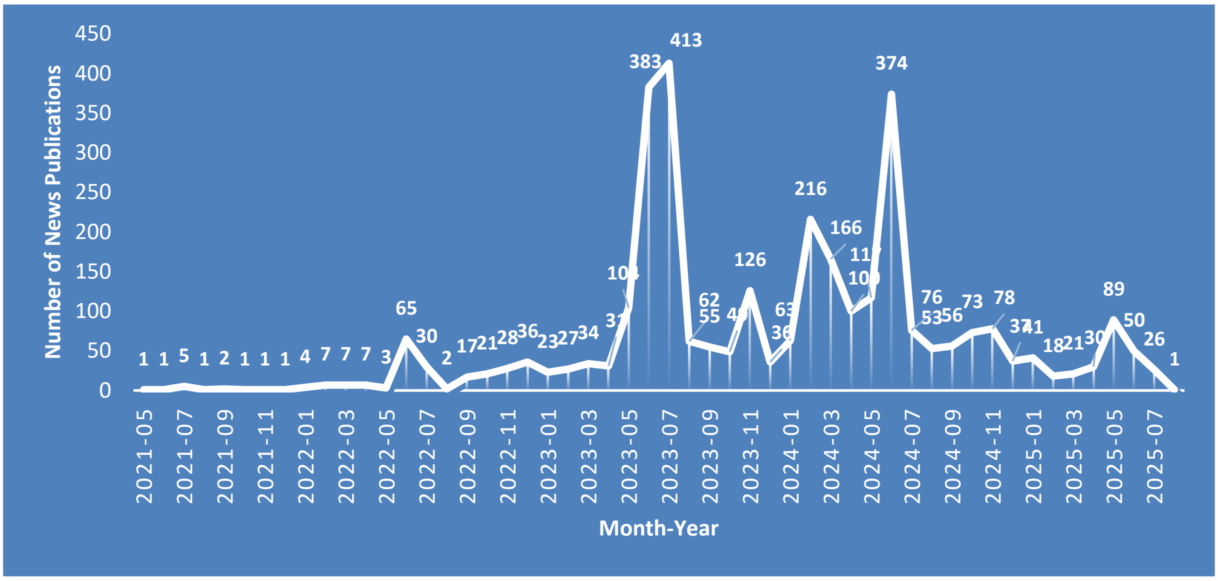

Figure 4. Evolution of News Coverage on the EU Nature Restoration Law (NRL) by Month (2022-2024), Data reflects monthly publication frequency from global media sources across multiple languages, capturing the international media response to the NRL. Peaks in coverage align with key moments in the legislative process and public debate, particularly in mid 2023 to mid 2024, which was when the legislation was implemented.

Support for the NRL extended beyond political circles, as it garnered attention from the private sector as well. A notable instance of this support emerged when over 35 European businesses collectively signed a statement endorsing the NRL and its legally binding targets (BirdLife International, 2023). These companies, such as Bergans of Norway, Iberdrola, and Spar, representing sectors such as energy, retail, and mobility, recognised that their business models rely on access to sustainable and resilient natural resources, even if they are not directly involved in land restoration efforts.

Recent statements from various firms have highlighted the significant economic value associated with the health of ecosystems, stressing the importance of taking proactive measures to protect vulnerable areas. Non-governmental organisations (NGOs) such as BirdLife International and World Wildlife Fund (WWF) have echoed this perspective, launching campaigns and making public statements that emphasise the urgent need for action in response to the mounting pressures on natural systems and the rapid decline in biodiversity (Miklasińska, 2023).

Editorials in The Irish Times have supported this view, describing the law as an essential step toward integrating biodiversity considerations into governance structures that have traditionally operated in isolation ('The Irish Times View on the EU Nature Restoration Law: A Plan Worth Supporting', 2023).

Argument	**Stakeholders**	**Framing / Rationale**
The law is necessary to reverse biodiversity loss and ecosystem degradation.	Environmental NGOs (BirdLife International, WWF, IFAW), Greens/EFA, S&D	The NRL addresses biodiversity collapse and represents an overdue ecological governance milestone.
Supports climate resilience and carbon sequestration.	European Commission (Timmermans), REPowerEU, WindEurope, Eurelectric	Ecosystem restoration contributes to climate mitigation and long-term resilience.
Restoration aligns with business interests that depend on healthy ecosystems.	Companies (e.g., Iberdrola, Spar, Bergans of Norway)	Business models depend on stable, resilient natural resources even if not directly involved in land restoration.
Institutionalises biodiversity governance across sectors.	EU policymakers, progressive MEPs	The NRL reflects a shift toward integrated and enforceable biodiversity legislation.
Enjoys broad public support across EU countries.	BirdLife International (2024 survey)	Public opinion is strongly in favor of the law, even in countries where governments opposed it.
Encourages sustainable agricultural transitions.	Some Fine Gael MEPs (Ireland), environmentalists	Agriculture must adapt to reduce ecological harm while maintaining food security.

Table 2. Key Arguments and Stakeholders in Support of the EU Nature Restoration Law (NRL)
Compiled from policy debates, media coverage, and stakeholder statements between 2022 and 2025. Summaries the main arguments used to justify support for the NRL and identifies the political parties, institutions, NGOs, and businesses endorsing its adoption. Supportive positions framed the law as a necessary response to biodiversity loss, climate instability, and long-term ecological and economic resilience.

By late spring 2023, the NRL faced organised opposition, particularly from agricultural lobbies, such as COPA-COGECA, and rural political figures. Central critiques revolved around land-use restrictions, economic viability, and concerns about procedural legitimacy. According to a report by Euractiv (Krzysztoszek, 2023), Polish farmers expressed growing anxieties that the law could result in a reduction of productive farmland without adequate compensation. A similar sentiment was noted in Finland, where the restoration obligations conflicted with the significant interests of the forestry sector (Romano, 2023). As shown in Figure 2, Finland registered the highest relative search interest in the NRL, suggesting that public attention was driven by efforts to monitor and defend sectoral interests. For many Nordic and Baltic nations, forest management became a particularly contentious issue due to its economic importance.

In contrast, environmental organisations defended the law, emphasising potential benefits such as synergies between ecological restoration, carbon sequestration, and agricultural resilience (Bailey, 2023). However, this discussion began to show signs of division, with differing narratives emerging in national media. These divisions were evident not just across different countries but also within political parties. In Ireland, for instance, internal conflicts emerged within Fine Gael, centre-right, liberal-conservative, Christian party of the Republic of Ireland. An opinion piece by MEP Mick Wallace in The Irish Times criticised the party's stance on the NRL, which he claimed was undermining clean energy projects. Wallace highlighted endorsements of the law from major energy-sector associations, such as REPowerEU, WindEurope, and Eurelectric (Wallance, 2023).

As the European Parliament approached a critical vote on the NRL, a notable political opposition emerged. The Irish Farmers Journal, as reported by Pat O'Toole in 2023, highlighted that the European People's Party (EPP), the largest political bloc in the Parliament, had officially retracted its support for the law. EPP President Manfred Weber characterised the legislation as a potential threat to food security, arguing that the legislation could lower food production and raise prices at a time of global instability (Vela, 2023). Additionally, EPP Member of the European Parliament (MEP) Christine Schneider voiced similar concerns, asserting that while nature restoration is important, the proposed framework of the NRL was poorly conceived and could hinder climate-related infrastructure initiatives (Lory, 2023).

This shift in political alignment led to intra-party divisions. In Ireland, some Fine Gael MEPs departed from the EPP's stance to back the law, emphasising the need for long-term climate resilience. Similar fractures were observed within centrist parties in France and Germany, highlighting the broader tensions that exist between rural and urban communities (Röhm-Malcotti, 2023).

In addition, farmer mobilisation across EU countries gained momentum, with protests taking place outside the European Parliament in Strasbourg, as reported by the Cyprus News Agency (Giannoukou, 2023). In the Netherlands, the LTO farmers' association cautioned that the NRL could worsen the existing nitrogen crisis (Stöckl, 2023). This situation represents a significant escalation in the broader debate, with discussions evolving from technical issues to encompassing deeper conflicts related to rural identity, territorial governance, and the legitimacy of institutions.

In July 2023, the European Parliament narrowly approved the NRL, prompting a shift in focus to the Council of the European Union. Here, opposition to the law became more firmly established, with Hungary and Poland characterising it as an infringement on national sovereignty and echoing broader criticisms of EU environmental governance.

Internationally, the debates surrounding the NRL garnered attention from environmentalists in Asia, as noted by Down to Earth (2023), with many viewing the law as a potential framework for incorporating restoration obligations into their own national policies. However, there was also widespread scepticism regarding the EU's ability to effectively balance ambitious environmental targets with the need for stakeholder engagement.

By the end of 2023, the NRL evolved from a primarily ecological initiative into a complex issue intertwining governance, national sovereignty, and socio-political dynamics.

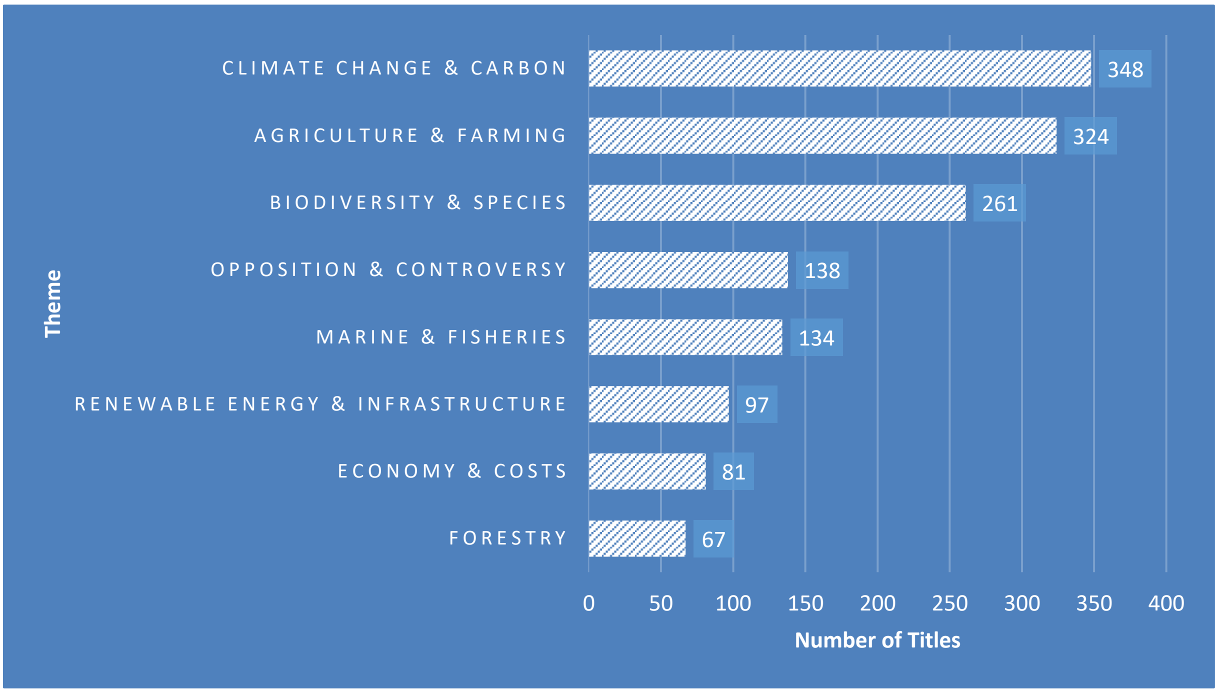

Figure 5. Most Frequently Referenced Themes in Media Coverage of the EU Nature Restoration Law (2022-2025)
Based on keyword analysis of 3,268 publication titles retrieved from Nexis Uni, filtered for the most commonly recurring themes across the coverage. Includes references to political actors, environmental concerns, agricultural opposition, legislative context, and biodiversity framing. Counts reflect number of title mentions per theme, with overlap across categories possible.

In early 2024, tensions surrounding the NRL led to significant political changes that hindered the approval process within the Council. A key turning point occurred in March 2024 when Hungary, which had previously shown support for the NRL, reversed its stance. According to a reporting by Cagney (2024), the shift was linked to growing concerns over the “sensitive nature of the agriculture sector and food security,” with the Hungarian environment state secretary arguing that the law lacked sufficient flexibility for national implementation.

Hungary's reversal was particularly impactful as it caused the proportion of supporting member state populations to fall below the 65% threshold necessary for qualified majority voting, effectively obstructing the NRL's formal adoption at that time.

Additionally, divisions appeared among member states. For instance, in Poland, the climate and environment minister's backing for the NRL was overridden by the party leadership, according to Krzysztoszek and Cagney (2024). Similarly, Italy re-evaluated its position on the legislation. These shifts raised concerns in the media regarding the EU's ability to manage such politically sensitive legislation. Despite the opposition from some countries, a study by BirdLife International indicated that a large majority of citizens in those nations actually supported the NRL. The study revealed that public support for the law reached 85% in Italy, 83% in Hungary, and 72% in Poland, highlighting a disconnect between citizens' opinions and their governments' positions (BirdLife International, 2024).

From a governance perspective, this phase underscored the vulnerability of ambitious ecological policies to shifting political alignments and the power of national-level veto points.

On June 17, 2024, a significant vote was held among EU environment ministers regarding the NRL. The proposal was approved with a narrow margin, with twenty countries voting in favour, meeting the necessary thresholds of 55% of member states and 65% of the population. Finland abstained from voting, while Hungary, Italy, the Netherlands, Poland, and Sweden opposed the measure. A pivotal moment in the vote was the decision by Austrian Environment Minister Leonore Gewessler, a member of the Greens party, to break ranks with her conservative coalition and cast Austria's vote in favour of the law. This action was widely recognised as crucial to the law's passage, with BirdLife International (2024) noting that the law advanced "thanks to Austria's Environment Minister… stepping up at the last minute." The majority was reportedly achieved by a slim margin of 1.07 percentage points after Slovakia and Austria shifted their positions.

Argument	**Stakeholders**	**Framing / Rationale**
Threatens food security and reduces productive farmland.	EPP, Irish Farmers Journal, COPA-COGECA, LTO (Netherlands), MEPs Sander and Tóth	Mandatory land restoration may displace food production and increase dependence on imports.
Harms rural livelihoods and economic stability in farming regions.	Farming unions, rural MEPs, Polish and Hungarian government officials	Farmers may be forced out of production; employment and competitiveness at risk.
Raises food prices and creates economic uncertainty.	EPP, MEP Manfred Weber, Renew Europe (partial)	Timing of the law adds financial burden amid inflation and post-pandemic instability.

Imposes top-down EU mandates and threatens national sovereignty.	Hungary, Poland, EPP-aligned governments	The NRL represents regulatory overreach and reduces member state autonomy in land management.
Lacks flexibility for national implementation.	Austria (prior to June 2024 vote), Hungary (2024 reversal)	Uniform targets do not account for local needs; implementation tools insufficient.
Conflicts with infrastructure and energy transition projects.	MEP Christine Schneider, EPP	Restoration zones may hinder development of renewable energy and climate-related infrastructure.
Damages forestry sectors important to Nordic economies.	MEPs from Finland, Sweden, and Baltic states	Restoration obligations perceived as a threat to forestry-based national economies.

Table 3. Key Arguments and Stakeholders Opposing the EU Nature Restoration Law (NRL)
Based on parliamentary records, media discourse, and public statements made by MEPs, farmer groups, and national governments between 2022 and 2025. Highlights core objections to the NRL, including concerns about food security, economic disruption, and regulatory overreach. Opposition was primarily driven by rural and conservative actors framing the legislation as a top-down threat to national sovereignty and agricultural livelihoods.

The vote has been characterised as both fragile and historically significant. The Guardian highlighted that the NRL, seen as one of the most controversial pillars of the Green Deal, just passing and subject to modifications that diluted its content prior to the vote. For example, rewetting targets for drained peatlands were significantly reduced from 70% to 50% of peatland areas by 2035, and the restoration ambition for agricultural soils was softened. Other notable changes include how earlier drafts aimed for a 50% elimination target for the use of both chemical pesticides and fertilisers by 2030. In the final text, these targets were significantly reduced and made more flexible (European Union, 2024).

Despite these adjustments, the NRL is recognised as the first binding nature restoration law, albeit in a weakened form. Environmental NGOs such as BirdLife International, WWF, and ClientEarth hailed the vote as a substantial victory following years of dedicated campaigning amid misinformation challenges. The Nature Conservancy, a global environmental organisation, described the EU law as a "world’s-first," proclaiming the final vote as "fresh hope" in the fight against biodiversity loss and climate change. They emphasised that the law would aid in protecting farmers and citizens against climate risks. Similarly, the International Fund for Animal Welfare (IFAW) regarded the adoption of the law on June 17 as a "landmark" achievement for nature, noting that binding restoration targets would now be incorporated into legal frameworks.

The recent passage of the NRL in the EU has sparked considerable political debate and analysis. In Austria, commentators highlighted the divisions within the ruling coalition as

Chancellor Nehammer publicly criticised Minister Gewessler for her dissenting views. Additionally, the government had threatened legal action against her, indicating the law's contentious nature. Observers noted that the final version of the NRL significantly diverged from its original proposal, with some Green leaders acknowledging that compromises had substantially diluted its intended impact (Plesea, 2023).

On an international scale, the adoption of the NRL was characterised as a demonstration of European ambition. News agencies such as Reuters and Al Jazeera reported it as a pivotal, albeit delayed, advancement in Europe's climate and biodiversity efforts (Al Jazeera, 2024). Environmental experts pointed out that Europe faces one of the most severe habitat losses globally, making the enactment of this law crucial and hard-earned amidst significant political negotiation.

The media narrative surrounding the NRL underscores the conflicting discourses between the vision of the Green Deal and the concerns of the agricultural sector, which influenced member states' positions throughout the legislative process. As a result, many of the law's strict restoration targets were softened, and its implementation has been postponed for further evaluation. Nevertheless, a version of the original ambition persisted due to dedicated advocacy and last-minute political manoeuvring. In relation to these narratives, Table A1 in the appendix demonstrates the relationship between publication numbers and significant discourses throughout the unfolding of the NRL.

This situation exemplifies how EU environmental governance in 2023-24 involved not just scientific and policy considerations but also the necessity of political storytelling and coalition-building. It presents the NRL's narrow passage as both a triumph for ecological governance and a cautionary story about the fragility of environmental consensus under economic and political strains.

Blogs such as Wild Europe have taken a more cautious stance, posing questions about the law's practical implementation and suggesting that the real challenge lies ahead (Kun, 2024). The realisation of the NRL will likely be influenced by ongoing resistance, funding disputes, and varied stakeholder support. Ultimately, while the NRL has come into effect, its future trajectory serves as a reflection of the challenges associated with ambitious governance efforts during periods of socio-technical transition.

3.2.3. Post-Implementation Analysis of the NRL

The implementation of the NRL was widely celebrated by environmental NGOs as a significant achievement toward the restoration of degraded ecosystems and the strengthening of biodiversity across EU landscapes. However, key concerns remain. Several core mandates were either weakened or rendered more flexible, allowing Member States considerable discretion in how they interpret and implement targets. This flexibility has raised concerns that transition efforts may be delayed or unevenly applied, thereby limiting the law's effectiveness in altering the entrenched dynamics between environmental degradation and agricultural production. A central concern relates to the continued use of chemical inputs in conventional intensive farming systems, particularly monocultures that rely on synthetic fertilisers and pesticides to sustain yields across large tracts of land. Even prior to the NRL, chemical input regulation has been a contentious issue at the EU level.

Although the EU maintains stricter standards than many non-EU countries, having banned substances still widely used elsewhere, such as certain neonicotinoids in the United States, long-term projections suggest slight increases in synthetic input use. This trend raises concerns that soil degradation and biodiversity loss may continue, even under the new legislative framework, thereby undermining the law's restoration ambitions. While the NRL marks an important step in advancing ecological governance, the compromises embedded in its final text signal that restoration remains a long-term and uncertain process, particularly if key drivers of degradation are not more directly addressed.

It is important to emphasise that the NRL does not seek to reduce or displace agricultural activity within Member States, but rather to align existing land-use practices with broader ecological objectives. The aim is to foster forms of production that are more compatible with ecosystem restoration, thereby improving environmental health while maintaining food security. Beyond its core target of restoring 20% of degraded terrestrial and marine ecosystems by 2030, the NRL introduces several measures that reflect a more ambitious and integrated approach to biodiversity governance.

These include specific mandates for rewilding threatened plant and insect species, restoring pollinator populations, and rehabilitating water systems that have been degraded by intensive land use. The regulation also encourages the development of seed varieties and genetic traits that support climate resilience, particularly in the face of increasing drought and temperature variability. In addition, it addresses the preservation and revitalisation of specific habitat types, many of which have been degraded by adjacent agricultural practices, by targeting the sources of ecological stress, such as nutrient runoff, soil erosion, and water contamination linked to fertiliser and herbicide use. A summary of key regulatory elements is provided below in Table 4.

Regulatory Focus	Key Provision	Page
Overall Target	Restore **at least 20% of EU land and sea areas by 2030**, and all degraded ecosystems by **2050**.	p. 1–2
Ecosystems Covered	Applies to **terrestrial, freshwater, marine, urban, forest, and agroecosystems**.	p. 1–2
Habitat Restoration	Obligations for habitats listed in **Annex II** (protected under Birds and Habitats Directives).	p. 7–10
Pollinators	Member States must **reverse pollinator decline** by 2030 and report every 6 years.	p. 4
Forests	Must improve **forest biodiversity** using indicators (e.g., deadwood, connectivity, carbon stocks).	p. 3
Rivers	Restore **at least 25,000 km** of rivers to **free-flowing** status by 2030.	p. 5
Urban Areas	Increase **urban green space** and canopy cover, especially in densely built-up areas.	p. 14
Tree Planting	Contributes to planting **at least 3 billion trees** across the EU by 2030.	p. 14
National Restoration Plans	Member States must adopt and report on **national restoration plans** with baselines and funding needs.	p. 14
Monitoring & Reporting	Use common EU indicators; progress reviewed via **EEA** and made publicly accessible.	p. 13
Funding	Member States must **mobilise EU and national funding**, including CAP and LIFE programmes.	p. 5

Table 4. Key Regulatory Elements of the EU Nature Restoration Law (2024/1991)
Adapted from Regulation (EU) 2024/1991 as published in the Official Journal (OJ L 2024/1991). Provides a simplified overview of selected restoration targets, obligations, and implementation mechanisms, including page references from the official legal text.

Regulations addressing the use of fossil fuels and pesticides were significantly weakened in the final version of the NRL compared to earlier drafts. This dilution can be attributed to successive rounds of negotiations, during which MPs argued that the agricultural sector lacks readily available or scalable alternatives capable of sustaining large-scale production without these inputs. Pesticides and fertilisers, both heavily dependent on petrochemical derivatives, form the basis of intensive farming systems, while fossil fuels underpin not only energy use but also the production and distribution of processes within the food supply chain. These interdependencies make them particularly resistant to policy intervention, as phasing out one component often requires systematic change across others.

From an ecological standpoint, the continued use of these inputs poses long-term risks. Excessive chemical application degrades soil health, disrupts natural nutrient cycles, and reduced the soil's capacity to regenerate. Moreover, sustained chemical exposure has been shown to produce resistance in pest species and weeds, leading to a cycle of increases dosage and environmental stress. While the NRL acknowledges these concerns in its early stages, reference to fossil fuels and pesticides were significantly reduced in the final text.

The following chapter focuses on these core components, fossil fuels, fertilisers, and pesticides, as central pillars of conventional agriculture. These cases have been selected not only because they exemplify resistance to decline within incumbent technological systems, but also because they reflect the structural entanglement between environmental harm and production capabilities. While other factors, such as trade policy, dietary shifts, or land tenure, also shape agricultural transitions, these three inputs remain among the most politically and economically contested dimensions of environmental regulation, and thus serve as key sites for examining decline functions and resistance strategies in practice.

CHAPTER 4

Implementation of Nature Restoration Law and Decline of Fossil Fuels, Fertilisers and Pesticides

4.1. Fossil Fuel Use within EU Agriculture

European agriculture is significantly reliant on fossil fuels, which are utilised for various on-farm operations as well as the inputs and services necessary for agricultural activities. A comprehensive analysis of energy consumption in EU crop production indicates that annual energy use by farms totals approximately 1,431 PJ, accounting for about 3.7% of the European Union's overall final energy consumption (Paris et al., 2022). Within this context, diesel used for machinery represents around 31% of this consumption.

Modern agricultural practices frequently involve the use of diesel or petrol to power tractors, combines, trucks, and irrigation pumps. Beyond fuel and energy, the sector also relies heavily on petrochemical products, including pesticides, herbicides, plastic mulch, and packaging materials. Additionally, post-harvest processing and cold storage operations often depend on electricity sourced from national energy grids, which may include fossil fuels depending on the country’s energy mix. These direct and indirect connections reveal that nearly every aspect of the conventional food chain, ranging from fieldwork to refrigerated transportation, is fundamentally supported by oil and gas, with electricity projected to increase as the introduction and use of electrical equipment in these processes grows (The International Energy Agency, 2025).

4.1.1. Technology and Historical Context

In Europe, the reliance on fossil fuels in agriculture has its origins in the post-war modernisation of farming practices. During the mid-20th century, the introduction of tractors and combine harvesters replaced traditional animal and human labour, leading to a significant increase in the demand for diesel fuel. Concurrently, the adoption of synthetic fertilisers and pesticides, which are derived from petrochemicals, play a crucial role in achieving considerable crop yields and solidifying high-energy consumption farming methods.

The Common Agricultural Policy (CAP) of the EU, established in 1962, further reinforced the trend towards agricultural intensification. The primary goals of the CAP were to "increase agricultural productivity" and "guarantee supplies," which were mainly realised through price supports and production-linked subsidies (Agriculture & Fisheries Council, 2025). This framework effectively incentivised large-scale, input-intensive farming. For instance, the assurance of high crop prices prompted farmers to invest in larger, fuel-intensive machinery, while also increasing their usage of fertilisers and pesticides.

Over the years, the investment in agricultural machinery and chemical inputs has risen significantly. As a result, the proportion of energy consumption within the agricultural sector has likewise grown, primarily driven by fuel-intensive technologies. Consequently, the policies associated with CAP and related regulations have established a farming model heavily reliant on fossil fuels and industrial inputs.

4.1.2. Key Actors and Networks

Various influential actors and institutions continue to support the high fossil fuel consumption system in modern agriculture. At the EU level, the CAP institutions manage various subsidy programs and rural development funds. These initiatives traditionally emphasise modernisation in agriculture, focusing on the adoption of mechanisation and increasing the use of agricultural inputs. Several Member States continue to provide fuel tax rebates or exemptions for farmers, including significant diesel rebates in Germany that amount to several hundred million euros annually (Wehrmann, 2024). These measures lead to considerably low fuel prices for the agriculture sector.

Industry associations, particularly COPA-COGECA, which represents the EU farmers' lobby, as well as various national farming unions, play a significant role in shaping policies in Brussels. These organisations typically advocate for solutions that emphasise the need for accelerating and advancing technology in the agricultural sector.

COPA-COGECA has officially expressed its support for the Farm-to-Fork goals, advocating for the need for "new EU enabling ways" to ensure a practical and realistic transition (COPA-COGECA, 2020). The organisation emphasises the importance of incorporating advanced machinery, low-risk alternatives to pesticides, innovative breeding techniques, and the development of biobased fertiliser markets to achieve these objectives. This stance highlights the need for effective strategies in the agricultural sector to meet sustainability targets while maintaining productivity.

Machinery manufacturers in Europe, represented by organisations such as the European Agricultural Machinery Association (CEMA) and the Committee for European Construction

Equipment (CECE), advocate for maintaining access to liquid fuels as they innovate and develop next-generation tractors. This ongoing dialogue highlights the importance of fuel availability in supporting advancements in agricultural machinery technology. A recent analysis by CEMA revealed that tractor registrations reached their lowest level in a decade in 2024. Although the report does not provide data on revenue developments, numbers may differ, particularly as registrations for high-powered tractors increased nearly 20% (CEMA, 2025). This decline indicates a significant shift in the market, prompting concerns voiced by industry stakeholders about the future of the sector.

At the national level, major agricultural unions, such as the Deutscher Bauernverband (DBV) in Germany and the Fédération Nationale des Syndicats d'Exploitants Agricoles (FNSEA) in France, actively influence government policies to uphold fuel subsidies and relax regulations regarding environmental standards.

For instance, in Germany, the leader of the DBV expressed concerns that reductions in diesel subsidies could be the "straw that broke the camel's back," emphasising that farmers currently lack viable alternatives to fossil fuel-powered machinery (Wehrmann, 2024). This collaboration among EU policymakers, corporate agribusiness, and farmer unions has significantly shaped the fossil fuel-dependent agricultural framework, impacting policies, subsidies, and the dominant practices within conventional farming.

4.1.3. Resistance Mechanisms and Decline Functions

a) Delegitimation

Delegitimation occurs as fossil-fuel-based agriculture is increasingly viewed as socially and ecologically unsustainable. Both public and expert discourses have criticised long-standing diesel rebates and fuel subsidies as "environmentally harmful" and incompatible with climate neutrality goals (Wehrmann, 2024). Scientific institutions and civil society groups have amplified these criticisms, connecting fossil fuel dependence to larger climate and biodiversity crises.

During the debates on the NRL, scientific evidence played a key role in shifting the framing from an economic burden to an ecological necessity. This shift took place despite strong counterarguments from farmers' unions and political figures, who portrayed EU regulations as "hostile" or disconnected from the realities of rural life. This conflict over meaning highlights how delegitimation is driven not only by changing facts but also by the active contestation of narratives and authority.

b) Guidance Toward Exit

Guidance towards exit is evident in regulatory and financial signals aimed at reshaping the agricultural system. The EU's Farm-to-Fork Strategy and CAP eco-schemes promote alternative practices such as agroecology, renewable energy, and low-input farming. Although these measures face resistance, with COPA-COGECA and national unions advocating for "realistic transitions" and highlighting the challenges of electrification and alternative fuels in rural areas, this pushback resulted in adjusted proposals and negotiated timelines instead of complete reversals.

EU Member States have demonstrated a division in their approaches to decarbonising agriculture, a divide that was particularly evident during the debates surrounding the NRL and related Green Deal initiatives. Several countries, particularly in northern and eastern Europe, have expressed concerns about the "stringent" nature and land use regulations. For example, the Swedish Parliament published an opinion stating that the agricultural and forestry provisions within the NRL were in violation of the principle of subsidiarity and deemed "disproportionate" to their objectives (Aubert & Underwood, 2024).

In a related context, the Dutch Parliament suggested the removal of specific "deterioration" clauses, cautioning that such regulations could lead to significant legal challenges for housing, infrastructure, and energy projects (Leeuw & Backes, 2024). Additionally, the Finnish government aimed to significantly revise assessment criteria to better align with national forest policy and reduce financial burdens on farmers.

In January 2024, significant demonstrations took place in Germany, with tens of thousands of protesters, including over 2,500 tractors, converging in Berlin (Press, 2024). This mobilisation was in response to a proposed removal of a 21¢€/L tax rebate, which had been a critical factor for farmers' fuel costs. In light of the protests, Chancellor Olaf Scholz agreed to roll back the subsidy cuts instead of an immediate repeal. Simultaneously, environmental authorities advocating for the elimination of these subsidies label them as environmentally detrimental. This situation illustrates a fundamental conflict between farmers, who prioritise maintaining low fuel prices and ensuring profitability, and the necessity of decarbonisation and fiscal responsibility.

A similar scenario unfolded in France at the end of January 2024, where the National Federation of Agricultural Workers' Unions (FNSEA) organised a series of highway blockades known as the "siege of Paris” (Girard, 2024). These actions effectively disrupted access to the capital and major roadways in response to government announcements regarding the reduction of agricultural fuel subsidies. In response to the backlash, the French government decided to reverse its subsidy cuts and suspended proposed regulations related to pesticides and land use in an effort to quell the protests.

This trend continued with protests in Belgium and at the EU level, where Belgian farmers took to the streets in Brussels in late January 2024. The demonstrations began with smaller producers raising concerns about economic vulnerability, calling for better protection of small-scale production, fairer pricing structures, and safeguards against market competition from non-EU imports (Dwyer, 2024). As the protests gained momentum, larger farming unions, including the Fédération Wallonne de l'Agriculture (Walloon Federation of Agriculture) representing the interests of Belgium farmers in Wallonia and national branches of COPA-COGECA, entered the scene, broadening the demands to include opposition to fuel subsidy reductions, frustrations with bureaucratic environmental rules, and criticisms of the European Green Deal (Schultz, 2024).

These events created a multifaceted protest landscape where nationalistic sentiments, economic uncertainty, and institutional distrust intersected. Union leaders argued that certain biodiversity and climate targets could jeopardise food security and undermine farm profitability, while also demanding a pause on reforms they framed as unrealistic or overly regulated. The convergence of these voices illustrates how diverse actors within the agricultural regime deploy different resistance narratives depending on scale, sector, and political alignment. In response to these protests, EU institutions displayed a degree of flexibility, with the European Commission deciding to postpone certain land use and ecological regulations.

The discussions surrounding fossil fuel issues have often been intertwined with concerns about the impact of regulations on farmers. Critics of decarbonisation policies commonly frame debates regarding fuel, fossil, and chemical bans as examples of "hostile" EU regulations that negatively affect farmers' ability to produce food. In contrast, advocates for these reforms emphasise the scientific evidence supporting their case, noting that over 6,000 experts have signed a petition in favour of the EU's Farm to Fork Strategy, which includes the NRL (Pe'er et al., 2023).

In addition, governments and research initiatives are conducting trials on green ammonia and biogas solutions, steering fertiliser and fuel systems away from fossil fuels (European Commission, 2025). These efforts align with the movement away from petrochemical pesticides and fertilisers, where institutional reform, such as pesticide bans and green procurement, has gradually shifted innovation pathways.

c) Market Decline

The significant drop in tractor registrations to their lowest level in a decade in 2024 (CEMA, 2024) indicates more than just an economic downturn. It highlights uncertainty surrounding subsidy reforms, emissions regulations, and input prices that are influencing investment decisions in the agricultural sector. Farmer protests, which aim to resist these changes, also demonstrate the increasing vulnerability of the fossil fuel-based machinery model.

As the future costs of diesel and the necessary infrastructure become uncertain, confidence within the market starts to diminish. Additionally, the broader decarbonisation efforts in the transport sector, exemplified by the EU's 2035 ban on internal combustion engines (European Parliament, 2022) further exacerbate this situation. This policy shift could result in the gradual reduction of the long-term viability of liquid fossil fuels throughout various supply chains.

d) Resource Demobilisation

Resource demobilisation signals a notable shift in institutional policy towards fossil fuel support. A key example of this is Germany's phased rollback of its €440 million diesel rebate, which occurred despite political concessions made to protesting farmers. This action reflects a broader trend in which governments are increasingly withdrawing financial and regulatory backing for fossil fuel-dependent practices. While the French and Belgian governments temporarily reinstated similar subsidies in response to public protests, these situations highlight a larger institutional ambivalence. On one hand, fossil fuel subsidies are being politically defended, while on the other, they are becoming increasingly unsustainable both financially and environmentally.

4.2. Synthetic Fertiliser use in EU Agriculture

Synthetic fertilisers have played a crucial role in shaping Europe's agricultural production model following WWII. Similar to advancements in machinery, the early years of the CAP encouraged high-yield farming techniques that relied heavily on chemical inputs to boost agricultural output (Bengtsson, 2016). As policies evolved to meet new expectations and challenges, significant reforms, such as the MacSharry reforms and Agenda 2000, shifted the approach to subsidies, moving away from output-based support. This shift led to a decrease in the economically viable use of fertilisers, resulting in a significant decline in their application

(European Commission, 2019). Today, while EU policy emphasises precision nutrient management, fertilisers continue to be a fundamental component of agricultural productivity and food security in the region.

4.2.1. Technology and Historical Context

Nitrogen fertilisers are produced through the Haber-Bosch process, which combines nitrogen (N) from the atmosphere with hydrogen (H_2). This method is known for its high energy consumption, with approximately 3-5% of global natural gas utilised in the manufacture of nitrogen fertilisers. Additionally, the cost of the natural gas component constitutes about 60-80% of the overall production expenses (European Commission, 2019).

Phosphate fertilisers are derived from the mining of phosphate rock, which is subsequently treated with acids. Potash fertilisers are obtained by mining ore and purifying it, a process that is considerably less energy-intensive compared to nitrogen production (Lalor, 2024). Both phosphate and potash fertiliser processes establish strong technological connections to the fossil fuel and mining industries, involving equipment such as reactors, power sources, and extensive global supply chains.

In the EU, around 75% of agricultural land is treated with mineral fertilisers. According to Fertilizers Europe, which represents the majority of fertiliser companies active in the EU, approximately 122.9 million hectares of arable land were fertilised with synthetic products in 2022. This application is primarily focused on cereals and grasslands. Notably, arable crops, particularly cereals, have the highest nutrient demand, comprising 26% of fertiliser use on just 15% of the land. Grasslands and oilseeds follow, accounting for 16% and 11% of fertiliser use, respectively, on 18% and 6% of land areas (Fertilizer Europe, 2023).

4.2.2. Key Actors and Networks

The fertiliser regime in Europe is supported by a complex and dense socio-technical network. Agriculture heavily relies on synthetic nitrogen inputs, with modern high-yielding crop varieties specifically bred for optimal performance in high nitrogen conditions. The farming equipment, including sprayers and banners, as well as storage systems, are designed with the assumption that chemical fertilisers will be readily available. As a result, seeds, fertilisers, and pesticides are often bundled together in input packages, leading to a situation where 95% of organic farming continues to depend on varieties developed for conventional high-input systems despite the organic farming ethos (Bueren et al., 2011).

In terms of regulation and civil dialogue, industry voices, such as COPA-COGEA, dominate the conversation and hold a significant presence in CAP consultation groups (Savage & Win, 2023). Labelling and approval processes tend to favour established fertiliser production methods, while alternatives such as organic manures and innovative bio fertilisers face considerable regulatory challenges. These interdependencies contribute to a path-locked system, hindering diversification in cropping or farming practices. Most service providers, including advisors, cooperatives, and banks, operate under the assumption of a high-input model, shaping their strategies accordingly.

The debate surrounding fertilisers in the European Union is shaped by a few key organisations and influential actors. Fertilizers Europe represents the interests of producers of nitrogen, phosphorus, and potassium fertilisers, focusing on sustainability issues and promoting research and development for greater efficiency in fertiliser use. COPA-COGECA plays a notably significant role in this landscape, often influencing discussions related to the CAP. The organisation has close ties with the Agriculture Directorate-General (Agri-DG) of the European Commission and takes an active role in drafting amendments with supportive MEPs (Savage & Win, 2023).

In addition to these organisations, major agribusiness corporations, including fertiliser manufacturers such as Yara and CF Industries and chemical companies such as Bayer and Syngenta, contribute to policy discussions. Recently, these corporations have collectively opposed certain reforms, with Bayer and Syngenta backing claims from COPA-COPEA that proposed changes would adversely affect farming operations (Carlile, 2023).

From a political standpoint, several Eastern and larger Western European nations have shown support for the current fertiliser policy framework. For example, France and Germany are responsible for about 3 million tons of the total 8.9 million tons of nitrogen used in the EU in 2022 (Eurostat, 2024). The same study indicates that farmers from France, Spain, Italy, and Romania collectively account for half of the phosphorus fertiliser usage within the EU. The agricultural ministers from these countries have aligned themselves with protests or parliamentary opposition against stringent fertiliser cuts. In contrast, smaller or more environmentally focused nations, such as Denmark, have advocated for stricter regulations on fertiliser use. The share of organic agriculture in these countries is detailed in Table 5 below.

Country	% of total utilized agricultural area (UAA) farmed organically	Year of datapoint	Key source
Italy	19.8%	2023	Ciccarese et al. (2024)
Spain	12.2%	2023	Quintana (2025)
Denmark	11.8%	2023	FiBL (2025)
Germany	11.4%	2023	Kuhnert (2024)
France	10.36%	2023	Girard (2024)
Romania	≈5%	2024 (latest statement, 2023 area)	Romania Observer (2024)

Table 6. Share of Certified Organic Agricultural Lan in Selected EU Countries (2023-2024)
Compiled from national and EU-level sources. Shows the percentage of each country's total utilised agricultural are (UAA) either fully certified organic or in conversion, based on the most recent available data.

In Brussels, the centre-right European People's Party (EPP), which includes numerous national agricultural ministers, has often aligned itself with the interests of the farming and industrial sectors. For instance, EPP members of Parliament have advocated for the cessation of the NRL, claiming that it poses a risk to food security, and have called for additional impact assessments (Silva, 2023).

In contrast, the European Commission and Green/Left MEPs, supported by NGOs such as Greenpeace and the Nature Conservancy, have pushed for more stringent environmental regulations. This includes the establishment of nitrogen reduction targets within the Farm-to-Fork Strategy and the Soil Health Strategy.

Overall, the ongoing debate involves a range of stakeholders. On one side, pro-reform advocates comprise the European Commission, Green MEPs, and certain member states pursuing green initiatives. On the opposing side, defenders of the existing agricultural frameworks include organisations such as COPA-COGECA, Fertilizers Europe, large agribusiness entities, and numerous conservative national governments, resulting in a polarised discussion surrounding agricultural policies.

4.2.3. Resistance and Decline Functions

a) Delegitimation

Recent discussions around synthetic NPK (nitrogen, phosphorus, and potassium) fertilisers have highlighted a significant debate regarding their sustainability and impact on climate change. Critics have raised concerns about the legitimacy of these fertilisers, suggesting they contribute to environmental issues. However, this viewpoint has been met with robust counterarguments from lobby groups and supportive politicians, who have characterised these criticisms as misinformation.

For example, the European People's Party (EPP) and various farming lobby groups have issued warnings that reducing the use of fertilisers could lead to severe food supply issues. They have utilised media channels to amplify their claims against the Farm-to-Fork targets, which they argue are unfounded. In contrast, the Socialists & Democrats (S&D) have offered a more cautious endorsement of the Farm-to-Fork Strategy, expressing support for its environmental objectives while simultaneously echoing concerns over food security and the potential socioeconomic impacts on farmers. In several instances, key S&D members have backed amendments that soften binding reduction targets for fertiliser and pesticide use, indicating internal tensions between sustainability goals and agricultural stakeholder interests (Malingre, 2024).

Meanwhile, the Identity and Democracy (ID) group, which includes several far right and nationalist parties, has positioned itself more firmly against the strategy. Framing the policy as an overreach of EU green agendas, the ID has capitalised on rising rural discontent to advance a narrative of national sovereignty and economic protectionism, particularly emphasising the burden such regulations impose on small-scale and traditional farmers (European Greens, 2024; Casert, 2024). This growing discourse and resistance have further complicated the political terrain surrounding the implementation of Farm-to-Fork targets.

In response, scientific communities have contested these claims, providing evidence to support the targets. Additionally, organisations such as COPA-COGECA have actively defended the use of synthetic NPK fertilisers by emphasising the existence of safe application doses. They argue that environmental targets may threaten farmer livelihoods, framing the debate as one of agricultural sustainability versus environmental regulation. This ongoing contest between differing narratives highlights the significant resistance encountered during the process of delegitimising synthetic fertilisers.

b) Guidance Toward Exit

The European Union's green farm policies provide formal direction aimed at reducing reliance on intensive fertiliser usage. Notably, the 2020 Farm-to-Fork strategy sets a goal of achieving a 20% reduction in fertiliser use by the year 2030 (Appunn, 2021). The European Commission has reiterated this goal and is promoting the implementation of efficiency measures. However, the impact of these initiatives has been weakened by significant pushback. Member states and the farming organisation COPA-COGECA have advocated for delays in the proposed changes.

Additionally, the agricultural committee of the European Parliament has called for comprehensive impact studies before moving forward with the NRL. Various governments have also secured concessions, such as extending exemptions under the Nitrates Directive, which has slowed the transition from existing practices. Consequently, the intent of the guidance often conflicts with a strong resistance that seeks to maintain current standards.

Critics, including representatives from COPA-COGECA and EPP politicians, argue that the provisions outlined in the NRL are either overly vague or excessively stringent. They caution that these regulations could disrupt agricultural land and production, potentially leading to significant crop yield losses (Silva, 2023). For instance, the Secretary General of COPA has highlighted that if the NRL measures do not align with the anticipated growth in food demand, farmers' capacity to produce food will be diminished.

Similar conflicts arise with the pending Soil Health Law proposal in the EU, alongside the existing Nitrates Directive. Farmers frequently oppose strict nitrate limits and operational restrictions, claiming these could result in loss of income. Environmental advocates counter this by referencing EU data that shows persistent nitrogen surpluses, which contribute to water pollution and may adversely affect soil viability and local ecosystems (Silva, 2023).

The debate surrounding these issues has become heavily politicised. A coalition of 3,339 scientists has publicly denounced the spread of misinformation regarding the Farm-to-Fork targets, characterising it as unscientific and reminiscent of war-mongering tactics (Carlile, 2023).

In summary, the NRL and related policies have sharpened fault lines over soil health and nutrient pollution. Environmental groups link intensive fertiliser use to eutrophication, biodiversity loss and soil degradation, whereas farming groups and unions portray restrictions as endangering food security.

c) Market Decline

The European fertiliser market is currently experiencing a contraction. Since 2017, mineral fertiliser consumption within the EU has decreased by 15.9%, reaching its lowest level in a decade by 2022 (Eurostat, 2024). This decline can be attributed to a combination of external shocks and specific policy targets aimed at reducing fertiliser use. Despite the shrinking demand, companies within Fertilizer Europe are actively seeking to maintain their market share. In response, they are exploring new avenues, such as increasing exports to non-EU markets and promoting nutrient-saving technologies, including controlled-release fertilisers, which may perpetuate reliance on industrial inputs among farmers.

In addition, government interventions have been implemented to bolster supply. Following a significant price spike in 2022, the European Commission introduced a Fertiliser Communication aimed at guaranteeing availability, with an emphasis on supply security rather than an immediate transition away from fossil fuel dependency (Garske, Heyl, and Ekardt, 2024). Overall, while demand for fertilisers is decreasing, the industry is working to stabilise the market by adapting its strategies and lobbying for supportive policies, including subsidies and tax incentives.

d) Resource Demobilisation

Demobilisation in the fertiliser sector involves the potential transition from synthetic fertilisers towards alternatives such as organic options or green ammonia. However, this transition has faced challenges. The Fertiliser Communication of 2022 primarily seeks to preserve the existing infrastructure and import networks, thereby maintaining the EU's gas-dependent framework for fertiliser production.

As a result, focus has largely been on enhancing efficiency or negotiating lower gas prices for fertiliser manufacturing. There has been noticeable resistance to moving away from conventional methods, manifesting as calls for increased funding in research and development and the exploration of renewable pilot projects, albeit without a commitment to divest from conventional practices. Consequently, entrenched interests have hindered any significant reallocation of capital within the sector.

4.3. Pesticide Use in EU Agriculture

The EU agriculture sector relies significantly on synthetic pesticides, although there is a noticeable downward trend in their overall usage. In 2022, total pesticide sales across the EU fell to around 322,000 tonnes, marking the lowest levels since 2011 (Eurostat, 2024). This figure represents approximately a 10% decrease compared to 2021 and is 12% lower than the levels recorded in 2011. Notably, four countries, France, Spain, Germany, and Italy, account for over half of the total pesticide consumption within the EU, highlighting their substantial role in the agricultural landscape and cropland usage. Together, these countries also represent over two thirds of the EU population (Statista, 2025).

4.3.1. Technology and Historical Context

In 2022, the largest category of pesticide sales by substance type was fungicides and bactericides, which accounted for 43% of the total market. Herbicides followed closely, representing 35% of sales. Other categories, including insecticides, molluscicides, and growth regulators, made up only single-digit percentages of the overall volume (Eurostat, 2024).

Synthetic pesticides are utilised through various technologies. In field crops such as cereals and oilseeds, modern tractor-mounted boom sprayers are commonly used with vaporiser liquid formulations. Additionally, seed treatments involve coating grains with insecticides or fungicides. Emerging precision tools, such as spot sprayers, drones, and sensors, are beginning to be adopted; however, EU regulations, such as those banning aerial spraying (European Parliament, 2009), impose restrictions that limit their widespread use. In industries such as orchards, vineyards, and horticulture, other applications, including sprayers and vaporisers, are frequently employed.

Despite the introduction of innovative methods, such as biological controls, pheromone traps, and mechanical welding, pesticide applications continue to be a standard practice within intensive cropping systems. These practices are often promoted in the Integrated Pest Management (IPM) strategy to minimise pest control and reduce reliance on traditional chemical methods.

Pesticide use in the EU operates within a complex framework of laws, institutions, and agricultural practices. A key component of this framework is the EU pesticide legislation, specifically Regulation 1107/2009, which regulates the approval processes for pesticide products. Additionally, the Sustainable Use Directive (2009/128/EC) plays a critical role by mandating risk mitigation strategies in pesticide use. For instance, this Directive requires all professional pesticide users to follow IPM (integrated pest management) practices.

IPM emphasises sustainable agricultural techniques such as crop rotation, biological pest control, and the use of resistant crop varieties to minimise reliance on chemical pesticides. The Directive also enforces stringent application standards, including a ban on aerial pesticide spraying, regular inspection and calibration of spraying equipment, and mandatory training and certification for users, advisors, and distributors to ensure the safe handling of pesticides.

In practice, each EU Member State has developed a national institution that outlines specific measures aimed at reducing pesticide risks. These plans typically include training programs, regulations for buffer zones, and the promotion of low-input techniques to further enhance safety and sustainability in pesticide use.

Agronomic norms play a significant role in promoting the use of chemicals in agriculture. Farmers often receive training and advice through EU-funded extension courses and from cooperative agronomists, which frequently emphasise the importance in maintaining high yields. In several Member States, specialised pesticide application services are widely available.

Despite the growing popularity of organic farming, supported by one of the EU's target to have 25% of all farmlands devoted to organic practices by 2030, most farmers still rely heavily on conventional chemical methods. Additionally, the types of crops grown can influence demand. For example, large monocultures, as well as crops such as cereal, corn, and rapeseed, typically require herbicides, while orchards and vineyards necessitate regular fungicide applications. Notably, certain chemical compounds, such as “calda bordalesa”, are permitted under biological certification and have long been authorised for use on French farms (Acientistaagricola, 2019).

In summary, while EU regulations and farm training have institutionalised safe pesticide use practices, they have not fully eliminated the reliance on intensive agricultural systems that depend on synthetic pesticides. This persistence reliance suggests that structural and market dependencies are also underpinned by institutional knowledge framework, reinforcing cognitive bias that may resists more transformative shifts away from pesticide-intensive practices.

4.3.2. Key Actors and Networks

The European Union's pesticide regulatory framework involves a diverse array of influential stakeholders, including powerful agrochemical companies. Major industry players such as Bayer, Syngenta, BASF, Corteva, and Adama dominate the mobilisation and research sectors in Europe, providing the majority of pesticides used across the continent. These companies benefit from extensive research and development pipelines and maintain a significant presence in Brussels, influencing regulatory discussions.

In addition to the agrochemical firms, farmer organisations and cooperatives, particularly COPA-COGECA, along with other national unions, work to represent the interests of growers at both the EU and Member State levels. These groups have effectively argued that swift reductions in pesticide usage could jeopardise agricultural competitiveness and crop yields. Notably, leaked documents indicate that COPA-COGECA has urged EU policymakers to reconsider pesticide reduction targets outlined in the Farm-to-Fork strategy, framing the issue within the context of food security challenges, exacerbated by the war in Ukraine (Carlile & Healy, 2022).

On the regulatory front, the European Commission, along with agencies such as the European Food Safety Authority (EFSA) and the European Chemicals Agency (ECHA), plays a crucial role in risk assessment and policy formulation. Additionally, national agencies, such as Italy's Istituto Superiore di Sanità, are responsible for conducting localised evaluations of pesticide uses and their impacts.

Civil society organisations and research institutions play a crucial role as counterweights in the ongoing discourse surrounding pesticide use. Non-governmental organisations (NGOs), such as Pesticide Action Network Europe (PAN Europe), actively campaign on pesticide issues by referencing health and environmental studies. These organisations successfully mobilised support for a European Citizen Initiative titled "Save Bees and Farmers," which garnered over one million signatures advocating for a phase-out of pesticides (European Commission, 2023). More recently, the coordinator of PAN Europe has highlighted that pesticide pollution continues to pose a significant threat to natural water bodies, human health, and biodiversity (PAN, 2024).

Furthermore, independent scientists and research agencies have provided compelling evidence linking pesticide exposure to serious health concerns, including cancer and neurological disorders, as well as the decline of pollinator populations (Brzeziński, 2023). In contrast, industry representatives, such as BAYER, promote their analyses, emphasising scientific risk assessments to support their stance. For instance, BAYER referenced the European Food Safety Authority's (EFSA) conclusion that glyphosate meets approval criteria as a basis for asserting its safety. This sets the stage for an ongoing debate between stakeholders who defend the existing regulatory framework and advocates who are calling for stricter controls or alternative solutions.

Glyphosate is a widely used herbicide that has become a focal point of public health and regulatory debate. Despite being classified as a “probable human carcinogen” by the International Agency for Research on Cancer (IARC) in 2015, the EU renewed glyphosate’s approval in late 2023 for an additional ten years, following votes to reach a qualifies majority among member states (International Agency for Research on Cancer, 2015; Tidey, 2023). The reapproval included some restrictions, such as phasing out pre-harvest use and requiring buffer zones, but stopped short of implementing a full ban. In response, NGOs including ClientEarth and PAN Europe launched legal challenges, arguing that regulators have relied too much heavily on studies supported by industries while discounting independent scientific research that documented risks such as carcinogenicity, neurotoxicity, and microbiome disruption (ClientEarth, 2024).

The glyphosate case illustrates the contested nature of risk assessment and regulation, particularly when economic interests and agricultural lobbies are deeply embedded in the policy process. Although it is chemically an herbicide, its health-related implications place it at the centre of broader environmental and public health debates, exposing the limits of institutional capacity to act decisively even when credible scientific concerns are present.

4.3.3. Resistance and Decline Functions

a) Delegitimation

Public support for chemical pesticides is increasingly declining due to growing awareness of their negative impacts. Recent studies and media coverage have raised concerns regarding the pollution of waterways and soil, potential links to various cancers, and the decline of beneficial insect populations (The Wildlife Trusts, 2021). Reflecting this shift in public sentiment, 84% of Europeans report being worried about the impact of harmful chemicals on both their health and the environment, and over half believe that current protections are insufficient (Eurobarometer, 2023). As a result, both farmers and consumers are becoming more critical of intensive pesticide use, particularly when alternative solutions are available. Environmental campaigns, such as the PAN petition, along with data on the decrease of pollinator populations, have framed the use of pesticides as harmful to both ecosystems and human health.

In light of these concerns, some industry representatives and policymakers have pointed out that they adhere to regulatory standards that claim to ensure safety. For example, following the mixed findings of glyphosate by ECHA and EFSA in 2022, Bayer publicly contended that no "critical areas of concern" were identified (Brzeziński, 2023). This ongoing dialogue illustrates how the delegitimation of one technology can be countered by legitimising the arguments of established stakeholders.

b) Guidance Toward Exit

Several notable policy events have recently underscored the ongoing conflict surrounding pesticide regulations in the European Union. In November 2023, the European Parliament voted against the proposed Sustainable Use Regulations (SUR), which was a key component of the Green Deal aimed at reducing pesticide usage by 50% by 2030. The proposal was rejected by a vote of 229 against 207 in favor, emphasising substantial lobbying efforts from the farming and agrochemical sectors (Brzeziński, 2023). These groups argued that the SUR would threaten the competitiveness of EU agriculture. As a consequence of the political pressure and widespread farmer protests, the Commission President subsequently withdrew support, halting the EU-wide pesticide reduction targets, despite the existence of various national regulations.

On a national level, France has adopted a more proactive approach regarding certain pesticides. In 2018, it became the first EU country to ban all outdoor uses of five significant neonicotinoid insecticides in an effort to protect bee populations (Dupraz-Dobias, 2018). President Macron has also committed to phasing out glyphosate, yet France abstained from the EU vote on glyphosate renewal, resulting in a 10-year reauthorisation period and the postponement of its 2021 ban deadline (Brzeziński, 2023). Additionally, l'Agence Nationale de Sécurité Sanitaire (ANSES), the French pesticide regulatory body, is actively reassessing the safety of hazardous chemicals and, in 2023, proposed a ban on the herbicide S-metolachlor due to its toxicity in water.

The NRL proposal prominently features a binding target aimed at reversing the decline of pollinators by the year 2030 (European Commission 2025). Given that synthetic pesticides are significant contributors to the losses of bees and other insects, meeting the goals outlined in the NRL will necessitate the implementation of stringent restrictions on toxic chemicals in agricultural environments. Additionally, the revised Pollinators Initiative of the European Union explicitly connects the recovery of pollinators to both the NRL and the reduction of pesticide use. This initiative establishes legal commitments to mitigate pesticide risks and enhance habitats on farmland.

c) Market Decline

The current economic trend indicates a decline in demand for certain synthetic products, particularly in the pesticide sector. Data from Eurostat reveals a consistent decrease in pesticide sales within the EU (Eurostat, 2024). Notably, major companies like Syngenta have reported a 17% drop in sales during the first half of 2024, which they attribute in part to destocking practices (Syngenta Group, 2024). In contrast, Bayer experienced a 1.1% growth in Crop Science sales in the second quarter of 2024, primarily driven by glyphosate-based herbicides. However, the company also reported significant declines in sales of non-glyphosate herbicides and fungicides, particularly in Latin America and the Asia-Pacific region, amid falling prices and adverse weather conditions (Bayer CropScience, 2024).

Despite these fluctuations, overall sales figures remain substantial, with companies defending their existing product lines. For example, amid a deadlock in the EU Committee regarding the renewal of glyphosate, they opted to extend its approval for an additional decade, effectively delaying its exit from the market. Thus, while the market is gradually becoming more receptive to alternatives, established firms continue to seek ways to maintain their sales and avoid market decline through intensive lobbying at the EU-level.

d) Resource Demobilisation

The landscape of conventional pesticide systems is undergoing a gradual shift, with agrochemical companies increasingly diversifying their investments into areas such as biotechnology, digital farming, and biological solutions. The biopesticide industry has expressed concerns over significant regulatory delays within the EU, which can extend the approval process for new products to between 7 and 10 years.

According to comments from a biocontrol company through the International Biocontrol Manufacturers Association (IBMA), these delays have prompted many biocontrol firms to consider relocating their investments outside of Europe (NIAMH, 2024). This trend highlights a critical issue, as the diversion of capital and expertise can weaken the existing system. Despite these challenges, established players in the market continue to allocate considerable resources toward lobbying efforts, with leading companies spending approximately €10.5 million in Brussels in 2021. In fact, the agricultural sector has emerged as one of the most powerful lobbying forces globally, outspending even oil and has in the United States in recent years, supported by extensive financial resources, strong political connections, and a highly coordinated lobbying infrastructure (Financial Times, 2024).

CHAPTER 5

Discussion and Conclusion

5.1. Discussion of Empirical Research

The development of the Nature Restoration Law (NRL) unfolded in parallel with three peak moments of political contention, namely the Commissions proposal in June 2022, the Parliament's negotiations in July 2023, and the eventual implementation in June 2024. Each of these moments coincided with distinct spikes in media coverage and lobbying activity, indicating that regime resistance to the NRL was closely tied to its evolving legal and political shape. The three technological systems examined, fossil fuels, synthetic fertilisers, and pesticides, were not targeted uniformly in the NRL text, but actors within each sector perceived the law's broader restoration goals as a threat to their legitimacy and operational continuity. Across all three cases, the most prominent and fiercely contested decline function was delegitimation. The analysis below explores how delegitimation unfolded in each case, before turning to a comparative reflection on shared patters and system-specific dynamics.

In the case of fossil fuels, delegitimation was challenged primarily through narratives centred on energy security, rural viability, and just transition. Although the NRL did not contain explicit measures targeting fossil fuels, opponents interpreted the law's restoration targets, particularly those concerning ecosystem emissions and land-based energy transitions, as a signal for accelerated fossil phase-out. Delegitimation efforts were led by environmental NGOs and scientific institutions, which posited fossil-based inputs as incompatible with the EU's long-term climate and restoration objectives. However, resistance actors mobilised three intersecting frames.

First, industry and farm union stakeholders highlighted rural economic dependency, citing the rising costs and limited availability of electrified machinery as evidence that alternatives to diesel remained economically unviable. Second, energy security was invoked not only in response to the war in Ukraine but also in longer standing discourses around European sovereignty and fuel self-sufficiency. Member states such as Poland and Hungary had already expressed concerns about over-reliance on imported fuels prior to the conflict, and the war intensified these concerns. Third, the absence of a just transition framework for agriculture gave space for opponents to frame the NRL as socially inequitable. This framing proved influential, particularly in France and Germany, where protests and lobbying resulted in reversal of diesel-tax reforms. Delegitimation, therefore, remained fragile. While civil society successfully introduced new normative critiques of fossil-based farming, these failed to anchor broader political consensus or to trigger guidance toward exit or resource demobilisation.

In the fertiliser case, delegitimation also emerged as a central terrain of contestation, but it unfolded through a more technocratic and policy-driven arena. The reframing of synthetic fertilisers and environmentally harmful chemicals gained traction through awareness of nitrate pollution, soil degradation, and water quality risks. However, this reframing encountered persistent resistance from institutional actors and industry groups, particularly through claims that fertiliser inputs are essential to European food security. The sharp increase in fertiliser prices in 2022 was repeatedly used to justify policy caution, while stakeholders arguing that any reductions would create unacceptable risks to yield stability and global supply chains.

Different to the fossil fuel case, where resistance mobilised strongly around security and protest, the fertiliser case was shaped by long-standing institutional lock-ins. These included the structure of CAP subsidies and financing systems that favor high-input conventional farming. Resistance actors did not reject sustainability outright but instead positioned themselves as pragmatic partners in the green transition, advocating for sustainable nutrient management strategies such as precision application. This, in part, assisted them in maintaining legitimacy while avoiding binding reduction targets. The political debate, though less polarised in public discourse, was no less divided in institutional spaces. Parliamentary committee debates revealed clear partisan splits, with the European People's Party (EPP) and Identity and Democracy (ID) groups opposing regulatory tightening, while Green and Left parties advocated more ambitious nutrient caps. Delegitimation in this case advanced more gradually, constrained not by the absence of public concern, but by the institutional and financial architecture that continues to reproduce fertiliser-intensive practices and slow the articulation of clear guidance toward exit.

The pesticide case revealed the most advanced and publicly visible delegitimation dynamics. The contested renewal of glyphosate and the failure of the Sustainable Use Regulation (SUR) served as flashpoints in a broader battle over scientific authority, public health, and ecological risk. Unlike the other two technologies, pesticide use was directly addressed in the NRL’s pollinator restoration targets, allowing environmental and health actors to tie the legitimacy of pesticides to the law's success or failure. Delegitimation was driven by a broad coalition of actors, including civil society organisations, scientific networks, and the "Save Bees and Farmers" initiative, which collected over one million signatures and brought the issue into mainstream political debate.

At the same time, industry actors and national-level farming unions responded with an equally coordinated defence, challenging the scientific basis of regulatory decisions and promoting their own risk assessment frameworks. The glyphosate case became emblematic of this dynamic, while the International Agency for Research on Cancer (IARC) labelled the chemical a "probable carcinogen," the European Food Safety Authority (EFSA) found mixed results, which prompted Bayer to suggest "no critical areas of concern." Both positions were strategically amplified by different sides of debate, revealing how scientific claims were not only evidence-based but politically mobilised. This dynamic exposed deep divisions within the European Parliament and between member states, ultimately leading to a deadlock on the SUR. Although delegitimation advanced furthest in this case, undermining public trust in unregulated pesticide use and generating legal challenges from NGOs, it did not lead to coherent guidance toward exit or significant resource demobilisation. Instead, it generated highly visible yet politically unstable consensus.

Taken together, these three cases demonstrate that delegitimation serves as the primary entry point for resistance and contestation in the implementation of the NRL. Across all systems, actors opposed to phase-out trajectories worked actively to preserve or reframe the legitimacy of their practices. What differed was the discursive repertoire used and the institutional terrain on which these struggles played out.

In the fossil fuel case, resistance actors emphasised energy security, economic dependency, and social fairness, shaping delegitimation as a threat to rural autonomy. In the fertiliser case, resistance was grounded on institutional continuity and productivity concerns, with legitimacy preserved through claims of incremental reform. In the pesticide case, delegitimation unfolded most forcefully through direct public engagement and expert controversy, yet its outcomes were marked by intense political division and policy impasse.

The NRL itself influenced these dynamics by shaping the terrain on which delegitimation unfolded. Where the law established clear, measurable ecological indicators, such as pollinator restoration, it empowered environmental actors to link specific technologies to legal obligations. In more ambiguous domains, such as soil health or nutrient management, resistance actors were more successful in framing targets as aspirational or impractical. As a result, while delegitimation was necessary to initiate trajectories of decline, it was not sufficient to trigger broader systemic change. Its impact depended on the interaction between public discourse, institutional structures, and the evolving framing of the NRL.

5.1.1. Transition Pathways and Resistance

To further interpret resistance patterns, this section relates each case to transition pathways identified in the socio-technical transitions literature. Drawing on Geels (2016), the aim is to better understand how technological conditions, actor relations, and institutional dynamics shape the nature and strength of regime resistance. Particular attention is paid to how institutional change occurs, whether through displacement, conversion, or layering, with layering referring to the incremental addition of new rules or goals on top of existing structure, without removing or replacing the dominant regime. A summary or transition pathway types and their underlying mechanisms adapted from Geels (2016) is available in Table A4 in the appendix.

The fossil fuel case within EU agriculture displays traits of a transformation pathway, where incumbent actors adapt incrementally in response to rising environmental pressure but without structural reconfiguration. Technological alternatives, such as electrified farm equipment and low-carbon energy sources, are developing but remain limited in deployment. Incumbents, including national farm unions and supportive Member States, have continued to frame fossil energy as economically necessary and strategically vital, especially in the contexts of rising costs and geopolitical instability. Institutional changes have been modest, with most policy adjustments framed around efficiency or rural exemptions, rather than substantive shifts away from fossil dependence. As outlined by Geels (2016), transformation pathways tend to emerge when pressure from the landscape, in this case, climate policy and public discourse, triggers regime adaptation rather than displacement. The resistance observed here aligns with this pattern in which stabilising responses aim to sustain the status quo, thereby delaying more ambitious decline trajectories.

In relation to transition pathways, the fertiliser case most closely resembles a de-alignment and re-alignment patters, albeit in an early stage. While public contestation and policy proposals, such as the Farm-to-Fork Strategy, signal a weakening of regime resistance legitimacy, no clear alternative configuration has emerged. The technological conditions for change remain relatively radical, with organic or bio-based alternatives requiring substantial shifts in infrastructure, agronomic practice, and value chain coordination.

Actor dynamics are similarly unbalanced, with dominant lobbying bodies, such as COPA-COGECA and Fertilizers Europe successfully framing their role as essential to food security, while emerging actors remain fragmented. Institutional change has largely taken the form of weak layering, where proposals such as fertiliser reduction targets have been diluted through exemptions and procedural delays, leaving core support structures intact. As such, the trajectory of decline remains tentative and heavily contested. Geels (2016) notes that in de-alignment pathways, the erosion of regime legitimacy does not necessarily lead to transformation unless niche alternatives gain traction and are reinforced by supportive policy coalitions, a dynamic not yet visible in this case.

The pesticide case suggests a hybrid trajectory that combines elements of transformation and reconfiguration. Many of the technologies being developed, such as biocontrols and precision application, are modular and can be integrating into existing farming systems without dismantling current structures. This supports a transformation dynamic in which agrochemical incumbents adapt their portfolios while seeking to retain market dominance. At the same time, reconfiguration is visible through the uptake of Integrated Pest Management (IMP) and national restrictions, particularly in countries such as France. Resistance remains high, however, with persistent lobbying against binding targets and a tendency to reframe chemical inputs as essential to productivity. According to Geels (2016), reconfiguration pathways often involve a more complex interaction between old and new elements, where change proceeds through the recombination of existing structures rather than substitution. In this context, the pesticide case illustrates how resistance can simultaneously delay systemic decline while also enabling partial accommodation of sustainability pressures.

Across the three systems, regime resistance manifests in distinct ways that align with different transition pathways. Fossil fuels follow a transformation patters, marked by slow adaptation and institutional continuity. Fertilisers reflect a de-alignment and re-alignment process, with a weakening regime but no coherent alternative. Pesticides combine transformation and reconfiguration, where incumbents begin to adjust without ceding structural control. These differences illustrate how the Nature Restoration Law encounters uneven resistance across domains. Rather than operating on a neutral governance terrain, the NRL interacts with regimes in varied states of disruption or stability, shaping both direction and strength of its potential to influence decline.

Sector	Transition Pathway(s)	Technological Conditions	Key Actors	Institutional Changes	Decline Progress ★
Fossil Fuels	Transformation	Less radical; alternatives exist but limited uptake	Dominated by incumbents; few new entrants	Mostly layering; limited change	★
Fertilisers	De-alignment and re-alignment	More radical; alternatives require systemic shifts	Incumbents dominant, new entrants fragmented	Weak layering; low institutional change	★
Pesticides	Transformation + Reconfiguration	Moderately radial; alternatives more easily integrated	Incumbents adapting; some civil society pressure	Layering with some early adjustments	★★

Table 7. Comparative Overview of Resistance Patterns, Transition Pathways, and Decline Progress Across Fossil Fuel, Fertiliser, and Pesticide use in EU Agriculture

This table relates each case to one or more transition pathways (Geels, 2016), comparing technological conditions (how systemic alternatives are), key actors (extent of new entrant involvement), and institutional changes (from minimal to transformative). Decline progress is rated using a three-star scale based on case evidence, reflecting the extent to which decline functions are activated or blocked. ★ indicates early or minimal progress, with strong resistance and limited institutional change; ★★ reflects moderate progress amid ongoing contestation; ★★★ would indicate advanced decline with structural change and weakening of regime control, a stage not reached in any of the cases studied.

5.1.2. Policy Recommendations

Drawing from the empirical findings, several governance-oriented recommendations emerge for how the EU, and initiatives such as the NRL, can be structured to proactively manage regime resistance and strengthen decline functions.

The pesticide and fertiliser cases revealed the strong influence of agricultural unions such as COPA-COGECA in shaping subsidy frameworks and policy priorities under the Common Agricultural Policy (CAP). Despite rising societal and ecological concerns, environmental objectives were frequently diluted when implemented through voluntary measures. Instruments supporting reduced-input practices, such as eco-schemes and agri-environmental payments, were present but remained optional and secondary. Integrating stricter environmental requirements into CAP payment structures, particularly those tied to pesticide and fertiliser reduction targets, could strengthen guidance toward exit and resource demobilisation. The findings show that where environmental goals lacked enforceability, as in the failed SUR, they were easily sidelined.

The fossil fuel case illustrated how, in the absence of a sector-specific transition framing, resistance actors framed restoration policies as threats to farmer livelihoods and fuel access. While environmental and scientific actors pushed for fossil fuel phase-out, resistance actors emphasised economic feasibility and dependency. Extending the just transition narrative into agriculture, by recognising farmer livelihoods and regional variation, could help support delegitimation and guidance toward exit. These framings should be clearly communicated and reflected in NRL implementation strategies.

A consistent weakness across all three cases was the lack of strong, enforceable EU-level targets. Even where political signals were present, fragmented national implementation created opportunities for resistance. The findings suggest that ensuring consistency through binding targets, accompanied by clear allocation of responsibilities and legal accountability, is essential to strengthening guidance toward exit. Clarifying how targets are distributed, potentially through benchmark-based frameworks, would reduce the scope for delay or selective compliance.

Market decline remained weak in all three cases. In the pesticide case, sales remained steady despite heightened public concern. In the fertiliser case, market volatility was driven by external shocks, not policy. The fossil fuel case showed minor signs of hesitation, such as declining tractor registrations, but profitability remained high. These findings suggest that stronger economic instruments will be necessary to reinforce phase-out pathways. Procurement rules, fiscal incentives, and investment planning aligned with restoration goals could help translate political signals into structural change.

In the fossil fuel case, decentralised actors such as cities and civil society contributed to shaping narratives around phase-out. In agriculture, this form of engagement was less prominent. Although public concern was high, particularly around pesticide use, organised resistance actors maintained greater institutional access. The NRL could address this imbalance by supporting consultation rights, regional pilot programmes, and local participation in restoration planning. While not sufficient on their own, such measures could help broaden the coalition supporting transition and reduce the concentration of resistance at the national level.

5.2.3. Future Research Directions

While this thesis offers an in-depth empirical application of the decline functions framework to resistance in the EU agricultural and environmental context, future research could expand this approach both conceptually and geographically. Comparative analyses across sectors and regions, for example, in Latin America or Southeast Asia, could help assess whether the patterns of resistance observed here are specific to EU institutional arrangements or reflect broader dynamics of socio-technical decline.

Further work is also needed to explore the different ways in which resistance is expressed and how these forms interact with decline processes. While this study focused on lobbying by incumbent actors and political negotiation around implementation, resistance also operates through institutional design, subsidy pathways, and narrative framing. Future studies could examine more systematically how these mechanisms relate to the fulfilment, or obstruction, of specific decline functions over time.

In addition, other decline functions may exist beyond the four identified in this thesis. Knowledge destruction, for example, may occur as technical expertise erodes, such as in the nuclear sector, where ageing workforces and retiring engineers lead to competence loss, or, as declining technologies generate new knowledge to resist displacement, as seen with internal combustion engines. Similarly, dematerialisation involves the divestment of infrastructure or manufacturing capacity, such as the closure of factories or withdrawal or investment in outdate production systems. These decline functions could be further explored to refine the conceptual framework and test its applicability across different sectoral or technological contexts.

Finally, integrating insights from political economy and transition justice could help expand the conceptual scope of the decline framework. Political economy perspectives may offer a clearer understanding of how subsidy regimes, institutional path dependencies, and structural power imbalances shape the persistence of incumbent systems. Transition justice concepts, particularly those concerned with legitimacy, distributional fairness, and long-term accountability, could also support more nuanced analysis of resistance and phase-out processes. Together, these perspectives may enhance the capacity of socio-technical decline research to address contested transitions in politically and economically embedded contexts.

5.2. Concluding Remarks

This thesis set to explore how regime resistance influences the decline of unsustainable agricultural practices, using the Nature Restoration Law (NRL) as a point of entry into EU environmental governance. Through the cases of fossil fuels, synthetic fertilisers, and pesticides, this dissertation demonstrated how resistance takes different forms depending on the technologies, actors, and policy processes involved. The NRL's broad legislative scope, spanning multiple environmental and agricultural domains, created overlapping sites of contestation where various types of resistance emerged.

Each case illustrated distinct patterns. In fossil fuels, resistance focused on energy security and economic viability. In fertilisers, it centred on institutional continuity and productivity claims. In the pesticide case, it revolved around scientific uncertainty and risk framing. These dynamics shaped how decline functions unfolded, often slowing or weakening processes such as delegitimation, guidance toward exit, market decline, and resource demobilisation. The NRL's integrated structure brought distinct forms of resistance into the same political process. While this enabled negotiation across sectors, it also multiplied the points where resistance could be mobilised. This underscores a broader governance tension, combining multiple environmental goals in a single framework can increase coherence, but also amplify implementation pressures.

The comparative analysis showed that resistance interacts differently with each decline function across cases. These variations were traced in the empirical chapters and synthesised in the comparative discussion to highlight broader patterns and case-specific differences. While the NRL exposed interdependencies across systems, it also showed how sectoral pressures can interfere with coordinated legislative efforts.

By applying the decline functions framework, this thesis demonstrates how resistance shapes the pace and direction of socio-technical change. It also offers a foundation for future research on how governance instruments might be designed to engage with, rather than bypass, the resistance that emerges during phase-out processes.

As a governance innovation, the NRL played an important role in reframing environmental degradation as a legally actionable priority, shifting political discourse toward biodiversity recovery, and introducing new forms of policy integration at the EU level. Its legally binding targets and procedural requirements created pressure for Member States to respond, even in sectors with historically high resistance. This pressure enabled new framings and generated openings for environmental actors to challenge incumbent interests. In this way, the NRL helped activate certain decline functions, particularly delegitimation, and laid groundwork for longer-term reconfigurations in the governance of soil health, pesticide use, and fossil-fuel based inputs.

However, important limitations also became visible. The NRL's impact was uneven across the three domains studies, largely shaped by existing regime structures and transition dynamics. In cases such as fertilisers, where alternatives remain underdeveloped and institutional layers is weak, the NRL struggled to advance decline. In other cases, such as pesticides, the law encountered strong resistance that diluted proposed measures and stalled implementation. These findings suggest that while the NRL can disrupt discursive and procedural routines, it faces structural constraints in sectors dominated by powerful incumbents and deeply embedded subsidy frameworks. Its success depends not only on policy design but also on alignment with broader socio-technical dynamics.

Appendix

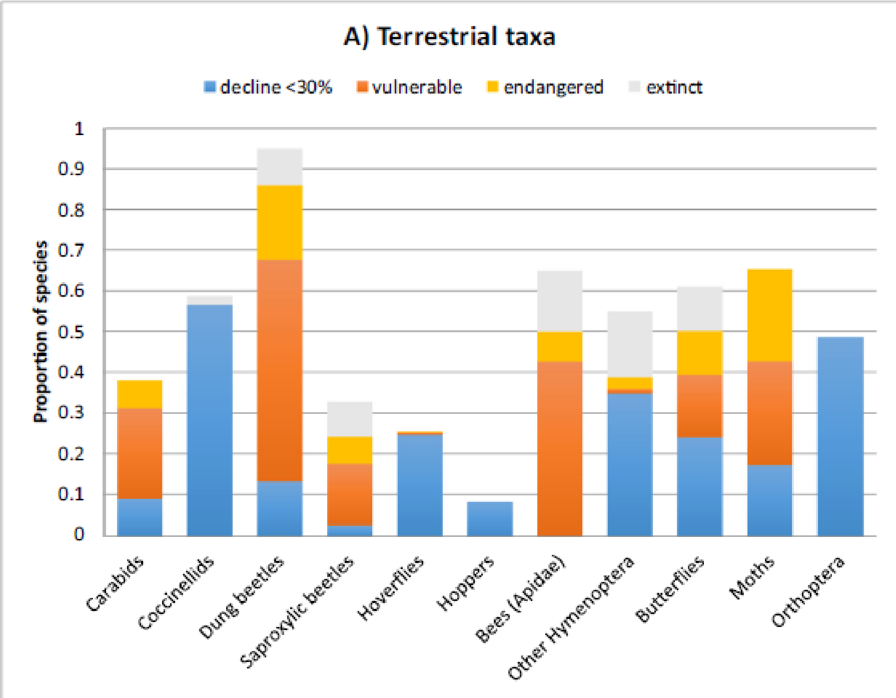

Figure A1. Proportion of Terrestrial Insect Species in Decline or Locally Extinct.

Adapted from Sánchez-Bayo & Wyckhuys (2019). Based on IUCN criteria: vulnerable species (>30% decline), endangered species (>50% decline), and extinct (not recorded for >50 years). Only terrestrial taxa (original panel A) are shown.

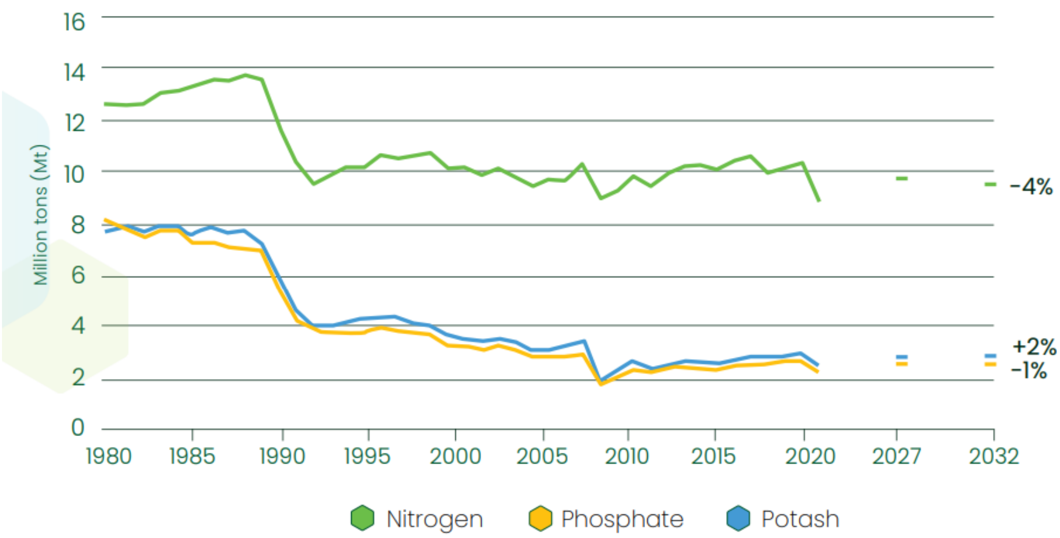

Figure A2. Projected Fertiliser Consumption in the EU by Nutrient Type (Nitrogen, Phosphate, Potash) by 2031/2032.

Adapted from Fertilizer Europe (2023). Based on projected trends considering economic outlooks, cropping area, and post-2022 recovery. Includes historical averages (2019/2020–2021/2022) and forecasted figures for 2031/2032, applied to 123.9 million hectares of farmland.

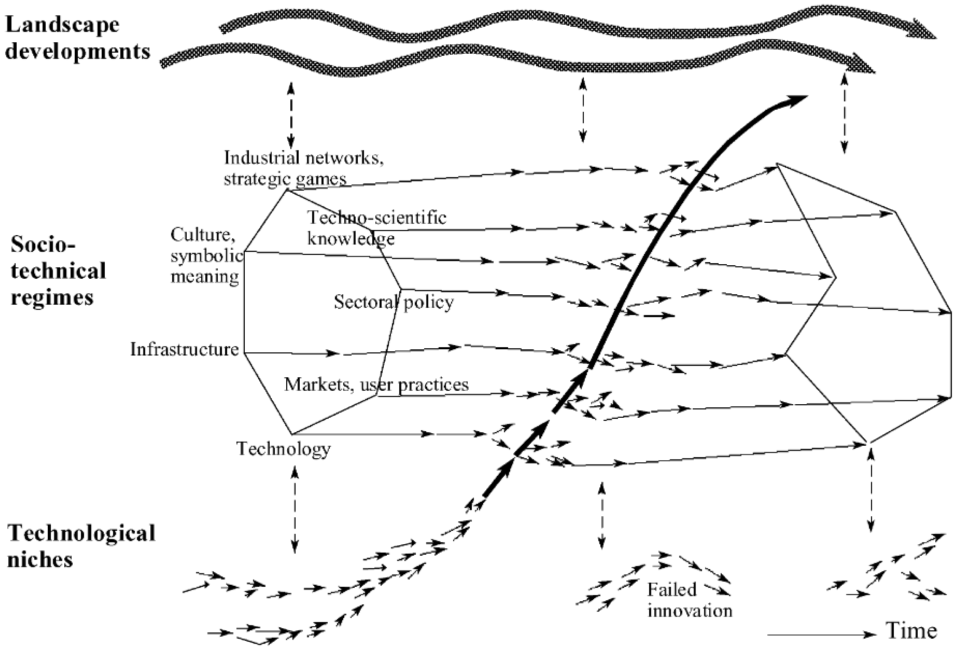

Figure A3. Multi-Level Perspective on Socio-technical Transitions: Interactions Between Niche, Regime, and Landscape Levels

Adapted from Geels (2002, Fig. 5). Illustrates the seven interacting dimensions of the socio-technical regime (e.g., technology, infrastructure, symbolic meaning, policy), as well as the dynamics of radical innovation at the niche level and long-term developments at the landscape level. Arrows represent ongoing processes, tensions, and windows of opportunity where transitions emerge from inter-level linkages. Demonstrates how socio-technical transitions (TT) involve both material and institutional change across multiple system levels.

Month	Article Count	Key Event
2022-06	65	Initial NRL proposal introduced by the European Commission
2023-05	104	Draft version debated in Parliamentary committees
2023-06	383	Massive campaign by NGOs and agri-lobbies; protests and petitions
2023-07	413	Parliamentary vote delayed; major media attention
2023-11	126	Shift in voting positions by Austria and Slovakia reported

2024-02	216	Council revisits and amends final draft
2024-06	374	Formal adoption and passage of the NRL

Table A4. Key Moments of Political and Media Attention Surrounding the NRL

This table outlines the most significant spikes in news coverage and correlates them with key events in the legislative trajectory of the NRL. Each moment reflects a critical juncture in either institutional negotiations, public mobilisation, or changes in member state positions, helping to contextualise the timing and intensity of both support and resistance.

Reformulated and differentiated transition pathways.

Transition pathway	Actors	Technologies	Rules and institutions
(1) Substitution	New firms struggle against incumbent firms, leading to overthrow	Radical innovation(s) substituting existing technology	Limited institutional change, implying that niche-innovation needs to compete in existing selection environment ('fit-and-conform') ('Incremental adjustment', 'Layering')
	Different kinds of 'new entrants' (e.g. citizens, communities, social movement actors, incumbents from different sectors) replace incumbents		Creation of new rules and institutions to suit the niche-innovation ('stretch-and-transform') ('Disruption', 'Displacement')
(2) Transformation	Incumbents reorient incrementally by adjusting search routines and procedures	Incremental improvement in existing technologies (leading to major performance enhancement over long time period).	Limited institutional change ('Layering')
		Incorporation of symbiotic niche-innovations and add-ons (competence-adding, creative accumulation)	
	Incumbents reorient substantially, to radically new technology or, even more deeply, to new beliefs, mission, and business model	Reorientation towards new technologies: (a) partial reorientation (diversification) with incumbents developing both old and new technologies (b) full reorientation, leading to technical substitution	Substantial change in institutions ('Conversion', 'Displacement')
(3) Reconfiguration	New alliances between incumbents and new entrants	From initial add-ons to new combinations between new and existing technologies; knock-on effects and innovation cascades that change system architecture.	From limited institutional change ('Layering') to more substantial change, including operational principles ('Drift', 'Conversion')
(4) De-alignment and re-alignment	Incumbents collapse because of landscape pressure, creating opportunities for new entrants	Decline of old technologies creates space for several innovations which compete with one another	Institutions are disrupted by shocks and replaced, possibly after prolonged uncertainty ('Disruption')

Table A5. Typology of Socio-technical Transition Pathways

Adapted from Geels (2016, Table 2). Outlines five transition pathways, reproduction, transformation, substitution, reconfiguration, and de-alignment and re-alignment, based on variation in landscape pressure, niche maturity, and regime response. Each pathway is characterised by different combinations of technological innovation, actor dynamics (e.g., incumbents vs. new entrants), and institutional change. Highlights how transitions unfold under varying conditions of resistance, agency, and structural openness, offering a framework to analyse regime decline trajectories in response to governance innovation.

References

Acientistaagricola. (2019, October 16). Como preparar a calda bordalesa: Conheça a receita desta solução. A Cientista Agricola. https://acientistaagricola.pt/2019/10/16/como-preparar-a-calda-bordalesa/

Al Jazeera. (2024, June 17). EU states push past opposition to adopt landmark nature restoration law. Al Jazeera. https://www.aljazeera.com/news/2024/6/17/eu-states-push-past-opposition-to-adopt-landmark-nature-restoration-law

Ali, M., Raza, S. A., Puah, C. H., & Amin, H. (2019). Consumer acceptance toward takaful in Pakistan: An application of diffusion of innovation theory. International Journal of Emerging Markets, 14(4), 620–638. https://doi.org/10.1108/IJOEM-08-2017-0275

Appunn, K. (2021, March 5). EU's Farm to Fork strategy impacts climate, productivity, and trade. Clean Energy Wire. https://www.cleanenergywire.org/factsheets/eus-farm-fork-strategy-impacts-climate-productivity-and-trade

Atasu, A., Duran, S., & Wassenhove, L. N. V. (2021, June 18). The Dark Side of Solar Power. Harvard Business Review. https://hbr.org/2021/06/the-dark-side-of-solar-power

Aubert, G., & Underwood, E. (2024, July 15). The Nature Restoration Law – A hard-fought victory for biodiversity and society. IEEP AISBL. https://ieep.eu/publications/the-nature-restoration-law-a-hard-fought-victory-for-biodiversity-and-society/

Augère-Granier, M.-L. (2019). The EU poultry meat and egg sector: Main features, challenges and prospects | Policy Commons. https://policycommons.net/artifacts/1337506/the-eu-poultry-meat-and-egg-sector/1945404/

Bailey, I. (2023, August 3). Understanding the targets of the EU Nature Restoration law. SLR Consulting. https://www.slrconsulting.com/insights/understanding-the-eu-nature-restoration-law-which-targets-made-the-final-vote/

Bayer CropScience. (2024, August 6). Bayer Q2 2024 results: Modest performance in challenging agricultural market environment – Group outlook confirmed. Grainews. https://news.agropages.com/News/Detail-51015.htm

Bengtsson, J. (2016). How Agricultural Intensification Affects Biodiversity and Ecosystem Services. Advances in Ecological Research. https://www.academia.edu/113002746/How_Agricultural_Intensification_Affects_Biodiversity_and_Ecosystem_Services

Bento, N., Nuñez-Jimenez, A., & Kittner, N. (2025). Decline processes in technological innovation systems: Lessons from energy technologies. Research Policy, 54(3), 105174-. https://doi.org/10.1016/j.respol.2025.105174

Bergek, A., Hekkert, M., Jacobsson, S., Markard, J., Sandén, B., & Truffer, B. (2015). Technological innovation systems in contexts: Conceptualizing contextual structures and interaction dynamics. Environmental Innovation and Societal Transitions, 16, 51–64. https://doi.org/10.1016/j.eist.2015.07.003

Bergek, A., Jacobsson, S., Carlsson, B., Lindmark, S., & Rickne, A. (2008). Analyzing the functional dynamics of technological innovation systems: A scheme of analysis. Research Policy, 37(3), 407–429. https://doi.org/10.1016/j.respol.2007.12.003

Bilyard, L. (2023, October 2). Leading environmental organisations call for national roadmap to accelerate ecosystem restoration. Greening Australia. https://www.greeningaustralia.org.au/restoration-decade-alliance-national-roadmap/

BirdLife International. (2023, April 19). Press release: Beyond short-term profit - businesses call for a strong Nature Restoration Law. BirdLife International. https://www.birdlife.org/news/2023/04/19/press-release-beyond-short-term-profit-businesses-call-for-a-strong-nature-restoration-law/

BirdLife International. (2024, June 17). Historic win for EU's nature: EU Council seals the deal on Nature Restoration Law. BirdLife International. https://www.birdlife.org/news/2024/06/17/historic-win-for-eus-nature-eu-council-seals-the-deal-on-nature-restoration-law/

Borrás, S., & Edquist, C. (2013). The choice of innovation policy instruments. Technological Forecasting and Social Change, 80(8), 1513–1522. https://doi.org/10.1016/j.techfore.2013.03.002

Brzeziński, B. (2023, November 22). Conservative backlash kills off EU's Green Deal push to slash pesticide use. POLITICO. https://www.politico.eu/article/european-parliament-kills-off-landmark-pesticide-reduction-bill/

Bueren, E. T. L. can, Jones, S. S., Tamm, L., Murphy, K. M., Myers, J. R., Leifert, C., & Messmer, M. M. (2011). The need to breed crop varieties suitable for organic farming, using wheat, tomato and broccoli as examples: A review. NJAS: Wageningen Journal of Life Sciences, 58(3–4), 193–205. https://doi.org/10.1016/j.njas.2010.04.001

Cagney, D. (2024, March 25). Environment ministers rally to save nature restoration law—But Hungary remains defiant. Euractiv. https://www.euractiv.com/section/biodiversity/news/environment-ministers-rally-to-save-nature-restoration-law-but-hungary-remains-defiant/

Carlile, C. (2023, June 14). Scientists Condemn 'Misinformation' Used to Attack EU Reforms to Protect Nature. DeSmog. https://www.desmog.com/2023/06/14/scientists-condemn-misinformation-used-to-attack-eu-reforms-to-protect-nature/

Carlile, C., & Healy, H. (2022, December 9). Flagship EU Green Farming Reforms in Peril as Lobbyists Exploit Ukraine War. DeSmog. https://www.desmog.com/2022/12/09/eu-farming-reforms-pesticides-targets-in-peril-lobbyists-exploit-ukraine-war/

Casert, R. (2024, April 18). Frustrated farmers are rebelling against EU rules. The far right is stoking the flames. AP News. https://apnews.com/article/europe-democracy-farmers-protest-green-deal-elections-a0278919b2fe47c7476c0c56ccf4850b

CEMA. (2025, April 8). CEMA - European Agricultural Machinery—European tractor registrations at 10-year low in 2024. https://www.cema-agri.org/publications/18-news-publications/1093-european-tractor-registrations-at-10-year-low-in-2024-1

Ciccarese, L., Daffinà, R., & Silli, V. (2024, December 31). FARMS ADOPTING ENVIRONMENTALLY FRIENDLY MEASURES AND PRACTICING ORGANIC FARMING | Indicatori ambientali. https://indicatoriambientali.isprambiente.it/en/agriculture/farms-adopting-environmentally-friendly-measures-and-practicing-organic-farming?utm_source=chatgpt.com

ClientEarth. (2024, June 27). Glyphosate: EU Commission rejects request to cancel re-approval, NGOs go to EU court | ClientEarth. https://www.clientearth.org/latest/press-office/press-releases/glyphosate-eu-commission-rejects-request-to-cancel-re-approval-ngos-go-to-eu-court/

COPA-COGECA. (2020). Copa and Cogeca Position on the Farm to Fork Strategy. https://www.copa-cogeca.eu/publications

D. T. E. Staff. (2023, July 12). European Parliament passes nature restoration law with 336 votes in favour, 300 against. Down To Earth. https://www.downtoearth.org.in/environment/european-parliament-passes-nature-restoration-law-with-336-votes-in-favour-300-against-90587

Darnhofer, I., Schermer, M., Steinbacher, M., Gabillet, M., & Daugstad, K. (2017). Preserving permanent mountain grasslands in Western Europe: Why are promising approaches not implemented more widely? Land Use Policy, 68, 306–315. https://doi.org/10.1016/j.landusepol.2017.08.005

Diaz, M., Darnhofer, I., Darrot, C., & Beuret, J.-E. (2013). Green tides in Brittany: What can we learn about niche–regime interactions? Environmental Innovation and Societal Transitions, 8, 62–75. https://doi.org/10.1016/j.eist.2013.04.002

Directorate-General for Climate Action. (2023, November 13). Looking at how to mitigate emissions from agriculture. https://climate.ec.europa.eu/news-your-voice/news/looking-how-mitigate-emissions-agriculture-2023-11-13_en

Directorate-General for Environment & European Commission. (2020). Pollinators: Importance for nature and human well-being, drivers of decline and the need for monitoring. https://data.europa.eu/doi/10.2779/070

Domingo, G. C., Underwood, E., Aubert, G., & Baroni, L. (2022). The proposed EU Nature Restoration Regulation: The path to nature's recovery.

Don, M. (2025, January 10). How Nitrates Increase Plant Growth. OgGardenOnline.Com. https://oggardenonline.com/how-nitrates-promote-the-growth-of-plants.html

Driessen, P. P. J., Dieperink, C., van Laerhoven, F., Runhaar, H. A. C., & Vermeulen, W. J. V. (2012). Towards a Conceptual Framework for The Study of Shifts in Modes of Environmental Governance—Experiences From The Netherlands. Environmental Policy and Governance, 22(3), 143–160. https://doi.org/10.1002/eet.1580

Dróżdż, D., Wystalska, K., Malińska, K., Grosser, A., Grobelak, A., & Kacprzak, M. (2020). Management of poultry manure in Poland – Current state and future perspectives. Journal of Environmental Management, 264, 110327–110327. https://doi.org/10.1016/j.jenvman.2020.110327

Dupraz-Dobias, P. (2018, September 5). France bans all uses of neonicotinoid pesticides, outpacing European Union measure. C&en. https://cen.acs.org/environment/pesticides/France-bans-uses-neonicotinoid-pesticides/96/i36

Dwyer, O. (2024, February 5). Analysis: How do the EU farmer protests relate to climate change? Carbon Brief. https://www.carbonbrief.org/analysis-how-do-the-eu-farmer-protests-relate-to-climate-change/

EC. (2019). Communication on The European Green Deal—European Commission. https://commission.europa.eu/publications/communication-european-green-deal_en

EPP. (2023, May 31). EPP Group withdraws from negotiations on nature restoration law. https://www.eppgroup.eu/newsroom/epp-group-withdraws-from-negotiations-on-nature-restoration

Erdenesanaa, D. (2023, December 7). Climate Change Makes East Africa's Deadly Floods Worse, Study Finds. The New York Times. https://www.nytimes.com/2023/12/07/climate/climate-change-flooding-east-africa.html

Eurobarometer. (2024). Attitudes of Europeans towards the environment—May 2024—- Eurobarometer survey. https://europa.eu/eurobarometer/surveys/detail/3173?s=03

Euronews. (2022, July 18). Nearly half of EU exposed to 'warning' drought levels, report says. Euronews. https://www.euronews.com/my-europe/2022/07/18/nearly-half-of-eu-exposed-to-warning-drought-levels-report-says

European Centre for Disease Prevention and Control. (2024, June 4). Dengue worldwide overview. https://www.ecdc.europa.eu/en/dengue-monthly

European Commission. (2019). Market analyses and briefs—European Commission. https://agriculture.ec.europa.eu/cap-my-country/performance-agricultural-policy/studies-and-reports/analytical-briefs/market-analyses-and-briefs_en

European Commission. (2025a, March 13). Innovations in 'green' ammonia production. CORDIS | European Commission. https://cordis.europa.eu/article/id/457205-innovations-in-green-ammonia-production

European Commission. (2025b, April 24). Pollinators—European Commission. https://environment.ec.europa.eu/topics/nature-and-biodiversity/pollinators_en

European Environmental Agency. (2025, June 18). Reversing pollinator decline: Why Europe must act now. https://www.eea.europa.eu/en/newsroom/news/reversing-pollinator-decline-why-europe-must-act-now

European Greens. (2024, May 23). A battle against the far right, and for the Green Deal. European Greens. https://europeangreens.eu/news/a-battle-against-the-far-right-and-for-the-green-deal/

European Parliament. (2009, October 21). Directive—2009/128—EN - EUR-Lex. https://eur-lex.europa.eu/eli/dir/2009/128/oj/eng

European Parliament. (2023, November 22). No majority in Parliament for legislation to curb use of pesticides | News | European Parliament. https://www.europarl.europa.eu/news/en/press-room/20231117IPR12215/no-majority-in-parliament-for-legislation-to-curb-use-of-pesticides

Eurostat. (2024a, May). Agri-environmental indicator—Consumption of pesticides. https://ec.europa.eu/eurostat/statistics-explained/index.php?title=Agri-environmental_indicator_-_consumption_of_pesticides

Eurostat. (2024b, May). Performance of the agricultural sector. https://ec.europa.eu/eurostat/statistics-explained/index.php?title=Performance_of_the_agricultural_sector

Eurostat. (2024c, June 28). Use of fertilisers in EU agriculture down 10% in 2022. https://ec.europa.eu/eurostat/web/products-eurostat-news/w/ddn-20240628-1

FAO. (2022a). Soil Heath—Biological and Chemical | FAO SOILS PORTAL | Food and Agriculture Organization of the United Nations. https://www.fao.org/soils-portal/soil-degradation-restoration/global-soil-health-indicators-and-assessment/soil-heath-biological-and-chemical/en/?utm_source=chatgpt.com

FAO. (2022b). The future of food and agriculture – Drivers and triggers for transformation. FAO ; https://openknowledge.fao.org/handle/20.500.14283/cc0959en

Fertilizer Europe. (2023). Fertilizer Industry Facts and Figures 2023. https://www.fertilizerseurope.com/publications/

FiBL, R. I. of O. A. (2025, February 11). Almost 11 percent of agricultural land in the European Union is organically farmed. https://www.fibl.org/en/info-centre/news/almost-11-percent-agricultural-land-eu-organically-farmed

Food and Agriculture Organization of the United Nations. (2023). Food Outlook – Biannual report on global food markets 2023 | FAO. https://www.fao.org/family-farming/detail/en/c/1643117/

Foote, N. (2023, July 10). Timmermans: EU climate goals 'hinge on' success of nature restoration law. Euractiv. https://www.euractiv.com/section/agriculture-food/news/timmermans-eu-climate-goals-hinge-on-success-of-nature-restoration-law/

Fuenfschilling, L., & Truffer, B. (2014). The structuration of socio-technical regimes—Conceptual foundations from institutional theory. Research Policy, 43(4), 772–791. https://doi.org/10.1016/j.respol.2013.10.010

Garske, B., Heyl, K., & Ekardt, F. (2024). The EU Communication on ensuring availability and affordability of fertilisers—A milestone for sustainable nutrient management or a missed opportunity? Environmental Sciences Europe, 36(1), 19. https://doi.org/10.1186/s12302-024-00842-8

Geels, F. W. (2002). Technological transitions as evolutionary reconfiguration processes: A multi-level perspective and a case-study. Research Policy, 31(8), 1257–1274. https://doi.org/10.1016/S0048-7333(02)00062-8

Geels, F. W. (2005). Technological transitions and system innovations: A co-evolutionary and socio-technical analysis. Elgar.

Geels, F. W., Kern, F., Fuchs, G., Hinderer, N., Kungl, G., Mylan, J., Neukirch, M., & Wassermann, S. (2016). The enactment of socio-technical transition pathways: A reformulated typology and a comparative multi-level analysis of the German and UK low-carbon electricity transitions (1990–2014). Research Policy, 45(4), 896–913. https://doi.org/10.1016/j.respol.2016.01.015

Geels, F. W. (2020). Micro-foundations of the multi-level perspective on socio-technical transitions: Developing a multi-dimensional model of agency through crossovers between social constructivism, evolutionary economics and neo-institutional theory. Technological Forecasting & Social Change, 152, 119894-. https://doi.org/10.1016/j.techfore.2019.119894

Geels, F. W. (2024). Advanced introduction to sustainability transitions. Edward Elgar Publishing.

Geels, F. W. (2022). The Great Reconfiguration: A Socio-Technical Analysis of Low-Carbon Transitions in UK Electricity, Heat, and Mobility Systems. In The Great Reconfiguration (pp. iii–iii).

Geels, F. W., & Verhees, B. (2011). Cultural legitimacy and framing struggles in innovation journeys: A cultural-performative perspective and a case study of Dutch nuclear energy (1945–1986). Technological Forecasting & Social Change, 78(6), 910–930. https://doi.org/10.1016/j.techfore.2010.12.004

Giannoukou, E. (2023, July 11). Farmers protest in Strasbourg ahead of vote on nature restoration law. ΚΥΠΕ. https://www.cna.org.cy/article/5229088

Girard, L. (2024a, January 29). Why French farmers are continuing to protest. https://www.lemonde.fr/en/economy/article/2024/01/29/why-french-farmers-are-continuing-to-protest_6475144_19.html

Girard, L. (2024b, June 18). France's organic farmed land shrank for the first time in 2023. https://www.lemonde.fr/en/economy/article/2024/06/18/france-s-organic-farmed-land-shrunk-for-the-first-time-in-2023_6675100_19.html

Greenhalgh, T., Robert, G., Macfarlane, F., Bate, P., & Kyriakidou, O. (2004). Diffusion of Innovations in Service Organizations: Systematic Review and Recommendations. The Milbank Quarterly, 82(4), 581–629. https://doi.org/10.1111/j.0887-378X.2004.00325.x

Guo, J. H., Liu, X. J., Zhang, Y., Shen, J. L., Han, W. X., Zhang, W. F., Christie, P., Goulding, K. W. T., Vitousek, P. M., & Zhang, F. S. (2010). Significant Acidification in Major Chinese Croplands. Science, 327(5968), 1008–1010. https://doi.org/10.1126/science.1182570

Haahr, T. (2024, February 27). Nature restoration: Parliament adopts law to restore 20% of EU's land and sea | News | European Parliament. https://www.europarl.europa.eu/news/en/press-room/20240223IPR18078/nature-restoration-parliament-adopts-law-to-restore-20-of-eu-s-land-and-sea

Hausfather, Z. (2024, April 4). Factcheck: Why the recent 'acceleration' in global warming is what scientists expect. Carbon Brief. https://www.carbonbrief.org/factcheck-why-the-recent-acceleration-in-global-warming-is-what-scientists-expect/

Hekkert, M. P., Suurs, R. A. A., Negro, S. O., Kuhlmann, S., & Smits, R. E. H. M. (2007). Functions of innovation systems: A new approach for analysing technological change. Technological Forecasting and Social Change, 74(4), 413–432. https://doi.org/10.1016/j.techfore.2006.03.002

International Agency for Research on Cancer. (2015, March 20). IARC Monographs Volume 112: Evaluation of five organophosphate insecticides and herbicides. https://www.iarc.who.int/news-events/iarc-monographs-volume-112-evaluation-of-five-organophosphate-insecticides-and-herbicides

International Renewable Energy Agency. (2016, June 1). End-of-life management Solar Photovoltaic Panels. https://www.irena.org/publications/2016/Jun/End-of-life-management-Solar-Photovoltaic-Panels

Kannan, M., Elavarasan, G., Balamurugan, A., Dhanusiya, B., & Freedon, D. (2022). Hydroponic farming – A state of art for the future agriculture. Materials Today: Proceedings, 68, 2163–2166. https://doi.org/10.1016/j.matpr.2022.08.416

Köhler, J., Geels, F. W., Kern, F., Markard, J., Onsongo, E., Wieczorek, A., Alkemade, F., Avelino, F., Bergek, A., Boons, F., Fünfschilling, L., Hess, D., Holtz, G., Hyysalo, S., Jenkins, K., Kivimaa, P., Martiskainen, M., McMeekin, A., Mühlemeier, M. S., … Wells, P. (2019). An agenda for sustainability transitions research: State of the art and future directions. Environmental Innovation and Societal Transitions, 31, 1–32. https://doi.org/10.1016/j.eist.2019.01.004

Krzysztoszek, A. (2023, July 14). Polish politicians slam Nature Restoration Law over potential agriculture consequences. Euractiv. https://www.euractiv.com/section/politics/news/polish-politicians-slam-nature-restoration-law-over-potential-agriculture-consequences/

Kuhnert, H. (2024, July 24). en: Organic farming in figures. https://www.thuenen.de/en/thuenen-topics/organic-farming/aktuelle-trends-der-deutschen-oekobranche/oekolandbau-in-zahlen?utm_source=chatgpt.com

Kun, Z. (2024, February 28). Nature Restoration Law passed – lessons for the future. Wild Europe. https://www.wildeurope.org/nature-restoration-law-passed-lessons-for-the-future/

Lalor, C. O. (2024, October 7). Geo explainer: What is phosphate mining – and why is it important? - Geographical. https://geographical.co.uk/news/geo-explainer-what-is-phosphate-mining-and-why-is-it-important

Leeuw, B. J. de, & Backes, C. W. (2024). The Non-Deterioration Obligation in the Nature Restoration Regulation – a Necessary and Proportionate Addition to the Habitats Directive or a Monstrosity with Disastrous Consequences for Society? https://doi.org/10.1163/18760104-21010004

Lessley, B. J. (1978). KEYBOARD RETRAINING: QWERTY TO DVORAK [ProQuest Dissertations & Theses]. https://www.proquest.com/docview/302903967/abstract/

Loorbach, D., Frantzeskaki, N., & Avelino, F. (2017). Sustainability Transitions Research: Transforming Science and Practice for Societal Change. Annual Review of Environment and Resources, 42(1), 599–626. https://doi.org/10.1146/annurev-environ-102014-021340

Malingre, V. (2024, January 29). Europe's Green Deal is attacked on all sides. https://www.lemonde.fr/en/environment/article/2024/01/29/europe-s-green-deal-is-attacked-on-all-sides_6474382_114.html

Markard, J., Bento, N., Kittner, N., & Nuñez-Jimenez, A. (2020). Destined for decline? Examining nuclear energy from a technological innovation systems perspective. Energy Research & Social Science, 67, 101512. https://doi.org/10.1016/j.erss.2020.101512

McCray, N. (2023, February 12). 12 Pros & Cons of Hydroponic Farming. Earth.Org. https://earth.org/hydroponic-farming/

Meadowcroft, J. (2009). What about the politics? Sustainable development, transition management, and long term energy transitions. Policy Sciences, 42(4), 323–340. https://doi.org/10.1007/s11077-009-9097-z

Mick Wallance. (2023, June 6). FG is distorting EU nature restoration law. The Irish Times. https://www.irishtimes.com/opinion/letters/2023/06/06/fg-is-distorting-eu-nature-restoration-law/

Miklasińska, O. (2023, May 25). AGRI and PECH committees voted for a full rejection of the Commission's proposal for the EU Nature Restoration Law. WWF. https://wwfcee.org/news/agri-and-pech-committees-voted-for-a-full-rejection-of-the-commissions-proposal-for-the-eu-nature-restoration-law

NIAMH. (2024, April 22). Biocontrol market now worth 1.6 billion Euro, but EU policies are a bottleneck to unlocking full potential. IBMA-GLOBAL. https://ibma-global.org/press-releases/biocontrol-market-now-worth-over-1-6-billion-euro-but-eu-policies-a-bottleneck-to-unlocking-full-potential

Ohler, A. (2023, October 10). Hydroponic Growing Nutrients 101: The Complete Guide. Bright Lane Gardens. https://brightlanegardens.com/hydroponic-growing-nutrients/

Our World in Data. (2023, October 31). Methane emissions from agriculture. Our World in Data. https://ourworldindata.org/grapher/methane-emissions-agriculture

Ozer, M., & Tang, J. W. (2019). Understanding the trade-off between familiarity and newness in product innovation. Industrial Marketing Management, 77, 116–128. https://doi.org/10.1016/j.indmarman.2018.11.016

PAN Europe. (2024, October 1). Conference calls for better protection of citizens health and biodiversity against pesticides. PAN Europe. https://www.pan-europe.info/blog/conference-calls-better-protection-citizens-health-and-biodiversity-against-pesticides

Paris, B., Vandorou, F., Balafoutis, A. T., Vaiopoulos, K., Kyriakarakos, G., Manolakos, D., & Papadakis, G. (2022). Energy use in open-field agriculture in the EU: A critical review recommending energy efficiency measures and renewable energy sources adoption. Renewable and Sustainable Energy Reviews, 158, 112098. https://doi.org/10.1016/j.rser.2022.112098

Pe'er, G., Kachler, J., Herzon, I., Hering, D., Arponen, A., Bosco, L., Bruelheide, H., Friedrichs-Manthey, M., Hagedorn, G., Hansjürgens, B., Ladouceur, E., Lakner, S., Liquete, C., Quaas, M., Robuchon, M., Saavedra, D., Selva, N., Settele, J., Sirami, C., … Bonn, A. (2023). Scientists support the EU's Green Deal and reject the unjustified argumentation against the Sustainable Use Regulation and the Nature Restoration Law. Zenodo. https://doi.org/10.5281/zenodo.8128624

Peneva, M., Draganova, M., Gonzalez, C., Diaz, M., & Mishev, P. (2014). High nature value farming: Environmental practices for rural sustainability (pp. 97–111). https://doi.org/10.1079/9781780642192.0097

Pinto-Correia, T., Gonzalez, C., Sutherland, L.-A., & Peneva, M. (2014). Lifestyle farming: Countryside consumption and transition towards new farming models (pp. 67–81). https://doi.org/10.1079/9781780642192.0067

Proposal for a Regulation of the European Parliament and of the Council on Nature Restoration (2022). https://eur-lex.europa.eu/legal-content/EN/ALL/?uri=CELEX:52022PC0304

Quintana, A. (2025, February 21). España retoma el liderazgo europeo en superficie ecológica. EFEAgro. https://efeagro.com/espana-lidera-superficie-ecologica-ue/

Richa, A., Touil, S., Fizir, M., & Martinez, V. (2020). Recent advances and perspectives in the treatment of hydroponic wastewater: A review. Reviews in Environmental Science and Bio/Technology, 19(4), 945–966. https://doi.org/10.1007/s11157-020-09555-9

Rip, A., & Kemp, R. (1998). Technological Change. In: Rayner S., Malone E.L. (editors). Social Science & Medicine - SOC SCI MED, 327–399.

Rogers, E. M. (1983). Diffusion of innovations (3rd ed.). Free Press.

Rogers, E. M. (2003). Diffusion of innovations (5th ed.). Free Press.

Rogers, E. M., & Bhowmik, D. K. (1970). Homophily-Heterophily: Relational Concepts for Communication Research. The Public Opinion Quarterly, 34(4), 523–538.

Röhm-Malcotti, E. (2023, July 18). EU Nature Restoration Law narrowly survives crucial vote. https://www.axpo.com/es/en/newsroom/magazine/renewable-energy/eu-nature-restoration-law-narrowly-survives-crucial-vote.html

Romania Observer. (2024, July 2). Agriculture: Organic agriculture represents 5% of Romania's agricultural area - Romania News. https://romaniaobserver.com/agriculture-organic-agriculture-represents-5-of-romanias-agricultural-area/

Romano, V. (2023, January 13). Lawmakers split over forestry in EU nature restoration law. Euractiv. https://www.euractiv.com/section/climate-environment/news/lawmakers-split-over-forestry-in-eu-nature-restoration-law/

Sánchez-Bayo, F., & Wyckhuys, K. A. G. (2019). Worldwide decline of the entomofauna: A review of its drivers. Biological Conservation, 232, 8–27. https://doi.org/10.1016/j.biocon.2019.01.020

Sartipi, F. (2020). Diffusion of Innovation Theory in the Realm of Environmental Construction. Journal of Construction Materials, 1, 4–6. https://doi.org/10.36756/JCM.v1.4.2

Savage, S., Fray, K., Hancock, A., & Pooler, M. (2024, August 22). The global power of Big Agriculture's lobbying. Financial Times.

Savage, S., & Win, T. L. (2023, June 29). The truth behind Europe's most powerful farmers lobby. POLITICO. https://www.politico.eu/article/copa-cogeca-farmering-lobby-europe/

Schiller, S., Gonzales, C., & Flanigan, S. (2020). More than just a factor in transition processes? The role of collaboration in agriculture. (pp. 83–96).

Scott, S. D., Plotnikoff, R. C., Karunamuni, N., Bize, R., & Rodgers, W. (2008). Factors influencing the adoption of an innovation: An examination of the uptake of the Canadian Heart Health Kit (HHK). Implementation Science, 3(1), 41. https://doi.org/10.1186/1748-5908-3-41

Silva, I. M. da. (2023, June 1). European farmers challenge current nature restoration proposal. Euronews. https://www.euronews.com/my-europe/2023/06/01/european-farmers-challenge-current-nature-restoration-proposal

Singh, S., Anil, A. G., Kumar, V., Kapoor, D., Subramanian, S., Singh, J., & Ramamurthy, P. C. (2022). Nitrates in the environment: A critical review of their distribution, sensing techniques, ecological effects and remediation. Chemosphere, 287, 131996. https://doi.org/10.1016/j.chemosphere.2021.131996

Smith, A., & Raven, R. (2012). What is protective space? Reconsidering niches in transitions to sustainability. Research Policy, 41(6), 1025–1036. https://doi.org/10.1016/j.respol.2011.12.012

Staletovich, J. (2018, July 13). What's an algae bloom and how did it wind up sliming Florida's biggest lake? Miami Herald. https://www.miamiherald.com/news/local/environment/article214620390.html

Statista. (2025, February 24). EU member states: Population 2024-2050. Statista. https://www.statista.com/statistics/253383/total-population-of-the-eu-member-states-by-country/

Stöckl, B. (2023, July 13). Dutch farmers' association slams EU Nature Restoration law. Euractiv. https://www.euractiv.com/section/politics/news/dutch-farmers-association-slams-eu-nature-restoration-law/

Sutherland, L.-A. (2014). Transition pathways towards sustainability in agriculture: Case studies from Europe. CABI.

Sutherland, L.-A., Madureira, L., Elzen, B., Noble, C., Bechtet, N., Townsend, L., Zarokosta, E., & Triboulet, P. (2022). What Can We Learn from Droppers and Non-adopters About the Role of Advice in Agricultural Innovation? EuroChoices, 21(1), 40–49. https://doi.org/10.1111/1746-692X.12353

Syngenta Group. (2024, August 29). Syngenta Group Reports H1 2024 Earnings | Syngenta Group. https://www.syngentagroup.com/newsroom/2024/syngenta-group-reports-h1-2024-earnings-0

The Associated Press. (2024, January 21). Tens of thousands protest in Germany against the rise of the far right. NPR. https://www.npr.org/2024/01/21/1225882007/tens-of-thousands-protest-in-germany-against-the-rise-of-the-far-right

The International Energy Agency. (2025, February 14). Growth in global electricity demand is set to accelerate in the coming years as power-hungry sectors expand—News. IEA. https://www.iea.org/news/growth-in-global-electricity-demand-is-set-to-accelerate-in-the-coming-years-as-power-hungry-sectors-expand

The Irish Times. (n.d.). The Irish Times view on the EU nature restoration law: A plan worth supporting. The Irish Times. Retrieved 1 May 2025, from https://www.irishtimes.com/opinion/editorials/2023/06/19/the-irish-times-view-on-the-eu-nature-restoration-law-a-plan-worth-supporting/

The WildLife Trusts. (2021, September 15). New report reveals pollution is biggest threat to wildlife on our waterways | The Wildlife Trusts. https://www.wildlifetrusts.org/news/new-report-reveals-pollution-biggest-threat-wildlife-our-waterways

Tidey, A. (2023, November 16). Brussels allows use of glyphosate across EU for 10 more years after member states fail to reach deal | Euronews. https://www.euronews.com/my-europe/2023/11/16/brussels-allows-use-of-glyphosate-across-eu-for-10-more-years-after-member-states-fail-to-

TODAY, G. H. U. (n.d.). Egg prices to increase by more than 40% in 2025, according to USDA report. USA TODAY. Retrieved 3 July 2025, from https://www.usatoday.com/story/money/food/2025/02/26/egg-prices-to-rise-2025-usda/80452571007/

UNEP. (2021, August 20). Methane emissions are driving climate change. Here's how to reduce them. https://www.unep.org/news-and-stories/story/methane-emissions-are-driving-climate-change-heres-how-reduce-them

United Nations. (2024). Background—Desertification Day. United Nations; United Nations. https://www.un.org/en/observances/desertification-day/background

United Nations Statistics Division. (2024, June 28). The Sustainable Development Goals Report 2024. https://unstats.un.org/sdgs/report/2024/Goal-15/

Vaarst, M., Steenfeldt, S., & Horsted, K. (2015). Sustainable development perspectives of poultry production. World's Poultry Science Journal, 71(4), 609–620. https://doi.org/10.1017/S0043933915002433

Vela, J. H. (2023, June 27). EPP's Manfred Weber vows to vote down EU nature law. POLITICO. https://www.politico.eu/article/epp-manfred-weber-vows-vote-down-eu-nature-restoration-law-european-parliament/

Voss, J.-P., Bauknecht, D., & Kemp, R. (2006). Reflexive governance for sustainable development. Edward Elgar.

Voß, J.-P., & Bornemann, B. (2011). The Politics of Reflexive Governance: Challenges for Designing Adaptive Management and Transition Management. Ecology and Society, 16(2), 9-. https://doi.org/10.5751/es-04051-160209

Voß, J.-P., Smith, A., & Grin, J. (2009). Designing long-term policy: Rethinking transition management. Policy Sciences, 42(4), 275–302. https://doi.org/10.1007/s11077-009-9103-5

Wagner, S. C. (2011). Biological Nitrogen Fixation | Learn Science at Scitable. https://www.nature.com/scitable/knowledge/library/biological-nitrogen-fixation-23570419/

Wehrmann, B. (2024, January 9). Q&A – How are farmers' protests in Germany linked to climate policy? Clean Energy Wire. https://www.cleanenergywire.org/factsheets/qa-how-are-farmers-protests-germany-linked-climate-policy

Wellin, E. (1955). Wellin: Water boiling in a Peruvian town—Google Scholar. https://scholar.google.com/scholar_lookup?title=Water%20boiling%20in%20a%20Peruvian%20town&publication_year=1955&author=E.%20Wellin

WeMove Europe. (2023, April). Bring back nature in Europe now! WeMove Europe. https://action.wemove.eu/sign/2023-04-restore-nature-petition-EN

World Weather Attributor. (2023, December 7). Compounding natural hazards and high vulnerability led to severe impacts from Horn of Africa flooding exacerbated by climate change and Indian Ocean Dipole – World Weather Attribution. https://www.worldweatherattribution.org/climate-change-indian-ocean-dipole-compounding-natural-hazards-and-high-vulnerability-increased-severity-of-flooding-in-the-horn-of-africa/