Getting unstuck

Transformation to sustainable agriculture in the Netherlands

Niko Wojtynia

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I dedicate this thesis to my grandmothers Gisela and Lisa, who I credit with planting the seed for my interest in food and agriculture. Your magic in the kitchen, excursions to the chicken coop, and cellars full of mason jars are among my fondest memories.

Table of Contents

Preface	The promise and premise of regenerative agriculture	**10**
Chapter one	Introduction	**13**
Chapter two	Five mechanisms blocking the transition towards 'nature-inclusive' agriculture: a systemic analysis of Dutch dairy farming	**33**
Chapter three	A new green revolution or agribusiness as usual? Uncovering alignment issues and potential transition complications in agri-food system transitions	**61**
Chapter four	Spheres of transformation: exploring personal, political and practical drivers of farmer behaviour change in the Netherlands	**87**
Chapter five	Learning and design for regional farming system transformations	**107**
Chapter six	Conclusions and reflections	**135**
References		**157**
Appendices	Appendix to chapter two: Table of workshop participants and activities	**177**
	Appendix to chapter four (A): Farm and farmer characteristics	**177**
	Appendix to chapter four (B): Regenerative farming themes	**178**
	Appendix to chapter four (C): Interview questions	**179**
Summary		**181**
Samenvatting		**182**
Acknowledgements		**183**
About the author		**184**

Preface: the promise and premise of regenerative agriculture

At a time when the alarm bells about the future of our planet are ringing louder than ever, the promise of a way of farming that can "reverse climate change" has a strong appeal. These were the words of Allan Savory, a Zimbabwean biologist and farmer, who in 2013 gave a TED-talk about regenerative agriculture. Savory claimed that livestock farming in a "Holistic Management" grazing regimen, which mimics the way wild herbivores used to roam in nature, "can take enough carbon out of the atmosphere and safely store it in the grassland soils for thousands of years" to effectively halt and reverse global warming (Allan Savory, 2013).

Epic narratives and groundbreaking promises like Savory's have the power to create great interest in alternative ways of farming in popular and practitioner circles (Cabral & Sumberg, 2022). In the United States and Australia, regenerative farming has found an increasing number of followers (Regenerative Farmers of America, n.d.). Popular documentary movies like "The Biggest Little Farm" and "Kiss the Ground", released in 2018 and 2020 respectively, have gained a wide audience around the globe. Major agribusiness actors have also adopted the term in their sustainability strategies (Arla, n.d.; Danone, n.d.; General Mills, n.d.). However, the scientific premise of regenerative agriculture had been thinly substantiated until recently. By the end of 2019, only twenty-eight academic papers had provided some definition of the term (Schreefel et al., 2020), and the efficacy and universal applicability of Holistic Management have been scrutinized and refuted (Briske et al., 2013; Giller et al., 2021; Gosnell et al., 2020; Newton et al., 2020).

Regenerative agriculture was not a well-known term and only had a niche following in North-West Europe, where agriculture's impacts on environment and society are acute (more on this in the **introduction**). How could regenerative agriculture alleviate these pressures in the context of the region's maritime temperate climates, spanning from Ireland to the North German Plain and from the Southern tip of Norway to the Garonne in France? How can this way of farming be applied in a specific agronomic, socioeconomic and cultural context? And how can this farming paradigm contribute to an overall shift in the way we produce food? These were the questions around which the Regenerative Farming project was structured.

The Regenerative Farming project I was involved in was a consortium of universities, think tanks, private sector actors and NGOs initiated in 2018. The project aimed to develop a long-term vision and a set of outcomes for regenerative farming in the Netherlands, assess current practices of regenerative farmers against those outcomes, identify how farming practices should change to realize those outcomes across scale levels, and develop transition pathways and scenarios to realize a regenerative farming system by 2050. Besides various other activities, it funded two PhDs, one investigating the biophysical and economic aspects of regenerative agriculture in the Netherlands, and another – the thesis you're reading – investigating the transition to regenerative agriculture from a social science perspective. We convened a group of twenty farmers in a learning network to assess farm-level outcomes against the set of requirements the project developed (Groot Koerkamp et al., 2021), and to instigate learning and knowledge exchange between farmers. The project aimed primarily to help practitioners realize regenerative outcomes in a transdisciplinary way of working (Popa et al., 2015) without prescribing certain practices or farming styles. This reflects the reality of our learning network, where most farmers apply a variety of farming practices that may or may not be characterized or labeled as regenerative.

As a social scientist in a context where the concept isn't yet well-established, my thesis is not exclusively focused on regenerative agriculture: other alternative ways of farming also contribute to making our food systems more sustainable, and likewise are not well-established. I take a broad scope of diverse farming styles, strategies, and philosophies to better understand modern farming's crisis and the potential for a transformation to more sustainable agriculture.

Chapter one

Introduction

1. Contours of the agri-environmental crisis

Today, more food is produced worldwide than ever before, owing to improvements in productivity and expansion of cultivated land. Yet, the way food is grown has serious negative consequences for ecosystems and society, and threatens the viability of agricultural production itself (IPCC, 2022; S. Díaz et al., 2019). The aim of this thesis is to explore how the Netherlands, where the negative social and ecological consequences of agricultural production are acute, can move towards a more sustainable agricultural sector. This section describes the currently unsustainable situation globally and for the Netherlands, before outlining how agri-food systems came to be stuck in producing unprecedented amounts of food as well as causing considerable environmental and social damage. The UN Food and Agriculture Organization (FAO) defines agri-food systems as "the totality of actors involved in the production, distribution, and consumption of food, the relations between them, and the regulatory apparatus governing these arrangements" (2021). This thesis studies the Dutch agri-food system's sustainability transition with an interdisciplinary social science approach, blending sociology, human geography, entrepreneurship, innovation studies, political science, and science and technology studies. It attempts to answer two research questions. First, why is the Dutch agri-food system locked into producing unsustainable outcomes? Second, what can be done to break out of this lock-in? This introduction explains the agricultural sustainability crisis and diverse forms of lock-in as the motivation for my research and outlines the analytical approach for the rest of the thesis. It concludes with a summary of the chapters that form the main body of the thesis: an analysis of the Dutch dairy farming innovation system, an analysis of alignment between societal stakeholders on the future of Dutch agriculture, a study of farmers' strategies and motivations to follow alternative ways of farming, and an exploration of whether the redesign of an experimental demonstration farm has potential for bottom-up system change.

1.1. Overview: from insufficiency to abundance to excess

Agricultural productivity has increased enormously since humankind began to farm because of combined processes of intensification and expansion. Whereas foraging hunter-gatherers needed around 500 hectares to feed one person, farming societies of Ancient Egypt and Mesopotamia needed only one hectare to feed one person (Smil, 2019, p. 29). By the 19th century, intensive farming in fertile areas such as Southern China could feed as many as five people per hectare, which is the current global average. The number can exceed ten people per hectare in today's most productive farming systems (ibid). US wheat yields have increased from around 0.8 tons per hectare (t/ha) in 1866 to 3.1 t/ha today (Smil, 2019, p. 119) and global staple grain production quintupled in the past century (Smil, 2019, p. 391). Meanwhile, land under cultivation has also increased massively. Since 1700, global cropland has increased from 260 Mha to 1,500 Mha today, and grassland has increased from 500 Mha to 3,500 Mha over the same period (Smil, 2019, p. 386). More than a third of global arable land is now used to produce food (World Bank, 2018), trending upward until at least 2050 (Smil, 2019, p. 386).

These trends can be observed in the Netherlands as well. While 100 people working in agriculture fed 177 people around 1500, this increased to 277 by 1800 (Feng, 1998). Between 1810 and 1880, wheat and barley yields increased by 69%, while milk production per cow increased by 32%; over the same period, agricultural land grew from 1.796 million hectares to 2.015 million hectares (Feng, 1998). Today, these yields are another 241% and 276% higher, respectively (see also Figure 1).

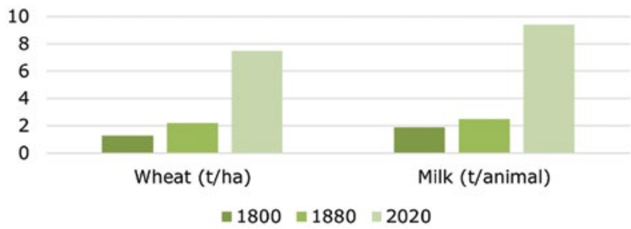

FIGURE 1 | Wheat and milk yields per annum in the Netherlands for the years 1800, 1880 and 2020 (Feng, 1998; Smit, 2020; H. Van der Meulen, 2020).

The intensification (productivity growth per hectare of cultivated land and per animal) and expansion (area growth) of farming were brought about by agronomic, technological, economic, and political changes. In the technological domain, we see crop and animal species that are specifically bred to yield far more than ancient cultivars. We also see farmers enable these crops and animals to reach their yield potential by using biocides, artificial fertilizers, and fossil-fuel powered machinery. In the economic domain, financing of the means of production – land, machinery, inputs, planting material, and livestock – allows farmers to deploy the aforementioned technologies before they have sold their harvests (both annually and long-term). From a macroeconomic perspective, prices are no longer set between farmers and consumers locally, but are instead determined internationally due to globalized trade and financialization. The conditions for these technological and economic changes have been created through political decision-making. Policies for the exploitation and consolidation of land for farming transformed ecosystems (by draining marshes or reclaiming land from the sea) and social relations (through voluntary, incentivized, and forced resettlements), and subsidies incentivized the growth and maintenance of agricultural output. In the Netherlands, these modernization processes can be illustrated by a 105-fold increase in artificial fertilizer imports after 1880, average annual gross production growth rates of 3.8%-4.6% between 1950 and 1980, and an average annual increase in the use of tractors and milk machines of 7.3% and 10.1% respectively between 1950 and 1979 (Feng, 1998). Average farm size increased from 5.7 hectares in 1950, to 13.9 hectares in 1980, to 32.4 hectares in 2016, while farm numbers declined from 410,000 to 55,000 over the same period (Feng, 1998;

Wageningen University and Research, 2018a). This average farm size includes all sectors; typical dairy and arable farms have an area of 59 and 63 hectares respectively. In terms of contribution to global food supply the Netherlands is not a major factor (see Figure 2); however, in Western Europe[1] it produces more than 40% of all tomatoes, and more than 10% of all potatoes, beef, poultry, pork, and milk. This accounts for the strong Dutch agricultural trade balance, second only to the USA worldwide. Western Europe in turn produces more than 9% of the world's potatoes, pork, and milk, and almost 30% of global sugar beet.

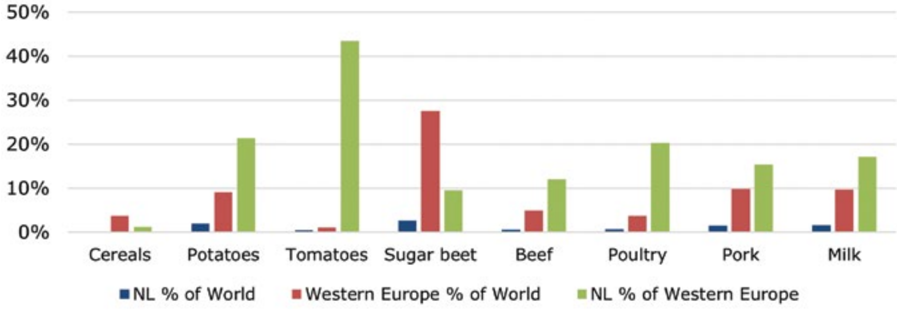

FIGURE 2 | Dutch contribution to World and Western European food supply in 2020 (FAO, 2022).

By virtue of its widespread land use and intensive production methods, modern agriculture contributes significantly to today's environmental and social crises. This manifests itself externally – outside of primary production sectors – as well as internally, threatening the very viability of producing enough food for a growing population.

1.2. External manifestations

The so-called "doughnut of social and planetary boundaries" framework illustrates the impacts of agriculture on environment and society (Fanning et al., 2022). This framework conceives of humankind needing to stay within planetary boundaries (Rockström et al., 2009) while providing sufficient social outcomes for a good life (Raworth, 2017). In other words, it conceives of sustainability as staying below an ecological "ceiling" while providing a decent "foundation" for a life free from deprivation (Fanning et al., 2022). It is composed of eleven social and nine biophysical indicators. Between 1992 and 2015, the share of countries worldwide improving on social indicators increased for six out of eleven indicators; on average, there has been a decline in biophysical indicators across the board.

The social indicators have been relatively stable for the Netherlands, falling just short of the threshold for Employment (% employed labor force) and Social Support (% population with family or friends they can depend on). The country overshoots all planetary boundaries (see Table 2); only Land-use change had been at or just under the boundary until 2011, trending slightly upwards over the boundary since

1 Austria, Belgium, France, Germany, Luxembourg, the Netherlands, and Switzerland.

then (Fanning et al., 2022). This is no surprise, given that agriculture occupies 60% of this densely populated country's land surface (Voskuilen, 2022). The above is further illustrated by the fact that 90% of Dutch habitats and 75% of species in the Netherlands exist in a mediocre or unfavorable state (IPBES, 2019).

TABLE 1 | Netherlands performance on biophysical planetary boundary indicators, with overall value for year 2015, share of agricultural sector, and country threshold (Bouma et al., 2020; Fanning et al., 2022).

Biophysical indicators (unit)	Value in 2015	Allocation agriculture	Threshold
CO_2 emissions (cumulative megatons since 1990)	11,093	16%	2,397
Phosphorus use (kg / capita / yr)	1.3	69%	0.8
Nitrogen (kg / capita / yr)	14.2	63%	8.4
Land-use change (t C embodied in biomass / capita)	2.6	-	2.4
Ecological footprint[2] (ha / capita)	6	30%	1.7
Material footprint (t used raw materials / capita)	26.7	-	6.8

There are also clear negative effects of farming on Dutch society. Particulate matter (PM) emissions have remained stable since 1990, and in 2019 agriculture accounted for just under a third of PM emissions (RIVM, n.d.). Exposure to these pollutants "increases the incidence of premature mortality from cardiovascular disease, cancer, and stroke" (Domingo et al., 2021, p. 1) and increases with proximity to livestock farming (RIVM, n.d.). A related issue is odor nuisance from livestock farming, affecting the subjective life experience in rural areas (Planbureau voor de Leefomgeving, 2019a). The aforementioned climatic effects of global warming, which can be attributed to agriculture to a considerable degree, have led to literal death and destruction: fourteen out of thirty heatwaves between 1901 and 2022 have occurred since 1990, leading to excess mortality of the elderly in particular (CBS, 2020; KNMI, 2022); and floods in the Southeast of the country in 2021 caused €1.8bn in property damage (NOS, 2021). Large fields of monoculture grass and crops – primarily maize for livestock feed – dominate landscapes and are perceived, together with large modern farm buildings, as a thorn in the eye of rural populations and those seeking recreation in the countryside; Dutch journalist Jantien de Boer even coined the term "landscape pain" to describe a "green desert" in rural areas (de Boer, 2019). An exodus of rural populations to urban centers, partly due to consolidation of farms and declining farmer numbers, leads to the erosion of rural social and cultural life and the decline of basic social services and amenities.

A number of the aforementioned environmental and social issues have come to a head in recent years and triggered economic and political upheaval. In 2019, the

2 This indicator "measures how much of the regenerative capacity of the biosphere is occupied by human demand" (Fanning et al., 2022, p. 33)we analyse the historical dynamics of 11 social indicators and 6 biophysical indicators across more than 140 countries from 1992 to 2015. We find that countries tend to transgress biophysical boundaries faster than they achieve social thresholds. The number of countries overshooting biophysical boundaries increased over the period from 32–55% to 50–66%, depending on the indicator. At the same time, the number of countries achieving social thresholds increased for five social indicators (in particular life expectancy and educational enrolment.

highest administrative court of the Netherlands declared the Dutch policy around permits for nitrogen emitting activities illegal. This has not only halted permits for farm expansions, but also tens of thousands of construction projects in a country with a housing shortage. Because livestock farming is the primary source of N emissions in the country, politicians and civil society organizations called for cutting livestock numbers to deal with the issue. This led to widespread and partly violent protests, as well as intimidation of politicians by radical farmers, testing Dutch democracy and societal cohesion (van der Ploeg, 2020). Proposals to tighten water protection regulations are projected to increase costs of Dutch farmers by up to 17%, which has the potential to cause further upheaval (Ecorys, 2021; European Commission, 2022b). These current and looming crises are emblematic of an agri-food system that is stuck, producing unsustainable outcomes that are increasingly difficult to deal with through existing institutions and policy frameworks.

1.3. Internal manifestations

It is clear that agriculture is the source of serious stresses on ecosystems and societies. However, the negative effects of today's farming system ultimately also affect its own sustainability: farming's environmental impacts on climate, soil and biodiversity undermine the conditions that are necessary to produce food. Climatic conditions are perhaps the most obvious of these. Changes in temperatures, both warming generally and in the form of weather extremes (acute cold spells and heatwaves), lead to crop failures and increased stress on livestock (Agovino et al., 2019; IPCC, 2022). Decreases in water availability threaten the productivity of 20% of croplands and 16% of grasslands in Europe (Fitton et al., 2019). More than half of agricultural land is affected by soil degradation as a consequence of erosion, loss of soil organic matter, salinization, over-application of fertilizer, acidification, loss of biodiversity, nutrient leaching and eutrophication; it is estimated that further degradation by 2045 could "reduce global food productivity by 12%, increasing food prices by 30%" (Kopittke et al., 2019, p. 3). Adverse impacts on biodiversity through habitat degradation and use of biocides is leading to a decline in insect numbers, threatening pollinator-dependent farming sectors (Fijen et al., 2019; IPBES, 2019).

Social impacts too threaten the viability of future farming. Most farmers, including in high-income countries, are stuck in a poverty or commodity trap: dependent on income from commodities whose prices are determined on global markets, they are exposed to high price risk and uncertainty, while dependent on expensive inputs and technology to produce these commodities (Tittonell & Giller, 2013). In the Netherlands, this is illustrated by an average debt per animal of €12,700 for dairy farmers (de Beer et al., 2019). Precarity, uncertainty and environmental changes are the drivers of a mental health crisis among farmers in the USA (Becot et al., 2019; Henning-Smith et al., 2022), Australia (Daghagh Yazd et al., 2020) the Netherlands (Kuijk et al., 2022) and elsewhere (Shah, 2012). Partly due to these "push factors" that make life as a farmer less appealing, and partly due to broader societal changes that "pull" young people into urban areas and other professions, farming sectors around the world have a succession problem. Already in 2012, a third of European farmers were older than 65, and only 5% of farmers in OECD countries were younger than 35 (Jöhr, 2012).

1.4. The Dutch and European agricultural policy landscape

As a member of the European Union (EU), the Netherlands is subject to EU law in the domain of food and agriculture. The main policy instrument is the Common Agricultural Policy (CAP). The CAP was initiated at the founding of the European Economic Community (EEC) in the 1957 Treaty of Rome. At the time, many European countries had much higher employment in farming than agriculture's contribution to GDP, and food insecurity during and shortly after World War Two was a popular concern (some countries still had food rationing). As a result, the initial purpose of the CAP was to increase agricultural productivity, increase farmer living standards, and assure a stable and affordable food supply (Harvey, 2015). The instruments were import tariffs and intervention purchases to buy surplus production. This was costly: the CAP accounted for more than 80% of the EEC budget. Another side-effect was considerable overproduction, leading to the infamous butter mountains and milk lakes. In the 1980s, overproduction was countered through quota on, among others, milk production. By the early 1990s, with the EU enlarged with the accessions of the UK, Denmark, the Iberian peninsula, and the fertile arable lands of East Germany, European agriculture had distorted global grain prices to such an extent that the World Trade Organization (WTO) exerted considerable pressure on EU CAP reform. This came in the guise of the 1992 MacSharry reform, which saw the intervention shift from internal market support to area and livestock headcount-based payments, which were conditional on taking some land out of production. These reforms allayed the concerns of the WTO (Harvey, 2015).

Throughout the 1990s, the environmental damage of high-input agriculture had become a political factor, and food safety and animal welfare became popular concerns due to foot and mouth disease and bovine spongiform encephalitis (BSE, popularly known as "mad cow disease") outbreaks. These concerns fed into the Fischler reform of the CAP in the mid-2000s, where the CAP was split in two "pillars": the first remained direct payments based on acreage and livestock headcount, while the second had the purpose of rural development and environmental conservation. In addition, pillar one payments were conditional on further compliance with food safety, public health, environmental, and animal welfare measures. The 2013 reform saw the abolition of sugar and dairy quotas, and yet more conditions for pillar one payments on pro-environmental measures (Harvey, 2015). Post-2020, the CAP has been reformed to include more flexibility in member states' use of funds, better targeting of funds for small farms and young farmers, and stricter conditionality of pillar one payments for environment and climate friendly farming (European Commission, 2022c).

Despite the 2013 and 2022 reforms, scholars still conclude that the CAP is not "fit for purpose" (Pe'er et al., 2020, 2022). Shortcomings include low efficiency of payment distribution, low coherence between member states, and insufficient impacts in turning the tide on environmental and climate change (Pe'er et al., 2017). At EU and national level, long-term strategic plans have been drawn up to address these shortcomings. The EU Farm to Fork strategy for example foresees a 50% reduction in pesticide use and increase land under organic production to 25% by 2030 (European Commission, 2020a). The latest CAP reform has started to align its objectives with this long-term strategy (European Commission, 2022c). In the Netherlands, various ministries have developed policy missions around agri-food sustainability challenges like biodiversity decline and GHG emissions. Dealing with societal challenges, rather than increasing economic growth, is the core aim of these "mission-oriented" policies (Wanzenböck et al., 2020). An important instrument in the Dutch case is the so-called "top sector" knowledge and innovation agenda, a public-private partnership between government, research organizations, and agribusiness (Sonnema & Osinga, 2019; Topsector Agri & Food, 2019).

1.5. Lock-in and path dependence

The situation sketched above is untenable and change is urgently needed for the future of humankind and a viable food production system. Before I introduce the paradigm shift presented by alternative forms of agriculture, I broadly describe the various ways in which the current situation has come to be – how the farming system got stuck, or "locked-in".

Path dependence is a phenomenon describing how choices made in the past condition and limit current and future action perspectives (Garud & Karnøe, 2013). This theory has been developed and applied in the domain of evolutionary economics and the emergence of technological innovations. In the context of sustainability and climate change, the term "carbon lock-in" has been proposed to describe the paradoxical situation in which we currently find ourselves: despite widespread knowledge that there are negative consequences to burning fossil fuels to power modern life, and despite known alternative technologies, carbon-intensive technologies and infrastructures continue to be used (Unruh, 2000). This happens for a number of reasons. User preferences converge towards a dominant design, enshrining a particular technology as the norm for a given purpose. Once infrastructures are built around such a design – such as the modern road system around the internal combustion engine car – and users get used to it, alternatives become increasingly difficult and costly to use (Unruh, 2000). Private institutions of norms and customs as well as societal expectations emerge around these technologies (Borup et al., 2006), and governments institutionalize and subsidize their use (Unruh, 2000).

In the domain of agri-food systems, lock-in and path dependence are also at play. Oliver et al. (2018, p. 3) detail various forms of lock-in for the global agri-food system. The first is knowledge-based lock-in – ignorance, uncertainty and lack of access to knowledge. Actors may not understand the negative impacts current farming systems have, and therefore feel no need to change them. For those actors that do have such an understanding, the uncertainty of the benefits of alternative paradigms may prevent their implementation. And even when an actor is aware of the impacts and convinced by the benefits of change, they may not have access to the required technical knowledge or skills training to allow them to implement different practices.

The second type of lock-in is of an economic and regulatory nature. First movers are at a disadvantage, whether in retail (e.g. stocking only sustainable products, making shopping more costly and less convenient) or farming (e.g. realizing price increases for organic production comes only after official certification, while output usually declines somewhat). Meanwhile, in the absence of penalization for negative effects of harmful farming practices, the logic of profit maximalization incentivizes business as usual across the value chain. Because most countries export significant portions of their agricultural output, the prices are set on international markets, and any pro-environmental regulation that could harm competitiveness is avoided. Subsidies tend to favor large farms (in acreage and livestock numbers) rather than better environmental outcomes (Pe'er et al., 2020).

The third kind of lock-in is sociocultural. Here, the first-mover disadvantage presents itself as a social factor: deviating from the mainstream, especially in tight-knit rural communities, can incur a social cost to innovators as change is often seen as an implicit criticism of those who do not change. A related factor is that farmers are reluctant to lose social networks because changing the way they farm results in less common ground and fewer shared experiences. On the consumer side, a major sociocultural barrier is the expectation of cheap food, which leads retailers to tailor their sourcing practices and pricing strategies accordingly – to the detriment of farmers and nature. Another, broader factor is the lack of a common identity between those who make unsustainable choices and those who bear the costs, including non-human entities and future generations. In addition, a compounding abdication of responsibility can occur when consumers expect government to regulate for better environmental outcomes, while governments expect consumers to act in their best interest and therefore refrain from making policy that changes the status quo. Finally, there is a widespread belief in technological solutions or "fixes" to agri-environmental problems, partly due to historic successes of technologies in addressing societal challenges (e.g. the invention of penicillin in medicine). Faith in technologies that do not yet exist or work at a large scale can lead to decision-makers postponing more fundamental interventions in the structure of farming.

The factors described above reinforce each other so that the combination of these forms of lock-in – knowledge-related, economic and regulatory, and sociocultural – creates an agri-food system that is completely stuck. Farmers, businesses, governments, and consumers have little incentive to change how they act, and while voluntary behavior change is commendable it remains limited. This raises the question of how the negative outcomes from the dynamics presented above can be reduced, eliminated, or avoided.

1.6. Moving from reducing externalities to producing positive outcomes

The observations made above are not new; environmental issues in modern agriculture have been identified systematically more than twenty years ago (Stoate et al., 2001); in fact, one of the seminal texts of the modern environmental movement – Rachel Carson's "Silent Spring", published in 1962 – centered around the detrimental effects of the biocide DDT (Carson, 1962). For decades, the challenge that scientists, governments, farmers, and philanthropists took upon themselves in response was to produce more food with fewer emissions – in other words, to produce more efficiently[3]. This has been described as sustainable intensification, a response to agri-environmental problems that prioritizes increased food production while "avoiding" unnecessary resource use and "minimizing" harmful impacts of farming practices (Garnett et al., 2013; Pretty & Pervez Bharucha, 2014). Central to this approach is producing more food on the same amount of land (so-called "land sparing") to avoid agriculture encroaching on natural habitats. Sustainable intensification was adopted by major international research and policy organizations like the Consultative Group on International Agricultural Research (CGIAR), the UN Food and Agricultural Organization (FAO), the World Economic Forum (WEF) and the World Business Council on Sustainable Development (WBCSD); prominent funders include governments from across the globe, the World Bank, philanthropic organizations like the Bill & Melinda Gates Foundation, and agribusiness corporations like Syngenta (CGIAR, n.d.).

While sustainable intensification has gained traction with key actors in the global agri-food system, critics assert that "the current model of agricultural intensification is not sustainable (socially and thermodynamically), it is neither ecological nor eco-efficient, it is ineffective at feeding the world, it is harmful for the environment and contributes to biodiversity loss" (Tittonell, 2014, p. 54). This has less to do with the definition of sustainable intensification than with its interpretation and uptake by the types of actors listed at the end of the previous paragraph: if the principle aim is to increase yields while making more efficient use of resources, and minimizing and avoiding negative impacts is the condition, what emerges is at best a slight modification of business as usual wherein input- and technology-focused farming practices continue to dominate (Collins & Chandrasekaran, 2012). This approach is furthermore legitimized and justified by calls to double food production by 2050 to feed a growing world population, an ambition that is "problematic given that it does not address problems of climate change, diet-related ill health and does not

3 Increased efficiency is one of five principles of sustainable agriculture as defined by the UN Food and Agricultural Organization. The other four principles are 2) conserving, protecting and enhancing natural ecosystems, 3) protecting and improving rural livelihoods and social well-being, 4) enhancing the resilience of people, communities, and ecosystems, and 5) promoting good governance of both natural and human systems (Oberč & Schnell, 2020, p. 5)

substantially reduce absolute levels of hunger" (Tomlinson, 2013, p. 88). This dynamic is also at play at the scale of the Netherlands, where an efficiency and output-maximization oriented farming system produces the least amount of emissions per unit of product, while causing the highest amount of environmental stress per hectare of land in the EU (van Grinsven et al., 2019). In other words, the efficiency gains of intensive agricultural production methods have an extreme rebound effect resulting in the highest stress on nature in the EU. This productivist paradigm that "is geared to producing large amounts of standardized foods" (Gaitán-Cremaschi et al., 2019, p. 1) is legitimized by statements from research, government and agribusiness actors that the Netherlands can and should continue to "feed the world" (Schouten, 2018) – a sentiment echoed in the international press (Viviano, 2017).

Whereas the sustainable intensification paradigm emphasizes the reduction of negative externalities – the symptoms of an unsustainable agri-food system - a range of alternative approaches seek to tackle its causes. These more systemic and holistic approaches address these shortcomings through changes in land use patterns, practices, and technologies for agricultural production, as well as the incorporation of nature conservation and the production of positive socioeconomic outcomes besides food and resource production (Oberč & Schnell, 2020). Regenerative agriculture is one such approach. It has been defined as "an approach to farming that uses soil conservation as the entry point to regenerate and contribute to multiple provisioning, regulating and supporting ecosystem services, with the objective that this will enhance not only the environmental, but also the social and economic dimensions of sustainable food production" (Schreefel et al., 2020, p. 5). In aiming for 'net positive' outcomes, it is fundamentally different to sustainable intensification that only seeks to reduce or minimize externalities. It is conceptually related to conservation agriculture, which also focuses on maintaining soil health, and carbon farming, which focuses on carbon sequestration in soil and plant organic matter to combat climate change (Oberč & Schnell, 2020). Other concepts, like agroecology, high nature-value farming, or nature-inclusive farming, strive for similar outcomes with a greater focus on habitat restoration and the nurturing of ecosystem services (ibid). Such alternatives go beyond seeking efficiency gains or reducing losses in the system as it currently functions, and instead require changes of institutions, relationships between actors, strategies, fundamental assumptions, as well as farming practices and technologies. These are ambitious challenges, requiring changes in complex systems.

1.7. Research questions

From the perspective of social and ecological sustainability, the Dutch agri-food system currently does not function well. Promising alternatives present the challenge of reorienting this system, with the potential of creating a way of producing, trading, processing and consuming food that is in balance with nature and without adverse impacts on society. How can the Netherlands move towards such a system? This is the overall empirical question at the heart of this thesis. To answer it, two more specific research questions will be asked.

1) What are the specific causes of lock-in for the Dutch agri-food system?
   Section 1.4 above outlined types of lock-in that constrain global agri-food systems in producing unsustainable social and ecological outcomes. In order to find out how viable alternatives to the current paradigm can be brought into the mainstream, it is necessary to identify more specific lock-in dynamics that block the development of such alternatives in the Dutch context.

2) What can be done to break out of this lock-in?
   Having assessed lock-in from a system perspective, the next question focuses on the principal agents in this transition – farmers. The literature on lock-in and path dependence acknowledges not only the various ways in which complex systems can get stuck, but also how they can get "unstuck", i.e. how new paths can be created. Therefore, the second question I explore is what Dutch farmers are currently doing to overcome barriers, which barriers they continue to face, and how alternative solutions can be scaled out to the majority of currently conventional farmers.

The next section introduces the theoretical basis for answering these questions.

2. Perspectives on complex systems change

Alternative farming paradigms require a different way of farming, but it should be clear from section 1.2 above that farmers do not operate in isolation from other actors: insofar as they are stuck or locked-into farming the way they do, they are motivated and incentivized to do so by other actors and institutions around them. In other words, their agency is conditioned and constrained by the structure in which they operate (Giddens, 1986; Upham et al., 2018). Moving from the situation sketched above to one where alternative forms of agriculture are the norm in the Netherlands implies complex and difficult changes in behavior, social relations, institutions, technologies, and farming practices – in other words, complex systems change. A range of frameworks exist to explain, and in some cases actively intervene in, such change processes. Reviews by Feola (2015) on how these frameworks generally address environmental and climate change, and by El Bilali (2020) on the frameworks most frequently employed in the study of agri-food system change, provide an overview. This section first briefly describes the frameworks' general theories of change, and then assesses the overlaps and differences between them.

2.1. Framework descriptions

In the multi-level perspective (MLP) framework, system change occurs when the meso-level sociotechnical "regime" – incumbent industrial and government actors;

markets and user practices; dominant technologies, infrastructures, cultures, and knowledge systems – changes in response to influence from the macro-level "landscape", i.e. broader societal trends, or micro-level "niches", i.e. social and technological experiments (Geels, 2002). The MLP is used to assess how niches and sociotechnical regimes interact to change dominant modes of production, research, or institutional logics. This analytical model is the basis for several more action-oriented frameworks, such as transition management (TM) and strategic niche management (SNM), which were created to intervene in changing trajectories of socio-technical systems as a whole and niches, respectively. Bui et al. applied this framework in France, identifying how community-oriented food and farming initiatives in rural and urban areas used strategies of visioning and institutional entrepreneurship to alter the functioning of the French food regime (Bui et al., 2016).

TM approaches are specifically "concerned with actors' capacity of triggering institutional transformation" (El Bilali, 2020, p. 1707).™conceives of a cycle, similar to a quality management plan-do-check-act cycle, of 1) problem structuring, convening stakeholders and visioning; 2) developing coalitions and change agendas; 3) mobilizing actors to implement projects and experiments; and 4) monitoring and evaluating (Rotmans & Loorbach, 2009).™ has been applied in the development of new farming concepts (Beers et al., 2014) and in changing the regulatory environment for agricultural nitrogen and phosphorus (Hoppe et al., 2016). SNM is concerned specifically with the niches of the MLP. It aims to create protective spaces that allow innovators to experiment and generate new technologies, user practices and organizational models without being outcompeted by already-existing technologies, practices etc. in the sociotechnical regime (Schot & Geels, 2008). SNM includes the "articulation of expectations and visions, building of social networks, and learning at multiple levels" (El Bilali, 2020, p. 1710). It also emphasizes the learning and networking relationships between niche and regime actors in a process of bottom-up change. SNM has generated studies on bottom-up transition processes in farming, for example on how the permaculture community in the UK attempts to discursively influence regime knowledge production (Maye, 2018).

Similar to SNM, Technological Innovation System (TIS) approaches[4] aim at better understanding the environment that allows the development and diffusion of new technologies and practices. TIS conceives of innovation systems as having both structure and functions. Structure comprises the "moving parts" of a system, and includes actors, such as farmers and companies; infrastructure, such as ports, roads, and processing plants; institutions, including "soft" institutions like norms and values, and "hard" institutions like laws and regulations; and networks, i.e. formal and informal collaborations between multiple actors. Functions include entrepreneurial activity, knowledge development and diffusion, guidance and directionality, market

4 Frameworks based on TIS include the agricultural innovation system, mission-oriented innovation system, and problem-oriented innovation system frameworks (Ghazinoory et al., 2020; Hekkert et al., 2020; Turner et al., 2017)uncertain, operating at multiple levels (field to global value chains. These are all based on the TIS framework, albeit with a different scope and differently formulated or additional functions.

formation, resource mobilization, and creation of legitimacy (Wieczorek & Hekkert, 2012). On the basis of an analysis of the functions for a particular innovation system, deep-seated and interconnected problems can be identified, and suitable policy interventions can be proposed. TIS has been used to determine how well agricultural innovations disseminate among a user base in a certain region or country and identify barriers to greater levels of adoption. Some of these analyses investigate technologies or practices, such as low-tech irrigation (Sixt et al., 2018). Others take a broader view on innovation and look at how sets of practices or agricultural paradigms perform in a given context (Schiller et al., 2020; Turner et al., 2016).

While TIS and SNM deal with existing niches and innovations and their performance in a sociotechnical regime, other approaches seek to actively facilitate the creation and discovery of innovations. Reflexive interactive design and anchoring conceive of iterative cycles of 1) exploring sustainability challenges and specific needs that are under-fulfilled; 2) questioning the assumptions of current practices and technologies that do not meet those needs; 3) facilitating the interactive design of new solutions by practitioners and experts; and 4) "anchoring" the new solutions in incumbent organizations, institutions and networks (Elzen & Bos, 2019). This method has been applied in livestock production and urban infrastructure sectors (Bos et al., 2009; Grin, 2020; Groot Koerkamp & Bos, 2008).

Deliberate transformation (DT) pursues change not only in sociotechnical systems but in broader societal relations and institutions (O'Brien, 2012; Pelling, 2011; Pelling et al., 2015). A key concept is the social contract, which asks us to recognize the "legitimizing force of citizen consent to the authorities that limit their freedoms, and the role of social institutions in upholding a dominant rights settlement" (Pelling et al., 2015, p. 115). In such a reading, change is successful (or transformative) when the rights and responsibilities between actors, typically between citizen and state, are balanced more equitably. DT therefore has a more explicit ethical and justice focus than the previously described frameworks. DT has also been defined as "a psycho-social process involving the unleashing of human potential to commit, care and effect change for a better life" (O'Brien, 2012, p. 4), emphasizing a social psychological or even spiritual component. Key to DT is a strong normative orientation, in the sense that the change process is purposive rather than emergent (Smith et al., 2005).

DT has been operationalized in several more concrete frameworks. One of these is the Spheres of Transformation framework. It conceives of transformation as occurring in three interlinked spheres: the practical, representing "both behaviors and technical solutions"; the political, capturing the "systems and structures that create the conditions for transformations in the practical sphere"; and the personal, which includes "individual and collective beliefs, values and worldviews that shape the ways that the systems and structures (i.e., the political sphere) are viewed, and influence what types of solutions (e.g., the practical sphere) are considered 'possible'"(O'Brien & Sygna, 2013, pp. 4–5). The connections between the spheres are considered the key to both positive transformative change as well as the locus of barriers that prevent action. It has been applied in the cases of regenerative cattle ranchers in Australia and fisheries in Norway (Gosnell et al., 2019; Karlsson & Hovelsrud, 2021).

These frameworks differ in how they define system borders and boundaries, how they conceive of the temporal dynamics of change processes, where they locate the source of agency and causality in complex systems, and what they consider the final result of change processes (Feola, 2015). Because of these differences, I will apply a variety of frameworks in my thesis. Before I motivate the choice of frameworks, the next section describes the differences between them. The MLP is used as the "default" model for systems change, and the other frameworks are described in relation to it.

2.2. Characteristics of systems change

To orient the reader, this section repeatedly refers to different aspects of the MLP. Figure 2 below visually represents the landscape (blue waves at the top), regime (red hexagon and arrows), and niche levels (small green arrows at the bottom), and provides a general overview of the basic system change dynamics in transitions theory.

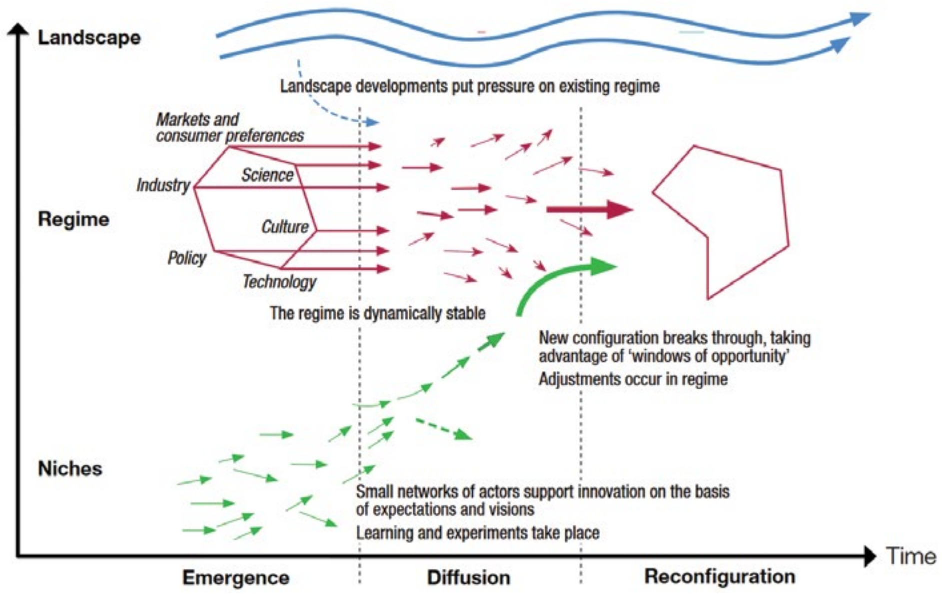

FIGURE 3 | Multi-Level Perspective framework. Adapted from (International Science Council, 2019).

2.2.1 System boundaries and definition

The MLP, TM, SNM, design and anchoring, and TIS frameworks focus on sociotechnical systems or regimes, depicted by the red cluster or hexagon of consumer preferences, skills, science, culture, investments, and policy in the middle of Figure 2. Studies applying the MLP tend to look at systems broadly and consider changes in how they fulfill societal functions like transport, nutrition, or heating.™ rests on similar system boundaries, but is more concerned with intervention in the system rather than an analysis of it, striving for the definition of a "to-be" situation (the reconfigured red regime level cluster on the right hand side in Figure 2) and the development and implementation of an agenda to get there. SNM is concerned specifically with creating and protecting niches (small arrows at the bottom of Figure 2) and attempting to influence the regime through innovations (thick arrow at the bottom of Figure 2). TIS is likewise concerned with niche upscaling, but includes research and development of incumbent actors as well as niche experimentation. Design and anchoring aims to create new solutions and embed (anchor) them in the sociotechnical regime, spanning a trajectory from niche emergence (bottom left in Figure 2) to regime adjustment (center middle in Figure 2) when an innovation becomes adopted by incumbents.

DT takes a broader view of social systems *embedded in* biophysical processes; this contrasts with the aforementioned frameworks that focus on sociotechnical systems that have *negative effects on* nature that need to be avoided or mitigated. Unlike the aforementioned frameworks that focus on sociotechnical regimes and regime-niche interaction, DT includes the macro-level landscape level, "e.g. changing the nature of capitalism or nature-society interactions" (Köhler et al., 2019a, p. 2) as well as the micro-level of "individual choices, attitudes and motivations" (ibid).

2.2.2 Outcome

All frameworks under scrutiny here entail some form of system change. In the MLP, it is a *different* regime; this can be one that has reinvented or reconfigured itself "internally" through the adoption of new partnerships, technologies, business models and institutions, or one that has been disrupted or even replaced by niches (Geels et al., 2016). SNM can be seen as a framework that fosters the latter type of regime change (Schot & Geels, 2008). In™ on the other hand, the focus is on creating a *new* regime, "to erode the existing deep structure (incumbent regime) of a system and ultimately dismantle it" (Rotmans & Loorbach, 2009, p. 189); note that "erode" and "dismantle" is rather drastic compared to "reinvention" or "reconfiguration". TIS considers the widespread adoption of sustainable innovations as successful (Wieczorek & Hekkert, 2012), and design and anchoring aim for the creation and adoption of an innovation by incumbents in a given context. DT has a stronger normative character, and the outcome of transformational processes ought to be, variously, a better life (O'Brien, 2012), a new social contract (Pelling, 2011), or the capacity to achieve desired human values in harmony with environmental processes (Park et al., 2012).

2.2.3 Temporal dynamics

Most of the frameworks reviewed here go through phases or cycles. Changes in sociotechnical systems as conceived of in MLP, SNM and™ scholarship are typically seen as following an S-curve of predevelopment, takeoff, acceleration, and stabilization

(Feola, 2015), with specific change trajectories for different ways of regime-niche interaction characterized as substitution, transformation, reconfiguration, and de- or re-alignment (Geels et al., 2016). The™ framework can be seen as a prescriptive model for how such a trajectory can be organized and propelled, following the four cycles described in section 2.1. In TIS scholarship, "motors of change" have been identified that can trigger "virtuous cycles" for the development of an innovation (Hekkert et al., 2007, p. 426). Design and anchoring follows iterative cycles of system and actor analysis, structured design, and anchoring (Elzen & Bos, 2019). The change trajectories of DT processes are less formalized.

Another way to categorize these frameworks is by the time span of analysis usually employed. Design and anchoring, TM, and SNM tend to be future-oriented, aiming to create actionable results to actively intervene in systems. DT and TIS approaches can include historical analyses of past change processes, practices or innovation trajectories, as well as the analysis of currently operating systems and behavior. Research using MLP tends to study change processes that have already taken place.

2.2.4 Agency and causality

Another important way to distinguish between these frameworks is whether they conceive of change as emergent or deliberate. In the MLP and TIS, agency is recognized – albeit at a certain level of abstraction and aggregation – as a driving force behind innovation, niche experimentation and regime functioning. TM, SNM, DT, and design and anchoring go a step further, not just recognizing that human agency plays a part in systems change but providing models for the initiation and manipulation of such change processes. An important difference between DT and other theories is the conception of landscape developments and events. Frameworks that primarily focus on regimes and niches tend to view the landscape as exogenous and see landscape pressure influence regimes whenever it occurs. DT on the other hand seeks to intervene in the landscape and to some extent even welcomes disruptions to the status quo, even when this can have negative side-effects in the short-term: DT scholars emphasize the opportunity of building anew following disasters and crises (Pelling, 2011).

2.3. Criticisms and complementarities

By necessity, studying the structure of, and collective action in, large complex systems, scholars using frameworks like MLP, TM, SNM or TIS tend to aggregate individual experiences and notions of agency (Upham et al., 2020). This produces pragmatic "middle-range frameworks" (Geels, 2020) that respond well to "policy demands for justification and legitimation" (Stirling, 2011, p. 85), but deeper engagement with individuals' experiences of transitions, or their behavior in transitions, is lacking (Kaufman et al., 2021). This is where the focus on human vulnerability in DT offers complementary perspectives. The Spheres of Transformation framework, as a concrete framework in DT theory, makes a compelling bridge between individual, everyday action in the "practical sphere" with meso-level institutions in the "political sphere" (O'Brien, 2018).

Another common criticism of the MLP and related approaches is their lack of engagement with power and politics. With its tendency to integrate, aggregate and simplify, this type of scholarship often doesn't reflect the diversities of technological options, development paths, and the human values underpinning them (Stirling, 2011). This shortcoming is arguably "built into" common transitions approaches: even if different concepts of power are mapped onto the constituent parts of the MLP (Avelino, 2017), the implicit categorization of a certain technology or practice as 'niche' with a particular type of power vis-à-vis 'the regime' obscures other possibilities of sociotechnical change, and may furthermore not reflect the reality of different power relations and change trajectories concurring (Fuenfschilling & Truffer, 2014). A related criticism is that markets are assumed to be central to the development and diffusion of innovation, which diminishes the discipline's potential to challenge the neoliberal paradigm that has contributed significantly to the kinds of problems transition scholars seek to address (Beumer et al., 2022). DT could be an enriching influence to frameworks focused on sociotechnical systems change because of the foregrounding of resilience, justice, and wellbeing.

While the principal aim of this thesis is to empirically explore the Dutch transition to a more sustainable agri-food system, a secondary ambition is to explore the potential for closer integration and "cross-fertilization" between the different frameworks reviewed in this section. As I have shown in section 1.1 above, agri-food systems are characterized by a host of intersecting and intractable failures that no one framework could possibly tackle. I will therefore apply a variety of frameworks from different scholarly traditions and consider the implications of the findings from multiple angles in the conclusion.

In this thesis I choose to deploy the TIS, Spheres of Transformation, and design and anchoring frameworks. These were chosen due to the conceptual and practical fit for my research aims. The TIS and Spheres of Transformation frameworks are suitable for an *ex-durante* study of an ongoing sustainability transition. This makes them suitable to better understanding the current situation in the Dutch agri-food system. Both furthermore can take recent developments into account, and provide further details on the causes of lock-in (RQ 1, see Section 1.6 and chapters two and three). The Spheres of Transformation framework furthermore enables a suitable analysis of individual farmers' perspectives on transformation processes and their agency, which is crucial for a better understanding of the potential for bottom-up change by farmers (RQ 2, see Section 1.6). Given the action research agenda of the research project (see **Preface**), it is also necessary to deploy design and anchoring as a concrete, action-oriented framework. This allows me to explore the potential for bottom-up change beyond the farm (RQ 2, see Section 1.6).

3. Approach

Each of the following four chapters will follow a more specific methodology which I will describe there in more detail. The section concludes with an overview table (Table 3) outlining a short description of each chapter's topic or case, theoretical approach, method, and data types.

3.1. Chapter summaries

Chapter two is an attempt to answer research question one: what are the specific causes of lock-in for the Dutch agri-food system? It applies the TIS framework to analyze the innovation system for nature-inclusive dairy farming, an alternative to the productivist farming regime that is to a considerable degree responsible for the environmental and social issues in Dutch agriculture. Nature-inclusive farming, which is similar to agroecology, is based on principles of caring for nature through landscape and nature management, the use and protection of ecosystem services, and the reduction of emissions and increased resource use efficiency. While this type of farming provides a number of benefits, it is currently only followed by a small amount (roughly 10%) of Dutch dairy farmers. By reviewing scientific and grey literature, consulting experts and conducting a focus group discussion, we identified five blocking mechanisms that are currently hindering the broader adoption of nature-inclusive practices and provide some guidance to policymakers on how to address these.

Chapter three approaches research question one by exploring the extent to which normative guidance and direction in the Dutch agri-food system are aligned. Guidance and directionality are widely considered an important element in deliberate complex systems change, for example in function four of the TIS framework, and are particularly important from the perspective of mission-oriented policy. Lacking or ambiguous guidance can contribute to lock-in by increasing the risk of first-mover disadvantage and preventing actors from focusing on promising solutions. Such guidance is often contained in vision documents, where societal actors set out their expectations for a future system. The same is true in the case of Dutch agriculture, where public and private sector stakeholders periodically publish their visions and strategies to achieve these. Ideally, such visions should be coherent in what kinds of problems they want to see solved and how, but as chapter two shows this is not the case for Dutch agriculture. The aim of this chapter is to identify the level of agreement between societal stakeholders on problems and solutions for a range of issues. To do so, we analyzed the content of 49 vision documents published by Dutch organizations between 2015 and 2019. We determine the extent to which these visions are aligned and suggest strategies for better alignment.

Having studied various causes of lock-in in the Dutch agricultural sector in depth in chapters two and three, the second half of this thesis addresses research question two, namely what can be done to break out of this lock-in. The fourth chapter looks at the strategies and motivations of Dutch farmers who belong to the small proportion of farmers that don't follow the mainstream, productivist farming model. We specifically interviewed twenty farmers who had made considerable changes to their business model with an intention to produce food more sustainably. Because they navigate a complex system of ecology (weather, climate, plants and animals), society (relationships with other farmers, consumers, rules and regulations) and economy (market demand, cost of production) we applied the Spheres of Transformation framework to understand these farmers' experiences of personal, political and practical spheres of transformation (see section 2.1). Interviews were conducted over the winter of 2020/2021, in person, and followed a semi-structured plan. We uncovered diverse strategies, motivations and barriers at the farm level.

While it is important to understand how individual farmers transform their business models, from a systemic perspective it is crucial to better understand how farmers and practitioners can learn about possible ways to transform their operations. This likewise contributes to research question two. In chapter five we therefore focus on a workshop that aimed to redesign a university-owned demonstration farm that has a mission to generate and share knowledge on sustainable dairy farming practices in its region. The workshop was facilitated following the reflexive interactive design method, which is an established approach to fundamentally redesign animal production systems. The aim of this chapter is to better understand learning at two levels. First, what did workshop participants learn from their experience? To answer this question, we conducted pre- and post-workshop surveys on participants' understanding of the dairy farming system and its impacts. Second, what can we learn about the broader transition from the workshop output? To answer this question, we assessed the scaling readiness of solutions in four design scenarios developed during the workshop. We discuss these findings in light of the need for system-level transformative change in the sector.

TABLE 3 | Chapter summaries of the thesis, including topic or case, theoretical approach, methods and data types.

Chapter	Topic / case	Theoretical approach	Method	Data types
Two	Nature-inclusive dairy farming	TIS	Literature review, focus group discussion, expert consultation	Grey literature, scientific literature, expert opinion
Three	Alignment between visions for future of Dutch agriculture	TIS / mission-oriented innovation policy	Literature review	Grey literature
Four	Farmers' motivations and strategies for transformation	Spheres of Transformation	Semi-structured interviews	Interview recordings, transcripts
Five	Redesign of demonstration and experimentation farm	Design and anchoring	Surveys, observation, grey literature review, scaling readiness assessment	Photos, videos, workshop notes, workshop report, survey data

Chapter two

Five mechanisms blocking the transition towards 'nature-inclusive' agriculture: a systemic analysis of Dutch dairy farming

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1. Introduction

There have been numerous and high-level calls to transform dominant industrial agricultural production systems into sustainable ones that deliver food production within ecological limits (European Commission, 2020a; FAO, 2018; IPBES, 2019; Springmann et al., 2018). As the FAO notes, "It is unlikely that high-input, resource-intensive farming systems – which have been blamed for deforestation, depletion of land and water resources, loss of biodiversity and high levels of GHG emissions – will deliver sustainable agricultural production." (FAO, 2018, p. 33). Agroecology, a farming practice that "seeks to boost the resilience and the ecological, socio-economic and cultural sustainability of farming systems" (Oberč & Schnell, 2020 p. 10), has been promoted as a promising and innovative alternative to dominant agricultural systems. However, its uptake is limited. Organic agriculture, for instance, which is a farming practice that shares some characteristics with agroecology (see Oberč & Schnell, 2020), only covers 1.5% of agricultural land worldwide and 7.5% in the European Union (European Commission, 2020c; IFOAM, 2020).

The Netherlands is a prime example where highly intensive agriculture dominates the landscape; with grassland for dairy production covering more than a quarter of its land surface (Centraal Bureau voor de Statistiek, 2019). The country has more than four times the average European livestock density and is the EU's fourth-largest milk producer by volume (European Commission, 2020b). However, this production intensity comes at a high cost for biodiversity. Mean Species Abundance and the Living Planet Index (both measures of biodiversity intactness) have decreased from around 40% in 1900 to 15% in 2010, and from 1 in 1990 to 0.8 in 2018 respectively (Planbureau voor de Leefomgeving, 2014; Wereld Natuur Fonds, 2020). In addition, the dairy sector is responsible for 25% of the country's nitrogen deposition (Sikkema, 2019). This has detrimental effects on biodiversity, and the legislative response led to social unrest and economic uncertainty in recent years (Heer et al., 2017; K. van Laarhoven, 2020).

In response to these problems, farmers, scholars and policymakers in the Netherlands have fairly recently developed the concept of nature-inclusive agriculture (NIA). It was introduced as a policy term in a vision document for Dutch nature by the Ministry of Economic Affairs (Ministerie van Economische Zaken, 2014). Its three underlying and interconnected principles are to "employ ecosystem services rather than external inputs; minimize environmental pressures and contribute maximally to 'non-functional' biodiversity and landscape quality" (Runhaar, 2021, p. 228). To that end, practicing NIA implies conserving, improving and exploiting the services of water and soil; closing nutrient cycles and minimizing harmful emissions to water, soil and air; and constructing and conserving landscape elements (Erisman et al., 2017).

Despite this concept being specifically used in the Netherlands, there is some overlap with other sustainable agriculture approaches (see Figure 1, which illustrates the three dimensions of nature-inclusive agriculture (1A) and the conceptual similarities and overlap between NIA and other sustainable agriculture approaches (1B)). This is further explored in section 2. All approaches, implicitly or explicitly, assume that agriculture should be profitable for the farmer. The intensity of dairy farming and spatial competition between agriculture and other types of land use in the Netherlands make such an approach particularly timely, but also challenging. Currently, less than 10% of Dutch dairy farmers are considered nature-inclusive (Bouma, Koetse, & Polman, 2019; also see section 4). A much larger group of farmers would like to become more nature-inclusive, however, or feels s/he is required to do so (Trouw, 2018). This requires better insight into the typical barriers hampering the adoption of nature-inclusive agriculture in the Dutch dairy sector, to understand how a sustainability transition in this sector could be supported. In addition, in order to understand systemic change, linkages between problems (e.g. problem chains) need to be understood. This in turn enables identification of more specific interventions. Earlier studies have already highlighted various barriers to adoption of sustainable farming practices (e.g. in the context of organic agriculture, low-external input farming or agro-ecology, see Hermans et al. 2010; Vanloqueren and Baret 2009; Levidow, Birch, and Papaioannou 2013). While these studies provide vital insights into typical adoption problems, interlinkages between key types of barriers are understudied. We therefore aim to explore which barriers prevent a further uptake of NIA by a larger proportion of farmers in the Dutch dairy sector, and investigate how these barriers are connected.

To this purpose, we draw from the sustainability transitions literature, which focuses on processes of change of large complex systems towards a more sustainable state (Köhler et al., 2017). The Innovation Systems Analysis (ISA) is a widely applied framework, which has been used to study the "weaknesses in innovation networks, institutional failures and infrastructure failures that explain the limited dissemination and adoption of niche innovations as well as how these mechanisms are affected by interactions among actors" (El Bilali, 2020, p. 1712). Whereas this framework has originally been applied to technological innovation in energy and utilities sectors (Dewald & Truffer, 2011; Foxon et al., 2010; Negro et al., 2008), it has also been applied to innovation in the agricultural sector (see for instance Spielman et al. (2008), Klerkx, Aarts, and Leeuwis (2010), Lamprinopoulou et al. (2014), Garb & Friedlander (2014), Kruger (2017). Other examples are studies on irrigation practices in Jordan (Sixt et al., 2018), the fresh produce sector in the UK (Menary et al., 2019), and the agroecological transition of Nicaragua (Schiller et al., 2020). Therefore, this framework is well-suited to studying the diffusion of NIA practices in the Dutch dairy sector. In this paper, we consider NIA as a niche innovation because it is a way of farming that has not been widely adopted and the meaning of which has not crystallized yet (van Doorn et al., 2016; Runhaar, 2017).

The contribution of this paper is twofold. First, it aims to gain insights into key barriers hindering adoption of nature-inclusive practices in the Dutch dairy sector. By unravelling interlinkages between these barriers, this paper identifies intervention points to accelerate the transition towards NIA in the Netherlands. This provides handholds for policymakers. Second, this paper aims to make a specific contribution to the (agricultural) innovation systems literature (e.g. Hekkert et al., 2007; Klerkx et al., 2012) by further development of the conceptual framework. Most Innovation Systems Analyses have a primary focus on the internal processes and a secondary focus on the external factors that influence innovation system functioning. In this paper we aim to unpack niche-regime interactions through an explicit focus on how regime factors influence the functioning of the NIA innovation system.

This leads to the following research questions:

1) Which aspects of the innovation system currently hamper a large scale uptake of nature-inclusive agriculture (NIA) in the Netherlands?
2) What is the role of the current dairy regime in preventing the transition towards this form of agriculture?"

2. Background: NIA in the Netherlands

As mentioned in the introduction, NIA is defined as "the pursuit of a positive, reciprocal relationship between farm management and natural capital" (van Doorn et al., 2016, p. 5). Nature-inclusive dairy farming practices include (Erisman et al., 2017):

- Manure management (such as applying solid manure instead of slurry) to improve soil structure and soil health;
- Local feed production to eliminate overseas impact of feed production (primarily deforestation for soy production);
- Primarily grass-based feeding due to higher soil organic content of grassland relative to arable (feed crop) land;
- Diversification of the sward and more permanent grassland for improved above- and below-ground biodiversity as well as soil carbon storage;
- Grazing to improve botanical composition and biodiversity of meadows, close nitrogen cycles and reduce ammonia emissions;
- Use of lightweight machinery to reduce soil compaction;
- Phased mowing to reduce direct impacts on ground-breeding birds and to improve survival chances of chicks;
- Creating landscape elements such as marshland systems, dykes, ditch banks, living fences and tree alleys to provide habitat for species;
- Extensification of the farm, i.e. reducing the number of livestock units per hectare of grassland.

These measures can be applied in different intensities and combinations, leading to a range of possible sustainability and productivity outcomes (Erisman et al., 2016). These practices above can be classified into three main dimensions in Figure 1A: (1) care for nature, (2) use functional agrobiodiversity and (3) reduce environmental impact (Van Doorn, 2016). Van Doorn (2016) further compares these three dimensions of NIA (see Figure 1A), to the focus of other sustainable agriculture approaches (see Figure 1B). For instance, some other approaches overlap on the dimensions of using functional agrobiodiversity and caring for nature (regenerative agriculture), whereas other concepts overlap more on reduced environmental impact (organic agriculture and circular farming). While the latter concepts indirectly target biodiversity by reducing environmental impacts, NIA and agroecology also directly target biodiversity and integrate nature in farm management. As the concept of NIA has emerged recently in Dutch policy-making, further comparisons between NIA and other concepts have not been undertaken yet.

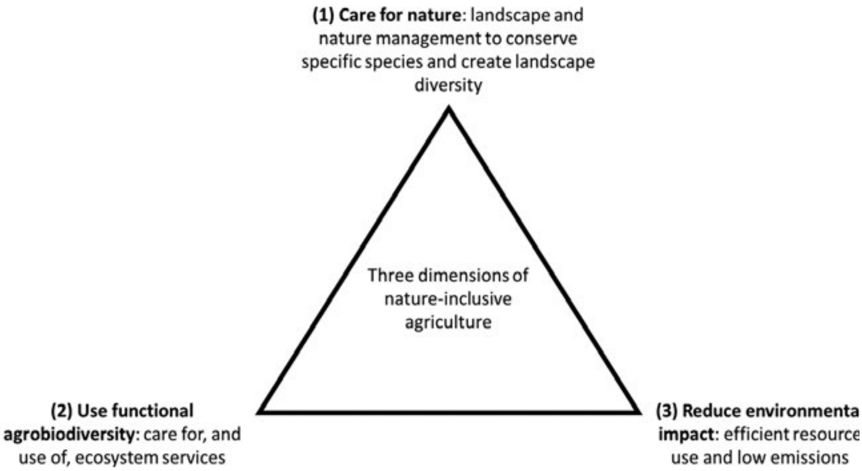

FIGURE 1A | Three dimensions of nature-inclusive agriculture. Adapted from van Doorn et al. 2016, 12.

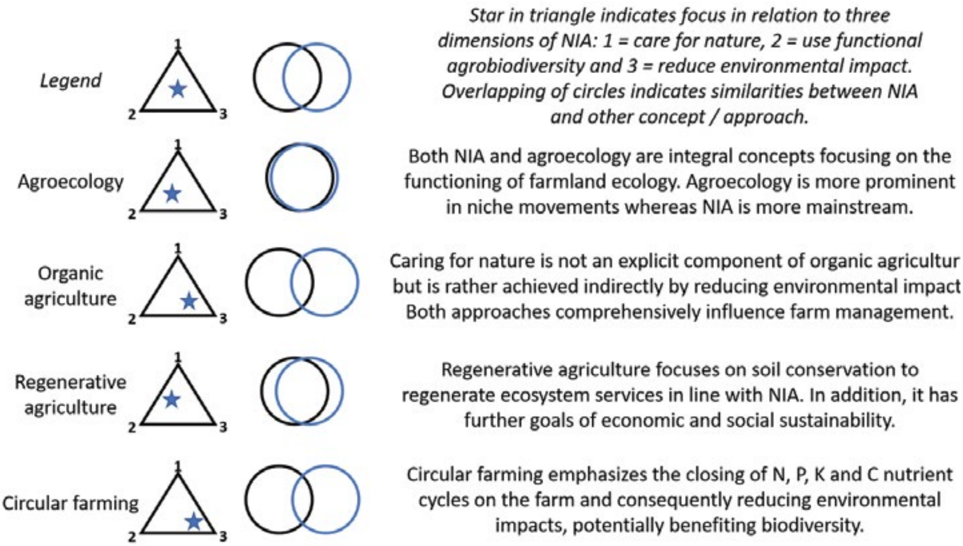

FIGURE 1B | Similarities and differences between NIA and other sustainable agriculture approaches. Adapted from van Doorn et al. 2016, 25-30; definition of regenerative agriculture taken from Schreefel et al. 2020.

In 2019, grassland for dairy production covered 907,000 ha or 27% of Dutch land (Centraal Bureau voor de Statistiek, 2019). This land was used by 16,256 dairy farms who together held 1.6 million dairy cows; this translates to an average farm size of 55.8 ha and 98 cows. There is a clear trend of farm upscaling, as average farm size has almost doubled from 30.7 ha and 51 cows in 2000 (H. Van der Meulen, 2020).

There are no clear statistics on the exact number of farmers applying NIA. Based on a survey among farmers and expert judgement, Bouma et al. (2019) and Erisman & Verhoeven (2019) estimated that less than 10% of Dutch farms can be considered fully nature-inclusive.[5] The picture that emerges is that of a small proportion of "frontrunners" who practice NIA, with the vast majority of "conventional" farmers not practicing NIA in a substantial way. However, a larger group of farmers is willing to become more nature-inclusive, or feels s/he is required to do so. Tellingly for this study, in a 2018 newspaper survey involving 2287 Dutch farmers, approximately 50% of respondents agreed with the statements "we need to switch to nature-inclusive agriculture, considerate of the environment and biodiversity" and "in the next ten years I will switch to a more sustainable form of agriculture" (Trouw, 2018; author's translation). This dichotomy between actual farming practice and the wishes of farmers to make a switch both individually and as a sector informs the scope and direction of this paper.

This study took place against the backdrop of an agri-environmental crisis which manifested itself, among other things, in unprecedented farmer protests and increased attention on the impact of agriculture on the environment and society (Bouma et al., 2020; Schouten, 2018; van der Ploeg, 2020). As NIA offers a possible solution to agri-environmental issues, policymakers from the Netherlands Enterprise Agency and Ministry for Agriculture, Nature and Food Quality commissioned the research which produced this paper. In addition to sharing the results of our analysis, we participated in five workshops with policy makers; made preliminary findings available to advisory commissions; and shared our recommendations with the government of the province of Gelderland[6]. These interactions highlight the societal relevance of our research, as well as the utility of the approach we followed.

3. Analytical framework

This paper takes an innovation system approach, in line with previous work published in this journal (Kruger, 2017; Lamprinopoulou et al., 2014). We consider an innovation system to extend beyond technology or knowledge transfer and its associated support systems or infrastructures (see also Klerkx, van Mierlo, and Leeuwis 2012). In this view, innovation systems are "societal subsystems, actors, and institutions contributing in one way or the other, directly or indirectly, intentionally or

5 This was confirmed in our focus group meeting.

6 https://www.gelderland.nl/programmaAgrifood

not, to the emergence or production of innovation" and serving a particular societal need such as transport or food provision (Hekkert et al., 2007). Innovation systems are composed of structural elements (see Table 1).

TABLE 2 | Structural elements of an innovation system (Wieczorek & Hekkert, 2012)

Structural element	Definition
Actors	Individuals, organizations and networks engaged in the development, experimentation and diffusion of innovation. This includes companies of all sizes, government entities at different levels (national, provincial, municipal), research and education organizations, civil society and others such as banks.
Institutions	The "rules of the game". This encompasses hard institutions like laws and regulations, and soft institutions like shared social and cultural values
Interactions	Relationships between actors, both bilateral (such as between a company and its bank) and in networks (such as in an industry association).
Infrastructure	Physical (machinery, roads, ports, buildings), knowledge (data, expertise, information) and financial infrastructure (grants, subsidy schemes).

An innovation system should be seen as a complex system with many feedback loops between its elements and complex, non-linear dynamics. How well an innovation system is performing can initially be assessed through analyzing how well innovation system functions are fulfilled, as defined in Table 2. The assessment of innovation system functioning can be done using a number of "diagnostic questions" (Wieczorek & Hekkert, 2012) or indicators (Hekkert et al., 2007), as is further elaborated in the methodology.

TABLE 3 | Functions of an innovation system (Hekkert et al., 2007: 421-425).

Function	Definition
1. Entrepreneurial activity	Firms using the potential of new knowledge, networks and new markets to experiment with novel technologies, introducing these innovations to the market and investing in production capacity to diffuse the innovations and take advantage of business opportunities
2.Knowledge development	The generation of new knowledge, both tacit (learning by doing) and formal (through research and development)
3. Knowledge diffusion	The exchange of information and knowledge between actors
4. Guidance of the search	Steering the directionality of the innovation process through the articulation of expectations and preferences
5. Market formation	Opening a market for the innovation, for example by means of a protected niche market, by raising consumer interest or by creating a level playing field through legal, economic and tax-based policy instruments
6. Resource mobilization	Allocating financial and human resources to functions 1 and 2 to allow for successful entrepreneurship and learning
7. Legitimacy creation	Overcoming resistance to change caused by 1) powerful incumbents with vested interests in the technology, 2) unsupportive legal conditions, 3) unawareness in society regarding the novelty, 4) deeply embedded societal norms and habits that are at odds with the novelty in question.

Poor fulfillment of innovation system *functions* can be explained by underlying *systemic problems* related to either the *structural elements* of the innovation system or to factors external to the innovation system. In case of structural elements usually a distinction is made between an element's presence or absence, as well as its quality or capacity, which both can negatively affect innovation system functioning and thereby hinder the diffusion of the innovation. Systemic problems may also be external to the innovation system. In Bergek et al. (2015) several contexts of innovation systems are proposed where these systemic problems may be found. In this paper we will show that many of these systemic problems are related to the dominant dairy regime. As such these contextual systemic problems provide insight in the regime-niche interactions that slow down niche development and uptake in the regime.

The literature makes a distinction between systemic problems and blocking mechanisms, see Kieft et al. (2017). Sometimes definitions of both terms are used interchangeably. We follow Kieft et al. (2017) and De Oliveira and Negro (2019) by defining systemic problems as isolated factors that influence innovation system functioning while blocking mechanisms are sets of systemic problems that through interaction impact innovation system functioning. Blocking mechanisms therefore indicate a more dynamic account of the factors that influence innovation system functioning than systemic problems (see for example De Oliveira and Negro 2019; Schiller et al. 2020; Turner et al. 2016). In order to speed up the development and diffusion of innovation, systemic problems and blocking mechanisms may be targeted by governments, private sector or civil society.

While our understanding of innovation is chiefly based on a framework originally termed *"Technological* Innovation System", we note that this framework has increasingly been applied to the study of agricultural innovation (El Bilali, 2020), where the term "*Agricultural* Innovation System" is used. The core concepts contained in Tables 1 and 2 are often shared between the two approaches (Klerkx, van Mierlo, et al., 2012).

4. Methodology

4.1. Data collection

Data was collected from different sources and was organized around the innovation system functions as described in Table 1 (section 2). Firstly, a review was conducted of grey and academic literature. Academic literature was searched for using Scopus and the search terms (biodynami* OR agroecolog* OR agro-ecolog* OR nature-incl* OR nature OR biodiversity) AND (farm OR agricul*) AND (dairy OR milk) AND (Netherlands OR Dutch). We limited ourselves to these terms as they cover the most prominent alternatives to conventional dairy farming that share the aim of NIA to improve ecosystem functioning. "Organic" and "circular" were not included due to the limited overlap with nature-inclusive farming and especially their less explicit focus on nature and biodiversity, see for example van Doorn et al. (2016) as well as Figure 1B. A full review of the prominence in academic literature of different concepts, including for example "regenerative" or "high nature value" farming, is beyond the scope of this paper. A second search was performed with the search terms (farm OR agricul*) AND (dairy OR milk) AND (Netherlands OR Dutch) to put this in the context of research on conventional Dutch dairy production systems in general. Secondly, we performed a review of 271 newspaper and trade magazine articles published on the topic using the Lexis Nexis search engine using the search terms "nature-inclusive" (natuurincl*) AND "dairy sector" / "dairy" (melkveehouderij OR zuivel). This allowed us to get an understanding of the recent debates and discourse on the topic. Thirdly, additional information was gathered through four meetings with experts: two workshops with academic researchers at the authors' university in December 2019 and January 2020 to operationalize the ISA framework for the case study and generate a coding scheme and indicators for the structural-functional analysis; a meeting with government representatives, dairy sector representatives and stakeholders in January 2020 to collect these actors' perspectives on the system functions and barriers; and a focus group session with sector experts to validate initial findings and score the system functions in February 2020. During multiple workshops with a small group of people, discussions were held in which the authors actively took part, while in a single focus group discussion only authors three and eight were present to elicit responses from experts. We note that a focus group is specifically interesting compared with individual interviews since it allows for interactions between participants, which makes individual reasoning more explicit, and results in richer discussions and reflections on the subject (Runhaar et al., 2016; Säynäjoki et al., 2014). The focus group session was attended by 12 experts from sustainable farming initiatives, NGOs, the financial sector, government agencies, research institutes, the financial sector as well as independent advisors. The experts were chosen based on two criteria: for having a broad overview of the sector, and for collectively representing a large group of stakeholders. The focus group session allowed us to validate our findings regarding the functioning of the innovation system for nature-inclusive dairy farming and to identify barriers[7] underlying poorly performing functions. Additional information and perspectives were sought through personal communication from those dairy cooperatives, educational professionals and government actors who were unable to attend the focus group session. Literature, news articles and transcripts of meetings and personal communication were analyzed after the focus group session using a coding scheme based on the ISA framework described in section 2. A full overview of the number of workshops for data collection and verification can be found in the appendix.

7 For the purposes of the workshops and focus group session we simply used the term "barrier" as a commonly understandable descriptor of limitations to the innovation system, rather than introducing the terminology of systemic problems and blocking mechanisms at each meeting.

4.2. Data analysis

Data analysis followed common steps for an ISA (Wieczorek & Hekkert, 2012). Firstly, the structure of the innovation system was mapped by identifying relevant actors, institutions, networks and infrastructure (see section 2). Secondly, system functions were assessed using diagnostic questions in line with Wieczorek and Hekkert (2012) such as “Is there sufficient market demand for nature-inclusive dairy?” or “Do existing networks sufficiently spread knowledge about NIA among conventional dairy farmers?” (c.f. Wieczorek and Hekkert, 2012). The authors’ initial assessment of the state of each system function, based on desk research, was presented to the focus group to verify and enrich this assessment, by asking experts to give scores between 1 and 5, qualitatively described as follows:

1: Function forms no barrier for further adoption and diffusion of nature-inclusive practices
2: Function forms a slight barrier
3: Function forms a moderate barrier
4: Function forms a considerable barrier
5: Function forms an extreme barrier

Each function was discussed separately. Consensus was sought via a discussion in which each expert had the opportunity to express her or his opinion, and after which the group was explicitly asked whether they agreed with the proposed score. Discussions during the workshop provided insights into the reasons for poorly scoring system functions. These findings were then further enriched with results of desk research (see section 3.1). Thirdly, part of the research team (the two first authors and the last author) determined together which structural elements posed systemic problems for the poorly performing functions. They then added further underlying reasons to explain the systemic problems. Information on these problems was gathered across data collection steps and recorded as such. Fourthly, the systemic problems were mapped visually using a whiteboard and post-it notes, creating a web of blocking mechanisms; this was informed by the assumption in the ISA framework that problems are connected (Wieczorek & Hekkert, 2012). This fourth step was simultaneously performed by authors 1 and 2 independently of each other and then compared. A small number of differences (<5) were identified and discussed, which ultimately led to a version commonly agreed upon. Lastly, problems were identified that had multiple links to other problems, as these can be assumed to present a priority for policymakers and other actors.

5. Results

5.1. Structural-functional analysis

For each of the 7 system functions (see Table 2) we first describe the extent to which each function is already performing well (e.g. to what extent are networks, financial resources, and stimulating policies already present?), and then elaborate on factors (or barriers) that hamper the performance of each function. Here, we provide both statements from the focus group to illustrate these barriers, as well as evidence from desk research. We also provide the result of the focus group score for each function (grade on a Likert scale from 1 – 5, 1 = function forms no barrier and 5 = function forms an extreme barrier), see Table 3 for an overview. Following this assessment of system functions we explore the relationships between barriers that surfaced for each function. Here we uncover underlying issues that are shared across the innovation system and which, through their interactions, constitute blocking mechanisms.

TABLE 3 | Results of focus group scores for each function (grade on a Likert scale from 1 – 5, 1 = function forms no barrier and 5 = function forms an extreme barrier). These scores were jointly agreed upon by the 12 participants.

Functions	Score: 1-5
1. Entrepreneurial activity	2
2. Knowledge development	4
3. Knowledge diffusion	4
4. Guidance of the search	5
5. Market formation	4
6. Resource mobilization – financial	4-5
6. Resource mobilization – human	4
7. Legitimacy creation	3

5.1.1 Function 1: Entrepreneurial activities

Regarding what is already working well, different business models for nature-inclusive agriculture are currently emerging (Polman et al., 2015). The business model of nature-inclusive farmers is often based on selling products at a price premium in the consumer market. Environmental NGO's are important actors that create legitimacy for these products by endorsing and advertising the premium brands developed by these farmers (Vermunt, Negro, et al., 2020). Unfortunately, the market for these premium products is limited. Therefore, the first reason for this low uptake of the innovation is a lack of economic incentives for farmers. The majority of conventional Dutch dairy farmers produce for the bulk market (domestic and export) at persistently low prices. Therefore, efficiency measures, such as cost reduction and scale enlargements are the main business strategies in the sector (Maij et al., 2019). Implementing NIA, however, may imply a decrease in farming intensity, an increase in the cost of production, or both (see section 4.1 and Erisman et al., 2017). This impacts farmers' financial bottom lines, and currently is not fully compensated for by the market (a sufficiently high price premium) or other incentives like payments for ecosystem services. This lack of economic incentives was stressed as the most important barrier by our focus group.

A second and related barrier is the limited action perspective of farmers. One participant in the focus group stated: "In recent decades many possibilities to be an entrepreneur as a farmer have been eliminated. Farmers are often trapped in a specific situation, facing many risks. And a lot of risks are passed on to the farmer." In financial terms, this is best illustrated by the fact that a Dutch dairy farmer has an average debt of €12,700 per cow; this is four times higher than in Germany or France (de Beer et al., 2019). In operational terms, farmers are often limited in the extent to which they can implement NIA practices: switching to fully grass-based feed for example requires additional hay storage capacity that may not exist on the farm. Furthermore, current regulations are at times too strict to allow optimal implementation of NIA practices, for example regarding mowing or the application of manure as fertilizer (Maij et al., 2019; Westerink et al., 2018). Farmers are price-takers, with a small number of value chain actors "dictating prices" and leaving farmers with little power to negotiate (Berkhout et al., 2019: 52). Their high dependencies on other actors limits the freedom to shift to different practices (Runhaar et al., 2017a; Vermunt, Verweij, et al., 2020). According to a 2018 survey, 55% of Dutch farmers have experienced pressure to accept lower prices from buyers (Baltussen et al., 2018), prompting regular calls to make sales of agricultural goods below the cost of production illegal (e.g. ChristenUnie, 2016).

Despite the limited number of farmers who are currently implementing NIA practices on substantial parts of their farm, the focus group participants concluded that entrepreneurship was in itself not a major limiting factor for further adoption of NIA: "It isn't that there is not a large group of entrepreneurs, it's mainly that the entrepreneurial interest is missing: there is no economic relevance yet" (participant focus group). Providing farmers with adequate incentives and a broader action perspective would enable them to experiment with, and implement, NIA practices. Therefore, the focus group of experts considered the lack of entrepreneurial activities taken by farmers as only a slight barrier (score: 2 out of 5).

5.1.2 Functions 2 and 3: Knowledge development and exchange

Several knowledge structures for NIA already seem to work well. In the Netherlands, there is a growing number of on-the-ground knowledge networks for NIA. Several 'living labs' have been established at the provincial level, in which practical knowledge is developed, exchanged and implemented within local networks of farmers and other stakeholder organizations (Prins, 2019). Furthermore, the national government has issued several 'Green Deals' to cover legislative risks to support farmers who are experimenting with innovative nature-inclusive approaches that do not fit the incumbent regime (Rijksoverheid, 2019b).

However, several barriers are currently hindering knowledge development and dissemination. A first barrier is the lack of integral knowledge that can be applied by farmers. Scientific knowledge on NIA for instance, is considered too focused on details and abstract understanding. This was identified in the focus group workshop as an essential characteristic for knowledge to be effective in engaging farmers outside the niche experiments, i.e. the large group of farmers that currently farm in a conventional way, but would be interested in adopting nature-inclusive practices. This can be illustrated by the following quote from a participant in the focus group: "The majority of farmers do not need detailed knowledge, instead they want handholds. We haven't organized this well at the moment".

Second, organized monitoring and knowledge dissemination to others outside the current knowledge networks is limited, and knowledge that is documented and published was perceived as too scattered by our expert consultation. This notion is supported by Cuperus et al. (2019), who identified 117 different offline and online information sources about nature inclusive dairy farming. This is in sharp contrast to knowledge available for conventional dairy farming, which enjoys strong support from agricultural universities as well as the value chain, including institutionalized data collection, yearly updated information reports supported by the main agricultural university and online feedback and support tools (Tittonell, 2013; Wageningen University and Research, 2019). A Scopus literature search performed by the authors yielded only 44 peer reviewed scientific papers on nature-inclusive dairy farming, against 1,098 papers on conventional dairy farming in 2019.

As a consequence of the predominant focus of current knowledge systems on conventional farming specific knowledge supportive of NIA is missing. This concerns in particular knowledge on creating an adaptive and holistic perspective, rather than conventional farming (Erisman et al., 2016); knowledge specific to the local context of the farm and its environment (van Dijk et al., 2020); knowledge on value creation beyond food production (Polman et al., 2015; van Dijk et al., 2020); and knowledge on alternative business models, organizing societal support, market creation and access, and the acquisition of subsidies for societal services. (Cuperus et al., 2019; van Dijk et al., 2020). To some extent this lack of knowledge is understandable, as the "market" for this knowledge (from the perspective of knowledge providers) is small compared to the type of knowledge demanded by the conventional dairy sector. Since advisory services in the Netherlands are dominated by private organizations (Knierim et al., 2017), these new forms of knowledge that could support a transition remain marginalized.

A high dependence of farmers on commercial actors (usually suppliers and other value chain parties) for knowledge acquisition and exchange was also identified as a barrier by our focus group. One participant stated: "Knowledge should not be supplied by the animal feed industry or other stakeholders with a commercial interest" and another said: "This discussion requires more focus on advice provided by commercial stakeholders. It is an enormous struggle to get rid of this knowledge, and this is blocking innovation". These findings are confirmed by recent studies (Cuperus et al., 2019; van Loosdrecht, 2019). Dependence on commercial actors reinforces innovation that matches the status quo and the interests of current regime actors, who often lack knowledge on alternative ways of farming. The focus group emphasized the need for a 'nature-inclusive agricultural information service' – similar to a previous information service run by the government until the 90s. The focus group confirmed the importance of empirical knowledge that fits farmer knowledge needs and empowering farmers again in knowledge structures: "Farmers need to be given the lead more in developing knowledge questions and in knowledge exchange. Other stakeholders should only facilitate this process."

Our focus group workshop regarded this function as highly problematic and hindering the growth of the innovation system, mainly due to the lack of integral and applicable knowledge, the current knowledge structure which is steered by commercial interests, and the fact that it is not sufficiently built up around farmers themselves and their knowledge questions (score: 4 out of 5: considerable barrier).

5.1.3 Function 4: Guidance of the search

Different institutional levels already provide guidance on NIA. At the European level the Common Agricultural Policy's second 'pillar' includes the objective of "restoring, preserving and enhancing ecosystems dependent on agriculture and forestry" (Nègre, 2020). The EU Habitats and Birds Directives also provide context for agricultural areas (European Commission, 2018). In addition to implementation of EU policy, the Dutch government provides guidance in the form of the 2018 vision "Agriculture, nature and food: valuable and connected" (Schouten, 2018). Provincial governments and other stakeholders, like NGOs and farmer associations, also publish visions for agriculture and rural areas, containing goals for biodiversity restoration (Wojtynia et al. 2021, under review). The three Northern provinces of Drenthe, Friesland and Groningen as well as the national government have also signed the "Regional Deal Nature-Inclusive Agriculture Northern Netherlands" to promote NIA in the region (Rijksoverheid, 2019b). Stakeholders from the private sector and civil society have also published visions for the Dutch agri-food system, many of which contain goals for biodiversity restoration (e.g. Commissie Grondgebondenheid, 2018; LTO, 2017; Natuur & Milieu, 2017). In addition, a large dairy cooperative, a bank and an NGO developed an instrument to value biodiversity with key performance indicators for biodiversity. This instrument, called the "biodiversity monitor", can be used by supply chain actors, or different actors, to provide direction and incentivize farmers (Van Laarhoven et al., 2018). In the aforementioned visions, biodiversity is one of the most prominent issues. The term NIA is explicitly mentioned in at least four visions, including that the Ministry of Agriculture (Schouten, 2018). This indicates a broad recognition of the need to restore biodiversity in agricultural areas, including grassland used for dairy production.

However, despite these positive elements, there are still considerable barriers related to the current institutions, which were considered confusing rather than helpful in guiding farmers towards NIA. The main barriers are related to a lack of clarity, consistency and coordination. The focus group found the government's vision to be ambiguous and therefore not sufficiently clear for farmers. While the governments' vision states that NIA can be an instrument in achieving its vision of sustainable agriculture, it also endorses scale enlargement and export orientation (Schouten, 2018). Furthermore, the government's use of the term "circular agriculture" in the title of its vision and other policy strategies indicates a lack of conceptual clarity and prioritization of a different concept. The export orientation of the current regime is reflected in multiple visions (Wojtynia et al., 2021). Many Dutch farmers endorse this vision, though almost 60% of farmers feel this model is not sustainable in the long run (Trouw, 2018; van der Ploeg, 2020). Under these circumstances, stakeholders are struggling to provide an alternative vision that would help motivate farmers to transition to NIA, as illustrated by the following quote: "Farmers won't make big investments because they don't know what will be required of them in the future. How can we still offer guidance? It is not just about herb-rich grassland, it is also about sustainable management of soils, nitrogen, water and animal welfare. This is a struggle for us as well. What is the action perspective that we can offer farmers, in such a way that they feel confident enough to invest?" (participant focus group).

Second, focus group participants mentioned a lack of clear ambition levels, setting targets and requirements for more nature-inclusive dairy farming by the various actors involved in developing guidance. The focus of the vision and its implementation plan is mostly to facilitate and experiment on a voluntary basis, without aiming to make nature-inclusive practices a legal requirement. Furthermore, to date, only a voluntary target of growing 65% of feed protein on the farm itself or within a 20 kilometer distance from the farm has been set by the main dairy farmers' association (Commissie Grondgebondenheid, 2018).

Both the ambiguity in direction and the lack of clear ambition levels are compounded by the complexity of the topic, the potential tradeoffs between different ecosystem services, and the differences between regions and landscapes (Runhaar, 2020; Zijlstra et al., 2019). Based on a lack of clarity and a lack of clear ambitions and targets, the focus group of experts judges this function as an extreme barrier for the further diffusion of nature-inclusive practices (5 out of 5).

5.1.4 Function 5: Market formation

Recent efforts by the dairy industry and civil society have focused on the development of labels and certification of nature inclusive practices: the NGO Bird Association labeled various brands as "meadow bird friendly" since they complied with the requirements for meadow bird protection (creating herb-rich grassland and wetland areas). Such labels also include a price premium. Most of those brands are relatively small and collaborate with small groups of farmers who operate locally:

"Weerribben Zuivel" from the North of the Netherlands for example processed 9 million kg of milk in 2019, or only 0.1% of Dutch production (Mons, 2019). Another example of a recent effort is the development of the "On the way to planet proof" label owned by FrieslandCampina, the largest dairy cooperative in the Netherlands. About 700 farmers participated in this label in 2019 and as of 2020, these farmers receive a premium of €0.02 per liter. While public information NGO Milieu Centraal rated "On the way to planet proof" a 'top label', it was rated the least nature-inclusive of a number of labels by the Bird Association NGO[8]. The cooperative has furthermore slowed down the uptake of new farmers participating in the scheme in February 2021 due to low demand[9].

The benefits that NIA provides, such as higher biodiversity levels, improved water quality and carbon sequestration, are not captured in current market prices or financial incentives. It is estimated that an additional €0.02-0.03 per liter of milk (i.e. 6-10% above current prices) is required to compensate the costs a "conventional farmer" makes in the shift to NIA (Beldman et al., 2019). However, a recent choice experiment showed that a price increase of 10% would only motivate 5-7% of participating conventional farmers to switch to some form of NIA (Bouma, Koetse, & Brandsma, 2019). In consumer surveys conducted in 2017 and 2018, between 41.6% and 86% of respondents stated a willingness to pay such a price premium for sustainably produced milk (I&O Research, 2017; Morren et al., 2018), though this might potentially be the result of differences between stated and revealed preferences (Huang et al., 1997). In sum, although there seems to be some potential for a consumer market for NIA dairy products, at present such a market is quite small. This lack of markets for most of the benefits provided by NIA led our focus group to assess this function as facing considerable barriers.

The focus group participants pointed to the lack of willingness from supermarkets to pay price premiums. This can be explained by the intense price competition between supermarkets and the resulting focus on cost-reduction, which is considered a major barrier to the development of markets for nature-inclusive dairy (Erisman & Verhoeven, 2019).

Another barrier mentioned by the focus group is the current export of Dutch dairy products, which makes accounting for NIA in product prices more complicated: "Export makes it all very complicated. Where do you account for the extra costs of NIA: the price for the farmer, prices in the supply chain, or retail? It is really very complicated. The government should play a role here." (participant focus group). Two thirds of Dutch dairy products are exported, the majority of which to countries nearby like Germany and France (De Nederlandse Zuivel Organisatie, 2020). While these countries have the world's second and third largest markets respectively for organic products, it is unknown whether consumers in these countries can present enough demand for Dutch-produced nature-inclusive dairy to "move the needle" in

8 https://www.vogelbescherming.nl/bescherming/wat-wij-doen/onze-boerenlandvogels

9 https://www.nieuweoogst.nl/nieuws/2021/02/10/frieslandcampina-gaat-verder-met-minder-planetproof-boeren

the domestic production system, especially considering that nature-inclusive dairy is not necessarily organic certified (FiBL, 2020). This barrier was difficult to corroborate: while foreign organic brands for example are available in Dutch supermarkets, the companies behind them have operations based in the Netherlands. The Danish cooperative Arla for example has Dutch dairy farmer members and operates a milk factory in the Netherlands, though it is unclear how much of the milk processed there is in fact produced or consumed in the Netherlands[10].

A final barrier mentioned was the lack of focus on other services that farmers deliver with nature-inclusive agriculture, next to dairy or other 'common' commodities. This was illustrated by the following quote: "There are a lot of services that farmers deliver, I think we should see these as markets as well. It's just a different market, with different customers." (participant focus group). In this case dairy consumers are not the customer, but for instance municipalities, companies, water authorities or nature conservation organizations. Related to this, the participants noted that "stacking" multiple incentives or subsidies from different sources that are sometimes available (e.g. from government agencies, the supply chain or nature protection organizations) is difficult to coordinate.

Based on the problems related to a lack of willingness to pay the price premium, the export focus, and also the lack of markets for ecosystem services provided by NIA, the focus group rated this function as considerably hindering the growth of the innovation system (4 out of 5).

5.1.5 Function 6: Resource mobilization – financial

Currently, the Common Agricultural Policy (CAP) forms an important source of financial resources to farmers. Greening measures and agri-environmental schemes are supported within Pillar 2 at approximately €61.4 million, which is less than 10% of Pillar 1 (direct income support). Agri-environmental schemes are provided as subsidies to collectives of farmers. However, by 2018, only 9% of grassland was managed according to such schemes (Boonstra & Nieuwenhuizen, 2019).

Furthermore, if farmers have transitioned to NIA, there are no structural financial resources to compensate for the lower yields due to extensification or higher costs. Farmers cannot cover these lower yields or higher costs themselves. To illustrate this, in the period 2014-2018, the average income of a dairy farmer's household was only €59,600. However, 35% of dairy farmers had an income below the national 'low income' level in the same period. Financial debts are high, in particular due to the high land cost of grassland of €59,000 per hectare, the highest in the EU (Eurostat, 2018b; Silvis, 2020). Structural budget shortages are common amongst farmers, with average long-term debts of €1.1 million and an average solvency of 73% (H. Van der Meulen, 2019). In addition, 88% of dairy farmers lease at least some of their land, and 11% of these farmers are for more than 30% dependent on short-term lease contracts. This means they are unsure if they can implement a long-term

10 https://www.arla.nl/arlafoods/over-ons/onze-geschiedenis/

management plan with insecure but higher lease costs (Silvis & Voskuilen, 2018). Moreover, a shift towards NIA can involve depreciation costs due to extensification of farms, e.g. overcapacity of barns (van Veluw & de Wit, 2017).

However, a switch to NIA often implies more extensive farming systems, which in turn often results in writing off costs. An example is depreciation costs due to overcapacity of barns, as reducing herd sizes implies redundant stable capacity (van Veluw & de Wit, 2017). Our focus group mentioned a lack of financial support in such situations as an obstacle, for instance from banks. Nature-inclusive business models don't "fit the mold" of how banks evaluate business prospects, and banks consider such business models too risky (Drion, 2018). Farmers making the switch to NIA often experience a decrease in revenues while they have to continue to pay off loans for buildings or machinery that the conventional production system requires. In addition, buying or renting additional land to extensify without reducing herd size is difficult due to the high cost of land mentioned above. Also, the focus group mentioned that in order to stimulate farmers, a different focus of the government is needed in terms of financial resources: "The government focuses on the few frontrunners with subsidies. But for the group of farmers behind the frontrunners, incidental subsidies will not help" (participant focus group).

Based on the barriers mentioned by the focus group, this group of experts assessed this function of financial resource mobilization as representing a considerable to extreme barrier, hampering farmers to transit to NIA (*4-5 out of 5*).

5.1.6 Function 6: Resource mobilization – human (education and training)

In recent years, there have been several positive developments regarding education on NIA. Courses have been developed by nature management organizations and agricultural education institutes for current farmers. Furthermore, with a new national agreement (a "Green Deal nature-inclusive education"), several agricultural education institutes have pledged to increase their focus on nature inclusive teaching by developing new teaching material for vocational and professional training institutes.

The overall performance of this function, however, was still judged to be problematic for the transition. The focus group mentioned several barriers. A first barrier is the lack of teaching materials. Despite increased attention on the topic, our focus group found that teaching materials are still not adjusted to the requirements of NIA; they are not developed integrally; and they are dispersed over different educational institutes and not equally available. A second barrier mentioned is a continued high legitimacy of the dominant "productivist" agricultural model. Many students grow up on farms that follow this model and expect in their education to be taught how to efficiently produce large volumes of food, which often requires practices that are not in line with NIA. This was expressed by a dairy sector specialist in our focus group with experience in educating young farmers. One of the participants stated, however: "Some students do it differently than their parents. This has a lot to do with norms: what makes a good farmer? When you talk about change, this is a key issue." This same way of thinking is prominent among agricultural extension workers and advisors, who similarly receive little training on NIA (van Loosdrecht, 2019).

The focus group judges this function as a considerable barrier hampering farmers to transition to NIA, mainly based on a lack of sufficient teaching material, and the "productivist" culture which is still dominant in most educational institutes (*focus group score: 4 out of 5*).

5.1.7 Function 7: Creation of legitimacy / counteract resistance to change

The small group of farmers that have adopted NIA includes grassroot initiatives or niches that experiment with new approaches, techniques and business models that deviate from those of the current regime. Front runners in NIA seek to increase their legitimacy by demonstrating the value and viability of NIA. A common strategy is to try to counteract the arguments of critics with data and information about the performance of NIA on environmental, social and economic aspects (Farjon et al., 2018; van Dijk et al., 2020), and to demonstrate that viable business models based on multiple value creation are possible (Polman et al., 2015). This reinforces the need for new knowledge and monitoring systems that specifically focus on NIA (ISA functions 2 and 3) and that use indicators that go beyond efficient food production as the main performance indicator (De Olde et al., 2016; van Dijk et al., 2020). The creation of certified labels for NIA can be successful in creating legitimacy (e.g. Vermunt et al., 2020). Furthermore, monitoring and assessment schemes have been set up by value chain parties to stimulate nature-inclusive production through price premiums (Van Laarhoven et al., 2018). This is therefore a good example of an effort to coordinate monitoring NIA.

On the whole however, NIA does not nicely fit within cultural norms according to which a good farmer is highly productive, has a "neat" farm (precluding possibilities to include landscape elements for increased biodiversity), and perhaps most importantly does not deviate too much from the mainstream (Westerink et al., 2019). These new practices are therefore often regarded as alien by regular farmers and fall outside of what is considered 'good farming practice' (Burton, 2004; Westerink et al., 2019). This extends to the value chain, as well as financers, research and educational institutes, and policy makers, leading to a lack of the legitimacy that is needed to warrant access to financial, scientific and policy support (Geels, 2010; Van Oers et al., 2018). Decades of success in producing cheap food at high volumes mean the value chain has difficulties adjusting to a move away from this model (Erisman & Verhoeven, 2019; van der Ploeg, 2020). Similarly, Dutch consumers have become used to cheap food: household spending on food is in the bottom quartile of EU countries, explaining the low demand for and market share of nature-inclusive dairy (European Commission, 2019b; see also 5.1.4).

This deviation from conventional agriculture in turn leads to the sense that NIA challenges the incumbent way of working, which is generally oriented at incremental and predictable change rather than radical innovations of business models (Geels, 2010), and in response to that a resistance against adopting newly developed nature-inclusive practices. This is clearly manifested in the public discourse in opinion pieces advocating against NIA. These opinions not so much oppose the urgency of more sustainable farming but tend to focus mainly on pragmatic difficulties, and try to undermine the legitimacy of NIA. Our analysis of 277 news articles contained 31 definitively negative statements on the topic. These mainly concerned the conceptual clarity and definition of nature-inclusive farming, the perceived lower productivity and feasibility of such a farming model, and that such an approach would be too ambitious for most farmers. However, most positive or neutral articles also contained doubts or mentioned barriers pertaining to feasibility of viable business models, regime resistance and regulatory issues, indicating legitimacy problems for NIA.

The legitimacy of NIA was considered a moderate barrier by our focus group. While we observe a growing number of advocates of NIA from various initiatives, the focus group asserted that these actors insufficiently cooperate to amplify their advocacy. Another reason is the absence of farmer figure heads to which the majority of the farmer community could relate to. The focus group judged this function as a moderate barrier *(3 out of 5)*.

5.2. Blocking mechanisms

Section 5.1 outlined the state of each innovation system function, providing an overview of the barriers to mainstream adoption of NIA practices in the Dutch dairy sector. In this section we explore the connections between the weak system functions and the underlying systemic problems to better understand why the innovation system is not functioning well (Wieczorek & Hekkert, 2012). We unravel five blocking mechanisms that each cover a distinct theme, and highlight links between them.

5.2.1 Blocking mechanism 1: missing financial incentives

The first blocking mechanism revolves around the lack of a business case for NIA and insufficient economic incentives for farmers, which negatively influence the system functions resource mobilization and entrepreneurial activity (see Figure 2). As shown in the functional analysis above, farmers do not receive sufficient premiums from the value chain, including consumers, supermarkets and cooperatives, to stimulate a transition to NIA; farmers are price takers given the export orientation of the sector; the provision of ecosystem services is not compensated by alternative markets; and stacking incentives is difficult to coordinate.

An underlying systemic problem for the aforementioned problems is that externalities from conventional farming are not priced, so a level playing field is missing in the market (Farjon et al., 2018; TEEB, 2018): agricultural practices which negatively impact biodiversity are not taxed, and those practices that enhance biodiversity are not sufficiently rewarded or compensated. Ultimately these problems result from a lack of regulation and binding agreements which would oblige value chain actors to account for biodiversity and ecosystem services in product prices, and to pay for negative externalities, such as water pollution or soil depletion (Van Grinsven et al., 2015).

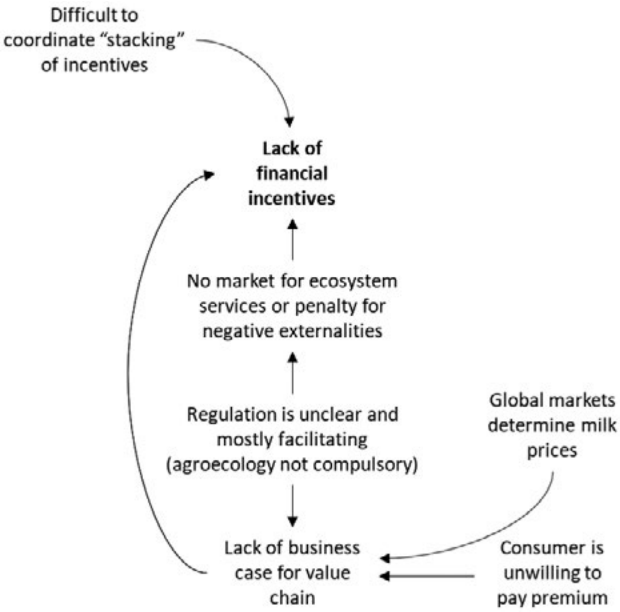

FIGURE 2 | Blocking mechanism around missing financial incentive systems.

5.2.2 Blocking mechanism 2: Limited action perspective of farmers

A weak spot identified in our desk research and confirmed in the focus group session was the limited action perspective of many dairy farmers, which negatively influences entrepreneurial experimentation. Multiple factors negatively influenced farmer perspectives to act (see Figure 3). A first one is that structural budget shortages are common amongst farmers, as we identified in the functional analysis. Budget shortages can in turn be attributed to a lack of financial incentives for nature-inclusive practices (see 5.1.1) and to the high capital intensity of the sector (see 5.1.5).

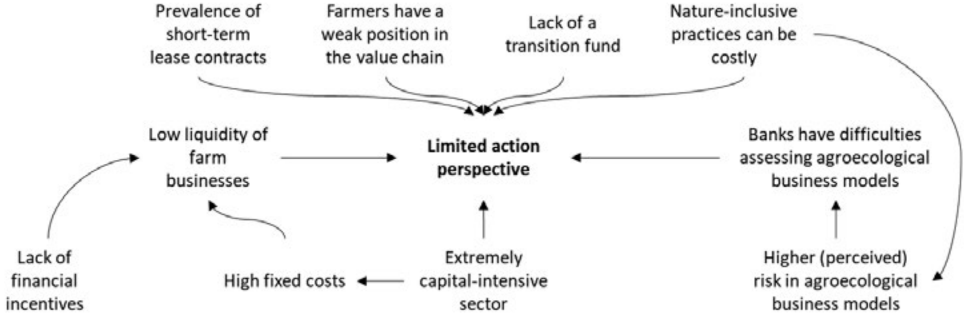

FIGURE 3 | Blocking mechanisms around limited action perspective for farmers.

Another factor contributing to a limited action perspective is the vulnerable position of farmers in the value chain, as they are the price-takers (see 5.1.1). Further, dependencies on short-term lease contracts and depreciation costs of land contributed to farmers' limited action perspectives (see 4.3.6). Structural funds that could cover some of these transition costs are not widely available. A last problem is lack of access to finance from banks (see 5.1.5). This in turn is partly a result of the nature of NIA, which in the current agri-food system implies higher costs and therefore higher (perceived) risks to be unable to pay loans back.

5.2.3 Blocking mechanism 3: Lack of a shared and concrete vision for NIA

Another blocking mechanism we identified is the lack of a unified vision and concrete ambition levels for NIA, which negatively influence function four (guidance of the search). Various underlying factors are at play here (see Figure 4). Firstly, the relation between biodiversity and agriculture is complex (Fijen et al., 2019), which makes setting tangible goals and standards difficult. This is further complicated by regional differences in soil type and landscape characteristics, as the development of the Biodiversity Monitor showed (Vermunt, Negro, et al., 2020).

Secondly, as shown in the function analysis (see 5.1.3) the vision is ambiguous; endorsing both regional approaches as well as upscaling and export orientation, the latter being in line with the paradigm of the current regime (Gaitán-Cremaschi et al., 2019). Another challenge is the strong compartmentalization of dossiers within the Ministry of Agriculture (e.g. on issues like biodiversity, nitrogen and phosphate) and even between Ministries. This policy-making "in silos" hampers an integral approach to providing guidance.

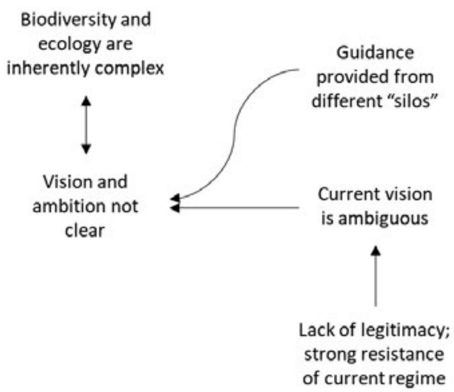

FIGURE 4 | Blocking mechanism around vision and ambition.

5.2.4 Blocking mechanism 4: Obstacles to knowledge transfer

Obstacles to knowledge transfer are caused by various underlying problems (see Figure 5). Some of these were already noted in section 5.1.2: knowledge is scattered and barely existent on several topics; not integral enough; too reliant on commercial actors; and complicated by the complexity of biodiversity. Moreover, an unclear vision and liberal regulations hamper knowledge transfer (see 5.1.3). This has led to a situation in which farmers, according to our focus group session, often simply do not know what types of knowledge and information they need to switch to NIA (see in Figure 5: “knowledge requirements are not clear to farmers”).

One underlying reason put forward by the experts we consulted is that knowledge development tends to be a top-down, expert-driven process without sufficient involvement from farmers. Another is the absence of an independent extension or information service, a result of privatization and the prevalence of public-private partnerships as a model for knowledge development (Hermans et al., 2015; van der Heide et al., 2011). A further underlying reason is the strength of the current regime, which directly affects knowledge and human resource development by perpetuating a demand for education according to the “productivist” model (see 5.1.6), and which also indirectly leads to a lack of clarity for farmers on knowledge requirements because in the current regime nature-inclusive farming is “just” an option, not a requirement.

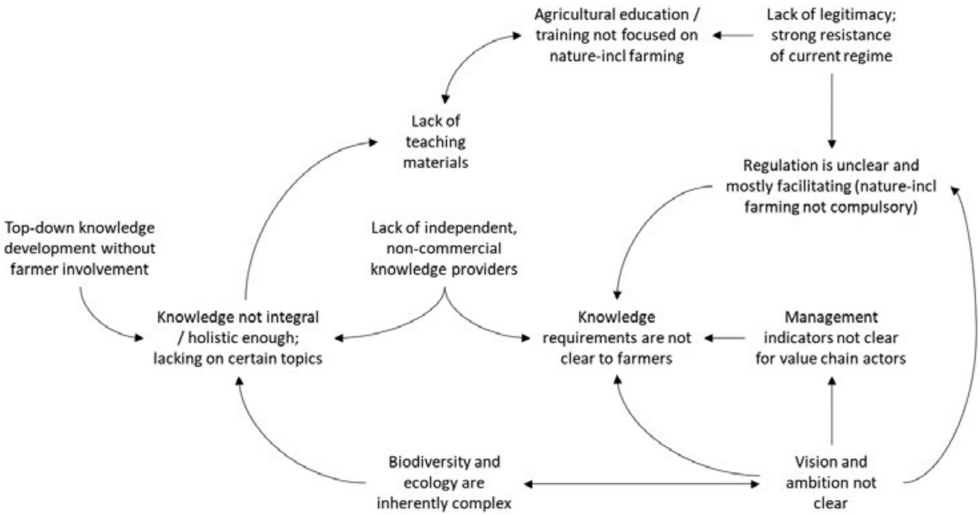

FIGURE 5 | Systemic problem around knowledge development and exchange.

5.2.5 Blocking mechanism 5: Regime resistance against nature inclusive agriculture

Since this paper studies regime transformation, change is dependent on existing regime actors, and requires a change in regime configurations. Regime resistance contributes to each problem set described in the preceding sections (see Figure 6).

Regime resistance leads to a lack of incentives in two ways. First, given the strength of the conventional “productivist” model, NIA is an option rather than a requirement. Regulations and markets reflect this: in the current system farmers are not sufficiently compensated for the benefits that NIA provides (see 5.1.1 and 5.1.5). Second, as stated in 5.1.7, decades of success in producing cheap food at high volumes mean the value chain and consumers have difficulties adjusting to a move away from this model (Erisman & Verhoeven, 2019; van der Ploeg, 2020). Furthermore, cost-efficient and capital-intensive production systems are culturally valued and considered an ideal by many farmers in the current regime (Westerink et al., 2019). These factors limit farmers' financial action perspective, as they have a high perceived need to invest in expensive machinery and therefore have relatively low liquidity, limiting their ability to switch to NIA.

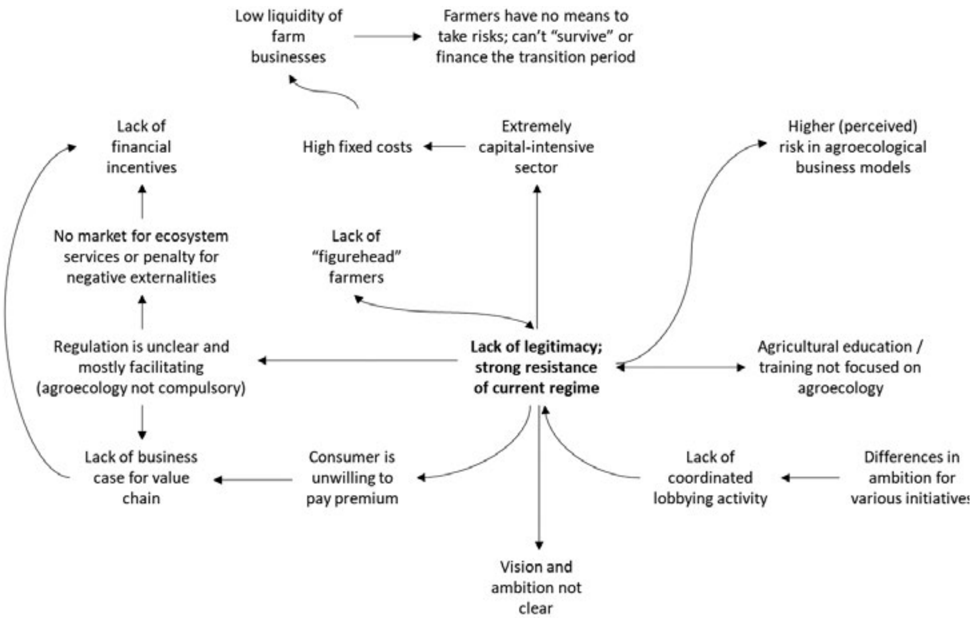

FIGURE 6 | Systemic problem around regime resistance.

Problems with regard to vision and ambition are also affected by the regime, as the export orientation of the current regime is reflected in multiple visions including the government's (see 5.1.3). Simultaneously the differences in ambition between proponents of NIA, as well as the pillarization within the Ministry of Agriculture (see 5.1.3), do not amount to a sufficiently strong challenge to the conventional model, thus keeping the regime intact.

As stated above, knowledge is often provided by commercial actors whose business models depend on the high-input / high-output farming model (see 5.1.3). Independent advisors are concerned advice to switch to NIA may lead to drops in revenue or other risks contrary to expectations of growth and predictability (van Loosdrecht, 2019). Moreover, agricultural education is still heavily focused on the conventional model, with many students growing up on conventional farms demanding education in line with what they have experienced so far (see 5.1.6). This is not only a barrier to more education on NIA, but also another dynamic that keeps the regime intact.

Lastly, the cumulative effect of the aforementioned systemic problems is that only a few farmers farm in a nature-inclusive way which also means that there are few “figurehead farmers” who can showcase their success to neighbors and in broader farmer networks. This lack of figureheads is another underlying reason for the strength of the regime, since NIA is often regarded as alien by regular farmers and fall outside of what is considered ‘good farming practice’ (Burton, 2004; Westerink et al., 2019).

6. Discussion and conclusion

This paper aimed to understand the factors that prevent the mainstream adoption of nature-inclusive dairy farming practices in the Netherlands, by applying an innovation system approach. We identified knowledge development and exchange, guidance of the search, market formation and resource mobilization as weak system functions. The causes for these weak functions can be explained through five blocking mechanisms, each of which contains several systemic problems that interact and collectively influence the innovation system. The blocking mechanisms are centered around five themes: (1) missing financial incentives, (2) limited action/financial perspective of farmers, (3) lack of a shared and explicit vision and ambition for NIA, (4) problems in knowledge transfer and (5) regime resistance. We showed that that the most important barriers to NIA’s mainstream adoption lie in the "productivist" regime. These barriers reinforce and compound each other, which makes challenging this regime increasingly difficult. One example is that non-binding regulations and an uneven playing field in the regime, combined with little financial incentives to transition to NIA, are compounded by the fact that the sector is geared towards a capital-intensive business model that restrict farmers’ liquidity. Together, low liquidity and limited financial incentives severely limit farmers’ action perspectives, which in turn reduces the number of positive examples that could stimulate farmers to switch to NIA – a mechanism long recognized to be key in the diffusion of innovation (Rogers, 2005).

The explicit focus on the blocking mechanisms that affect innovation system performance for a specific subsector is an important contribution of our paper to the literature on system innovation. The geographical scope of a single region allows us to highlight problems in a specific institutional context (see also Kruger 2017; Schiller et al. 2020; Sixt, Klerkx, and Griffin 2018; Klerkx, Aarts, and Leeuwis 2010). Unlike most other ISA, this paper focuses on a particular farming style or approach (NIA) and subsector (dairy production). This focus allowed for a concrete investigation of the innovation system functions, particularly market formation and resource mobilization. In contrast to many ISA that focus on the nature of problems (e.g. Kieft et al., 2018), the approach taken in this paper enabled the exposure of linkages between problems as well as their relative importance. This approach allows us to highlight niche-regime interactions in transition processes and the identification of promising policy interventions needed to promote system change.

Considering the growing attention for adjacent concepts such as regenerative agriculture (Giller et al., 2021; Schreefel et al., 2020), as well as for agroecology in contexts beyond Europe (Bellwood-Howard & Ripoll, 2020), using our approach to study such concepts in the same and other contexts would be appropriate aims for further research. A broader evidence base for the barriers to alternative agricultural approaches can furthermore help confront detrimental policies at EU level and beyond (Pe'er et al., 2020). Another avenue for further research would be to empirically test the novel framework of mission-oriented (agricultural) innovation systems in similar cases, given the increasing popularity of mission-oriented policymaking (Klerkx and Begemann 2020; Hekkert et al. 2020). It is already apparent from prior research that clear definitions of, and directionality for, alternative agricultural approaches are lacking (Bellwood-Howard & Ripoll, 2020; Menary et al., 2019; Turner et al., 2016). This presents a dilemma: on the one hand, added clarity could aid in the diffusion and upscaling of such approaches; on the other hand, narrowing them down further risks promoting a "silver bullet" attitude that is difficult to reconcile with a growing recognition of the existence of – and need for – a diversity of solutions to agri-food system challenges (Berthet et al., 2018; Gaitán-Cremaschi et al., 2019; Niederle, 2018).

Challenging the current "productivist" regime requires a well-functioning innovation system. But, as we have shown, the development of such an innovation system is dependent on exactly the same regime actors, institutions and infrastructure which hamper development of this innovation system at the same time. In other words, there is a chance of remaining in a vicious cycle as change needs to come from within the regime. In the transition literature this type of transition pathway is described as 'regime transformation', instead of pathways of 'substitution' where new entrants play an important role (Runhaar et al. 2020; Vermunt, Verweij, and Verburg 2020). This shows that only stimulating niche innovation will not suffice, as was already noted over two decades ago (Kemp et al., 1998). Accordingly, where policy has tended to focus on strengthening emerging innovation systems, in this and similar cases it would be effective to more strongly focus on intervening in current regime dynamics. This would not only benefit NIA but also other alternative farming methods and technologies. But what is needed to stimulate action by key stakeholders to remove barriers and bring about regime change (Runhaar, 2021)?

A growing body of literature on regime destabilization (for an overview, see Frank et al., 2020) provides a number of avenues to deal with regime resistance and, more broadly, puts our findings in perspective. First, various authors note the importance of visions and discourses as having the potential to both "prop up" regimes and to delegitimize dominant logics, practices and technologies (Kuokkanen et al., 2018; Stegmaier et al., 2014; Turnheim & Geels, 2013). While we have shown that the Dutch government's vision in fact legitimizes export-oriented "productivist" agriculture, we can also observe a variety of stakeholders challenging this logic with their own visions. In addition to sharing their visions, these stakeholders can also point more specifically to the ways in which the political economy of food production leads to adverse socioecological outcomes. Second, rules can be changed to facilitate the phase-out of practices and technologies that are not sustainable (Heyen, Hermwille, and Wehnert 2017; Kivimaa and Kern 2016; Van Oers et al., 2021). This pertains to our finding that for NIA to have a chance of success, regulatory changes are needed to bring about a level playing field for all farmers in the dairy sector. To this end, a broader valuation of agricultural products and services based not only on their financial value but based on their sustainability and product quality needs to be institutionalized. Valuing ecosystem services provided by NIA, as well as accounting for the ecosystem 'disservices' brought about by conventional agriculture, could contribute to this leveling of the playing field (Swinton et al., 2007; Zhang et al., 2007). Third, architects of transition strategies must be considerate of the potential socioeconomic, cultural and political impact of such strategies (Stegmaier et al., 2014; van der Ploeg, 2020). To that end, the design of new business and organizational models, as well as policy-making, need to take place in dialogue with those who are directly affected by them. Recent efforts to draw up a new social contract for Dutch agriculture – a "landbouwakkoord" analogous to the "klimaatakkoord", or climate agreement, of 2019 – are promising.

Chapter three

A new green revolution or agribusiness as usual? Uncovering alignment issues and potential transition complications in agri-food system transitions

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1. Introduction

There is a great need and urgency to imagine different futures for our agri-food systems, as these systems are now increasingly seen as fundamentally unsustainable. They threaten to push ecological systems beyond safe boundaries, and undermine their future productive potential through strains on soils, water, air and functional biodiversity (InterAcademy Partnership, 2018; Springmann et al., 2018). Furthermore, agri-food systems are locked into logics and processes like an overemphasis on cost-price reduction that contribute to these unsustainable outcomes, and because of this lock-in are resistant to change (Oliver et al., 2018; Plumecocq et al., 2018). A transformation of the ways in which we produce, process, trade and consume food is therefore urgently needed (Gaitán-Cremaschi et al., 2019; Willett et al., 2019). Transforming such a large complex system also needs to be a collective effort, especially because of the economic interests of the large number of actors involved. In the EU alone, there were 9.8 million farm owners in 2016 (European Commission, 2020b). Changing the rules, structures and incentives that currently lead to the unsustainable outcomes outlined above requires a broadly shared understanding, or vision, of what needs to be different in the future (Caron et al., 2018). Such a vision can guide transformations, including the necessary agronomic innovation, setting a distant but desirable and achievable goal (Ostrom, 2009; Wiek & Iwaniec, 2014).

FIGURE 1 | Contrasting visions for sustainable dairy farming, showing an efficiency-focused approach with manure fermenter and low-diversity field (left) versus diversity-focused approach with free range grazing integrated with fruit trees (right). Both photographs by Jerry van Dijk.

Visions play a crucial role in changing the dynamics and outcomes of large, complex systems because they portray a desirable future state for a system that is currently not meeting societal needs or staying within ecological boundaries (Bui et al., 2016; Folke et al., 2005; Geels, 2002; Hekkert et al., 2007; Loorbach, 2010; Walker et al., 2002; Wanzenböck et al., 2020). Visions are part of a broader set of directionality-providing futuring and foresight outputs that include future images, i.e. “iconic symbols that mediate the exchange of values, ideas and information” (Beers et al., 2010, p. 724); scenarios, i.e. explorations of “how the future may unfold ... from a defined initial situation” (Mitter et al., 2020, p. 2); and transition pathways, i.e.

"patterns of changes in socio-technical systems unfolding over time that lead to new ways of achieving specific societal functions" (Turnheim et al., 2015, p. 240). As such, visions are more overarching and forward-looking than images; less grounded in the status quo as a starting point than scenarios; and more static – presenting a future *state* rather than a change *process* – than transition pathways. Like images, visions can be explicit or implicit, and rhetorical or written down (c.f. Sovacool et al., 2019). Unlike scenarios, which tend to rely on some form of quantification or following a formalized methodology and are thus mostly developed by experts, visions are often generated by non-expert stakeholders and through multi-stakeholder initiatives. Being broader than scenarios, visions can act as a starting point to describe in detail and quantify scenarios that fulfill the general desires set out in a vision; transition pathways can then be developed to lay out the steps required to reach a scenario.

Studies of innovation systems in the agricultural domain frequently highlight a lack of direction for a practice or technology; variously due to a lack of coordination between actors (Turner et al., 2016), divergent agendas of actors (Menary et al., 2019), "lack of a common vision and policy coordination problems" (Sixt et al., 2018), or a lack of focus by responsible government agencies (Schiller et al., 2020). Commitment to the outcome of a foresight exercise is important for follow-up and implementation; this can be compounded when various actors try to implement competing or not fully aligned visions (B. van der Meulen et al., 2003). Furthermore, implementation gains traction when pursued through networks and processes of social learning, highlighting the importance of alignment (ibid). The increasing mission-orientation of policy-making, including in the agricultural domain, provides a framework to formalize the follow-up to visions by linking the desired future state to coordinated structural change policies (or missions) to achieve this state (Hekkert et al., 2020; Klerkx & Begemann, 2020; Pigford et al., 2018; Wanzenböck et al., 2020).

Because of the often normative and value-laden stances of practitioners and even researchers, notions and concepts pertaining to the future of agri-food systems are often contested (Plumecocq et al., 2018). Two illustrations are the "land sparing vs. land sharing" debate (Mockshell & Kamanda, 2017; Phalan et al., 2011; van der Windt & Swart, 2018) and the recent critical scholarly examination of regenerative agriculture (Giller et al., 2021; Newton et al., 2020; Schreefel et al., 2020). While not all stakeholders in the transition of a large, complex system like an agri-food system need to share a uniform vision, a higher degree of alignment is beneficial to bringing about change in such a system for reasons of efficacy and legitimacy (Weber & Rohracher, 2012). This is especially the case when the transition is of a more fundamental, transformative nature and where transitions are mission-oriented (Hekkert et al., 2020).

This paper proposes a method to determine the degree of alignment between stakeholders on diverse issues in the transition of a large, complex system. This approach is valuable for those wishing to better grasp future trends and potential areas of friction in transitions. Using the Dutch agri-food system transition as a case study and vision documents by stakeholders as the empirical material, it asks how the exploration of alignment between visions of stakeholders on diverse issues in this transition can help identify where momentum can be created, as well as where tension or conflict are likely. This enables scholars and transition stakeholders to prioritize negotiation, experimentation and research avenues for such a transition.

2. Materials and method

2.1. Theoretical framework

The function of visions in changing large, complex systems is to guide the development of innovation (Bui et al., 2016; Hekkert et al., 2007; Wanzenböck et al., 2020); to help set long-term goals and targets (Folke et al., 2005; Geels, 2002); to help formulate change agendas and their monitoring frameworks (Loorbach, 2010); and to set the boundaries for scenario development (Walker et al., 2002). Visions can offer powerful 'leverage points' to intervene in such systems (Meadows, 1999); and their absence is a common form of 'directionality failure' hindering transformative change (Weber & Rohracher, 2012). The concept of directionality is key to our analysis, and we operationalize it in section 2.4.2.

The literature on visions presents vision development as a fairly straightforward process, where a group of stakeholders and experts deliberate on the system's problems and its desired future, and then produce a shared vision. This is the case for both socio-ecological systems governance and transition management frameworks (Folke et al., 2005; Loorbach, 2010). Such a process is possible where a relatively small system is concerned, e.g. in the case of a particular technology (c.f. Truffer, Voß, & Konrad, 2008) or landscape (c.f. Folke et al., 2005) where the majority of stakeholders can be gathered in a "transition arena" to reach consensus. Such a process is also possible in the context of food and agriculture where particular production systems are concerned, as for example in the design of new poultry husbandry practices (Klerkx, van Bommel, et al., 2012).

Where larger, more complex systems like a nation's agri-food system are concerned, a more complicated process of negotiation and alignment is usually needed to reach consensus: the nature of the transition itself is more complex, because of system size and complexity; the interests and underlying beliefs of different groups can diverge significantly, meaning more divergent worldviews need to be bridged; and an alignment of expectations within a specific actor group on a specific issue needs to be further "collectivized", i.e. shared between stakeholders in different sectors (Truffer et al., 2008). Exogenous events like an outbreak of avian influenza or food safety scandals can catalyze such processes of negotiation and alignment, although more commonly a lengthier process of policy learning and argumentation in public discourse is required (Bulkeley, 2000; Sabatier, 1988). This is echoed in the field of policy studies, where social learning is recognized as a governance and negotiation mechanism (Ison et al., 2014). This has been applied in agri-food system research pertaining to participation in rural development (Leeuwis, 2000), the reconfiguration of power dynamics in various case studies (Rossi et al., 2019), and conflict resolution in innovation platforms (Turner et al., 2020). We operationalize alignment as an outcome of such a social learning and negotiation process in section 2.4.2 below.

Recent attempts at operationalizing a mission-oriented perspective on innovation and dealing with societal challenges acknowledge this: societal challenges become relatively less wicked if stakeholders converge on an understanding of the problem, and then converge on a solution to that problem. This has been conceptualized as a “problem-solution space to contextualize missions,” where divergence on both the problem and solutions is characterized as “disorientation” whilst convergence on both the problem and solutions is characterized as “alignment” (Wanzenböck et al., 2020; see table 1). Section 2.4.2 below will operationalize this framework further.

TABLE 1 | Problem-solution space to contextualize missions. Creating alignment on a wicked societal challenge is a result of shared recognition of a problem (left to right column) and agreement on solutions to that problem (top to bottom row).

	Diverging views on the problem	Converging views on the problem
Diverging views on solutions	“Disorientation”	”Problem in search of a solution”
Converging views on solutions	“Solution in search of a problem”	“Alignment”

Without consensus on societal expectations, sustainability transitions may be hampered. A divergence of visions or lack of clarity on societal expectations can lead to uncertainty about technological developments, their legitimacy and potential uptake, thereby hindering entrepreneurial activity and innovation (Meijer et al., 2007; Negro et al., 2008). At a system level, dominant structures and power relations can remain locked-in if the challenge of alternative visions lacks concentration and support from a wide group of stakeholders and coalitions (Sovacool et al., 2019). Such situations are especially the case if dominant regime[11] actors are particularly powerful and can influence policy and discourse (Geels, 2014). In agri-food systems this is the case when there are relatively few but powerful actors at certain points in the value chain. In the EU for example, there is high market concentration in both upstream and downstream markets, and value capture has increased significantly for retailers while it has decreased for farmers in the last 20 years (van der Ploeg et al., 2016). Such actors are strengthened by the fact that they are part of the current regime of modern agri-food systems, which is tailored to their business model, and by their ability to mobilize a discourse of output maximization in the interest of feeding a growing world population (De Schutter, 2017).

At the same time, regimes are not monolithic: there is often, in practice, not one universal regime but rather a set of coexisting structures guided by different logics

11 We define regime in line with Geels as the “semi-coherent set of rules carried by different social groups … providing orientation and co-ordination to the activities of relevant actor groups, [thereby accounting] for the stability of ST-configurations” (Geels, 2002 p. 1260)

and responding to different kinds of societal expectations; regimes are in fact characterized by "institutional tensions and contradictions" as a result of different degrees of institutional coherence (Fuenfschilling & Truffer, 2014; Niederle, 2018). This means that a divergence in visions for food and agriculture need not necessarily translate to stalling the transition but offers the potential for different "subsystems" to go through their own transitions, and for diverse transition pathways to emerge (Gaitán-Cremaschi et al., 2019). The development of such pluriform systems-within-systems can be possible if the institutional configuration and coherence of the regime allows this, and if there is a relative absence of uncertainty for the "subsystem" in question. A period of contestation over visions and expectations can also be interpreted as a sign of society debating and sorting out its options for viable and legitimate transition goals (Smith & Stirling, 2010). Furthermore, societal challenges "will be contested, will be negotiated, and will evolve over time" (Kuhlmann & Rip, 2018, p. 451).

Ultimately then, the expression of visions can be seen as an important factor in societal contestation and negotiation. This is so not least because visions are an aspect of actors' discursive strategies, which can have a considerable impact on institutions (Beers et al., 2010; Hajer, 2005). The framework we develop in this paper can help to better understand these processes by which society deals with urgent, complex and evolving challenges. We apply it to the case of Dutch agriculture, which we introduce in the following section.

2.2. The Dutch agricultural transition

The Netherlands is highly efficient in the production of bulk food products for export. This is the result of social, economic and technological trends in the second half of the 20th century as well as policy responses to these trends (Council for the Environment and Infrastructure, 2013; de Haas, 2013; van der Heide et al., 2011). The main sectors are dairy farming, open and greenhouse horticulture, and arable farming (FAO, 2020). While highly productive, this system has led to a range of negative externalities: agriculture accounts for 15% of the country's greenhouse gas emissions (Coenen et al., 2018); it has had a devastating impact on biodiversity, especially insect and bird numbers (Planbureau voor de Leefomgeving, 2014); excessive nitrogen deposition has led to biodiversity loss in protected nature areas (Heer et al., 2017); excess ammonia, odor and fine dust emissions impact air quality near livestock farms, contributing to increased incidence of respiratory disease (Planbureau voor de Leefomgeving, 2018); ground and surface water quality are negatively affected by nitrogen and phosphorus losses, as well as the application of biocides (Berkhout et al., 2018; Centraal Bureau voor de Statistiek, 2020); there is high income inequality between farmers and the rest of society, with two thirds of farmers earning less than a modal income; and farmers are furthermore reportedly at higher risk of suicide and Parkinson's disease, as well as feeling unfairly criticized by society (Joosten, 2020; Natuur & Milieu, 2017; NOS, 2019; Trouw, 2018).

While the future of agriculture in the Netherlands and elsewhere in the EU has been debated and contested for some time (Dijksterhuis et al., 2007; Fischer et al., 2012; Mansholt, 1972; Veldkamp et al., 2009), two developments have recently sparked the discourse. First, in 2018, the Dutch ministry of agriculture published a vision for a transition towards circular farming as a solution for the problems identified above (Dutch Ministry of Agriculture, 2018). Second, in 2019, the Council of State (the country's highest administrative court) has ruled that the current policy to alleviate the impacts of nitrogen deposition in nature areas is at odds with EU policy agreements and therefore needs to be revised completely (Schaart, 2019). The ruling on nitrogen policy especially has put high pressure on agriculture to change, because it is the largest sector responsible for nitrogen emissions. Previous policies have led to emission reductions of for example nitrogen and greenhouse gases overall, but the rate of reduction is stagnating, legal targets for nitrogen deposition and water quality are not being met, and ambitious climate targets are looming (Berkhout et al., 2018). In the past, the main business strategy for most farmers had been a reduction of the cost of production through an increase in scale and efficiency. This was in line with post-WW2 policy goals of keeping food prices low and contributing to a positive trade balance (de Haas, 2013; van der Heide et al., 2011). While continued efficiency and output gains are no longer necessary for food security and affordability in Europe, the underlying economic logic of cost price competition prevails and the system is locked into unsustainable dynamics (Vink & Boezeman, 2018). After the Council of State verdict on nitrogen policy, however, it has become nearly impossible for farmers to get a production or expansion permit while continuing to adhere to such a business strategy.

Various stakeholders have been responding to these issues and to external incentives to change such as the Paris Climate Agreement. This takes many forms: farmers and consumers are experimenting with alternative farming practices and value adding processes, like strip farming crop rotation or processing beer brewing side streams into breakfast cereal (ERF BV, 2019; Instock, 2019). Other initiatives aim to bring consumers and producers closer together, such as community-supported agriculture (Van Oers et al., 2018). At a high policy level, the Dutch government has defined six food and agriculture related innovation and sectoral policy missions (Dutch Ministry of Economic Affairs and Climate Policy, 2019). Also, concurrently with and partly in response to the vision of the Ministry of Agriculture, farmers' associations (LTO, 2017), civil society organizations (Natuur & Milieu, 2017) and research and advisory institutes (Council for the Environment and Infrastructure, 2018) have produced their own visions. This increased "visioning activity", together with the increased pressure to change, present an interesting case to study which futures are being sketched for Dutch agriculture, how they overlap, and what the expected impact on the transition as a whole may be. More broadly speaking, this transition is emblematic of how diverse groups of stakeholders attempt to deal with complex societal challenges, or "wicked problems". Actors whose interests, norms and values are not always aligned need to collectively determine how to address an agroecological crisis within the boundaries of liberal democracy and free markets; this is the case across the EU (European Commission, 2019a) and other advanced economies such as Great Britain (Department for Environment Food & Rural Affairs, 2018).

2.3. Materials

This paper analyzes vision documents for the Dutch agricultural transition. A vision document is a written portrayal of a desired future state. We developed a threefold search strategy: a simple Google search; a more targeted search in the Lexis Nexis news archive; and via the researchers' network. Lexis Nexis covers 40,000 news sources from the past four decades (http://academic.lexisnexis.nl/). For both the Google and news archive search the following search terms (and their Dutch equivalents) were used: "Vision" OR "strategy" OR "future;" AND "farming" OR "agriculture" OR "food system;" AND "Netherlands" OR "Dutch." Furthermore, stakeholders involved in ongoing research projects of the authors were asked to provide us with vision documents their respective organizations had developed. This search strategy yielded 57 vision documents. To be included in the analysis, the documents had to fulfil the following criteria: publication since 2015 (to ensure that the foresight activities of different actors occurred in a similar post-Paris Agreement context and reflect the current position of the actor publishing the vision, to enable a reasonable comparison between visions); contain the expression of expectations of the future of the Dutch agri-food system or its impact on broader social and ecological systems; not be merely a forecast or extrapolation based on the current state of the system; not be a description of practices or principles applied in the present. This yielded 42 documents, which are listed with name, name of the publishing stakeholder and the type of that stakeholder in supplementary materials C.

2.4. Method of analysis

2.4.1 Identification of issues

Documents were inductively coded to identify issues discussed in multiple documents. This created distinct categories of statements concerning the state of the Dutch agri-food system. We chose a data-driven rather than a theory-driven approach (c.f. Fereday & Muir-Cochrane, 2006) so as not to impose thematic categories a priori. The issues are:

1. Agrochemical use
2. Antibiotics use
3. Biodiversity levels
4. Diet shift
5. Farmer livelihoods
6. Farmer-society relationship
7. Food waste

8. GHG emissions
9. Growth and scale of the sector
10. Human health
11. Individual farm business models
12. International food and feed trade
13. Meadow grazing
14. Mega barns
15. Nature areas
16. Nutrient circularity
17. Recreation
18. Regulatory intervention
19. Renewable energy production
20. Soil
21. Water availability
22. Water quality
23. Young farmers

A short review of the current state concerning these issues can be found in supplementary materials A. It shows that issues identified match current sustainability problems in Dutch agriculture. The documents analyzed differed in the extent to which they mentioned current problems: while some prefaced the vision of the future with an explicit description of the current situation (to justify and legitimize the vision), others omitted this and described only the future in a positive tone with different degrees of explicit justification. For example, while one document may describe at length the negative effects of nitrogen and phosphorus emissions before describing a future in which nutrient cycles are closed, another document may only state that in the year 2050, all nutrient cycles are closed at the farm level.

Having coded all documents according to these issues, the number of distinct vision documents making a statement on an issue was counted. Assuming that more frequently mentioned issues reflect actors' perceptions of the importance of an issue, these issue frequency counts give an indication of the priority of different issues in the Dutch agricultural transition. We acknowledge that there is a need to also look at the nature, specifically the power, of the stakeholders making statements on an issue; this is dealt with in the third step of the analysis (section 2.4.3).

2.4.2 Determining alignment

To determine alignment between stakeholders on the issues identified, statements were classified according to the *direction* and *ambition* of the statement. Speaking metaphorically, direction refers to the "dot on the horizon", while ambition refers to the desired rate and/or level of change. This second level of analysis allowed us to identify what kind of change relative to the status quo a vision contained, how drastically this change ought to be achieved, and the extent to which this is shared between stakeholders. As our focus is on the alignment between a variety of stakeholders publishing vision documents independently of each other, we do not assess the internal coherence or validity of individual vision documents. We measure alignment by analyzing whether stakeholders articulate standpoints in the same direction and with the same level of ambition.

For direction, the variables were binary: change in a progressive direction on the one hand or maintaining the status quo on the other hand. For the issue of "diet shift" for example some actors may advocate for less meat consumption whereas others may advocate for the currently prevalent diet. Direction is expressed as a single percentage, with 90% "for" implying 10% "against" and so on, expressing the proportion of stakeholders in agreement on a problem.

For ambition, three possible levels - low, medium or high - were assigned based on Donella Meadows' hierarchy of leverage points to intervene in a system (Meadows, 1999). This framework sets out an impact-achievability ranking of possible interventions in complex systems, ranging from adjustments to parameters (easiest to achieve, lowest impact) to transcending paradigms (highest impact but most difficult to achieve). It has been adapted to the sustainability transitions field, for instance to identify how different types of leverage points address different system characteristics (Abson et al., 2017). Following Abson et al. (2017) and as shown in figure 2, we hold that an actor can advocate for deep, transformational change in their vision by stating a desire for change of the system's design and intent (deep leverage points - high ambition level); they can espouse less fundamental changes to the system's parameters and feedbacks (shallow leverage points - medium ambition level); or they can make more superficial affirmations of norms and values underpinning the system without addressing any leverage points (no leverage points - low ambition level). For each issue, the proportion of statements falling into each ambition level is expressed as a percentage, producing three indicators.

To give an example, acknowledging the importance of soils with a statement such as "soil health is important" would be classified as low ambition: the statement does not address any leverage points or imply any changes. Aiming for increased soil organic matter would be classified as medium ambition, as it relates to a change in the parameters of a stock without any higher-level system changes. A high ambition in this example would be to let the soil's production capacity define the use of the land, indicating a paradigm shift from output-maximization to agroecology.

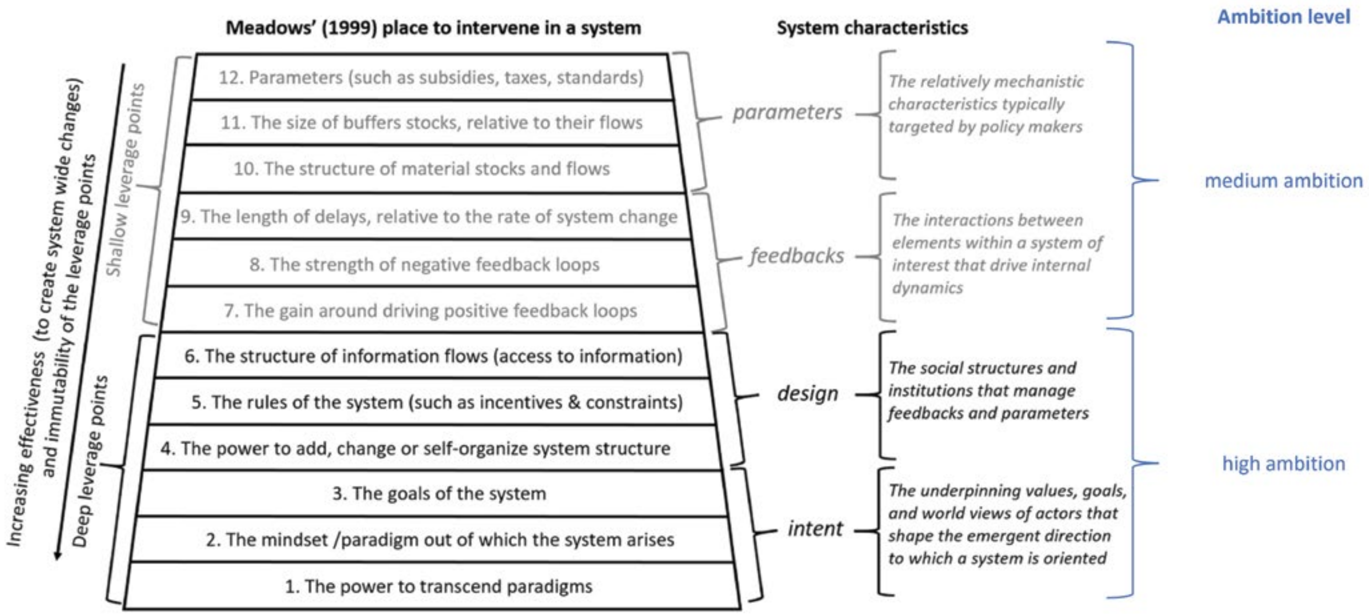

FIGURE 2 | Leverage points, system characteristics and corresponding ambition level, modified from Abson et al., 2017. Vision statements not addressing any leverage points were classified as "low ambition".

Our variables of alignment on direction and ambition can be transposed onto two common features of the frameworks reviewed in section 2.1: the need for a shared understanding of a problem, or more broadly speaking the fact that transitions need *some* normative guidance or directionality; and the subsequent need to formulate expectations of *how* a problem is to be solved in the future. These two dimensions align with the axes of the "problem-solution space" by Wanzenböck et al. (2020), shown in table 1 above. Agreement on direction is presented, in terms of this framework, as alignment on the problem: a statement in the direction departing from the status quo indicates that there is a problem with the current situation, whereas a statement against change or affirming the status quo indicates that there is no problem with the current situation. Likewise, agreement on ambition is presented as alignment on solutions: the different ambition levels signify different types of solutions, and when stakeholders share an ambition level they can be said to converge on a solution. This is not to say that agreement on ambition signifies agreement on a specific, concrete solution. Rather, we argue that when actors have similar views of a type of solution for an issue, they are likely to then support and implement concrete solutions as they become clear. Table 2 below describes all three ambition levels, details the types of solutions they correspond with, and gives examples from the data.

TABLE 2 | Descriptions of ambition levels, types of solutions and examples from the data.

Ambition level	Description	Type of solutions	Example
Low	Leverage points are not utilized; superficial treatment of the problem	Recognition of the problem; rhetorically ascribing importance to it	"Meadow grazing is valued by society" on the issue of meadow grazing (Dutch Ministry of Agriculture, 2018)
Medium	Shallow leverage points are utilized; system parameters and feedbacks are addressed	Aiming for resource use reductions or parameter changes; minor adjustments to existing rules	"Reducing the use of and replacing fossil resources by sustainably produced biomass" on the issue of GHG emissions (Dutch Ministry of Infrastructure and the Environment & Dutch Ministry of Economic Affairs, 2016)
High	Deep leverage points are utilized; system design and intent are addressed	Significantly changing the rules or directionality of the system; aiming for a change in mindset / culture; moving towards a new paradigm	"Net greenhouse gas emissions, including carbon sequestration, across a full dairy value chain are zero, or even negative" on the issue of GHG emissions (van Ooijen et al., 2016)

For the purposes of this paper, issues showing 90% agreement on direction or more were included in the category of issues showing full alignment on the problem. This is based on the assumption that if between 10 and 20 statements were made on an issue, one or two stakeholders (10%) would not be powerful enough to detract from the overall convergence of views on the problem. Similarly, issues with more than 80% agreement on ambition level were considered as essentially converging on the solution; note that the lowest possible value for ambition is 33%, as opposed to 50% for direction, and therefore the threshold for convergence on ambition is lower. Having calculated these percentages, we populated the problem-solution space with the issues identified in the first step of the analysis. This presents an overview of the level of alignment in the Dutch agricultural transition. In providing this analysis we do not take a normative stance on the need for full alignment on every issue; rather, we point out that a mismatch between stakeholders' positions in a transition (as evidenced by their visions) has the potential to lead to tensions and contestation, and therefore to impact that transition (Grin et al., 2010).

A sample of NVivo code summaries was verified by a researcher on the authors' research project who was not further involved in this study. That researcher's categorization of statements matched 89.9% of the first author's categorization of the same statements. Using a set coding scheme based on frameworks may have improved intercoder reliability, but the authors decided that this would have come at the cost of comparability of statements for issues that do not easily fit into pre-existing categories.

2.4.3 Expected transition dynamics

In addition to providing a framework to classify issues, Wanzenböck et al. (2020) propose three policy strategies to reach the lower-right quadrant of the problem-solution space, i.e. alignment on both the problem and the solution. These are a problem-led pathway focused on creating a broadly understood and legitimized problem framing; a solution-led pathway focused on creating innovations that will eventually "find" a problem and gain societal support; and a hybrid of the two which consists of iterations of negotiation and experimentation (see figure 3). The underlying theory is that when stakeholders agree on both the problem and the solution, moving towards implementing the solution (and trying to solve the problem) will be easier.

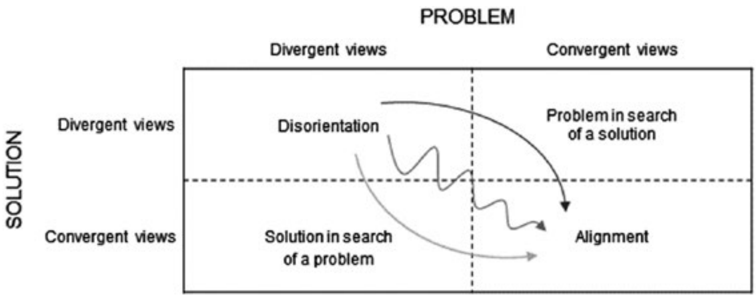

FIGURE 3 | Problem-solution space with schematic representation of strategies to reach alignment. Upper arrow: problem-led pathway; lower arrow: solution-led pathway; zig-zag arrow through center: hybrid pathway. Reproduced from Wanzenböck et al. (2020). Reproduction permitted under Creative Commons Attribution 4.0 International (CC BY 4.0).

In order to assess the likely success of these pathways in the case at hand, we tested issues with some degree of divergence against three additional criteria. First, we looked at how far removed actors were from alignment on the solution for an issue. Here we assumed that issues with agreement on ambition of >66% have a higher chance of reaching convergence on the solution than those of a lower level of agreement, because fewer other actors needed to be convinced of the solution proposed by the majority of actors. Second, we analyzed the mix of stakeholder groups in agreement. Here our criterion is that at least two actors each from the public sector, private sector and civil society should be in agreement for the transition to be legitimate. This is in line with Wanzenböck et al. (2020) who talk of "different social groups" having to come to a shared understanding, as well as Truffer et al. (2008) who posit that collective expectations for system transformations go beyond specific actor groups.

Third, we assessed whether at least two regime and two non-regime actors are present in the group of actors in agreement on the solution. The assumption here is that agreement among only regime actors or only non-regime actors is not sufficient to come to consensus: in the former scenario an exclusively incumbent-driven transition could meet societal resistance, while in the latter scenario it may be difficult to persuade powerful incumbents to change. Regime actors are defined as stakeholders in the conventional food and agricultural value chain, as well as government agencies who have the power to determine the rules and practices for the sector. This includes for example the major farmer associations, large dairy cooperatives, government ministries and political parties that have been in government in the period studied, but excludes NGOs, peasant farming movements, opposition parties or individual farmers that do not sell to major cooperatives or retailers. This is in line with a recent systematic review of research on sustainability transitions in agriculture and food systems (El Bilali, 2019).

Fourth, we assess whether actors with a diverging view on the problem are in a position of power. Different actors can exercise different forms of power: they may be able to exercise material power, i.e. mobilize capital to impact technologies, physical infrastructure and information flows; rule-setting power, i.e. make or change rules and regulations; agenda-setting power, i.e. influence the political agenda; and discursive or ideational power, i.e. shape framings and perceptions and thus influence institutions (Fuchs & Glaab, 2011; Hajer, 2005). If an actor with a diverging standpoint on a problem holds material or rule-setting power, this has a relatively higher negative impact on the transition than if a dissenting actor holds other types of power.

While non-incumbents can play a prominent role in framing problems and experimenting with solutions and thereby drive transition pathways (Gaitán-Cremaschi et al., 2019; Niederle, 2018), resistance from regime actors is likely to stifle transition efforts that are not supported by at least some incumbents (Geels & Schot, 2007). In addition, recent research indicates that regime transitions can also occur "from within" (Runhaar et al., 2020). Based on these criteria, issues were either classified as having a low, medium or high likelihood of reaching alignment (low: meeting none of the three criteria; medium: meeting one or two of the criteria; high: meeting all three criteria).

3. Results and analysis

In this section we present the results of our analysis in line with the three steps of our method. First, which issues appear important in the transition? Second, how aligned are stakeholders on these issues? Third, on which issues can we expect quick convergence, and where can we expect contestation and negotiation? We furthermore reflect on the analysis with reference to relevant literature where appropriate to allow for broader, more general reflections in the following discussion (section 4).

3.1. Importance of issues

The prominence of different issues, in terms of how many documents discuss each, ranges from 7 to 26. The top 10 issues were discussed in more than 15 visions, and the bottom 3 by less than 10; figure 4 below provides an overview.

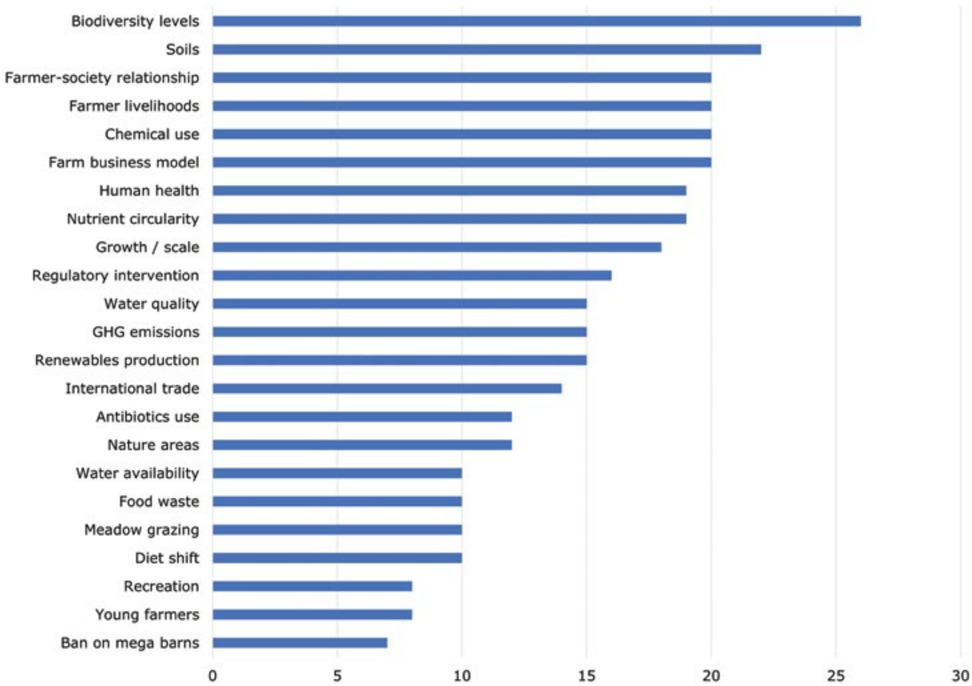

FIGURE 4 | Count of vision documents addressing each issue. Total number of documents was 42.

In general, environmental and social issues are more prevalent than economic issues: 174 statements were made on environmental issues, 140 statements on social issues, and 83 statements on economic issues. This indicates a high concern of most stakeholders for the effect of agriculture on Dutch ecosystems and society. The issues identified differ in kind: whereas some describe the state of the food system itself (e.g. soils or farmer livelihoods), others concern production techniques and technologies (e.g. antibiotics and chemical use) or the interactions between agriculture and other sectors (e.g. renewables production) as well as society as a whole (e.g. farmer-society relationship, human health). The issue of banning mega barns (barns housing more than 7.500 pigs, 120.000 laying hens or 250 dairy cows; Gies et al., 2007) is very specific and appears to be influenced by contemporary politics rather than the agri-food system's future: this issue was exclusively discussed by political parties in their election manifestos, indicating that it was particularly salient before the 2017 general election. The absence of digitalization or "smart farming" as a distinct issue may be due to the already relatively high diffusion of technology in Dutch farming; however this is speculative.

3

3.2. Stakeholder alignment

We explored the degree to which stakeholders (i.e. actors with an interest in the Dutch agri-food system) align on the direction and ambition of the various issues contained in the documents analyzed. Supplementary materials B provide detailed results per issue.

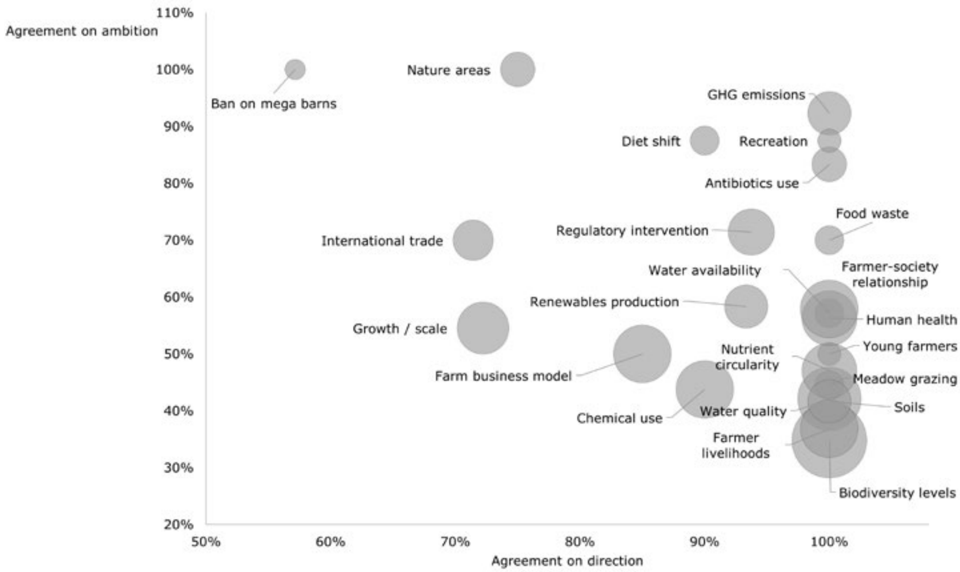

FIGURE 5 | Relative alignment on direction (x-axis) and ambition (y-axis) for different issues. Bubble size indicates prominence of the issue (count of stakeholders making a statement on the issue; see figure 4).

As figure 5 shows, a majority of issues (18 out of 23) show full or near-full (>=90%) alignment on direction. These are predominantly environmental and social issues, indicating that these kinds of issues are not only high on the agenda (as established in section 3.1) but are also based on a shared understanding of problems by the stakeholders. The remaining five issues show considerable disagreement on direction (57-85% alignment); three of these are of an economic nature, indicating that these types of issue are more contentious. Where ambition is concerned, nine issues have 70% or higher agreement levels, while the majority (14 issues) have agreement levels below 60%. This indicates that while actors in this transition generally have a common understanding of the problem, they do not necessarily agree on what types of solutions would be appropriate.

3.3. Expected transition dynamics

Using these results, we categorized the issues using the quadrants of the "problem-solution space" proposed by Wanzenböck et al. (2020) as presented in table 1 above. Issues are characterized according to level of convergence on the problem (columns) and solution (rows) in table 4 below.

TABLE 3 | Problem-solution space with vision analysis issues categorized by convergence on problem (related to direction) and solution (related ambition level); characterization of quadrant between quotation marks and the number of statements on the issue between brackets. Row and column categories, as well as characterization of quadrants, taken from Wanzenböck et al., 2020.

	Diverging views on the problem	**Converging views on the problem**
Diverging views on solutions	"Disorientation" • Farm business model (20) • Growth / scale (18) • International trade (14)	"Problems in search of solutions" • Biodiversity levels (26) • Soils (22) • Farmer livelihoods (20) • Farmer-society relationship (20) • Nutrient circularity (19) • Regulatory intervention (16) • Chemical use (20) • Human health (19) • Water quality (15) • Renewables production (15) • Food waste (10) • Meadow grazing (10) • Water availability (10) • Young farmers (8)
Converging views on solutions	"Solutions in search of problems" • Nature areas (12) • Ban on mega barns (7)	"Alignment" • GHG emissions (15) • Antibiotics use (12) • Diet shift (10) • Recreation (8)

Issues were further tested against three criteria to determine how easily the issue would move towards alignment (see section 2.4.3). With these criteria in mind, we will now explore each quadrant of the problem-solution space and the expected transition dynamics for the different issues.

3.3.1 Quadrant one: "Disorientation" (divergence on both problem and solution; three issues)

This is the most problematic quadrant, as stakeholders making statements on these three issues agree neither on the problem nor on possible solutions. These issues are the position of the Dutch agricultural sector in the global economy, the scale of the Dutch agricultural sector and size of Dutch farms, and the types of business models within that sector. With regard to the first, stakeholders are divided between a group that envisions limits to Dutch agriculture's impacts abroad and some limits to trade volumes, and a group that envisions a strong export orientation without additional limits. With regard to the second, one group envisions limits to farm size while another foresees continued growth and upscaling. And with regard to the third, most actors see business model diversification and innovation as the future while a smaller group of regime actors envision a reliance on existing business models.

These three issues are closely related to each other: the export orientation of the sector as a whole depends on increasingly productive farms, which in turn require business models that are cost-efficient and input-intensive (Thorsøe et al., 2020; van der Ploeg et al., 2016; Wageningen University and Research, 2018b). Moreover, these issues have considerable implications for virtually all other issues. This is illustrated by the fact that high-tech, intensive and large-scale farms generate greater nitrogen surpluses than smaller-scale, more extensive farms while providing less employment opportunities (Kleijn et al., 2012; van der Ploeg et al., 2016); and the fact that non-productive natural and social capital are not rewarded on high-input, profit-maximizing farmland (Sardaro et al., 2020). These tensions signify a fundamental disagreement on what the agricultural sector of the future will look like and how it will function. These tensions need to be defused before progress in other areas can be achieved. A logical order to negotiations on these issues starts with the sector's international orientation, as the volume of exports "required" shapes the size and character of sub-sectors and farms. This will be a difficult process, because private sector actors especially have legitimate concerns that limits to trade and farm growth threaten their business model, and because a logic of cost price reduction (made possible by farm upscaling and consolidation) is deeply embedded in the Dutch agricultural sector (van der Heide et al., 2011). It will also be difficult because of the power wielded by stakeholders with diverging views. Actors with rule-setting power favor the status quo when it comes to the sector's international orientation (the Christian-democrat party CDA, the Ministry of Economic Affairs and the provincial governments of Drenthe and North Brabant) as well as continued growth and upscaling (the Ministry of Agriculture and the conservative-liberal party VVD). On the issue of business models, it is the dairy farming and processing industry – with considerable material and agenda-setting power – that favors a continued reliance on existing business models.

3.3.2 Quadrant two: problems in search of solutions (convergence on problem, disagreement on solutions; 14 issues)

This quadrant contains the highest number of issues. Generally speaking, they fall into three categories. In the first group there are eight issues where the emerging coalition includes all types of stakeholders as well as regime and non-regime actors, but there is relatively low consensus on a solution – i.e. the largest emerging coalition is not substantially larger than groups proposing other solutions. Issues in this quadrant include biodiversity levels, soils, chemical use, farmer livelihoods, farmer-society relationships, nutrient circularity, human health and young farmers. They are also among the most prominent issues, being mentioned in 19 visions on average. For this quadrant, Wanzenböck et al. note that "the formulation of clear and approachable research and innovation missions … could indeed be an effective instrument for a targeted transformation" (Wanzenböck et al., 2020). The Dutch Ministry of Economics and Climate Policy has already formulated innovation missions for all these issues except for the young farmers (Dutch Ministry of Economic Affairs and Climate Policy, 2019). This indicates that in the Dutch context, the transition dynamic of finding solutions via a solution-led pathway is already underway and that we can expect relatively quick convergence on these issues. In the case of chemical use one of the actors not agreeing on the problem is the Christian-democrat party CU, which was part of the governing coalition and the party of the Minister for Agriculture, Nature and Food Quality from 2017-2021. By our criteria in section 2.4.3 this makes it a regime actor, and the party wielded rule-setting power despite its small vote share of 3.4% in both 2017 and 2021; however, it may not be part of the next government.

The second type of issue in this quadrant is characterized by relatively low agreement on ambition as well as a lack of buy-in from different stakeholder groups. These are the issues of renewable energy production, water quality and meadow grazing. Meadow grazing is interesting because the majority of actors are evenly split between a group aiming to make meadow grazing obligatory (high ambition), and another group trying to preserve the status quo where the practice is welcome but not obligatory (low ambition). It is also notable that the local branch of the Netherlands Agricultural and Horticultural Association (LTO) for the island of Texel is in the former group and the overall LTO dairy sector vision belongs to the latter. This highlights the importance of local context in developing a vision: whereas obligatory grazing is desired on the small island of Texel to aid in landscape management and to cater to tourists, such a measure may not be feasible for all farmers across the mainland. While there is an overall consensus on the problem here, a problem-led pathway may nevertheless be prudent to follow since the support base for apparent solutions is still relatively slim and legitimacy problems may arise if they were widely implemented. Given the context-dependent nature of these issues, provincial governments could play a facilitating role here to determine which solutions are most suitable for different regions. Notable for issues of this kind is that powerful regime actors tend to express non-committal and vague low-ambition standpoints. This can be interpreted in two ways. These actors may be uninterested in a transition and prefer not to engage on these issues. In this case, efforts by actors with higher ambitions to convince these regime actors to join their coalition may not be fruitful. Another interpretation is that regime actors make such statements due to a lack of knowledge on the topic or lack of knowledge of how other stakeholders prioritize these issues. In such a situation, actors with higher ambitions could lobby incumbents successfully and shift the balance towards certain transition strategies.

Lastly, there are issues with relatively high agreement on ambition but lacking certain stakeholders in the coalition. This suggests a solution is crystallizing but the support base is not broad or inclusive enough. A way forward on these issues could be for stakeholders making statements to test their plans with other stakeholders from other types of organizations both in and outside of the dominant agri-food regime.

One way to interpret the issues in this quadrant is that they are both considered as problematic and requiring attention and highly complex and difficult to find solutions for. This is true especially for issues concerning ecological aspects of the agri-food system. Biodiversity for example is impacted by non-agricultural activities like traffic, and highly variable between different types of landscapes (Concepción et al., 2008; Heer et al., 2017). This is compounded by a lack of knowledge on suitable management practices and possible technological solutions, as well as doubts about the cost and feasibility of such practices and solutions (Cuperus et al., 2019; Westerink et al., 2019). This underscores the need to invest in innovation and experimentation, though bearing in mind the need to innovate and scale responsibly (Wigboldus et al., 2016).

3.3.3 Quadrant three: solutions in search of problems (convergence on solution, disagreement on problems; two issues)

The two issues in this quadrant, the banning of mega barns and the enlargement of nature areas (which would likely come at the cost of agricultural land), are both highly polarizing in terms of direction and show full convergence on ambition for those stakeholders that do agree on direction. This can be explained by the fact that there was no nuance between the standpoints of stakeholders: nature areas were either to be better connected and enlarged or not; mega barns were to be banned or not. The former is frequently presented as a measure to improve the state of biodiversity, but two-thirds of the actors who oppose this measure also envision improved biodiversity levels (quadrant two). While connecting and enlarging nature areas is not the only way to reach this goal, this highlights the difficulty of developing – and creating legitimacy for – solutions to highly complex socio-ecological problems. Provincial governments have played a key role in nature protection since the decentralization of this policy domain in 2013, and an explicit goal of this decentralization was to create increased societal support for nature governance (Folkert & Boonstra, 2017). As visions from private sector actors contain no explicit statements on this issue, more inclusiveness towards this stakeholder group could be a point of attention for the provinces in this process.

3.3.4 Quadrant four: alignment (convergence on problems and solutions; four issues)

The last quadrant contains four issues where there is consensus on both the problem and possible solutions. These issues are greenhouse gas emissions, a diet shift from animal to plant proteins, antibiotics use, and recreation. The first two of these test well against all criteria for transition dynamics: agreement on the solution is high; both regime and non-regime actors are in agreement; and all types of stakeholders (public and private sector as well as civil society) are represented in the coalition. This is perhaps not surprising as climate change is a major policy priority for the Netherlands: the country is a signatory to the Paris Climate Agreement; the government has reached an ambitious cross-sectoral agreement to reduce greenhouse gases by 55% instead of the more common 49% by 2030 in a national Climate Agreement; and the Ministry of Economic Affairs has added "Climate Policy" to its title, elevating the importance of this dossier to the highest level (Rijksoverheid, 2019a). This suggests that the issue has already followed the alignment trajectory through the problem-solution space. In the case of the transition to a more plant-based diet, the only actor not agreeing on the problem was, understandably, the Dutch poultry farmers' association. This organization holds some agenda-setting power by virtue of being part of the wider Agricultural and Horticultural Organization LTO, but given the relatively small economic importance of this subsector (€1.59bn value added compared to €7.6bn of the dairy sector) this actor may not be in a position to stall the transition. For issues like these, it is suggested that policies "focus on the targeted development and diffusion of innovations, and the embedding (widening and deepening) of new social practices" (Wanzenböck et al., 2020). The Dutch Climate Agreement specifies more than 30 specific innovations that have been calculated to reduce sector emissions by 1.8-4.6 Mt CO_2e by 2030. The diffusion of social practices to aid in this transition is acknowledged in a goal to halve the climate effects of consumer choices by 2050, but specific measures or practices are not named (Planbureau voor de Leefomgeving, 2019b; Rijksoverheid, 2019a). We therefore suggest more explicit focus on consumer behavior and the embedding of climate-friendly social practices in the agri-food system as an additional policy focus. Furthermore, the Climate Agreement has a relatively short time horizon of 2030 as opposed to 2050. To reach 2050 targets of lowering emissions by 95% or more, more drastic measures need to be taken. These include reducing agricultural land use by as much as 11% and reducing livestock numbers by as much as 42% (Lesschen et al., 2020). This indicates that the coalition on this issue as apparent from our analysis may only stay aligned until the moment more detailed plans beyond 2030 are made. This is a further illustration of our main new finding: alignment that has been reached on crucial topics like greenhouse gas emissions may well dissipate if alignment on trade and sector size is not reached.

The other issues in this quadrant are characterized by high agreement on ambition and coalitions that include regime and non-regime actors but lack certain stakeholder groups: civil society in the case of antibiotics use, and the private sector in the case of recreation. In the case of antibiotics use, the vision of one civil society actor states that while antibiotics use has led to an increase in antibiotic-resistant germs, use levels have dropped considerably in past years (Natuur & Milieu, 2017). This suggests that this actor does not consider the issue important or worrisome enough to make a statement concerning the future of antibiotics use in the Dutch agri-food system, and that a lack of civil society visions on this issue is not an impediment to the transition. Furthermore, livestock sectors already follow sectoral plans and reference values to guide the further reduction of antibiotics use, suggesting that a diffusion of measures has taken place (CLO, 2019).

4. Discussion

Our approach of mapping issues in the Dutch agri-food system transition clearly shows issues on which stakeholders are aligned, which issues are contested, and which actors appear to form emergent coalitions around certain issues. This is a useful first step for the design of transition policies and can play a role in the mapping of missions in (agricultural) innovation systems (Klerkx & Begemann, 2020). We furthermore add a dimension to the mission-oriented innovation systems approach: the potential interdependencies and hierarchies between societal problems that are in different quadrants of the problem-solution space. Our methodology provides a starting point for researchers to bring these interdependencies to the surface. Furthermore, policymakers need to be aware of these interdependencies when they design and implement innovation missions.

This study took place against the backdrop of growing awareness and urgency about sustainability in the Dutch agri-food system. A key result is that for a majority of issues, stakeholders in the Dutch agri-food system acknowledge that there are in fact problems to be addressed. For a number of issues, broad and inclusive coalitions are emerging around a set of solutions (top-right quadrant of the problem-solution space; table 4). Many of these are supported by the Dutch government and are explicitly addressed by its innovation agenda to pursue a transition towards circular farming. In some cases, a solution is crystalizing but has yet to receive support from key stakeholder groups, including regime actors. Here the transition will require more awareness-raising, policy learning and negotiation before concrete solutions can be pursued with legitimacy and a chance of success. For a number of these issues, provincial governments seem well-placed to steer this process, especially considering regional differences in the size and nature of a problem. The decentralized governance structure of the Netherlands lends itself to such a role division.

Our main novel result is that a small number of issues are contested (top-left quadrant; table 4), and moreover present major constraints on the change potential of the aforementioned, relatively well-aligned issues. This echoes Zurek and colleagues, who warn that "there is the potential that the 'directionality' of pathways of change does not line up, with the risk of exacerbating trade-offs towards the future" (Zurek et al., 2021, p. 17). The current size and scale of the Dutch agri-food system, shaped by the strong export orientation of the sector, makes it difficult to meet long-term ecological targets as well as societal expectations with existing business models and technologies (Berkhout et al., 2018; Council for the Environment and Infrastructure, 2013; Planbureau voor de Leefomgeving, 2018; Wereld Natuur Fonds, 2020). This presents a great challenge for the sector, which can be dealt with in different ways. On the one hand, technologies can be developed to meet ecological targets while continuing with business (and trade) as usual. Nanotechnology, robotics, drones, gene editing and digitalization are just a selection of innovations that have the potential to reduce agriculture's negative externalities (The Food and Land Use Coalition, 2019). Critics however point out that such "techno-fixing" is simply a continuation of the industrialization and intensification of agriculture; that the long-term ramifications of such technologies are unknown; and that matters of responsible innovation and food sovereignty are often insufficiently considered by proponents of this type of solution (De Schutter, 2017; Della Rossa et al., 2020; Klerkx & Rose, 2020; Mooney, 2018; Zurek et al., 2021). An alternative is offered by more extensive, "low-tech" approaches like agroecology, permaculture or regenerative farming. These approaches commonly strive for the protection and utilization of ecosystem services as well as a reduction in resource use (Duru et al., 2015; Oberč & Schnell, 2020). Both approaches can help meet the social and ecological requirements that stakeholders almost universally acknowledge (top- and bottom right quadrants; table 4).

These insights can serve as starting points for the development of different scenarios which make the visions analyzed here more concrete (see for example Lesschen et al., 2020; Mitter et al., 2020). Such scenarios can show what is possible given the ecological limits and legal agreements an agri-food system is bound by, and can provide a transparent view of which tradeoffs will need to be made (Daw et al., 2015; Milestad et al., 2014). This can support the learning and implementation process bridging the development of visions as a type of futuring on the one hand and their implementation on the other (Klerkx & Begemann, 2020; B. van der Meulen et al., 2003). This pursuit of diversity is in line with a view of large complex systems as often being loosely structured around different institutional logics and allowing for multiple parallel development pathways (Fuenfschilling & Truffer, 2014; Niederle, 2018). Our method provides insights in the logics associated with perceived problems and solutions. Whichever transition course is embarked upon however will be constrained not only by the rules of an agri-food regime, but also by the rules and customs of political economy across scale levels. Furthermore, any changes in agri-food systems are limited by the demands of other sectors on scarce resources like land, water, finance and labor. The recent Dutch nitrogen crisis has made this question more pertinent than ever, as illustrated by the title of a high-level advisory report on the matter: “You can’t have it all.”

To some extent, the implementation of some visions can already be observed. The societal expectations apparent from the analysis have been translated into knowledge and innovation agendas by the Dutch government (Sonnema & Osinga, 2019) as well as the Top Sector Agri & Food, a platform organization for industry, science and government stakeholders (Topsector Agri & Food, 2019). In line with our analytical framework, the agendas are fairly concrete for issues where consensus is high on both problem and solution, primarily the climate challenge. In addition to these “fully aligned” issues, these research and innovation strategies also spell out priorities for issues where there is no consensus yet on the solution, such as nutrient circularity and biodiversity. This can be interpreted as a tentative search for solutions to problems that most stakeholders agree on. However, the proposals in these agendas largely fall into the category of high-tech solutions (such as nanotechnology, robotics and gene editing) to further improve input use efficiency. While this may be advantageous for agronomists studying such solutions, it also poses a problem because the issues are presented as “fixable” within the current socio-technical paradigm, leaving solutions within other paradigms insufficiently explored and as a consequence underfunded (Tittonell, 2013). Such a focus furthermore begs the question of who will pay for such technologies and who will benefit from their sale, especially given the widely acknowledged problem of farmers’ precarious livelihoods (in the Netherlands and elsewhere). Other avenues besides novel technologies need to be explored; in fact, we argue that it is the task of agronomists to demonstrate the viability of solutions that regime actors currently ignore. More importantly perhaps, it is the task of researchers to emphasize that the challenges our agri-food systems face can be dealt with by implementing a great variety of solutions in different contexts. The granularity of issues that our analysis of visions has brought to the surface shows that farmers can meet societally desired outcomes with many different farming styles. Continuing debates along the lines of false dichotomies (nature versus farming; high-tech versus low-tech; land sharing versus land sparing) will not bring us closer to achieving our goals. Researchers and policymakers are thus advised to pursue research, policy and governance paradigms that embrace diversity.

5. Conclusion

This paper has shown that a closer look at vision documents can give a preview of the degree of conflict and negotiation that is likely to occur in the transition of a large complex system. Most importantly, this can help identify issues that restrict the change potential and research agendas for other issues where the apparent level of agreement suggests that a transition is likely to proceed with relatively little conflict. We have shown for the first time that in the case of the Netherlands, there is broad consensus on which challenges need to be addressed, but less agreement on how these challenges ought to be addressed. Crucially, regime actors appear to be converging on high-tech solutions within the dominant economic paradigm, leaving limited space and funding for alternatives like agroecology or regenerative agriculture. This is also increasingly apparent at the EU level, with the new Common Agricultural Policy falling short of the holistic approach set out in the Farm to Fork Strategy and to a considerable degree continuing with business as usual (Pe'er et al., 2020).

Our analysis shows conflict over the underlying economic model in different visions, with incumbents favoring continued reliance on a growth-oriented paradigm. This leaves little hope for an open discussion, at a high level, of how this paradigm needs to change if broader societal goals are to be achieved. If this matter cannot be addressed head-on, pursuing food production models in line with "new social practices and narratives of post-capitalism, post-growth and post-consumerism" (Blühdorn, 2017, p. 58) would be a valuable endeavor (Koretskaya & Feola, 2020). Either way, policymakers must acknowledge the repercussions of dominant economic logics on agri-food system sustainability – and act accordingly.

Our novel methodological approach builds on the theory of a problem-solution space for mission-oriented innovation systems proposed by Wanzenböck et al. (2020), allowing identification of interdependencies and hierarchies in and between missions that may lead to trade-offs. In the case at hand, while there appears to be consensus on how to tackle ecological and social issues in the agri-food system, the future of that system's economic characteristics is contested, with powerful incumbents favoring the status quo. Any optimism about apparent alignment on ecological and social issues must be tempered when we acknowledge that the current economic paradigm constricts the solution space, something that is especially relevant for policy makers to be aware of when designing innovation missions and implementation strategies.

Agricultural sustainability research needs to focus more on highlighting the exact mechanisms by which prevalent economic models and logics pose a hurdle for long-term and holistically sustainable solutions, especially for those on which many stakeholders already align. This can prevent the implementation of costly, but ineffective policies. A prime example is the case of greenhouse gas reduction in Dutch dairy farming. All relevant stakeholders in the sector aligned on the need to reduce emissions, for which a stakeholder platform was organized. Using increased efficiency measures, the platform was successful in reducing the amount of greenhouse gas emissions per unit of production, but because the underlying economic model required continuous growth, the sector as a whole only increased its emissions (Doornewaard et al., 2017). Interdisciplinary research undertakings with colleagues from political science, science and technology studies, and other adjacent disciplines could help this. A first step in this direction can be for researchers to reflect on their research stance and identify dimensions or topics that could benefit from more attention from disciplines they are not familiar with (Hazard et al., 2020). A more structural solution could be for research funding bodies to establish more inter- and transdisciplinary research projects tackling societal challenges. Researchers can furthermore consider roles beyond knowledge production, for example as advocates confronting incumbent preferences or as brokers clarifying the implications of different policy pathways given the variety of stakeholder concerns (Pielke, Jr, 2007).

Chapter four

Spheres of transformation: exploring personal, political and practical drivers of farmer behaviour change in the Netherlands

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1. Introduction

1.1. Foregrounding the individual perspective in transitions research

The sustainability transitions community has produced important research on changes in socio-technical systems to better deal with grand societal challenges. This was done particularly through the development and application of meso-level frameworks that "conceptualize and explain how radical changes can occur in the way societal functions are fulfilled" (Köhler et al., 2019a, p. 2). Frameworks such as the multi-level perspective improve our understanding of long-term change in complex systems, and the study of innovation systems can identify barriers to the success of novel solutions to environmental issues (Geels, 2002; Wieczorek & Hekkert, 2012). These frameworks take worldviews, paradigms and other sociocultural constructs into account, but the aggregation and abstraction implicit in these prominent frameworks distances the analysis from the perspective of individual actors. While social practice theory does take individual behaviour as the primary object of analysis (Pantzar & Shove, 2010; Shove & Walker, 2010), the focus there is primarily on individual actors as users of a particular technology or consumers engaging in specific behaviour like recycling or showering (El Bilali, 2020). The field lacks perspectives that investigate the agency and behaviour of individual entrepreneurs and decision-makers within the constraints of cultural and institutional factors (de Vries et al., 2021; Kaufman et al., 2021; Upham et al., 2020). Our paper aims to address this gap by introducing and applying a framework that focuses on individual actors' behaviour in transitions and their experience of structural factors.

Foregrounding individual behaviour and social psychological factors in transitions research is important for a number of reasons. First, there are assumptions in transitions scholarship that change is required at all scale levels and stages of production and consumption, yet "interest in consumption and everyday life has remained relatively marginal" (Köhler et al., 2019a, p. 13). Everyday life is just as important in the study of entrepreneurship and innovation as it is in the study of consumption, as the literature on innovation as a lengthy process of "mindful deviation" has demonstrated (Garud & Karnøe, 2013). Second, individuals and their behaviour are a qualitatively different object of analysis compared to organizations and institutions (Upham et al., 2020). Fully grasping how human behaviour can be brought in line with sustainability transitions requires including psychological concepts in the study of individual actor-level transitions (de Vries et al., 2021). Third, if we accept that individuals are strongly shaped by sociocultural norms (Burton, 2004a; Upham et al., 2019), we need tools to understand how such sociocultural conditioning affects individual behaviour. Values, worldviews and ideals may form the "micro-foundations" of transitions frameworks (Geels, 2020), but this interaction between *personal* motivations and everyday *practical* behaviour needs to be more closely studied from the actor's perspective. In addition, institutions and other *political* factors co-determine behaviour but can also be shaped by individuals through institutional entrepreneurship, activism and other means (Upham et al., 2018). In short, we need an approach that also looks from the individual at the system, rather than exclusively from the system at the individual. To that end, we introduce the Spheres of Transformation framework in this paper and apply it to the case of Dutch farmers in transition (O'Brien & Sygna, 2013).

1.2. The person is the business: agriculture as a case study

Agriculture is emblematic in the transitions literature as food provision is a fundamental human need that is fulfilled (albeit unequally and often poorly) by a complex system with a host of sustainability challenges (Springmann et al., 2018; Willett et al., 2019). It is also emblematic because the study of food and agriculture in the sustainability transitions field is dominated by system perspectives and institutional analyses at the meso and macro level (El Bilali, 2019, 2020). Some scholars have studied food production at the individual level but with a relatively narrow focus on a particular technology or practice (Ely et al., 2016; Huttunen & Oosterveer, 2017). Nevertheless, farming is a highly suitable case study to introduce a framework that aims at putting the individual actor at the centre of attention.

Globally, some 608 million farms feed a population of 7.9 billion – one farm for every 13 people (Lowder et al., 2021). While that ratio has declined in Western societies, there are still more than 10 million farms in the EU (Eurostat, 2018a). Most of these are owned and run by families or individuals, and their personal lives and work are closely intertwined. This is a sector where an individual's beliefs, values and perceptions have a direct and critical impact on producers' operations and strategy (Burton, 2004a; de Snoo et al., 2013; Westerink et al., 2019). Individual or personal characteristics thus ultimately shape the sustainability of agri-food systems, reinforcing calls for the sustainability transitions community to focus more on agriculture (Hebinck et al., 2021). This stands in contrast with more centrally organized sectors serving similarly important human needs, such as energy or mobility, where much fewer individuals exercise the same degree of control: between 2013 and 2020, there were less than 81 electricity generating companies in the EU, of which some individual companies had a market share of 50% or higher in ten EU countries (European Commission, 2022a). At the same time, studying the way farmer-entrepreneurs navigate sustainability transitions should also be applicable to settings where individual decision making is mediated by group dynamics and other organizational psychological factors (Upham et al., 2020).

2. Theory

Our aim in this paper is to introduce the Spheres of Transformation (henceforth SOT) framework to the transitions literature. It is a multi-level framework that studies three dimensions determining individual behaviour and the micro-meso interactions between these dimensions. It is a tool to understand "how, why and where transformations toward sustainability may take place" (O'Brien & Sygna, 2013). It conceives of transformation as occurring in three spheres and through the interaction between these: the practical, representing "both behaviours and technical solutions"; the political, capturing the "systems and structures that create the conditions for transformations in the practical sphere"; and the personal, which includes "individual and collective beliefs, values and worldviews that shape the ways that the systems and structures (i.e., the political sphere) are viewed, and influence what types of solutions (e.g., the practical sphere) are considered 'possible'"(O'Brien & Sygna, 2013, pp. 4-5). Figure 1 shows a conceptual diagram of the three spheres, based on an interpretation in Gosnell et al. (2019).

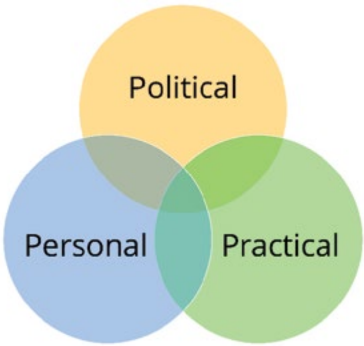

FIGURE 1 | Spheres of transformation depicted as overlapping areas of change (adapted from Gosnell et al., 2019).

The SOT framework takes up familiar concepts from the transitions literature, but also brings in the kinds of notions (individual-level behaviour, social psychology) that are at the centre of recent calls to update this scholarly field. The novelty of this approach lies in its investigation of the interaction between scale (spanning from a person's direct perceptions to reflections on information from all over the world) and conceptual levels (from the biophysical to the spiritual). The theory of change is that transformation in all three spheres brings the most potential for durable systems change. The spheres can have both positive or reinforcing as well as negative or restraining influences on another. We follow Gosnell et al. in describing the former as "zones of traction" and the latter as "zones of friction" (Gosnell et al., 2019).

The SOT framework has been applied quite broadly to issues similar to those tackled by the transitions research community. While working on similar topics in adjacent fields to transitions scholarship, scholars applying the SOT framework focus more on individual perspectives and the political dimension of change in complex systems. Work on the former includes for example studies on different perspectives on values for transformational change (Horcea-Milcu et al., 2019), while work on the latter for example emphasises citizen engagement (Wamsler et al., 2020) and social vulnerability (Eriksen et al., 2021).

The personal sphere has "a pervasive, often subconscious impact on the political and practical spheres, which in turn shape the context in which worldviews are reproduced or transformed" (O'Brien, 2018). The significance of the personal sphere, as well as the dynamics between the different spheres, are backed up by empirical studies of human behaviour. A person's intention or propensity to act is considered the most proximate factor predicting behaviour (Ajzen, 1991; Blumberg & Pringle, 1982; Krueger et al., 2000). Intention is also influenced by practical factors, specifically whether a person thinks they have control over a situation and whether opportunities to act otherwise are present (Ajzen, 1991; Ölander & Thøgersen, 1995). Factors in the political sphere can also have an influence on the personal sphere: farmers for example operate in cultural, political and economic systems where codified and uncodified expectations other actors have of them influence their views and behaviour (Burton, 2004a; Runhaar et al., 2017b). More broadly, informal institutions can mobilize values and emotions to create greater acceptance and legitimacy for an innovation (Tziva et al., 2020), and they can also constitute particular professional cultures that mediate the success of innovations (Wirth et al., 2013). On an everyday level, the "rules of the game" determine which practices individuals can implement, by for example banning certain chemicals in industrial processes or requiring certain livestock management practices. This can create friction when conditions and incentives are not in line with an agent's personal values, beliefs or identity (Burton & Paragahawewa, 2011; de Snoo et al., 2013). Lastly, the political and practical spheres can interact insofar as successes of innovations like alternative farming practices can first legitimize and eventually institutionalize such practices (Westerink et al., 2019). From the standpoint of transitions scholarship, it is therefore most interesting to investigate the intersections between spheres.

Psychological theories have become a part of the sustainability transitions literature, although Bögel and Upham (2018) found that the majority of papers only make implicit use of psychological theories. Social psychology, departing from mainstream psychology's individual focus, holds the potential to further our understanding of agency-in-context; approaches that examine psychological processes in human interaction "may be particularly useful through their explanation of individual agency within broader societal systems" (Bögel & Upham, 2018, p. 132). The SOT framework can serve as an approach that integrates different social-psychological perspectives on transition: the practical sphere for example can draw on an understanding of contextualized habits as proposed by practice theory (Shove & Walker, 2010). Moreover, SOT encompasses structural and institutional factors in the political sphere. We take up Kaufman et al.'s suggestion to draw on and explore "different perspectives with attention to what interconnections between behaviour and context they highlight, and obscure" (Kaufman et al., 2021, p. 599). The SOT framework's flexibility as a middle-range framework (c.f. Geels, 2020) lends itself to such an approach.

3. Materials and methods

3.1. Case study description

In this article we focus on the agricultural transition in the Netherlands. Most Dutch farmers operate according to the rules and norms of a productivist food regime, where the focus on the production and export of commodities necessitates a continuing drive for efficiency and cost reduction (Burton, 2004a; Gaitán-Cremaschi et al., 2019). The Dutch agricultural sector can be characterized by high land and labour costs, which partly explains the drive for efficiency. It is a competitive sector that is undergoing steady consolidation: the number of farms has dropped from 97,389 in 2000 to 52,695 in 2020 (Centraal Bureau voor de Statistiek, 2021b), while the average standard output – a measure of the economic size of a farm – has more than doubled from €194,000 to €449,000 (Centraal Bureau voor de Statistiek, 2021a).

Agriculture lies at the heart of a number of interconnected environmental and social crises in the Netherlands. The sector accounts for 15% of Dutch greenhouse gas emissions (Coenen et al., 2018), and has been a primary driver of a drastic biodiversity decline over the past half century (Bouma et al., 2020). Furthermore, societal and political tensions around agriculture have flared since a 2019 court ruling declaring the procedure for granting permits for nitrogen-emitting activities unlawful led to a series of farmer protests, some of which turned violent (van der Ploeg, 2020). This "nitrogen crisis" is emblematic of how a misalignment between SOT can lead to friction: regulations are driven by a political need to respond to emergency issues and change as frequently as new issues emerge (political); farmers have little financial room to invest in more sustainable production methods (practical); while they are often motivated by a long-term desire to maintain the business for future generations and as a result are risk-averse (personal).

While the majority of Dutch farmers operate in line with this conventional sector's norms and logics, contributing to and suffering from the consequences, an estimated 15% of farmers operate more sustainably (Erisman & Verhoeven, 2019). They incorporate nature conservation on their farms, utilize and protect ecosystem services, or strive for self-sufficiency in feed and circularity of nutrients. Speaking in terms of path dependence theory, while most Dutch farmers are locked into unsustainable trajectories, others have created new paths and have chosen to deviate from the dominant model. While innovation systems for alternative forms of farming do not function optimally (Vermunt et al., 2022), a considerable number of farmers are able to adopt unconventional practices and technologies to alter their business models. Looking at such farm-level transformations through the lens of the SOT framework can enrich our understanding of agency and behaviour in transitions and illustrate the merits of this framework. It can also provide policymakers and other agri-food system actors with insights to on the one hand remove unnecessary friction in their policies and programs, and on the other hand better understand how they can create more traction towards desirable change trajectories.

3.2. Data collection

We conducted interviews with 21 farmers in the winter of 2020/2021. These farmers are members of a learning network convened as part of the "Regenerative Farming" transdisciplinary research project[12]. Participants were found through purposive sampling and contacted through the network of researchers and practitioners in the project, and included farms of different types and sizes (Figure 2).

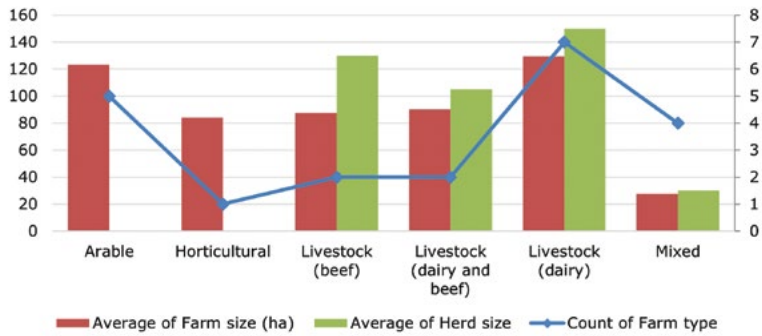

FIGURE 2 | interview subjects' farm types and sizes. Mean size (in hectares and/or number of livestock, left axis) and number of interview subjects per farm type (right axis).

Farmers were selected based on their interest in regenerative farming practices, which include holistic grazing, strip cropping, no-till farming and the creation and protection of nature elements (Oberč & Schnell, 2020). The farmers' actual experience with such practices ranged from none (only interest) to 40 years (see Table 1). Following the interviews we furthermore classified the interviewees according to innovation adopter categories (Rogers, 2005): we assigned a point for each characteristic in the different adopter categories (innovator, early adopter, early majority, late majority, laggard) that a farmer exhibited. While most of the farmers can be classified as innovators, a third more strongly exhibited characteristics of other categories. This yielded a diverse group of interviewees. Those that fall into the early and late majority categories provided a sample of more conventional Dutch farmers, although farmers with no interest at all in regenerative farming – or no awareness of this farming style – were not part of the analysis. However, the majority of farmers interviewed began the process of transforming their business models on regenerative principles in the last ten years; this allowed us to uncover

12 More information can be found at https://regenerativefarming.nl/

the "journey" from conventional to more sustainable business models and the friction and traction therein.

TABLE 1 | Interview subjects' demographic characteristics and innovation adopter categories.

Farmer gender	**No. of farmers (-)**	**Average age (y)**	**Min. and max. age (y)**
Female	1	53	n/a
Male	20	47.6	28; 72
Innovation adopter categories	**No. of farmers (-)**	**Average time since transformation (y)**	**Min. and max. time since transformation (y)**
Innovator	14	9.1	0; 40
Early adopter	2	2.5	2.5; 2.5
Early majority	-	-	-
Late majority	5	0.5	0; 2.5
Laggard	-	-	-

The interviews were conducted by the first author accompanied by MSc students who interned with the project for their thesis. The first author started the interviews and managed the flow of the conversation (see below), and the students were encouraged to ask additional questions at the end of each part of the interview. The interviewees gave written consent to record the conversation, take photos, share data with other researchers in the project, and to publish data anonymously. Interviews started with personal introductions, followed by explanation of the project and request to sign the consent and data sharing form. Next, basic information about the farm (including the main products and services offered, history of the land, short description of farming style and practices) and farmer (including age, sex, education and employment history, professions of parents and spouses if applicable) were recorded. The farmers then gave the interviewers a tour of the farm, during which we took photos and asked the farmers to explain their production practices.

After introductions and a tour, farmers were asked to assess their own performance on 16 outcomes for regenerative farming (Groot Koerkamp et al., 2021; also see Appendix B) for three time periods: the year 2000 or, if the farmer started working on the farm more recently, a more recent year; the fall of 2020, to assess the current situation; and the year 2040, to gain insights into the desired future situation on the farm. For each outcome and time period farmers were asked to score their farm's performance as basic, medium or high based on a short description provided (see Appendix B). This exercise facilitated a discussion about the areas that the farmer has worked on improving or has seen change in the past; to understand their current concerns; and to see what changes they wish to see in the future.

Second, farmers were asked to construct a timeline of significant events in their life from the moment they first contemplated farming as a livelihood to the present (see Figure 3). Farmers were asked to list moments, events or decisions that had the most impact in their subjective experience. In some cases, we prompted the farmers with examples. Interviewees were free to first list these moments with the year and short description and then talk about each in depth, or to move chronologically. We then discussed these with the farmer based on a previously prepared list of questions (see Appendix C) as well as notes from the conversation before the timeline exercise.

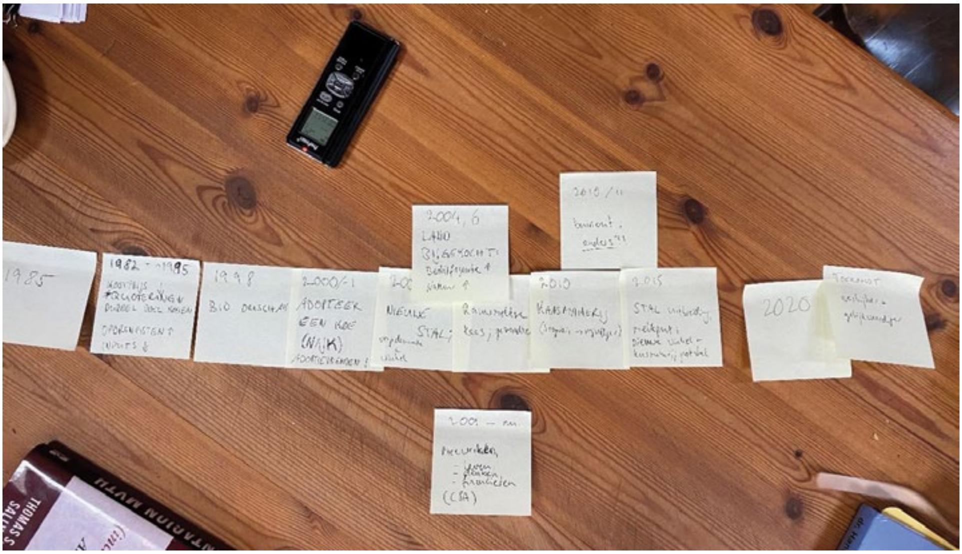

FIGURE 3 | Example of a timeline, with 1985 as the starting year (left) and 2020 the time of the interview (right). Between the two are post-it notes with key words and phrases relating to important moments and decisions in the life of the farmer.

The interviews were transcribed by the students, who were all native Dutch speakers, from audio to text within two weeks of the conversation. They were then imported into NVivo 12 for coding and qualitative analysis.

3.3. Data analysis

Interviews were analysed following a hybrid approach, in four steps (Fereday & Muir-Cochrane, 2006). First, we coded deductively using the three SOT as guidance. If a statement pertained to multiple spheres the statement was coded to all relevant spheres (addressing the overlapping areas of spheres in Figure 1). Second, we identified zones of traction and friction – i.e., positive and negative changes – within the spheres. Third, we synthesized and abstracted underlying themes found within the different codes using the constant comparison method (Given, 2008). Thematic categories were derived from the statements created in step two. Fourth, where spheres overlapped, we identified if one sphere was the source of traction or friction for another. For example, if an interviewee related that they experienced success with a new technology (practical sphere) and found this motivating or increasing their confidence (personal sphere), this statement was categorized as the practical sphere influencing the personal. This was difficult when all three spheres interact: if for example a subsidy (political sphere) allowed a farmer to experiment (practical sphere) and adjusted their mindset accordingly (personal sphere), it was often not clear from the interview transcripts whether the change in mindset occurred before the practical change or vice versa. We therefore present issues of traction and friction found in the overlap of all three spheres as one category.

After coding the transcripts to thematic categories, these thematic codes were compared and re-examined until all transcripts were coded and distinct categories emerged. Authors two and three independently checked author one's coding to ensure intercoder agreement.

4. Results and analysis

This section details the ways in which friction and traction occurred in and between the spheres of transformation. We start with individual spheres and their influence on the other two, before elaborating on the interaction of all three spheres – in theory the site of most durable transformation. Table 2 provides an overview of all zones of friction and traction.

TABLE 2 | Summary of issues from all interviews categorized according to the zones of friction and traction in three different spheres and their overlap.

	Friction	Traction
Practical	• Agronomical challenges • High cost of production • Lack of knowledge • Organizational challenges • Sales and marketing challenges	• Interaction and cooperation with non-farmers • Interaction with consumers • Lower operating costs
Political	• Inadequate vision and directionality from government and value chain • Policy focus on projects rather than system change • Power of large companies • Resistance of other farmers to change	• Increased awareness of alternative farming methods • Older farmers retiring • Potential for attractive lease conditions by "benevolent landlords"
Personal	• None	• Christian values • Confidence, daring, decisiveness • Entrepreneurship
Practical influences political	• None	• Circumventing regulations • Farming outside of the conventional farming system • Realizing payment for ecosystem services
Practical influences personal	• Inability to realize ambitions • Negative social consequences of farming differently	• Farming in, creating and experiencing an appealing landscape • Interacting and cooperating with like-minded farmers • Learning and figuring things out • Making mistakes and overcoming them • Meaningful and satisfying work • Receiving recognition and appreciation

	Friction	Traction
Political influences practical	• Difficult farming transition process • Higher cost of production • Regulatory challenges • System geared towards conventional farming • Unfavourable immediate institutional environment • Unfavourable market conditions	• Favourable market conditions • Institutional support
Political influences personal	• Conflicting values between farmers and other stakeholders • Fear of change of farmers • Negative and outdated image of farmers by society	• Alignment between norms and expectations
Personal influences practical	• Internalized productivist values • Time commitment to non-farming activities	• Intuition and common sense
Personal influences political	• Lack of trust in monitoring / Key Performance Indicator systems	• None
All three spheres	• Being pigeonholed • Difficult for frontrunners to influence conventional farmers • Farming has become less personal • Having no choice but to intensify • Low willingness to pay by consumers • No trust in the media • "Rule-bending" by some organic farmers	• Anticipating system change • Demonstrating the viability of an alternative farming model • Realizing the conventional farming system is not sustainable • Working towards ambitions and future plans

4.1. Influence of the practical sphere: source of (de-)motivation and means of institutional entrepreneurship

The practical sphere appears to cause considerable traction in other spheres. Tangible positive outcomes seem to have a powerful motivating effect on those whose actions are behind the outcomes, affirming beliefs and values. Experiences of interaction with like-minded farmers as well as receiving recognition from members of society are important sources of motivation and confirmation. Farming in, creating and experiencing an appealing landscape is another important source of motivation, mentioned by two-thirds of the interviewees:

> "This is the most beautiful region in the country. You have elevated terrain, small streams, so much variety. If you ride your bike here for a day you pass through the forest and other types of landscapes. It's just so amazingly beautiful."

Some farmers highlight that they consider their work meaningful because it is societally important, and feel they are able to "make a difference":

> "I can decide to plant cover crops. And my neighbour who lives in a flat, they can shout all they want that everything needs to change, but they can't do much. And I have the honour, and the luxury, to actually make a difference."

Zones of traction in the intersection of the practical and political spheres indicate the possibility of farmers creating and shaping social and economic structures, by for example setting up alternative organizational models with novel institutional arrangements, combining agricultural with institutional entrepreneurship. Some farmers were able to shape an institutional environment that suits them (by for example finding ways to get paid for providing ecosystem services) or bypassing official rules entirely (by for example circumventing regulations).

Some instances of the practical sphere leading to friction in the personal were reported. Farmers that have high ambitions sometimes fail to meet their goals, which was experienced as frustrating and demotivating. When the behaviour of the farmer is judged negatively by peers or neighbours the resulting negative social consequences can be hurtful to the farmer, in extreme cases leading to ostracization in the community.

4.2. Influence of the political sphere: structural conditions and normative (mis-) alignment

The zones of friction in this sphere clearly show how structure can limit agency. Economic factors threaten the business viability of regenerative farmers. Even beginning the transformation is difficult, as production often initially declines while higher prices may not be realized until later (through organic certification, which takes time, or by finding buyers that pay more for product quality). All but seven farmers described how unfavourable market conditions negatively affected their farming business and livelihood. Regulatory challenges are often mentioned, particularly by dairy farmers, and some farmers report operating in an unfavourable institutional environment (e.g. zoning restrictions, short-term land lease contracts).

The fact that the farming system is geared towards conventional farming affects the interviewed farmers widely on a practical level. They do not benefit from an enabling environment wherein banks, knowledge and information providers, subsidy schemes, inputs, and advisors are mostly set up to support an efficiency- and export-focused farming model:

> "It's mostly technical innovation that is subsidized. And if I apply with another type of solution then it's not accepted because it doesn't fit the picture."

Regarding advisory and extension services, a number of farmers criticized the lack of independent advisors, noting sarcastically that advice from a feed company is free. Similarly, some experienced that agricultural education is primarily focused on the dominant economic logic:

> "When I have interns here from the agricultural schools, they are told to do optimization calculations. And they always need to include loans and investments. Why can't you challenge people to leave things out, to reduce costs?"

The political sphere also negatively affects the personal. Farmers reported that the public discourse on farmers portrays them negatively. They experience this as demotivating and frustrating:

> "I don't run around with a red handkerchief around my neck and a stalk of grain in my hand, like you still see in children's books these days. That's really such an antiquated image, that really bothers me sometimes."

While these results show that predominantly zones of friction emanate from the political sphere, some instances of positive structural conditions and normative support were reported. Selling to the local community, having a strong position in the value chain due to a unique product, and good communication with value chain partners are all strategies that improved these farmers' position. Making use of subsidy schemes, for example for nature conservation and composting, allows farmers to benefit from institutional support. Farmers appear to have some degree of choice in value chain partners, landlords and other collaborators, while they cannot choose the laws they are governed by (though they can in some cases circumvent them). Often, structure is reshaped when value chain actors, landowners and other organizations make exceptions to institutional arrangements on the basis of farming methods, as illustrated by successful price negotiations for high-quality sustainable produce or payments for ecosystem services.

4.3. Influence of the personal sphere: doubt and drive

In some cases, farmers are undermining their potential for change in the practical sphere due to internalized productivist values, as their values and beliefs around biodiversity for example prevent them from changing their practices:

> "If you look out the window here you see a beautiful productive meadow, but it's only English ryegrass. A biologist would call it 'grassphalt'. And look, that's what you produce on expensive land, that's how I see it. Biodiversity is a luxury that you can only create on cheap land."

For other farmers that have successfully transformed their businesses, their commitment to non-farming activities – motivated by values of transparency and seeking connections with citizens – detract from their core activities. Zones of traction emanating from the personal to the practical include using intuition and common sense to take decisions that are not in line with what most other farmers would do, such as selling land to downsize the farm and finance the transition towards more costly regenerative production practices.

Numerous farmers have no trust in monitoring and Key Performance Indicator systems, which in the aggregate can lead to sentiments of scepticism and mistrust that undermine the institutions governing such systems (see also van der Ploeg, 2020). This shows that belief in institutions – or lack thereof – can be significant if enough actors hold these thoughts.

The frequently discussed zones of traction stemming from the personal sphere indicate this to be a strong positive driver of transformation. It is also one with a lot of "two-way traffic": personal traits enable, and beliefs motivate, practical action; successful outcomes in turn form and affirm beliefs and create motivation. Compared to the political sphere, the practical is one where positive experiences can be more easily sought or created by farmers: this can increase a sense of control and independence, but seems to require a certain mindset and perhaps also a somewhat advantageous "starting position" (in terms of e.g. financial situation, location of the farm or age). This supports the idea that, ideally, all three spheres align for transformation.

4.4. All three spheres interacting: virtuous circles and downward spirals

In theory, transformations are most durable and successful when all three spheres align; similarly, barriers are greatest when friction occurs in all three spheres simultaneously. Our case shows evidence of both dynamics. Two farmers stated that they found it difficult to influence conventional farmers if they are perceived as radical. Here their ambitions and hopes to influence other farmers clash with a culture in which their alternative farming practice is portrayed and perceived as radical, making it difficult or impossible to inform and convince other farmers to farm differently. This illustrates a well-known problem in the diffusion of innovation literature: there is a chasm between innovators and the majority of potential adopters (Rogers, 2005). This is difficult to bridge until enough members of the majority have started to adopt different farming methods and can serve as "figureheads", which in the Netherlands are lacking (Vermunt et al., 2022).

One farmer stated that they have no trust in the media, resulting from a clash between their own observations of wild animals and reports of biodiversity decline in what they call 'mainstream media'. They also found it offensive that consumers expect farmers to farm differently but are not willing to pay and thus do not help create more favourable market conditions. These experiences seem to have profoundly shaped their pessimistic and dejected attitude. Another farmer related that they had no choice but to intensify due to the capital intensity of the sector and low dairy prices, describing a feeling of powerlessness. Another farmer stated that being associated with organic farming led to them being pigeonholed by classmates during their education. These examples show that observations in the political sphere, coupled with experiences in the practical, can create and reinforce negative thoughts and feelings in the personal sphere.

The realization that conventional farming is not sustainable was a driver of change for multiple farmers. In some cases, it started with an observation of negative outcomes from one's own farming practices, which was then related to the embeddedness of these practices in the conventional farming system, and ultimately led to a change in beliefs and values. In other cases, it was a confrontation with new information about fossil fuel use in the farming system and the realization that it affected one's own farm too which led to the change in the personal sphere:

> "The soil here, it was useless. Working it you would use 100 litres of diesel per hectare. I remember, as a boy, you could go through it with a cultivator quite easily and sow grass. And 10 years later that same soil was useless. That was something that really got me thinking."

All three spheres aligned in the farmers' work towards fulfilling ambitions and future plans. In one case the farmer was strongly motivated by their ambition to promote fully grass-fed dairy farming, for which they see a wider role in meeting the country's sustainability challenges. Other farmers have similar ambitions, albeit on a smaller scale, wishing to for example create a more vibrant rural community, to prove they can farm without using chemicals, or to create a farm they can pass on to their children. A related zone of traction is demonstrating the viability of an alternative farming model; some farmers explicitly mentioned that they are proud of disproving doubt and scepticism from naysayers.

Another instance of alignment between the three spheres is when farmers anticipate system change. They work from a positive, proactive attitude and see societal change as an opportunity to meet societal expectations before they become "hard" requirements:

> "Most farmers only change things when they have to. I prefer to change a few years earlier, or even 10 years earlier. I prefer to try things in advance and see how that goes, because then you have time to adjust and understand it."

These zones of traction indicate strong virtuous circles when personal, political and practical spheres align.

5. Discussion

5.1. Reflections on the results

A number of interviewee characteristics stand out as relevant to the potential for change: risk-averseness, open-mindedness, reflective capacity, and sociability with peers.

With regard to risk-averseness, farmers 4 and 18 described their switch to a different farming model as a very sudden and almost rash process; both implemented substantial changes to their practices within a year and against the counsel of their advisors. Farmer 2, by contrast, was more concerned about uncertainties and implemented changes at the fringes of their farm, and even stopped a manure processing experiment because they found it too risky. This indicates that some appetite for risk may be necessary to experiment with new technologies or practices, increasing the potential for positive feedback between the practical (success with innovation) and personal (confirmation, motivation).

With regard to open-mindedness, farmer 1 talked at length about their openness to change as well as their attitude and strategy of anticipating rather than resisting change, while farmer 5 lamented societal trends at length and expressed their distrust of the media, science and social movements. Open-mindedness may therefore be required to allow an actor to recognize positive trends and signals in the political sphere to draw personal inspiration from, in turn stimulating more innovation in the practical sphere.

With regard to reflectiveness, farmer 11 described a gradual and evolving thought process of more than three years which eventually led to their adoption of regenerative practices, while farmer 21 has held firm convictions on biodynamic farming for over three decades, with little reflection apparent in our interview. Reflectiveness could allow one to be realistic about one's situation, contextualize one's ambitions and performance, and to realize when adjustments to practices or strategy in the practical sphere are required (Tschakert & Dietrich, 2010).

Sociability with peers requires more nuanced reflection. Farmer 9 is active in a conventional farmers' association while running a cooperative farm that is largely separated from the conventional farming system, while farmer 16 has been told by public officials that their drastic transformation away from conventional farming makes them a bad example for other farmers to follow. Farmer 1 exhibited both a sincere interest in transforming their farm and a high degree of sociability with conventional peers and farmer networks. Farmers 1 and 9 then are vital in bridging the gap between frontrunners and laggards because their achievements in the practical sphere are recognizable by their peers, and because they tend to engage proactively with those in charge of the institutions that make up the political sphere. Whereas frontrunners are rightly celebrated for their achievements in the practical sphere, they may not be the type of agent that can act as a local leader – in fact, a number of our subjects (farmers 4, 16, 21) freely described how their efforts at convincing others came to nothing or how they didn't even attempt to do so. It may help to consider this characteristic in terms of the niche-regime situatedness of an actor. Adherence to regime norms and interaction with mostly mainstream peers and media is unlikely to lead to transformation away from the status quo, as the personal sphere is too aligned with dominant paradigms. Niche actors on the other hand, who isolate themselves from regime norms and actors, may come to see the political sphere as beyond hope, and limit their information sources to a familiar small circle. While this allows strongly internally driven actors to deepen transformation within their own domain of influence, systemic change is unlikely to stem from such actors. Between the two extremes are hybrid actors who operate in niches and regimes simultaneously (Elzen et al., 2012). This not only enables them to reap the benefits of aligning their work with the political sphere, but also perhaps makes them better institutional entrepreneurs.

The results emphasize the importance of the personal sphere in farmers' transformations towards sustainable business models. When we consider examples of friction, we see that it is predominantly the political sphere that limits not only an actor's practical action perspective but also their cognitive perspective and intention to act. An example is the farmer quoted in Section 4.3 who cannot imagine anything but generating maximum profit on their land and who considers biodiversity a "luxury" condemned to marginal lands; another is the perceived need of many Dutch farmers to help "feed the world" that legitimizes the productivist regime (Viviano, 2017). This is in line with research in the transitions literature that shows how institutions hamper efforts to behave more sustainably (Plumecocq et al., 2018; Schiller et al., 2020; Sixt et al., 2018; Vermunt et al., 2022). Considering traction, there is a notable two-way dynamic with the practical sphere, where traction in one sphere has a positive effect on the other. This suggests that deep, radical change can be quite 'down to earth' and can be found within an agent's direct domain of influence: all farmers interviewed are bound by the laws of the jurisdiction they operate in, but when it comes to their immediate environments – their farms – it is a case of "where there's a will there's a way." Showcases of success created in this way are crucial to eventually influencing the political sphere by building advocacy networks, bridging the chasm between innovators and majority, and reaching tipping points towards rapid adoption of more sustainable practices (Bernstein & Singh, 2008; Moore & Westley, 2011; Rogers, 2005).

5.2. Reflections on the method

While following our approach to operationalizing SOT can provide a rich, detailed analysis, there may be limits to the population size in future studies if this level of detail is maintained. Scholars may be able to mitigate this by focusing the analysis on particular aspects of transformation or by employing a predefined coding framework, though this may obscure subtleties in the subjects' experiences. Future research could however work on elaborating the social-psychological foundations of the personal sphere and the way it affects and is affected by the practical and political. Subject choice is another matter for methodological reflection. Scholars investigating SOT may ask themselves what their subjects need to have in common to generate a meaningful analysis: do they need to have only considered, or actually attempted and even succeeded at transformation? If the latter, how should success be measured? In the case at hand we made a conscious choice to study farmers who cover the spectrum from innovator to late majority (Rogers, 2005). This uncovered a range of experiences of transformation processes, including some cases of resisting the idea of a transformation. While this gives a good insight into the complexities of overcoming diverse challenges by a diverse set of actors, and produced examples of zones of friction that some actors turned into or experienced as zones of traction, it may also be prudent to seek a more homogenous group of interview subjects for better intra-group comparability.

A follow-up study with a larger dataset could try to find connections between personal characteristics or even personality types and different kinds of transformation trajectories, to better guide policymaking and strategies for interaction with entrepreneurs interested in more sustainable business models. This ties in with an increasing interest in behavioural economics as a basis for policymaking for sustainability transition. Concepts like loss aversion and framing can be mobilized to influence more sustainable behaviour in for example food shopping (Bauer et al., 2022); preceding such interventions with an in-depth study of relevant spheres of transformation can help scientists and policymakers calibrate their instruments. More broadly speaking, looking at the subjects of policies through the lens of the three spheres can allow those making the 'rules of the game' to make more legitimate and durable institutional arrangements. This is especially true in decentralized polities where local circumstances create different kinds of traction and friction.

5.3. Reflections on theory

Research on complex systems from different perspectives has shown that regimes are not monolithic (Fuenfschilling & Truffer, 2014; Niederle, 2018), and it is no surprise that actors within such systems behave differently. The added value of the SOT framework is that it sheds light on *how and why* actors in the same system behave differently. The *how* tends to surface in the practical sphere, with farmers in this study elaborating on their "journeys" and experiments. The *why* tends to surface in the personal and political, detailing internal and external drivers and motivations. This explains why two farmers who grew up in the same area, went to the same agricultural college at the same time, and who both run relatively large dairy farms, have ended up with such different farming styles: farmer 6 runs a conventional operation focused on high input use efficiency and cost reduction, whereas farmer 18's business model is the extensive production of organic milk supplemented with income from selling carbon credits. The SOT approach enables the analysis of configurations of practices and agents as well as the structure surrounding them, and perhaps more importantly takes deliberate changes in practices (including stopping / starting) into account. This makes the SOT framework appropriate for studying processes of deliberate transformation, of people consciously "acting otherwise" (Giddens, 1986, p. 11), and sets it apart from practice theory.

An important consideration is how the investigation of spheres of *transformation* fits in the field of sustainability *transitions*. The former is typically understood as wider-ranging than the latter and as more fundamental in nature, requiring shifts not just in rules and outcomes but also the underlying values, beliefs and paradigms. The SOT framework's focus on the personal sphere and its links to the practical and political provides a useful approach to understanding transformation. However, the case at hand shows that positioning transition and transformation as an analytical dichotomy is not always representative of reality or useful. While some of the farmers clearly chose for a swift and fundamental reorientation of production methods, value chain links and relations to society, others took smaller, more cautious and more partial steps – and we don't know if the outcomes in terms of socioecological impact are different one way or another. Regardless of how one wishes to typify the change process, the perspective of the change agent is what the SOT framework uncovers, and it is clear that beliefs (such as farmer 14's conviction of the healing power of unprocessed milk), attitudes (such as farmer 1's can-do attitude and anticipating mindset) and other personal characteristics (the perseverance of farmer 12 who overcame a number of personal and operational crises) are important in understanding how change comes about. The framework therefore opens the door to a social psychology perspective in sustainability transitions research (de Vries et al., 2021).

The SOT framework should not be limited to the study of agrarian actors and can likely be applied to the study of decision-makers in organizations as well as individuals and organizations in other sectors. The personal sphere may have a relatively higher significance for family farms, where the boundaries between work, leisure, family, and individual identity are blurred. But there are other sectors in which important actors are relatively small organizations whose leadership is tight-knit and personal and interpersonal factors are important, as the literature on "hidden champions" and family firms purports to show (Lehmann et al., 2019; Zellweger & Sieger, 2012). Studying how multiple members of a team or even the management of larger corporate or public sector actors experience the SOT could be a fruitful extension of the study of (institutional) entrepreneurship vis-à-vis societal challenges (Garud & Karnoe, 2001). This is particularly important as the sustainability transitions community is moving away from a dichotomous understanding of niche and regime, instead considering the role of hybrid actors (Elzen et al., 2012) and possibilities of endogenous regime change (Runhaar et al., 2020; Vermunt et al., 2022).

6. Conclusion

Our aim in this paper was to uncover the social-psychological processes that determine behaviour change in sustainability transitions. We did so in an attempt to help fill the gap of scholarship on agency and behaviour in the sustainability transitions literature. The proposed spheres of transformation framework, already gaining traction in adjacent scholarly fields, has proved to be a middle-range framework that is well-suited to the analysis of a broad range of actors in transition.

In line with previous work employing the spheres of transformation framework, we discovered the significance of the personal sphere in Dutch farmers' transformations towards more sustainable farming practices. When agents derive motivation and self-affirmation from inner worlds, comprising values and beliefs, this personal sphere can be an important driver of change. It can also be the locus of doubt, fear and other negative emotions that hamper transformation. Scholars and practitioners of sustainability transitions should be sensitive to both the positive and negative aspects of this sphere. We also found that the interactions between spheres harbour significant dynamics of behaviour change. The subjects of our study derived great satisfaction, motivation and confidence at a personal level from successes in the practical sphere. This suggests that small-scale experiments and deviations from business as usual are a motor of transformation for individual actors. The political sphere on the other hand emanates a great deal of friction with both the personal and practical spheres, confirming widely demonstrated notions of institutions as a barrier to change, although we also found some noteworthy examples of institutions and networks facilitating positive change. The real value of this framework lies in the connection between the inner and outer worlds; it allows us to look at the system from the individual agent's eyes while allowing the great diversity of individual perspectives to come to the surface.

This study has three practical implications. The first is that hybrid actors – individuals that are familiar with, and comfortable acting in, both established regimes and emergent niches – should receive recognition for their achievements and support for their role in transitions. More attention should be paid, by policymakers and scholars alike, on how these hybrid actors can be supported in their vital role, and on how actors with regime or niche roots can transform into more hybrid actors. The second implication is that policymakers should recognize and reflect on the diversity of their subjects. Taking different personalities and mindsets into account (such as risk appetite and open-mindedness as identified in our study), both in policy design and in communication, can help eliminate unnecessary friction. This is particularly relevant for local and regional administrative levels as well as landlords and conservation agencies that set rules for behaviour, as these types of organizations tend to work more closely with the affected entrepreneurs. The third is that the different spheres may offer different departure points for encouraging and incentivizing transformation. One farmer may be encouraged to change their business model after successful practical experiments; another may do so only after a change of heart; yet another may only do so if regulations leave them no alternative.

Farmer protests from The Hague to New Delhi are testament to the fact that policies and market interactions not only have calamitous socioeconomic and environmental repercussions, but can also encroach on the dignity of the individual. Ultimately, traction is impossible without some friction: our analysis shows that farmers who have made substantial changes to their business models have overcome great hurdles. But not everyone can overcome the same amount and type of adversity, and policymakers must recognize and act on this insight. Finally, we ought to ask ourselves how the spheres of transformation perspective could shape a research and change agenda for corporate and state actors in a food system transition. If we expect only farmers to undertake difficult and often existential transformations, and see more powerful and less numerous actors as merely facilitating and supporting, such a transition will have a serious legitimacy deficit – and therefore may not succeed at all.

Chapter five

Learning and design for regional farming system transformations

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1. Introduction

The previous chapters of this thesis amply demonstrate that the Dutch agri-food system is stuck. Various forms of lock-in are at play that cement the dominance of an incumbent regime (Oliver et al., 2018). Regime change – the process of fundamentally altering or replacing a set of technologies, policies, user preferences, science, culture and industry – is very difficult: it usually only happens when alternative niches are viable and "ready" to replace the regime, and when landscape trends exert great pressure (Geels, 2002). Moreover, such processes usually take decades or longer (Smil, 2021); in the face of rapid and potentially disastrous environmental and climate change, this will take too long. An important question is therefore whether and how regimes can reorient themselves, and how this can be facilitated (Grin, 2020; Runhaar et al., 2020).

Learning is a useful lens through which to approach this question. Learning is a key part of system change (Geels 2002, van Mierlo & Beers 2020). At the individual level, cognitive learning is required for individual stakeholders to make sense of the situation and understand the problems that need to be solved. Individuals also need to reflect on their own agency and capabilities to know how to translate new knowledge into action, and on their relationships with others whose cooperation they may need to rely on. We've seen in chapter four how this enabled a diverse group of Dutch farmers to orient their business models towards more regenerative practices. Collectively, stakeholders need to come to some form of mutual understanding; their problem recognitions need to be in tune with another so that commonly supported and legitimate solutions can be pursued, as chapter three argued. They need to develop ideas for what can be done differently in the future, urgency and enthusiasm for implementation, and trust in each other to embark on an uncertain journey. Positive collective learning outcomes can reduce and eliminate the barriers we identified in chapter two (Geels et al., 2016; Turnheim et al., 2015).

Sustainability transitions are not just analytical, but also creative challenges: as Albert Einstein reportedly said, "We cannot solve our problems with the same thinking we used to create them." Design is therefore a form of learning that plays a key role in developing alternative and desirable futures (Gaziulusoy & Ryan, 2017). At the operational level, design thinking can be used to create novel solutions to particular sustainability challenges in a given context. This happens at different scale levels, with different resource requirements, and can be organized to different extents: a farmer might tinker in their shed over the winter months and invent a new piece of machinery at relatively low cost, while a food processing company might spend millions of Euros to create a new meat substitute through years-long structured research and development.

Our focus in this chapter is on a facilitated design intervention for the redesign of *De Marke*, a dairy farm run by Wageningen University as a demonstration and experimentation farm in the East of the Netherlands. The farm was established in 1990 to find ways to optimize resource use and circularity. It has done so by monitoring emissions, nutrient losses, and operations very closely, and sharing results and best practices with a network of farmers in the area. *De Marke* has been successful in this regard, as it produces more milk per cow and per hectare than similar farms, while having lower ammonia and greenhouse gas (GHG) emissions. It has also developed the *Kringloopwijzer*, or Annual Nutrient Cycle Assessment, a management tool to improve nutrient efficiency on dairy farms that is now widely used in the sector. However, its operations don't yet meet targets for a farming system within planetary boundaries (Zijlstra et al., 2019). Moreover, after thirty years the farm's buildings and technical installations are in need of renovations and renewal.

To find a new direction for its role as an experimental demonstration farm striving for ambitious sustainability targets, and to make sure that any renovations fit that role, *De Marke* embarked on a journey of designing scenarios for a future farming system in co-creation with scientists and regional stakeholders. It is a joint initiative of *De Marke* and the Regenerative Farming project, which aims to explore the potential to scale regenerative farming solutions in specific regions (see Preface). This process can be seen as a culmination of the work contained in the first three chapters of this thesis: the farm operates in a web of systemic barriers and opportunities (chapter two); it is navigating an uncertain future of poorly aligned and contradictory visions (chapter three); and it has the ambition to enable farm-level transformation processes through knowledge sharing with farmers in the region (chapter four). In other words, it is a site of action-oriented learning for the transition towards a more sustainable dairy farming system. This is particularly important because we know that farmers primarily learn from each other (Rogers, 2005; Wigboldus et al., 2016). It can also be seen as a regime actor in the Dutch dairy sector seeking reorientation. Our aim in this chapter is to explore what type of learning took place in *De Marke's* design journey, and to what extent the learning outcomes indicate regime reorientation in the Dutch agri-food system.

1.1. Theory: transition and design as learning

While learning is a core process in sustainability transitions – new knowledge of various forms is always, in one way or another, generated and transmitted between stakeholders in a transition process – it is only loosely theorized in the transitions literature, with a focus mainly on learning process in innovating niches (van Mierlo & Beers, 2020). We will therefore present learning traditions in this section that are relevant to better understanding the process of designing future farming system scenarios for an experimental demonstration farm that operates within the heart of the Dutch agri-food regime (c.f. Grin, 2020).

Van Mierlo and Beers (2020) reviewed four learning traditions relevant for sustainability transitions: collaborative learning, organizational learning, social learning and interactive learning. Collaborative learning describes a process of sense-making between members of a group with similar social characteristics and status, but with different cognitive perspectives. There is little normativity in this perspective: learning outcomes tend to be aligned closely with learning dynamics and specific learning tasks rather than some higher goal. Organizational learning takes place between "individuals with different backgrounds who develop and share common practices within an organization or another setting with which they identify" (van Mierlo & Beers, 2020, p. 261). The desired outcome of this type of learning is the adaptation of the learning organization to changes in circumstances. An important distinction is between single-loop learning, where existing strategies are upheld, and double-loop learning, which involves changes in underlying assumptions and values and an adjustment of the organization's goals. Social learning describes "interaction among a set of multiple stakeholders in which convergence of ideas takes place with regard to both their goals and the means and methods required to deal with their problems" (van Bommel et al., 2009, p. 404). A high diversity of learning individuals is valued to bring different kinds of knowledge, experience, values and goals to bear on the problem at hand. This learning tradition was conceived of in the domain of natural resource management, and so the desired outcome is "a basis for joint action regarding the natural resource issue, like in an integrated water management program" (van Mierlo & Beers, 2020, p. 263). Interactive learning is oriented towards the creation of profit-enhancing knowledge in innovating firms, and between producers and users of innovations. The combination of codified (know-why and know-what) and tacit knowledge (know-how and know-who) is particularly important. The ideal learning outcome is product or technical innovation that contributes to economic growth.

All four learning traditions are relevant to a better understanding of sustainability transitions, both in and between niches and pilot projects, and in organizations that operate within regimes. We have seen this in previous chapters: our innovation system analysis for nature-inclusive dairy farming (chapter two) concluded that the incumbent regime needs to change from within. This requires social and organizational learning to allow incumbent organizations (banks, dairy cooperatives, input providers, research and educational institutes, and government agencies) to reorient themselves towards (creating) new business models, strategies and institutions (Geels et al., 2016). Chapter three cautioned that progress on social and environmental matters in the future of Dutch agriculture requires consensus-finding on economic matters that are currently contested. The advocacy and negotiation required to come to a more shared perspective implies social learning: both shared problem understandings and suitable solutions need to be developed. In chapter four we discovered different forms of learning as part of farmers' transformational strategies. Almost all learned how to farm in a "traditional" agricultural education, where collaborative learning between students and teachers, students amongst themselves, and students and practitioners (during internships) took place. Some learned how to farm through internships or volunteering, during or after employment in another sector, while others continue to learn within the organizations (frequently cooperatives) they are a member of. Many collaborate with other farmers and relevant stakeholders like nature conservation agencies, municipalities and landowners, thereby gaining new knowledge and skills to master new practices and technologies.

1.2. Forms and types of learning in reflexive interactive design

The theory of change for the co-creation design workshops at *De Marke* embodies the learning traditions described above. The chosen method, reflexive interactive design (hereafter referred to by its Dutch acronym RIO), was developed primarily in response to crises in livestock sectors (Bos et al., 2009; Klerkx, van Bommel, et al., 2012). RIO aims to design, and prepare for the implementation of, innovations in complex and contested systems, focusing both on technical parameters and social-institutional features of a system (Elzen & Bos, 2019). It is a process in which actors, such as farmers and value chain representatives, learn together about each other's needs and requirements as well as the broader structures in which they operate. This kind of "second-order reflexivity" allows actors to challenge institutions and their underlying values to allow novel solutions to flourish, and allows solutions to become embedded, or "anchored", in regimes (Beers & van Mierlo, 2017; Elzen et al., 2012; Elzen & Bos, 2019). It consists of three phases (Figure 1); iterations between these are possible where necessary:

1) System & actor analysis: Define overall design goal and key challenges to be addressed. Assess the system in place, actor needs, and develop a brief of requirements.
2) & 3) Structured design: Define specific design goals and key functions the design has to fulfill. Develop a morphological chart mapping possible solutions to desired functions, and develop design concepts from combinations of solutions. Evaluate and iterate as necessary until a detailed proposal is generated.
4) Anchoring: Share and further develop the designs, build networks around them, create space for experiments, and implement designs in operations (at first partially and eventually more integrally).

Learning is expected to take place at all steps in the RIO process, albeit in different forms (as described in terms of learning traditions above), with different sets of participants (experts, stakeholders, moderators / facilitators, and practitioners), and with different types of outcomes (discursive interaction, i.e. "exchanging knowledge, information, and meanings;" and reflective action, i.e. "planning, action, and evaluation"; see van Mierlo and Beers, 2020, p. 266 and Table 1). Broadly speaking, it starts with collaborative learning between experts who prepare the design process; then moves into social and collaborative learning between stakeholders and experts or facilitators during the design process; and finally takes the form of organizational and interactive learning as the design output is disseminated and applied. The learning outcomes are initially of a discursive kind, generating knowledge, information and interpretation thereof, but as the design output starts to get translated into action it takes on a more reflective character. Know-why and know-what questions are important early on in the process, while later know-who and know-how predominate.

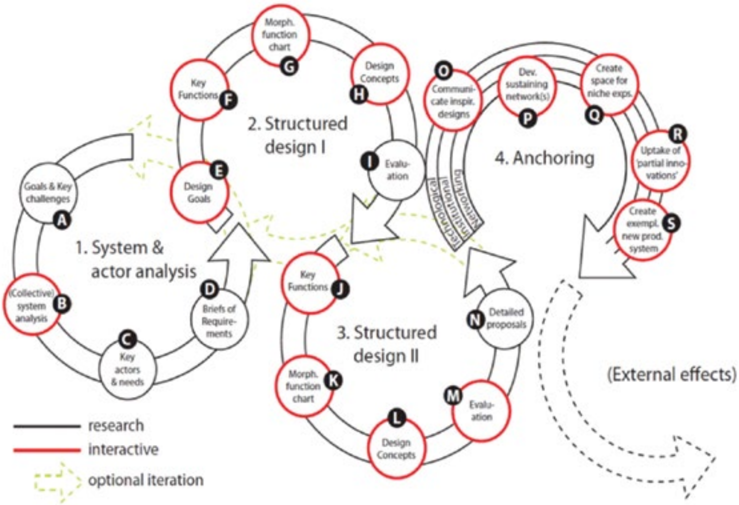

FIGURE 1 | Reflexive interactive design and anchoring framework. Copied from Elzen & Bos, 2019.

TABLE 1 | Expected forms of learning, participants, and learning outcomes at different steps of the reflexive interactive design process.

Step in RIO	Form of learning	Participants	Learning outcomes (DA = discursive interaction; RA = reflective action)
Goals & key challenges	Collaborative	Experts	Overall problem definition for the design process (DA)
System analysis	Social, collaborative	Experts, stakeholders	Mapping of system's biophysical and socioeconomic characteristics (DA)
Key actors & needs	Collaborative	Experts	Identification of key stakeholders and their needs (DA)
Brief of requirements	Collaborative	Experts	Set of requirements the new design needs to meet (DA)
Design goals	Social	Stakeholders, facilitators	Design goals (DA)
Key functions	Social	Stakeholders, facilitators	Functions the new design needs to fulfil (DA)
Morphological chart	Social	Experts, stakeholders	Matrix of functions and possible solutions (DA)
Design concepts	Social, collaborative	Stakeholders, facilitators	Scenarios, sketches, ideas for new design (DA)
Evaluation	Social	Stakeholders, experts	Assessment of design concepts by stakeholders (DA, RA)
Detailed proposals	Collaborative, organizational	Experts	Concrete plans for implementation (RA)

Step in RIO	Form of learning	Participants	Learning outcomes (DA = discursive interaction; RA = reflective action)
Communicate designs	Organizational	Stakeholders	Communication, advocacy (RA)
Develop networks	Organizational	Stakeholders, practitioners	Network-building (RA)
Create space for experiments	Organizational, interactive	Stakeholders, practitioners	Funding, organizing niches (RA)
Uptake of partial innovations	Organizational, interactive	Practitioners	Adopting design elements in operations (RA)
Create new production system	Organizational, interactive	Practitioners	Integrating designs into operations (RA)

Chapter two presented a set of systemic problems for the Dutch dairy sector, and discussed the dilemma presented by an innovation system that both requires action from, and is hampered by resistance from, incumbent regime actors. We may therefore ask how the process at *De Marke* - a research farm operating at the heart of the Dutch dairy farming regime - provides an opening for "regime change from within". To explore this question, we can turn to the theory on socio-technical transition pathways (Geels et al., 2016). These pathways describe the different ways in which socio-technical regimes transition towards a different state. A "transformation" pathway "consists of gradual reorientation of the existing regime through adjustments by incumbent actors in the context of landscape pressure, societal debates and tightening institutions" (Geels et al., 2016, p. 898). In a "reconfiguration" pathway, "niche-innovations and the existing regime combine to transform the system's architecture" (Geels et al., 2016, p. 899). Signs of endogenous regime change therefore include:

- Incumbent actors changing their operational procedures
- Incumbent actors changing beliefs, missions, business models
- Incremental improvement in existing technologies
- Adoption of new technologies by incumbents
- Institutional change
- New alliances between incumbents and niche actors

To the extent that these signs can be observed over the course of and shortly after the workshop, they will be included in our analysis.

1.3. Operationalization: measuring learning before, during and after the *De Marke* design workshops

Because learning can manifest in so many different ways, and because the journey from defining a design goal to seeing the system in question actually transformed is a long one, it is necessary to make some choices on what types of learning we collect data on and analyze. For the purposes of this chapter, we focus on two types of learning outcomes that could be observed over the course of the workshops:

cognitive learning of individual participants, and the collective creation of design scenarios by groups of participants.

1.3.1 Cognitive learning of individual participants

The first research question we aim to answer is: how did RIO workshop participants' understanding of dairy farming's impact on environment and society change? The hypothesis here is that by engaging in collaborative and social learning, participants share perspectives on the way the dairy farming system functions and develop new insights. This was captured by having workshop participants create individual mental models of their perception of the dairy farming system before and after the workshops, and analyzing any difference between the two. In our case, the system was defined as the local dairy farming system comprising twenty elements including farm operations, ecology, and society. These elements were chosen based on the interviews of graduate students with farmers and stakeholders, to reflect both how dairy farms operate and how they impact their social and ecological environments.

"Mental models are internal representations of an external system, which consists of causal beliefs about the functioning of a system" (van den Broek, Klein, et al., 2021, p. 353), and are therefore a useful concept to mobilize for the comparison of participants' perception of the system before and after the workshops. Mental models can be captured in different ways. They can be mapped manually, by transposing interview data to a system visualization (indirect mental model elicitation; see Jones et al., 2011). This is time-consuming and requires one-on-one time between respondents and researchers. An alternative is the mental model mapping tool (M-tool), a tool designed to easily capture mental models using pictograms and arrows between them (van den Broek, Klein, et al., 2021). This method has been validated as accurately capturing respondents' mental models, and it furthermore allows respondents to construct more complex mental models than is possible manually (van den Broek, Luomba, et al., 2021). It has been applied in the context of sustainable fisheries in Tanzania (van den Broek et al., 2023) and on perceptions of the spread of COVID-19 in the Netherlands (de Ridder et al., 2022).

Workshop participants were emailed a link to the M-tool two weeks before the workshop. After a practice exercise to familiarize themselves with the tool, participants were tasked first with mapping the influence of dairy farming on its socioecological environment, and second with mapping the influence of dairy farming on farmer well-being. These two tasks were chosen to reflect societal priorities (the state of nature and society) on the one hand and farmers' priorities (their wellbeing) on the other. The same twenty pictograms were available as elements of the system for both mapping exercises. After the workshops, participants were emailed the same link with instructions as before the workshops to complete the second mapping.

Data from the mental model mapping was analyzed using an R-script developed by the creators of the M-tool (van den Broek & van Boxtel, 2021). This analysis provides a number of metrics:

- Complexity: did the number of concepts, and connections between concepts, change between the two mapping exercises? Increased complexity could indicate higher levels of systems-thinking of participants.
- Importance: did the strength of concepts (weight of arrows to and from each concept) change? Changes in strength could indicate a reordering of participants' priorities when the associations between system elements and how participants think the elements impact each other change.

In addition, aggregate mental models of all participants for both mapping exercises were generated to allow for a visual comparison pre- and post-workshop. A total of eleven out of seventeen attending participants completed the mental model mapping exercises, although only nine entries were complete (i.e. data for two participants only exists for the pre-workshop or post-workshop exercises; this was due to an error in the back-end of the M-tool).

1.3.2 Collective creation of design scenarios

The second research question of this chapter asks to what extent the design scenarios developed in the RIO workshop are innovative and compatible with (or, conversely, a departure from) the current dairy farming regime. Here, we make a qualitative assessment of the technologies, practices, business models and institutions that make up the scenarios. To do so, authors one, two, four and six classified the solutions in the scenarios according to the scaling readiness framework (Sartas et al., 2020). This framework can be used to assess technological and non-technological agricultural innovations according to the innovation's innovation readiness level (the maturity and implementability of the solution, based on NASA's technological readiness levels) and its innovation use score (the extent to which the innovation has diffused). This method was chosen because it assesses two dimensions of innovation (for an overview of other methods, see Sprenkeling et al., 2022). The difference between the solutions and scenarios along these dimensions is important for *De Marke*, because its precise role in knowledge diffusion and stimulating innovation adoption depends on the readiness of solutions. Table 2 contains the names and descriptions of the levels and scores. In cases when our own expertise was insufficient to make an assessment, experts from our network were consulted.

In addition to the scaling readiness level, each solution in the scenarios was characterized as a technological, practice, business model, or institutional innovation. Without ascertaining the socio-ecological impact or cost of each design scenario or individual solution therein, this assessment provides an indication of the novelty of the output of the workshops. It is based on the written report of the RIO workshop, wherein each design scenario is described in terms of its principles and philosophy, and in terms of the solutions that are envisioned as part of the scenario (Janssen et al., 2022).

TABLE 2 | Innovation readiness levels and innovation use scores (Sartas et al., 2020).

Innovation readiness level	Name	Description
0	Idea	Idea formulated for an innovation to meet a goal. No science to back it up, no evidence.
1	Hypothesis	Idea is conceptually validated, hypothesis for how innovation meets goal is developed.
2	Basic model (unproven)	Conceptual research is being done on the innovation.
3	Basic model (proven)	Principles of the innovation are validated with existing scientific evidence.
4	Application model (unproven)	Existing evidence used to research innovation.
5	Application model (proven)	Capacity of innovation to meet goal validated using existing evidence.
6	Application (unproven)	Innovation tested in a controlled environment reflecting specific context innovation should function in.
7	Application (proven)	Innovation validated in real conditions in specific context.
8	Incubation	Potential of innovation to meet its goals tested in real conditions in specific context with R&D support.
9	Ready	Innovation is validated under real conditions in Its specific context without R&D support.
Innovation use score	**Name**	**Description**
0	None	Innovation isn't used at all.
1	Intervention team	Innovation is used by team developing it.
2	Effective partners (rare)	Innovation is used by some partners of the developing team.
3	Effective partners (common)	Innovation is used commonly by partners of the developing team.
4	Innovation network (rare)	Innovation is used by some stakeholders not directly involved in its development.
5	Innovation network (common)	Innovation is commonly used by stakeholders not directly involved in its development.
6	Innovation system (rare)	Innovation is used by some stakeholders working on similar, complementary or competing innovations but who aren't directly connected to developers or partners.
7	Innovation system (common)	Innovation is commonly used by stakeholders working on similar, complementary or competing innovations but who aren't directly connected to developers or partners.
8	Livelihood system (rare)	Innovation is used by some end-users not involved in development in any way.
9	Livelihood system (common)	Innovation is commonly used by end-users not involved in development in any way.

5

2. Workshop setup and learning features

Before the start of the workshops, a team of researchers (including authors one, four and a *De Marke* scientist) familiarized themselves with the characteristics of the farm, its surroundings, and the key challenges stakeholders in the region face. This included supervising two students who wrote their Masters and Bachelors thesis about challenges for farmers and for other stakeholders, respectively. Senior staff from *De Marke*, Wageningen Livestock Research and the Regenerative Farming project gave input on the goals for the workshops and ultimately the redesign of the farm. The research team then planned the three-day workshop series, based on the collected information and experience of conducting similar workshops. Two members of the research team, a university lecturer and an assistant professor who were both experienced in the setting-up and facilitation of RIO workshops, guided and moderated the workshop. Seventeen participants were invited from the following organizations (* indicates multiple staff from one type of organization were present):

- Individual farmers*
- De Marke*
- Livestock research institute*
- Regional water authority*
- Livestock feed company
- Dairy farming technology provider
- Biogas installation
- Dairy processor and cooperative
- Local municipality
- Province
- Ministry of Agriculture, Nature and Food Quality

The purpose of the first workshop day was to explore participants' understanding of challenges and as a group develop goals for the design. After a round of welcomes, the students who had investigated the challenges of farmers and other stakeholders presented these to the group. Participants subsequently toured the farm – primarily the barn and feed crop fields – to explore these challenges more tangibly. *De Marke* employees led the tour and explained the current production system and its challenges. A plenary session followed in which participants exchanged experiences and viewpoints. The last session of the day was devoted to determining, as a group, goals for a future dairy production system on sandy soil in the region. Day one was therefore characterized by social and collaborative learning: collaborative learning between experts produced the input in the form of design challenges and stakeholder priorities; and social learning during the day led to the definition of design goals.

The purpose of day two was to create space for solutions. Researchers presented performance indicators for the different design goals and discussed with participants

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the gap between the desired situation and current performance. Subsequently the group discussed which functions need to be fulfilled in the production system to reach the goals. The group then democratically chose the most important functions (every participant could "spend" a fixed number of votes across all the functions), and brainstormed solutions for the ten most frequently voted-for "key" functions. This information was used by the research team to develop a morphological chart, i.e. a table listing solutions for the key functions identified in the workshop, in preparation for the final day. The generation of both the key functions and the morphological chart were based on social learning between stakeholders, facilitators and experts.

The purpose of the third and last day was to use these solutions to create design scenarios. These can best be understood as collections of solutions around a central idea, rather than a blueprint that can be immediately implemented. At the start of the third day, the moderators suggested four directions for the design based on two axes: local-global (in terms of consumption, production and procurement of feed, and markets) on one axis, and nature-technology (utilizing ecosystem functioning or focusing on high-tech solutions) on the other axis. The scenarios attracted groups of three participants with a member of the research team accompanying each group to facilitate and document the design. This can be characterized as a mix of collaborative and social learning. At the end of the day, a group of senior decision makers from stakeholder organizations (including author six) joined and the scenarios were presented. The senior decision makers then provided feedback on each scenario before finishing the day with networking drinks.

The output of the workshops will be shared with participants as well as the steering group in the form of a report containing a description of the goals, challenges and key functions; the morphological chart; and the four design scenarios. The steering group will then use this report to discuss which scenarios and individual solutions they find most promising and viable and task researchers in their organizations with further elaborations of the solutions (i.e. determine feasibility, cost, emission reduction, cross-compatibility between solutions etc.).

3. Learning outcomes for participants

Beginning with a visual comparison of aggregate mental models (Figure 2), we see differences between the two tasks participants completed. The aggregate model for the impact of dairy farming on the environment before the workshop (top left in Figure 2) presents a diffused picture, a complex web of arrows between the concepts water, soil and livestock. The total number of arrows is forty-two. After the workshop (top right in Figure 2), we see only thirty arrows, denoting fewer connections between concepts, and thicker arrows denoting stronger connections. Both before and after the workshop the aggregate plot contains nineteen concepts. The aggregate plot for the second task, plotting the impact of dairy farming on farmer wellbeing, is less complex to begin with (twenty-four arrows between nineteen concepts; see bottom left in Figure 2) and only changes slightly, with an additional two arrows after the workshop and one additional concept (bottom right in Figure 2). This suggests that the effect of the workshop on participants' mental models was stronger for how they perceive the effects of dairy farming on the socioecological environment than for how they perceive the effects of dairy farming on farmer livelihoods.

The impression that mental models became more similar to another after the workshop for the first task (impact on environment) is borne out by the fact that per participant, the overall number of concepts and connections between them did not change much (increase by 2.5% and 4.2% respectively), while at the same time, the aggregate plot indicates that participants tended to use more of the same concepts and connections between them as other participants. The opposite is true for the second task (impact on farmer wellbeing): while the aggregate complexity of mental models didn't change, participants on average used 15.2% fewer concepts in their models and 17.6% fewer connections between them, but we can clearly see in Figure 2 that the aggregate plot of the mental models post-workshop (bottom right in Figure 2) does not look clearer or less diffuse than before the workshop.

The relative importance of concepts used for each exercise also changed (see Table 3). For the mapping of the influence of dairy farming on the environment, the concepts of "landscape" and "biodiversity" moved up nine positions each, while the concepts of "laws and regulations" and "wellbeing" did not make the top-ten after the workshop. This may reflect a stronger prioritization of biophysical issues in the dairy sector. For the mapping of the influence of dairy farming on farmer wellbeing, the top-5 are unchanged with only small changes in position, while two additional concepts - "weather and climate" and "biodiversity" moving up to the top-ten. Discussions of the effect of extreme weather (especially lack of rainfall) on dairy farming, and the sharing of experiences of agroecological farmers on the benefits and joys of biodiversity, could have led to a heightened awareness of the role of these concepts in the system.

These changes - apparently greater similarity of mental models between stakeholders on socioecological matters, with smaller changes apparent for the impact of farming on farmer wellbeing - may be a result of the focus of the workshops in two ways. First, the facilitation and planning of the workshops prioritized biophysical aspects. While the student assessments of farmer and stakeholder priorities showed that for farmers, topics like policy, finances and knowledge were seen as the most urgent, the workshop planners deemed these topics too difficult to affect through innovations in how *De Marke* operates. These matters were therefore framed as conditions to allow dairy farms in the region to function well, rather than design goals in themselves. The design goals in turn were primarily based on a discussion of emissions to air and water, landscape quality and biodiversity, and feed-manure circularity, in line with the priorities of *De Marke*, the Regenerative Farming project (Groot Koerkamp et al., 2021), and societal stakeholders. Second, this prioritization

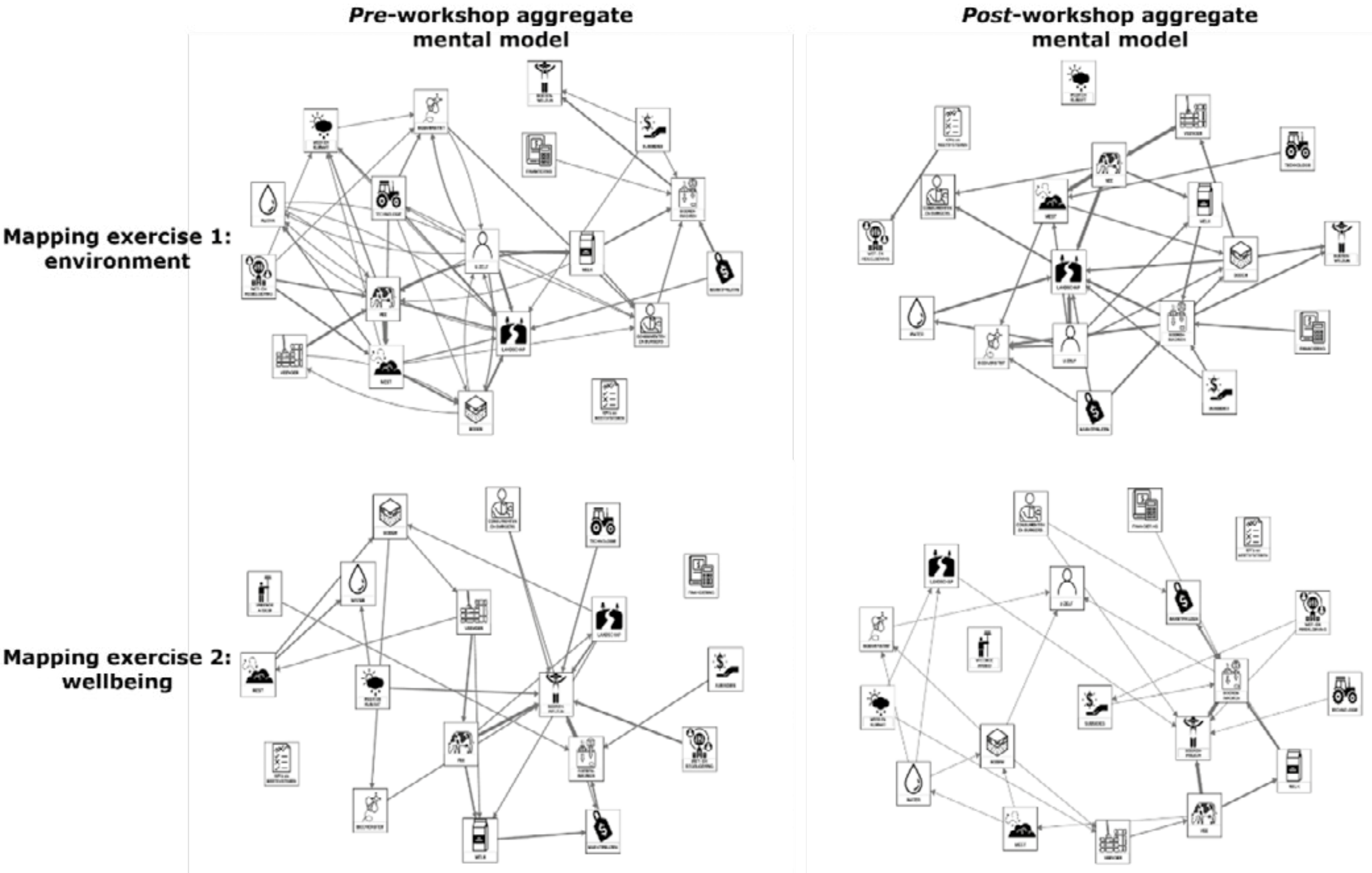

FIGURE 2 | Aggregate mental models for both mental model mapping tasks. Pre-workshop aggregate models on the left and post-workshop aggregate models on the right; mapping task on the influence of dairy farming on the environment above, task on the influence of dairy farming on farmer wellbeing below. Arrow thickness indicates the strength of connections between the concepts.

is reflected in the design goals formulated by the participants on day one of the workshop, where the first six of thirteen goals are of a biophysical nature (e.g. climate neutrality, soil and water quality), four reflect societal expectations like food safety and animal welfare, two relate to the role of *De Marke* as a learning organization, and one focuses on farmer welfare (sufficient income).

TABLE 3 | top 10 concepts included in mental models for both exercises, before and after the workshop. Numbers show sum of outgoing and incoming connections per concept, where 3/-3 are a very strong positive or negative connection, 2/-2 a strong positive or negative connection, and 1/-1 a moderate positive or negative connection. Plus, minus and equal sign in the far right-hand column indicate changes in ranking of the concept after the workshop.

Top-10 concepts for environment mapping pre-workshop	Sum of connections	Top-10 concepts for environment mapping post-workshop	Sum of connections	Relative position change
Livestock	2.3	Landscape	3	+9
Manure	1.6	Livestock	2.5	-1
Income	1.4	Income	2.4	=
Milk	1.3	Manure	1.5	-2
Yourself (participant)	1.2	Biodiversity	1.2	+9
Soil	1.1	Soil	1.2	=
Laws and regulations	0.8	Livestock feed	1.2	+1
Livestock feed	0.6	Yourself (participant)	1.1	-3
Landscape	0.5	Milk	0.8	-5
Wellbeing	0.4	Market prices	0.7	+5
Top-10 concepts for wellbeing mapping pre-workshop	**Sum of connections**	**Top-10 concepts for wellbeing mapping post-workshop**	**Sum of connections**	**Relative position change**
Wellbeing	5.9	Income	5.1	+2
Livestock	4.3	Wellbeing	5	-1
Income	3.1	Livestock	4.3	-1
Milk	2.9	Soil	3	+1
Soil	2.4	Milk	2.6	-1
Landscape	2.2	Water	1.8	+4
Manure	2.1	Weather and climate	1.6	+12
Market prices	2	Biodiversity	1.5	+7
Livestock feed	2	Landscape	1.5	-2
Water	1.7	Manure	1.5	-3

Another, complementary explanation for this apparent difference between learning outcomes on environmental aspects one the one hand and farmer wellbeing on the other, may be the character of workshop activities and the background of participants. Activities like the farm tour (providing all participants a hands-on experience of biophysical challenges like manure separation to prevent ammonia emissions or soil compaction and its effects on feed production) and a discussion of key performance indicators (KPIs) for themes such as air quality, water quality, soil quality and biodiversity foreground biophysical challenges. Moreover, of the seventeen participants, only four were farmers while the rest were scientists, technical experts or civil servants. Participant backgrounds may therefore have influenced both formal as well as informal interactions towards biophysical challenges.

4. Workshop design outcomes

The main output of the RIO workshop were four design scenarios for the future of *De Marke* as a pilot farm in the region. The participants had to create these scenarios in such a way that design goals and system functions were fulfilled, but they were encouraged to choose a diversity of solutions in their respective scenarios. The scenarios differ in several ways. The solutions they contain differ in the extent to which they deviate from current regime practice; the extent to which organizational and business models are elaborated to show how the solutions would be implemented or paid for; and the degree to which principles, motivations and discourses are mobilized in support of the scenarios; and the extent to which these principles, motivations and discourses deviate from business as usual.

In scenario "Techno World" dairy is produced for world markets with technology as the main type of innovation. It is motivated by three megatrends: decreases in labor availability and the need for greater automation, population growth and the need for efficient food production, and geopolitical instability and the need to reduce dependence on imported inputs / resources. As the name suggests the scenario has a heavy focus on technology in production, side activities and monitoring. While the main business model remains dairy production for world markets, the creators of this scenario imagined a situation in which consumers have a fixed carbon "budget" constraining their consumption behavior. This is seen as an opportunity, because if the farm produces milk with a lower carbon footprint consumers have an added incentive to buy it. To facilitate the legitimacy of this, the farm will be as transparent as possible. This scenario was developed by a feed company's innovation manager, a conventional farmer, and a project manager at a large dairy cooperative. Figure 3 shows this scenario's scaling readiness plot.

In scenario "(Bio)Diversiteit" the market orientation remains global but nature-based solutions outweigh technological solutions. The underlying principle of this scenario is that since the Netherlands has a favorable climate for grass production, and a large area of grassland, it plays an important role in contributing to global food security through the efficient production of dairy on land that is not ideal for human food crop production. While the main business model remains dairy production for global markets, some milk will be processed locally and marketed as a regional product. This scenario was developed by a conventional farmer and livestock geneticist, one of *De Marke's* managers, and a conventional farmer and biogas entrepreneur.

"De Marke 3.0" combines technological solutions with predominantly local sales channels. The purpose of the farm in this scenario is to supply the local economy with milk and energy. Innovations in dairy production are primarily of a technical character; similar to "Techno World" this scenario foresees the use of technologies like biogas production, manure separation, and various sensors to monitor emissions. The business model of this farm is primarily the sale of dairy products to local customers, but in a delivery subscription offered as a bundle with energy (biogas and electricity from renewables). Society is engaged with a 24/7 webcam and periodical blogs about the farm; for knowledge exchange, student housing is offered. This scenario was developed by a provincial civil servant, a researcher at a farm technology company, and a conventional farmer and biogas producer.

"De Marke Natuurlijk" is motivated by an anticipation of a fossil-free future in which the use of fossil fuels in farming operations, the production of inputs, and in the transport of feed over large distances is no longer viable. Accordingly, natural processes and animals are used to replace processes that so far predominantly rely on fossil fuels, and milk is sold to local customers. The cropping plan prioritizes food crops over feed crops and grassland; however, because of the sandy soil in the region, only 20% of the farm is used to produce crops for human consumption. Dairy is processed in cooperation with other farms in the area and sold locally. In addition, payments for ecosystem services like improved biodiversity add to the farm's finances. In this scenario, Dutch dairy farmers have set up a "milk cartel" to realize better prices than they would if they sold to global markets. Knowledge exchange focuses on farmers who are not yet convinced of an agroecological, extensive dairy farming model – the aim is to counter skepticism against this farming style. Finally, citizens can finance the farm through crowdfunding and land banks, and are involved in decision-making. This scenario was developed by a biodynamic farmer, a conventional farmer and *De Marke* researcher, and an agroecology researcher.

We created a "scaling readiness plot" for each scenario, displaying the scores of all solutions in the scenario according to innovation readiness (maturity of a solution) and innovation use (current diffusion of a solution), as well as the number of solutions that were given a particular score. Figure 3 provides an overview and visual comparison of the four scenarios. A first observation is that solutions that are ready for implementation and available (innovation readiness level nine) and already widely used by many, if not most, dairy farmers (innovation use score nine) make up the majority of solutions in all scenarios: there is a notable concentration of scenarios in the top right-hand corner of all four plots. This could be because group discussions on solutions for the redesign of De Marke relied on pre-existing knowledge and experience of participants, and a lack of exercises specifically targeted at creative development of "out-of-the-box" solutions. Another observation is that there are only six solutions with an innovation readiness level below five. Of these, only two – building a mobile cow barn on tracks or wheels in scenario "De Marke 3.0", and setting up a "milk cartel" in scenario "De Marke Natuurlijk" – were conceived of during the workshop. Another solution with a low readiness level (two) and a use level of zero, namely substituting human waste for chemical fertilizer, is common to all scenarios except "(Bio)Diversiteit"; the idea however is prominent

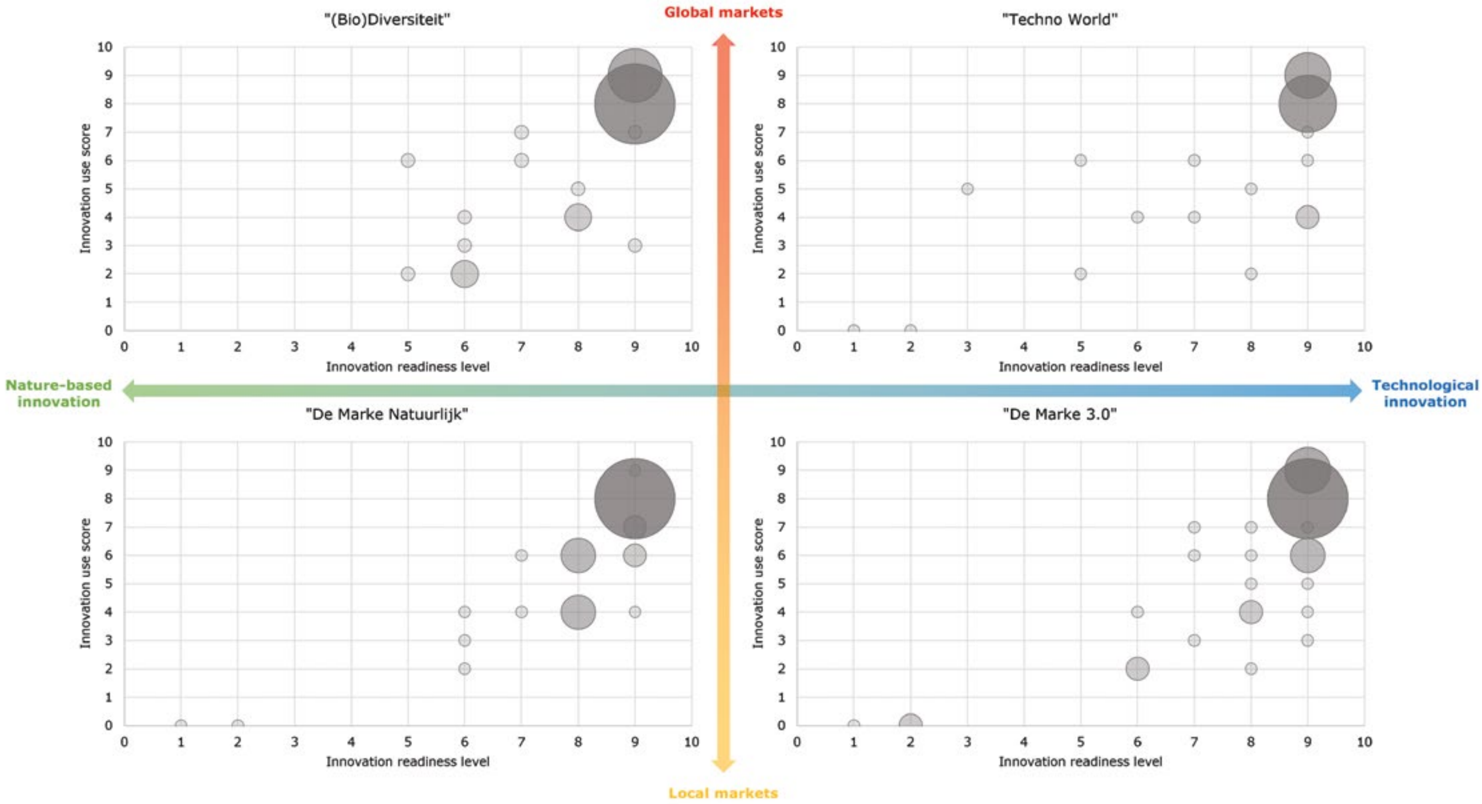

FIGURE 3 | Scaling readiness plots of all four scenarios. Plot titles between quotation marks indicate scenario names. X-axes indicate innovation readiness level (0-9), i.e. the maturity of solutions. Y-axes indicate innovation use scores (0-9), i.e. the current diffusion of solutions. Bubble size indicates the number of solutions with a particular score: the smallest bubble in each plot equals one scenario for that particular score. Double-ended arrows crossing the four scenarios indicate the axes along which the scenarios were developed.

in discussions of closing nutrient cycles in agriculture (Groot Koerkamp et al., 2021; Harder et al., 2019). In addition, the workshop outcomes include four solutions that are common to all four scenarios and eleven that are common to three scenarios. This leaves the impression that, overall, the workshop did not create a plethora of radically new solutions, and that there is a fair amount of overlap between scenarios.

There are however some interesting differences between the scenarios. When we look at the scaling readiness plots in Figure 3, we can observe a larger spread of innovation readiness levels in the technology-oriented scenarios (right-hand side of Figure 3) than in the nature-oriented scenarios. This suggests that in these scenarios, *De Marke* would have a more experimentation and R&D-oriented role to bring technologies like green hydrogen production, various monitoring and remote sensing technologies, or cultivation robots to maturity. Another difference is that all scenarios except "De Marke Natuurlijk" have four solutions with an innovation use score of nine, whereas "De Marke Natuurlijk" contains only one solution at that score. This indicates that this scenario was the least influenced by current practice and is least in line with business-as-usual in the dairy sector. This could suggest that in this scenario, the role of *De Marke* would be to demonstrate the viability of a production system that combines many elements that individually are already proven, but that taken together with the more innovative aspects of this scenario still present a challenge for most farmers.

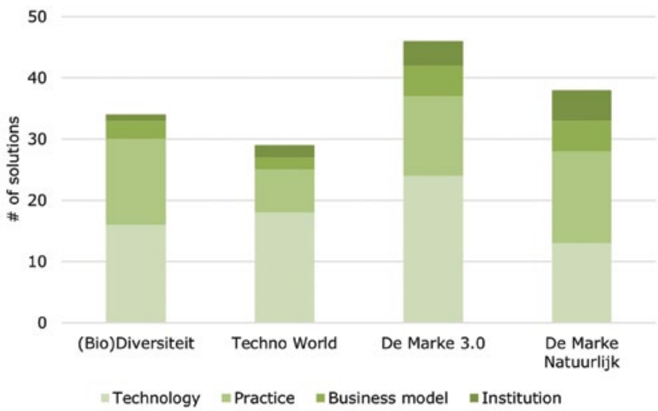

FIGURE 4 | Number (x-axis) and types of solutions (shades of green) included in the four scenarios.

Another way to differentiate between the scenarios is to look at the mix of solution types across the scenarios. Figure 4 shows the distribution of technology, practice, business model and institutional solutions in the four scenarios. Generally speaking, technologies and practices predominate, albeit in different proportions across the scenarios. This reflects the technology / nature axis that the scenarios were based on. At the same time, scenarios "De Marke 3.0" and "Techno World" also include some practice innovations. This is because many solutions were characterized as both technological and practice-related: using a new or different technology often implies a different management practice as well. For example, producing and applying bokashi or compost as fertilizer requires inputs to help produce these fertilizer alternatives as well as different practices to spread them. The local market oriented scenarios on the other hand include more business model and institutional solutions. This is necessary when farms no longer follow the dominant business model of export-oriented commodity production. Farms in such a scenario will have to find new ways to sell their products and get financing. This often requires institutional innovation as well: new rules need to be created – both generally, and between farms and their direct customers and stakeholders – to implement new ways of farming.

Some aspects of the scenarios were difficult to classify as a particular type of solution and were moreover difficult to score according to the scaling readiness framework. In "(Bio)Diversiteit", a prominent idea was to have livestock forage on cover crops. This however was difficult to assess because of a lack of specificity. Likewise, "Techno World" includes the solution of minimizing ploughing, but this could mean a number of things ranging from surface seeding to the use of a disc harrow. In "De Marke Natuurlijk" an important principle is to let farm animals and natural processes do as much work as possible in the absence of fossil fuels, but such a principle is impossible to score and assess in the same way as e.g. the use of a particular manure processing technique. Having said that, we felt it important to include these in the chapter to reflect the breadth of workshop outcomes.

5. Discussion

5.1. Reflection on the results

One of the aims of the RIO method is to foster second-order reflexivity among participants (Bos et al., 2009). In our case, this would mean that farmers, government officials, value chain representatives, and other stakeholders learn together about each other's needs, as well as about the environment they co-exist in. Determining whether second-order reflexivity was achieved can be approached in two ways. The first would be to look at the learning outcomes of the workshop itself. Here, we see not just a co-design of scenarios for the future of the farm, but also design goals and system functions that were discussed and democratically chosen by participants. Another way is to look at the results of the mental model mapping, where we see a shift in priorities and increased similarity of participants' views of the system. Looking at the results in both of these ways reveals a focus on societal needs and priorities, and somewhat lower prioritization of farmers' needs and priorities, as discussed in section 3. This does not mean participants did not learn at all about farmers' needs; rather, it reflects the chosen focus of the workshop. In addition we could ask how realistic it is that this type of intervention leads to a heightened awareness of each type of stakeholder's needs and priorities. This is difficult when all stakeholder groups are not equally represented (numerically) in the workshop.

While we did not study them systematically, interactions between participants during the workshop will have an impact on learning. We observed for example that two farmers who follow different philosophies (one extensive and biodynamic, the other nature-inclusive and conventional) hardly spoke with each other and did not enter into a discussion of their respective practices, while each of the two interacted at length with other stakeholders. This illustrates that simply looking at participant composition and learning outcomes in the aggregate does not reveal nuances and details. Future research could focus on learning dynamics: how do workshop participants interact; how do they present their ideas to others and discuss them; and what is the role of educational and professional background or power in these dynamics? This would require a different research setup, with more observers present during the workshop and audio or video recording. Both would be more intrusive and require greater attention for matters of privacy. However, the findings could be insightful and either corroborate or refute some of the interpretations we made here.

In addition, a closer look at micro-level learning interactions could shed light on how the personal sphere of transformation – the focus of chapter four – comes to the fore in the learning process. Different personalities bring their thoughts into group discussions and exercises in different ways, and the dominance of particular characteristics – even virtuous ones – can hamper collaborative processes (Chambers et al., 2022). This needs to be carefully managed, and reflection on this matter should have consequences for workshop setup, participant diversity, and the facilitation process.

From the perspective of sociotechnical transitions, the scenarios correspond to different types of transformational pathways (Geels et al., 2016). More incremental transformations of the dairy farming regime would occur in the global market-oriented scenarios, as these scenarios imply a change in farms' operating procedures and technologies, but less so in farms' or other actors' business models and strategies. More substantial transformation would occur in the local market-oriented scenarios, because these imply a fundamental reorientation of business models and institutions. However, echoing our discussion in chapter three and the literature on the structuration of (food) regimes (Fuenfschilling & Truffer, 2014; Niederle, 2018), transformation is not a spatially and temporally universal process: a radical transformation at the farm level, supported by new entrants in the farm inputs and machinery sectors, could coincide with business as usual in the downstream value chain as long as farms keep producing enough milk that meets food safety and quality standards; similarly, a sector-wide reduction of livestock numbers to meet ecological goals is systemically transformative while a smaller number of farms could continue operating as they are now. This should serve to remind scholars and practitioners that transition frameworks and pathways are heuristics, not blueprints.

Concretely for *De Marke*, the differences in scaling readiness of the four scenarios imply different roles. Solutions with low innovation readiness levels require more

R&D partnerships with innovating companies to validate and test technological solutions. Low innovation readiness also implies a greater focus on experimentation on the farm. Low innovation use scores on the other hand would indicate a greater need for demonstration: if solutions work in principle and in practice, but few other farmers apply them, *De Marke* needs to focus more on outreach and extension. In addition to the different scaling readiness levels of solutions in the four scenarios, the types of solutions require a different role from *De Marke* and its stakeholders. Business model changes or institutional innovations don't require the same amount or type of scientific research and validation as technological innovations. Rather, they likely require institutional entrepreneurship and advocacy to create experimental space in the relationships between farms, value chain actors, and government. This could be facilitated by partnerships with NGOs, or government agencies like the Netherlands Enterprise Agency, who have experience in this domain.

An important question we cannot address in depth is whether more innovative solutions – those at a low innovation readiness level – are also more impactful, i.e. whether they would contribute more to meeting the ecological and social goals of a redesigned dairy farm than solutions that are already in use. Some of the solutions in the scenarios developed during the RIO workshop were also included in a quantified scenario study for the future of Dutch agriculture as a whole (Lesschen et al., 2020): grazing, sowing fields with herb-rich grass rather than maize, applying more solid manure, and most of all downsizing the dairy herd would all contribute to meeting emissions targets. These solutions are already at an innovation readiness level of eight or nine, but not yet used widely in the Dutch dairy sector. It is unclear by contrast how much the building of a mobile cow barn or the establishment of a milk cartel (both at level one) would contribute. This calls for a closer analysis of the impact of solutions in the scenarios, both individually and in different combinations: eliminating herbicide use for example will be more difficult to implement when also implementing no-till farming than when some form of tillage is maintained. Moreover, this reinforces the sense that focusing on innovation diffusion rather than technological novelty should be a priority.

We can also reflect on the solutions in these scenarios from the perspective of responsible innovation and just transitions (Klerkx & Rose, 2020; Köhler et al., 2019b). Emphasis of, and reliance on, high-tech solutions often sidelines low-tech and practice-oriented approaches. Such approaches tend to be under-funded and under-researched by comparison, although they harbor considerable potential in addressing agri-environmental issues (Oberč & Schnell, 2020). High-end technologies are often expensive and can increase farmers' debt burden, which is already high in the Dutch dairy sector (Vermunt et al., 2022). "Smart farming," i.e. the integration between online platforms and farm technology, is heavily endorsed by players across the agri-food system – from traditional actors in that system, like machinery manufacturers or the FAO, to new entrants like Google and Amazon – but its possible adverse implications are rarely considered (Fraser, 2022). Likewise, the scenarios that foresee sensors, robots and trackers throughout farm operations give little consideration to data ownership and privacy, and no consideration at all to power and value capture shifts towards already powerful actors. These discourses have a history of locking agri-food systems in to technological trajectories (Vanloqueren & Baret, 2009) and causing delays in farmers' adoption of adaptation measures (Gardezi & Arbuckle, 2020). We should critically ask who pays for, and who benefits from, technologies like cultivation robots, milk robots, manure separation and processing installations, or hydrogen production at farm-level.

In terms of the compatibility of solutions between the scenarios, there is more overlap and complementarity on the nature-technology axis than on the local-global axis. Moving towards a nature-based farming model that harbors and utilizes ecosystem services does not preclude for example the use of robots or a sophisticated manure separation facility. Selling all milk locally however would not fit a high-output global business model, and nor would a downsizing of the herd. In terms of moving forward with the selection of design scenario elements for the planning of the farm's redesign, choosing for a reorientation of the business model will be more difficult – and consequential – than for a series of technological and management changes. Interestingly, senior decision-makers of *De Marke's* stakeholders were not averse to a more extensive and locally-focused business model during the initial evaluation of scenarios. They expressed their enthusiasm for local market-oriented scenarios not necessarily because of a normative alignment with the institutional changes in these scenarios, but because they felt that *De Marke* should be a proof of concept for a business model and farming style which is currently viewed with skepticism.

5.2. Reflection on the process

As noted above, the scenario implying the most far-reaching institutional change (local market orientation and nature-based solutions) was considered interesting by a panel of senior decision-makers. This begs the question whether radical institutional change could have been more explicitly emphasized and facilitated in the workshop. The workshop scope was deliberately delineated around finding solutions for biophysical challenges. This generated many technological and management solutions, but allowed little room to explore ways to develop more resilient business models, improve farmer-consumer relationships, or create more adequate financing arrangements (although in some cases the implementation of a new practice or use of a new technology would necessitate business model or institutional changes as well). The activities during the workshop reinforced this: both explicitly, for example through discussing KPIs for emissions to soil, water and air; and implicitly, for example by choosing for a tour of the farm rather than an exercise that foregrounded socioeconomic challenges. This is not a criticism of the chosen scope and activities: focusing on solutions to biophysical challenges is necessary given the ambitions of *De Marke* and the Regenerative Farming project. Furthermore, a wider breadth of activities may have detracted from the depth of the solutions that were designed. However, the workshop planners may have been unnecessarily cautious of "confronting" regime actors on socioeconomic problems when it was apparent that senior decision-makers wanted to explore more radical designs. In the future, RIO workshop facilitators may consider a more extensive check of such decision-makers' "appetite" for institutional reorientation when the scope of the workshop is delineated, or on the first workshop day rather than at the end of the process. This would also more closely resemble the iterative character of RIO as depicted in Figure 1. Another suggestion would be to stretch the workshop over a longer duration than three days within a two-week period, although this may prove difficult when requesting voluntary attendance from a variety of stakeholders.

To address the apparent tradeoff between in-depth design of solutions to biophysical challenges and addressing contextual factors, facilitators could add a step in the process once solutions for the different functions have been identified. Facilitators can start a discussion with the following questions:

- Can we currently implement this solution?
- Are the technologies commercially available, affordable, and do farmers have the know-how to use them?
- Are practice or management solutions suitable for the farm, are farmers capable of implementing them?
- Do business model innovations require a change in relationship between the farm and its value chain actors? Would they require new partnerships, or even imply a change in the way the value chain as a whole operates?
- Generally speaking, are these solutions in line with current regulations and other institutions?

Discussing these questions during a RIO workshop can serve three purposes. First, it can put the solutions in context and give a more nuanced picture of how they fit the production system that is being redesigned. Second, this discussion may uncover overarching issues in institutional or value chain relations. Identifying and discussing them can help shape the anchoring trajectory of design scenarios and signal the kind of advocacy and negotiations required early on. Third, while the scope of the workshop might not allow for the resolution of any issues that arise from such a discussion, having the discussion allows all stakeholders to voice their concerns over the context in which they operate. This needs to be carefully balanced with the need to look beyond present-day barriers and have a creative interaction about the future.

Another point of reflection is how the development of, and search for, solutions is facilitated throughout the workshop. On the one hand an open process is desired, allowing facilitators to harvest a great variety of perspectives and solutions whose legitimacy stems from democratic input. On the other hand, having an open process with a strong presence of regime actors risks the outcome not straying very far from established ideas and practices: it is not surprising that participants representing a feed company, a major dairy cooperative, and four conventional farmers chose to work on scenarios in which producing dairy for export markets remains the core business model. To an extent this was mitigated by letting participants freely choose the quadrant they wanted to work on, as the more locally oriented scenarios demonstrate. RIO practitioners and researchers might therefore experiment with deliberately heterogeneous groups in the scenario design phase; additionally, this may have a different effect on cognitive and relational learning outcomes. Furthermore, they could choose to invest more time and effort in the expansion of the morphological chart between workshop days. Having a greater variety of solutions to choose from to fulfill the chosen functions could produce more diverse scenarios.

5.3. Reflection on methods and theory

The mental model mapping tool was effective in demonstrating cognitive learning of workshop participants, but the response rate was relatively low (nine out of seventeen participants), making it very difficult to statistically analyze the results. This was likely due to a combination of factors: the complexity of the exercise (twenty-one concepts available for modeling), the length of instructions, a user interface that some participants did not find intuitive, the fact that participants were asked to complete two mapping exercises both before and after the workshop, and lack of participant buy-in for the exercise. This could be mitigated to some extent by more clearly emphasizing the importance of the mental model mapping, having only one mapping task with fewer concepts, clearer and shorter instructions, a better user interface, and making time for the exercise at the beginning and end of the workshop while all participants are present and facilitators can assist.

Another matter for reflection is the position of the authors as workshop planners and facilitators on the one hand, and researchers of the process and outcomes on the other. This "wearing of different hats" may not have allowed us to make an assessment with sufficient distance. We attempted to mitigate this through the inclusion of co-authors not involved in the planning and not present at the workshop. An alternative in the future could be to have the first author of such a study not involved in workshop facilitation and planning at all, though this would make it more difficult to understand the motivation behind workshop scope and activities. It may therefore be prudent to focus either on the learning process or learning outcomes exclusively in a future study.

The use of the scaling readiness framework provided an insightful analysis of the solutions in the design scenarios created in the workshop, particularly with regard to the role of *De Marke* in realizing these scenarios. However, as noted above, it is important to see past the scaling readiness level of solutions and also assess the cultural, social and economic factors determining a solution's potential for implementation: "researchers should consider how farmers 'live with' technology, rather than simply how they 'act on' it" (Rose et al., 2022, p. 3). This is a strength of *De Marke*, because many of the farm managers and researchers who work there also manage their own family farms. This allows them to see a solution "through the regular farmer's eyes", and helps them understand not just if, but how and why a solution would move from a small network to an end-user. Tracking such a diffusion process closely with a partner like *De Marke* would create an opportunity to study the finer details of the innovation adoption process.

A more critical reflection on the scaling readiness framework relates once more to technology- and innovation bias. Retro-innovation and exnovation are an important part of farmers' repertoires for adaptation and transformation. This is evident in the literature (e.g. Gosnell et al., 2019; Rose et al., 2022), chapter four, and some of the design scenarios from this case study. However, these types of changes don't fit the model of R&D and innovation development underlying the innovation (or technological) readiness level assessment. This calls for more conceptual work to assess non-technological innovation. At the same time, just because a technology or practice was commonly used several decades ago doesn't mean it can be easily adopted by today's farmers, or within the current farming paradigm. This calls for new frameworks to help understand the "rediscovery" of old ways of working.

Looking at the group compositions for the creation of design scenarios of day three of the workshop, we noticed that more regime-aligned individuals tend to include solutions that are already part of, or not a major departure from, business as usual. The opposite is arguably also true, as the more transformative scenarios were created by individuals that are not easily characterized as regime actors (one included a biodynamic farmer, one of only seventeen in the province of Gelderland). This suggests that homogenous groups of more "transformative thinkers" generate more transformative outcomes, and felt comfortable doing so. However, diversity of participants is valued highly in the social learning literature (van Mierlo & Beers, 2020). Future studies of interventions like this RIO workshop could therefore assess, anonymously, whether participants felt they could freely share their opinions and feelings in group interaction, and whether this differs when groups are more or less homogeneous.

A final point of reflection is on the seriousness of the exercise. The workshop participants were all relatively close stakeholders in *De Marke*, and the purpose of the workshop likely felt very real to them: their ideas have a good chance of affecting a major investment decision and the future operations of the farm. The stakes were high, which may have led to a cautious approach of the facilitators in the framing of the workshop and of the participants in the kinds of solutions they proposed. With a more hypothetical exercise or with lower stakes, a more "far-out" set of goals could have been used to broaden the scope of the exercise and open up more sweeping changes, including radical institutional changes. The literature on serious games for example (den Haan & van der Voort, 2018; Stanitsas et al., 2019) offers potential to stimulate more "out-of-the-box" designs and develop more creative RIO workshops in the future.

6. Conclusion

The research aim of this chapter was to explore the potential of a reflexive interactive design workshop to instigate endogenous regime change towards sustainable dairy farming. Our case study was the redesign of *De Marke*, an experimental demonstration farm in the East of the Netherlands. We mobilized learning as a lens through which to approach this aim. We could observe learning at two levels: workshop participants' mental model changes, and design scenarios as the learning outcomes of the workshop. At the participant level, we observed both a shift in their priorities pre- and post-workshop, and a convergence of system perceptions between participants. This was observable for the mental model mapping task about dairy farming's effect on the environment, but not for the task about dairy farming's effect on farmer wellbeing. This reflects the workshop focus, stakeholder priorities, and most likely a choice the workshop facilitators had to make to prevent the workshop scope becoming too broad.

The design output of the workshop came in the form of four scenarios containing a different mix of solutions to address sustainability challenges for the local dairy farming sector. The solutions contained within these scenarios differ in terms of how mature and diffused they currently are, how well they align with current regime logics and discourses, and in the way in which *De Marke* and its stakeholders will have to operate to realize these solutions. This implies different foci for the process of anchoring the newly designed farming system in the regime. From a regime change perspective, some of the scenarios designed during the workshop would imply a substantial transformation of the dairy farming regime, if they were widely implemented. Other scenarios present a more incremental change, but still a departure from business as usual. In this sense, the chosen intervention has the potential to stimulate regime change from within.

The main question however is which scenario or mix of solutions are eventually implemented, whether *De Marke* succeeds in convincingly demonstrating the viability of new ways of farming, and whether farmers are willing and able to adopt these solutions in the near future. These are critical questions for future research, and call for a continued engagement with the process of anchoring by researchers. This echoes our suggestion from chapter four to study the agency and decision-making process of incumbent organizations across the food system: farms aren't the only actor that need to adapt and transform to bring about a sustainable agri-food system. Ultimately, there is a risk that if we leave it to the regime to reform itself, the transition does not proceed fast enough. If continued observation of the transformation of *De Marke* indicates that stakeholders opt for the least radical and impactful scenario despite the availability of more transformative options, there is a case to be made for stronger normative guidance from the state. This should be coupled with financing and a guarantee that the chosen path has legitimacy and a sound legal basis of operation.

Chapter six

Conclusions and reflections

In this concluding chapter of my thesis I reflect on the results by first summarizing the findings of chapters two to five, and then answering the empirical research questions. I then reflect on my research approach and the situated context of my research- project, focusing on the benefits, challenges and future improvements of such an action research approach. I conclude with implications for further empirical and conceptual work, and for policymakers, practitioners, citizens, and activists.

1. Reflection on the results

1.1. Overview of findings

Chapter two identified five mechanisms that are currently blocking the broader adoption of nature-inclusive practices in the Dutch dairy sector: lack of market incentives and state support for farmers to adopt such practices, low financial and regulatory action perspective of farmers, lack of a shared and concrete vision for nature-inclusive farming, and regime resistance against this alternative. We conclude that while actors in the incumbent farming regime are responsible for the existence of these blocking mechanisms, they are also instrumental in overcoming them. To aid this process, we suggest visioning and the development of alternative discourses that can challenge dominant logics and maintain pressure on incumbents; regulatory changes to create a level playing field so that the protection of ecosystem services is rewarded and the degradation of ecosystem services is penalized; and a strong emphasis on the socioeconomic, cultural and political ramifications of a transition to ensure its legitimacy.

Chapter three charted the problem-solution space for the future of the Dutch agri-food system (not limited to the dairy sector). It found that for a number of issues, such as greenhouse gas emissions and antibiotics use in agriculture, there is alignment both on what the problems are and the general approach to addressing these. A large number of mostly social and environmental issues are characterized by a shared problem perception, but lack consensus on solutions, which will necessitate further innovation and experimentation. Three economic issues were identified where stakeholders are divided on both the problem (some consider them highly problematic, others are content with how things are) and solutions (radical reorientation or continued business-as-usual): Dutch agriculture's export orientation, the size of the agricultural sector, and farm business models. These issues are problematic because making progress in areas where there is consensus will be difficult if the economic goals and principles of Dutch agriculture don't change. We recommend negotiation and advocacy as possible ways to address this situation.

Chapter four investigated farm-level change processes through the lens of spheres of transformation – the practical, personal and political dimensions of transformative change at an individual level. It found that the connection between inner and outer worlds of farmers – between their emotions, worldviews and everyday actions on the one hand, and the societal trends, markets and institutions they are exposed to on the other – is a crucial one in the change process on the farm level. We furthermore highlight the diversity of characteristics, like the ability to reflect and appetite for risk, that an individual farmer needs to possess to embark on a transformation towards sustainability. The findings emphasize that policymakers and value chain actors need to recognize the diverse facets of farmers' experiences if they wish to stimulate broader adoption of more sustainable farming models.

Chapter five investigated an effort to redesign an experimental farm so that it can demonstrate the benefits of regenerative dairy farming to farmers in the East of the Netherlands. The method used for this redesign was a reflexive interactive design workshop. We focused on learning as a key process in sustainability transitions, assessing both what participants of the workshop learned, and what sustainability transitions researchers can learn from the outcome of the workshop. We found some evidence supporting the hypothesis that this intervention would enhance participants' understanding of how dairy farming impacts its social and ecological environment, indicating that reflexive interactive design is a suitable methodology for social learning. The output of the workshop – four scenarios for a redesign of the demonstration farm – contained a diversity of technological, management and institutional innovations, although the scenarios differ in the extent to which they align with established market logics and the productivist paradigm. We conclude that design and anchoring of innovation is a useful approach with potential for regime transformation, although with room for improvement to better address sociocultural challenges and identify opportunities for institutional change.

1.2. Causes of lock-in in the Dutch agri-food system

The first research question I aimed to address concerns the causes of lock-in in the Dutch agri-food system. In the introduction, I highlighted three kinds of lock-in that prevent agri-food system sustainability (Oliver et al., 2018): knowledge lock-in, economic and regulatory lock-in, and sociocultural lock-in. Based on the findings of my research, I conclude that these types of lock-in all feature strongly in the Dutch agri-food system. Sociocultural lock-in is particularly pervasive, as patterns of thinking, cultural norms, and dominant discourses heavily influence and perpetuate the other kinds of lock-in. I now describe each type of lock-in in detail with reference to my research.

1.2.1 Knowledge lock-in

A transition to more sustainable agriculture in the Netherlands is hampered by uncertainty, lack of knowledge and poor knowledge access, and ignorance. Many farmers who made the switch to a regenerative farming model **(chapter four)** had to make a leap of faith. First, they could not be certain of the effects of different farming practices on aspects like biodiversity, soil and water. From the perspective of policymakers and value chain actors, stimulating such a transition is compounded by the range of soil types and properties in the country (e.g. peat soils and sandy soils present different challenges and therefore require different farming practices), and the inherent complexity of biodiversity, as reported by experts consulted for **chapter two**. Second, there is great uncertainty around the benefits and feasibility of alternative business models due to the economic, political and regulatory environment: price fluctuations, unclear government ambitions, and frequently changing and often contradictory regulations present a significant deterrent to farmers who might have the intention, knowledge and skills required to change the way they farm. All farmers interviewed for **chapter four** recounted this uncertainty in their farm transformation process, but not all were willing or able to accept it in equal measure: some farm transformations proceeded step-by-step or did not change their farm operations as radically, whereas others proceeded more rapidly or changed their farms more thoroughly.

Knowledge is also often not available at all or difficult to access. According to some interviewees from **chapter four**, the process of switching to new practices or technologies can only be described as "trial and error". This requires willingness and ability to experiment and take risks, which we cannot expect from the majority of farmers: they do not necessarily have the same risk appetite as the generally more daring and pioneering farmers we spoke to, and as **chapter two** showed, the average Dutch dairy farmer is heavily indebted. Furthermore, those that have successfully experimented are not necessarily in a position to widely share their knowledge and experience because they can be socially or geographically isolated. Meanwhile, our findings from **chapter two** show that most conventional farmers get new knowledge and advice from agrochemical and machinery salesmen who have little to gain from their clients' switching to alternative farming practices; both because this would in some cases undermine their employers' business models and because they are reluctant to suggest practices that are not guaranteed to work. In addition, they don't have the information and knowledge at their disposal due to the focus of their education, training and experience. While some information on such practices and their implementation in different contexts exists, it is scattered over different repositories and sources and not easily available.

A third aspect of knowledge lock-in is ignorance. Many actors throughout the agri-food system are unaware of the problems they face, why they exist, and what can be done about them; what makes it problematic is that this ignorance is fostered by powerful incumbents. One interviewee was confident that biodiversity decline was not an issue: they frequently saw wildlife on their farmland, while echoing skeptical sentiments about the negative effects of pesticides published in the professional farming press and on social media. This is not an isolated incident; in fact, Stichting Agrifacts, a self-styled "think tank" funded by the farming lobby and input companies Agrifirm and ForFarmers, routinely casts doubt on research concerning the harmful effects of modern agriculture from universities and the Netherlands Environmental Assessment Agency PBL. They do this by for example disseminating their own nitrogen emission and dispersal models (to contest the narrative around the nitrogen crisis, see **introduction**), and by suing universities that "dare" to persist in calling attention to the harmful effects of pesticides on insect populations[13]. Recent polls on Dutch farmers' perception of the nitrogen crisis similarly show that the majority of farmers don't take the problem seriously and think they have already done enough to address it[14]. Still more problematic is that some farmers apparently encourage each other to act against the rules in full knowledge of the consequences: investigations show how hundreds of farmers openly report ways they have "gamed the system" to expand their farms before applying for the required permits, and that many of them are prominent members of cooperatives and farmers' interest organizations who have shared their experiences[15].

Fourth, the Dutch research landscape favors knowledge production on conventional and efficiency-oriented farming rather than on more niche alternatives. Our research in **chapter two** found that in the year 2019, only 44 peer-reviewed papers on biodynamic, agroecological and nature-inclusive dairy farming were published by Dutch universities, compared to 1098 papers on conventional dairy farming. This may be a crude metric but it illustrates the skewed agricultural research policy agenda that contributes to knowledge lock-in, and echoes previous research on this topic (Tittonell, 2013).

1.2.2 Economic and regulatory lock-in

Due to the globalized trade in agricultural products, prices for Dutch farm output are to a large extent set on world markets. This means that farmers operate with relatively high production costs and relatively low prices. Conventional farmers tend to manage to do so – albeit precariously – by focusing on efficiency. This was evident in some interviews for **chapter four** with farmers who still operated their farms conventionally, as well as our expert consultation for **chapter two**. Farmers who try to follow a different paradigm have to compete with peers who, all else being equal, will have lower operating costs (Uematsu & Mishra, 2012). Reducing costs and increasing prices are two strategies (often combined; more on this in section 1.3 below) to deal with this situation, although these strategies are not straightforward either. Farmers we interviewed for **chapter four** reported that when they asked banks for financing based on a business plan to extensify their farms, they were rejected: banks were unwilling to finance operations that foresaw a drop in output, regardless of the goal to increase profits at lower costs. To increase prices, many farmers wish to get organic certification, but this comes with two problems. First, organic or biodynamic cooperatives that farmers can sell to long-term are not greatly expanding their membership base. This is partly because consumer demand

13 https://www.pbl.nl/publicaties/reactie-pbl-op-brief-van-de-stichting-agri-facts; https://www.ftm.nl/artikelen/agrifacts

14 https://www.ad.nl/binnenland/meerderheid-boeren-wij-hebben-geen-negatieve-invloed-op-natuur-en-klimaat~a06c7b6e/

15 https://fd.nl/economie/1440102/boeren-strijden-om-de-schaarse-ruimte-voor-mest

is stagnant and the market for organic food is saturated. Second, if a farmer does manage to find a buyer, they will first have to undergo a transition period mandated by organic certifiers during which they produce without biocides or artificial fertilizer while still receiving conventional prices. This "valley of death" needs to be endured or bridged with a financial buffer that many farmers don't have, or with taking on additional loans that they may not have the risk appetite for. This process has been recounted by numerous farmers interviewed for **chapter four**, and was also cited as a reason for the low diffusion of nature-inclusive farming by experts consulted for **chapter two**. Another option to realize higher prices is to sell to specific buyers who are happy to pay for products with quality and sustainability characteristics, or "the story" behind the product, but doing so requires more effort as well as marketing skills that many farmers don't have; of our interviewees for **chapter four**, only one farmer has had success with such a strategy.

While farmers following alternative paradigms are motivated by – and often achieve – improved ecosystem functioning, they are not structurally rewarded for doing so. Several farmers interviewed for **chapter four** go far beyond the requirements to receive subsidies or organic certification in their protection of ecosystems without receiving commensurate additional support or higher prices. At the same time, farmers who cause soil degradation, water pollution, contribute to climate change and other forms of environmental degradation are not penalized for doing so: the largely conventional Dutch agricultural sector causes €6.5 billion of environmental damage that society has to pay for, and regulations designed to curb this damage clearly do not suffice (Drissen & Vollebergh, 2018). The result is an uneven playing field. While the EU Common Agricultural Policy, the main source of agricultural subsidies in the Netherlands, has been revised to include more incentives for environment and climate action, it is still primarily based on farm size, perpetuating the productivist regime (Heyl et al., 2021).

1.2.3 Sociocultural lock-in

Dutch consumers prioritize cost of food over aspects like geographic origin, sustainability, or animal welfare (European Food Safety Authority, 2022). This partly explains the low market demand for more sustainable products, which typically come at a price premium (although recent studies suggest consumers can be "nudged" into higher spending on more environmentally-friendly food; see e.g. Bauer et al., 2022). This not only has economic effects as described in section 1.2.2, but also demotivates farmers who attempt to produce more sustainably and struggle to enter or expand the niche for such products. Farmers interviewed for **chapter four** describe this as part of a large perceived distance between producer and consumer. What is puzzling is that although the average German consumer values food cost even higher, and sustainability even lower, than the average Dutch consumer, the market for organic food is greater in Germany than in the Netherlands (European Food Safety Authority, 2022; FiBL, 2020). As long as the Netherlands continues to export most of its agricultural produce to neighboring countries, more research is needed to find ways to tap the apparently greater market for sustainable food abroad.

Dutch society and political culture value conformity and consensus over experimentation and innovative alternatives (Andeweg, 2001). Farmers are exposed to judgment from their peers, which prevents many from taking steps to implement different farming models (Westerink et al., 2019). Conversely, this social force maintains conformity around the business models, technologies, practices, and discourses that form the status quo (ibid). For those that change how they farm in spite of such peer pressure, who go against this "common sense" (Patnaik, 1988), it can have adverse social consequences. Interviewed farmers report having less and less in common with their peers in the neighborhood, and some even report feeling ostracized by the community. Lecturers at agricultural colleges, consulted for **chapter two**, report that many students expect to be educated in line with the paradigm they have grown up in on their family farms, and the "appetite" for alternatives is low; furthermore, several farmers we interviewed who were already interested in alternative farming models during their education reported being pigeonholed for their interests **(chapter four)**. At the level of policymaking and politics, the consensus-oriented political culture tends to seek the broadest possible mandate and support base, leading to policies based on the lowest common denominator rather than difficult but necessary choices. And because responsibility is shared between many parties, the electoral backlash then favors fringe parties, as demonstrated by the gains of Dutch far-right parties in the wake of the nitrogen crisis[16].

Another aspect of sociocultural lock-in is the cognitive separation between human and nonhuman nature, as well as the separation between land for production and land for nature. This type of thinking is deeply embedded in Western culture (Pattberg, 2007). In my research, I encountered it for example during interviews with more conventional farmers who stated that "biodiversity is a luxury you can only afford on cheap land" (see **chapter four**) and in conventional practices of relegating farmland biodiversity to the (subsidized) field margins. At a larger scale, the designation of some land as protected nature areas with other arable land designated for high-productivity farming arguably contributed to the nitrogen crisis, where the emissions from the latter "productive land" deteriorate the former "nature land". This is squarely in line with the sustainable intensification paradigm (see **introduction**) and the "land sparing" approach (c.f. Phalan et al., 2011; Tscharntke et al., 2012), although the scientific consensus now tends towards integration of farmland with protective spaces for species (Kremen & Merenlender, 2018; Pe'er et al., 2022).

A further cultural feature contributing to lock-in is a bias towards technology as a solution to ecological problems. So-called "techno-fixes" can be problematic when they only narrowly address an issue, have unintended consequences, are costly,

16 https://stukroodvlees.nl/niet-alles-kan-hoe-de-nederlandse-politieke-cultuur-een-stikstoffiasco-veroorzaakt-en-in-stand-houdt/

increase power concentrations of large companies, and come with data ownership and privacy concerns (Klerkx & Rose, 2020; Pfotenhauer et al., 2022; Wigboldus et al., 2016). One farmer we interviewed for **chapter four** related that they had subsidy applications rejected because they were focused on an alternative management practice rather than high-tech solutions. In **chapter five**, we observed a tech-bias in some of the scenarios designed for a future-proof farming system. Moreover, this technology orientation was deliberately chosen by the facilitators as a parameter for the design scenarios. At the level of the innovation system (see **chapter two**), we can observe the Dutch government's mission for circular and biodiversity-friendly agriculture narrowed down to "smart technologies" and "advanced robotics" in the agribusiness knowledge and innovation agenda (Topsector Agri & Food, 2019). Moreover, technology features strongly in many incumbent organizations' visions for the future for Dutch agriculture (see **chapter three**). This bias leaves low-tech, low-cost, practice-focused, and retro-innovation underexplored and underfunded.

1.3. Path deviation and creation from the bottom up

The preceding outline of knowledge, economic and regulatory, and sociocultural lock-in may seem rather pessimistic: it looks like Dutch farming is firmly stuck in producing a host of negative outcomes. I therefore now turn to our findings on path deviation and path creation from the bottom-up, and answering research question two: What can be done to break out of this lock-in system? The answer comes in two parts. First, I detail the experiences of farmers who managed to switch to regenerative practices and business models despite systemic constraints. Individual-level change is rare and difficult, but farmers with the right mindset, capabilities, resources, network, motivation and inspiration are able to fundamentally reorient their operations towards sustainability. Second, I describe our experience of trying to redesign a demonstration farm at the heart of the agri-food regime to stimulate a regional transition to regenerative farming. This showed that it is possible to facilitate a creative and collaborative process that changes the perspectives of individuals working for incumbent organizations, and can generate ideas for regime reorientation with transformative potential.

1.3.1 Strategies and outcomes of farm-level transformation

One of the core ideas behind regenerative farming is that it does not prescribe certain practices or technologies (Giller et al., 2021; Newton et al., 2020; Schreefel et al., 2020). The project under which I conducted my research in fact advocates for a "mosaic of solutions" to reach regenerative system goals (Groot Koerkamp et al., 2021, p. 5). This is reflected in the diversity of solutions adopted by the farmers in the project's community of practice, who we interviewed for **chapter four**.

By and large, the farmers we spoke to follow the principle of regenerative agriculture that crops and animals should be chosen to function in the service of natural processes and ecosystems. This is context-dependent: some dairy farmers on peat soils for example chose a cattle breed of a lighter stature so they could raise the water level on their land, which prevents peat oxidation (reducing greenhouse gas emissions) but makes it difficult for heavy machinery and animals to move on this land. Crops (including herbs, grasses and feed crops) were chosen to improve soil structure, for example oats and other grains rather than maize as feed crops. These were often planted in tandem with nitrogen-fixing legumes (e.g. field beans) to reduce fertilizer input. Cover crops or crop residues are often left on the fields during winter to prevent topsoil erosion. Other crop and livestock choices additionally had ethical motivations, for example for the farmer focused on raising steer calves that are usually slaughtered or euthanized at the earliest possible time. Others were motivated by the desire to create a novel or higher-value product, such as the farmer whose cover crops include soy and wheat that allow them to produce soy sauce.

Regenerative farmers follow a diversity of business models. Some farmers "only" change how they farm and remain members of large cooperatives, selling commodities for the bulk market. This is in part motivated by a desire for reliable and predictable sales channels. In some cases, the farmers choose to get organic or biodynamic certification to increase prices. These farmers often switch to a smaller cooperative that can still buy the farm's entire output, oftentimes at a higher price. Members of smaller cooperatives also appreciate the more direct communication with such a cooperative's board. Rarely, some arable farms manage to find a supermarket that can buy some or all of their produce at a higher price if the story behind the product has marketing value for the supermarket. More niche concepts are direct sales (through self-harvest days or farm shops) or subscription models where a farm supplies only its members. Often these models are combined, partly for added income and financial resilience and partly because more consumer interaction increases farmers' wellbeing and happiness.

To achieve the above – new practices and business models – the farmers followed a variety of strategies. These differ temporally, in terms of degree and depth of change, and in terms of the source of knowledge and inspiration for the change. A farm's transformation usually takes several years, and often more if we include the farmer's thought process. Very rarely is it feasible that a farmer is inspired to change or has a change of heart, and wakes up the next day changing every facet of their farm. Nevertheless, some farmers described their change process as quite swift once their decision had been made, although this tended to come at a cost: income losses could temporarily be substantial, and the sheer effort of reconfiguring farm operations (including designing a new cropping plan, changing livestock feed composition, adapting buildings and machinery) came at a significant cost to their physical and mental health. Others were more cautious and took their time experimenting with, and implementing, a few solutions at a time. This means that, at least temporarily, some farms were in a relatively "shallow" state of transformation to regenerative agriculture, focusing on a selection of outcome areas at a time. Others achieved more "depth" by integrating solutions with each other and striving for ambitious goals in all aspects, biophysical as well as socio-economic. Interestingly, these farmers were often rather modest about their achievements when we asked them to score their performance in a self-assessment during our interviews for **chapter four**. A further notable difference between the farmers was the source of inspiration and knowledge for their transformation. For some this was a process of learning, study and experience over a long period of time, through research, observations, and spirituality. For others it was quite incidental and serendipitous, with a single experience leading to an epiphany, like "flicking a switch". Still others were inspired and informed socially, through interactions in farmer networks and other social groups.

It's crucial to emphasize that the farmers in our network are a diverse group that, one way or another, exhibit special personal characteristics. In **chapter four** we identified risk appetite, open-mindedness, reflective capacity, and sociability with peers as important. Not a single farmer we interacted with exhibits all of these characteristics, and it is questionable whether even just one or two can be widely found among the general population; whether they can be "taught" or "induced" is another question altogether. Together with the often serendipitous nature of events that led farmers to change how they farm, the question we naturally ask next is how the isolated successes of the pioneers in our network can be translated to more systemic impact. How can we accelerate the transition to a farming system that quickly addresses the Dutch agri-food system crisis?

1.3.2 Redesigning a demonstration farm to accelerate the transition

Path dependence and lock-in (see **Introduction**) occur on the micro as well as the macro level. But lock-in can be overcome through path deviation, path creation and path destruction (Garud & Karnoe, 2001). I outlined above how farmers in our project's learning network have deliberately chosen to stop following the path of productivist, high-input farming, instead turned to a variety of regenerative practices and business models. Because overall this occurs at a relatively slow pace and in low numbers (see **chapter two**), a crucial aspect to the Dutch agri-food system transition is the inclusion of actors who don't have the resources, pioneering mindset, or transformative skills and capabilities of those who deliberately create new paths of their own accord. And because farmers primarily learn from each other (Rogers, 2005) and look to each other as a reference for "good farmer" behavior (Burton, 2004b), we studied the redesign of a pilot farm in **chapter five.** This farm serves as a model for innovative farming in the region and is part of several knowledge exchange networks with conventional farmers; it therefore has the potential to influence a high number of conventional farmers in the area. The intervention aimed to bring about collective learning, a key process in sustainability transitions (Geels et al., 2016).

The extent to which farmers in the region will actually learn from the new solutions that will eventually be tested and implemented on this pilot farm is uncertain, but it will likely depend on a number of aspects. First, the solutions need to address the socioeconomic concerns of farmers and suit their business and operational models – in other words, the solutions need to be profitable and implementable. While profitability depends on contextual factors that are not immediately under the farmers' or the pilot farm's control (see **chapters two and four**), the practical feasibility and suitability for typical farms in the area should be a priority for the work of the pilot farm. Second, the set of solutions implemented on the farm needs to align with long-term policy and government priorities. This provides legitimacy for the role of the farm in sharing knowledge and expertise, and in turn provides the adopting farmers with perspective. As **chapter three** demonstrated however, this perspective is currently not evident in expectations that various Dutch stakeholders have of the agricultural sector. A closely related requirement is that whatever solutions farmers are motivated to adopt have sufficient legal grounding to remain in operation for long enough to show results and validate the experiment: recent years have seen technologies like manure separation floors and air scrubbers declared ineffective by the courts, severely reducing state legitimacy. Third, the operations of the pilot farm need to be closely monitored and assessed. If the newly implemented solutions do not produce the outcomes that societal stakeholders and the value chain expect, the farm is not fulfilling its mission and should change course. A strength of the farm is that it can experiment with different solutions and can at some point "pick winners" from among the available options.

The matter of whether this kind of intervention can lead to regime change needs to be viewed with some caution. Some of the scenarios imply a slight reorientation, while others are more substantially transformative. In any case, it's up to the decision-makers of the pilot farm and its stakeholders to choose. This comes with the risk that if we leave it entirely to the regime to reform itself, it may not move fast enough and tend to choose for the least drastic and impactful scenarios (not for nothing, picking "low-hanging fruit" is such a popular phrase in the corporate world). We found some tentative evidence for this in the composition of workshop participants in the groups that developed scenarios: participants representing incumbent organizations tended to work on scenarios where the global market orientation for dairy farming persists. We may therefore argue for more prominent state involvement in providing normative directionality for such design interventions. This of course requires that the government develops a clear and unambiguous vision and strategy for the future of Dutch agriculture (see **chapter three**), and that it facilitates the implementation of new designs with financing and supportive policies (see **chapter two**).

1.4. Discussion of conceptual integration

To answer the two main research questions of this thesis – identifying the causes of agri-food system lock-in in the Netherlands, and exploring ways to break out of this lock-in – we applied a small range of frameworks for complex system change. In this section, I reflect on the approach we took, how the findings reflect the theoretical assumptions underpinning the approaches, and how we could deepen the analysis further.

Chapter two applied the technological innovation system (TIS) framework. It identified systemic barriers to the diffusion of nature-inclusive dairy farming, which we framed as a practice-based innovation. The chapter took the sociotechnical dairy farming regime as its system boundary, specifying in some detail how dominant regime logics around science and education, policy and governance, market demand and consumer preferences, and business and operational models condition the functioning of the innovation system. We suggest in the chapter that overcoming the barriers stemming from these logics requires endogenous regime change to allow for a more widespread adoption of nature-inclusive farming. By locating barriers primarily in these regime logics, our recommendations for change point to matters beyond the boundaries of the innovation system, namely deep-seated cultural patterns, values, and political and economic interests. Our recommendation for a new social contract for Dutch agriculture resonates with the deliberate transformation literature's focus on this concept. Framing the desired outcomes of a transformation process not just in terms of innovation diffusion or improved sustainability outcomes, but much more broadly in terms of human safety and wellbeing (as deliberate transformation scholars advocate), could help delineate the fundamental conditions for such a social contract. This requires strong normative directionality; however, this directionality is not yet evident in the Dutch case, as the next chapter showed.

Chapter three focused on guidance and directionality as a specific "ingredient" in achieving system change, investigating it from the perspective of mission-oriented innovation policy. This relatively new perspective on innovation regards the achievement of societal goals rather than the diffusion of an innovation (and that innovation's profitability) as the desired outcome. According to this literature, achieving alignment on recognizing societal problems as well as alignment on solutions to address these problems is key. While we were able to make some general policy recommendations to move towards better alignment, the absence of agency from the analysis makes it difficult to come to concrete proposals for change. As with **chapter two**, the kind of problem we identified – the discursive hegemony of a market logic that favors agricultural exports and farming's contribution to economic growth – goes beyond the boundaries of a sociotechnical regime. Addressing this hegemony will require a serious reorientation of Dutch political economy. This is an extremely ambitious task that implies not just a regime shift in the domain of food and agriculture but political change on a wider level. The goals of deliberate transformation scholarship to create a better life (O'Brien, 2012) and a new social contract (Pelling, 2011) could be read to imply such a change, but these frameworks fall short of providing strategies to achieve it. This calls for a deeper engagement with disciplines that focus on politics and power (Avelino & Wittmayer, 2016), and continued work on reframing prescriptive transitions frameworks towards deeper transformative outcomes (Park et al., 2012). An important implication for research based on the MLP framework is to stop viewing the landscape as an exogenous factor beyond the control of individual actors or actor coalitions.

Motivated by a lack of attention for agency and individual actors' perspectives in the transition literature (Upham et al., 2020), **chapter four** took an individual perspective through the spheres of transformation framework, a framework stemming from the deliberate transformation literature. The agency of individual farmers was the focus, and the outcome was each farm's transformation to its current state of farming more "regenerative" than before. The system boundaries here were arguably as big as society in general and as small as a farmer's plot of land, depending on the type of change process that was investigated. This flexibility, in combination with the lens of the three spheres – personal, political and practical – allowed us to identify the drivers and barriers to change that were most relevant for each farmer. Because this and previous chapters identified other actors – companies across the value chain, government, consumers – as the barrier to a transition, we propose applying this framework to organizations beyond the farm. This could enrich our understanding of what motivates a greater diversity of actors to behave the way they do, and identify avenues for institutional change.

Finally, **chapter five** focused on learning in transitions, assessing the process and immediate outcome of a reflexive interactive design (RIO) workshop (Elzen & Bos, 2019). While a recent paper integrates the design of innovations with their adoption in the regime (a process described as anchoring; see Elzen & Bos, 2019), it was only possible to explore this tentatively. An ex-durante study of such a long-term process can provide interesting insights in the way in which regime change develops over time (Beers et al., 2014): it can shed light on how and why new technologies and practices are developed and adopted, how regulatory change unfolds, how coalitions form and dissolve around changes, and so on. However, this requires a high degree of commitment (and job security) for researchers accompanying the stakeholders for a long time period. In theory the RIO method was designed to stimulate "double-loop" learning involving "changes in underlying assumptions, values, and goals" (van Mierlo & Beers, 2020, p. 261). This closely links with the intersection of the personal and practical spheres of transformation, which we observed in **chapter four** as an important dynamic for individual-level transformation. Whereas interviewees for that chapter reported on instances in which their interactions with others had made them see the world differently in the past, this workshop was an opportunity to observe the development of new ideas as it happened. This has means that the aggregated and somewhat distant view of agency in the MLP or TIS approaches can be complemented with a close study of innovation processes. At the same time, it is difficult to follow the further process of implementation following such an intervention, and at some point the attribution of agency and responsibility becomes more nebulous. This reinforces our argument that not only the agency, behavior, and decision-making of farmers or entrepreneurs, but also that of corporate actors and policymakers matters if we want to really understand and accelerate transformations.

2. Reflection on the approach

2.1. Knowledge co-production in a public-private partnership

My research was conducted under the umbrella of the Regenerative Farming project, coordinated by a public-private research consortium of universities, value chain actors, farmer interest organizations, and NGOs. The project's focus was on land-based agricultural production (i.e. dairy, mixed livestock, arable, and horticulture farming), leaving the rest of the agri-food system mostly out of scope. Arguably this was necessary given time and budgetary constraints. Moreover, it was important to develop a definition of regenerative agriculture with a sound scientific basis because the concept had so far received lots of media attention and "buzz" without a shared understanding of its principles and outcomes. In this, it has already been successful; the scientific paper defining the term (Schreefel et al., 2020) has been cited fifty times in two years, and has been widely shared and discussed in policy circles and on social media. The stakeholder composition and funding structure of this research project is emblematic of the Dutch research environment, where public research funding is conditional on private sector cash and in-kind contributions. More broadly speaking, it is also emblematic of society's drive to create knowledge and insights with which to tackle today's urgent societal challenges. While these kinds of endeavors for co-producing knowledge are clearly necessary, they are not unproblematic.

The co-production of knowledge for sustainability, in the domain of agri-food systems as elsewhere, needs to address 1) issues of unequal power relations; 2) depoliticization and dominance of scientific authority; and 3) the preeminence of technological and scientific specialization (Tschersich & Kok, 2022; Turnhout et al., 2020). Unequal power relations are a result of research funding arrangements that privilege incumbents like industry, government and research institutes, both in initiating research projects and in defining their scope. This allows them to shape projects in their interest. In addition, they tend to have more time, resources, knowledge and skills at their disposal than grassroots initiatives or other more marginal actors, which allows them to define the way research projects are undertaken. In our project, the scope of focusing on agricultural production puts the onus on farmers to change. This does not necessarily mean value chain actors, government and civil society can continue with business as usual, but the framing raises concerns over the justice and legitimacy of this transition. In terms of research consortium composition, our project has a strong presence of regime actors (the country's largest dairy and sugar beet cooperatives, its most important agricultural lender, a large farmers' interest organization, and two major universities) and a scarce representation of grassroots initiatives. While we had support from a nature-inclusive farming and landscape restoration NGO, they chose not to renew their partnership in a follow-up project because they favor a bottom-up and more farmer-inclusive approach, highlighting the difficulty of co-production between these different kinds of organizations. Having said that, I must note that representatives of regime organizations are not by definition close-minded, not open to new ways of farming, or even the idea of far-reaching structural change.

A second barrier to co-production for sustainable agri-food systems is the primacy of scientific expertise and an apolitical research stance. A rational and scientific approach "ignores political differences between participants, including positions, interests and beliefs, and pressurizes non-elite participants to stay within this scientifically sanctioned rationality" (Turnhout et al., 2020, p. 16). A closely related issue is the prioritization of biophysical and economic challenges in agri-food system sustainability research, with less attention on social and cultural factors. Our project addressed this imbalance to some extent, with outcomes of a regenerative farming system specified across domains. Moreover, my research on lock-in in the agri-food system and the potential to break out of this lock-in has found an audience of policymakers at all administrative levels across the Netherlands: the province of Gelderland for example has adopted our analysis and recommendations from **chapter two** in their strategy for 2030 (Provincie Gelderland, 2021). On the whole however, the project was focused more on the "measurable" domains of biophysical and economic system parameters, while social and cultural matters received less attention and were left rather vague. In our project's "Outline of a Regenerative Agriculture System at Scale" for example the socioeconomic and cultural outcomes are defined in much less detail than biophysical outcomes (the former being described on three pages, the latter on ten; see Groot Koerkamp et al., 2021). Moreover, these outcomes were defined with little input from farmers and other directly affected stakeholders. This gives the impression of a top-down and reductionist approach, risking further concerns over justice and legitimacy, as well as sidelining less tangible but equally important qualitative approaches. These factors may explain the absence of civil society actors who want to bring in different perspectives, and help explain the uneven distribution of stakeholder types in the project.

We attempted to address the barrier of over-specialization in a number of ways. First, the two fulltime researchers on the project came from different backgrounds: one has a mechanical and biosystems engineering background, the other (myself) a multidisciplinary social science background. This allowed for a multifaceted approach. Second, a wide range of experts worked on and were consulted for the project, combining expertise from ecology, veterinary medicine, agronomy, entrepreneurship, livestock farming, innovation studies, and governance. These experts included academic as well as applied researchers, helping close the gap between scientific research and application in the field. Third, the fundamental position of the project was that there are no silver bullets, and that a mosaic of solutions is required to create a regenerative farming system (Groot Koerkamp et al., 2021). This "solution-agnostic" stance makes room for technology, social innovations, and management practices. Nevertheless, feedback and input from the learning network of farmers to the researchers remained limited, for practical reasons as well as ontological differences. Communication and stakeholder management lacked dedicated staff and resulted in limited and irregular interaction with the farmers. Ontologically, the project's approach of assessing farm performance and measuring biophysical outcomes, while favored and appreciated by a majority of farmers in the network, was at odds with a small number of farmers who had strong spiritual beliefs about soil life and considered lab testing an insufficient reflection of the reality they perceived. This furthermore highlights the difficulty of addressing the needs of a variety of stakeholders in such a broad transdisciplinary project.

A final point of reflection concerns the choice of regenerative agriculture as the paradigm around which the project was organized. Other concepts, chief among them agroecology, are well-established in academia and civil society and have similar aims of transforming agri-food systems towards a better balance with the natural world. Unlike regenerative agriculture however, agroecology has a strong social movement and explicit ambitions to improve agriculture's socioeconomic and cultural outcomes. Despite or perhaps because of this, regenerative agriculture is gaining prominence in the global agri-food policy arena as well as vast amounts of funding from agribusiness (Cabral et al., 2022). While our project has gone some way in addressing this blind spot by defining socioeconomic and cultural outcomes alongside biophysical ones, much more work needs to be done to place these on an equal footing and strive towards a transition that is as regenerative in social, human and cultural domains as it is in the ecological domain. Whether this is in the interest of the corporate interests that pay increasing attention to regenerative agriculture remains to be seen.

These reflections on knowledge (co-)production and the different perspectives on regenerative agriculture emphasize the importance of foregrounding a diversity of values, worldviews, emotions, and beliefs in research on agri-food system sustainability. They echo one of the key findings in **chapter four**, namely the importance of taking the traditionally under-explored personal sphere of transformation into account in studying and stimulating change in complex systems. These insights and reflections should prompt a return to Donella Meadows, one of the foundational scholars of environmental change and complex systems: her framework of "leverage points" conceived of paradigms, and especially the power to see them as such and transcend them, as the most impactful – and most difficult – ways of systems change (Abson et al., 2017; Meadows, 1999). Fortunately, disciplines like behavioral psychology are gaining traction in the field of sustainability transitions research (de Vries et al., 2021), and we can hope that this can fruitfully complement the study of lower-ranked (though of course also important) leverage points like institutions and resources.

2.2. Research stance

After these broader reflections, some thoughts on my own research are in order. My subjective ontological perspective is that the social and political reality of an agri-food system is knowable. This necessitated an ambitious and oftentimes challenging embrace of complexity. Even within the scope of just one relatively small country I encountered seemingly infinite nuances, peculiarities, and tradeoffs between sectors, regions and stakeholders, as well as across the timespan between the start and finish of the project. This kind of perspective requires transparency about the (sometimes limited) scope of analysis, and modesty about the limits of knowledge and "the knowable". This did not necessarily change my ontological stance, but rather made me more aware of the context-specificity of the research I have pursued.

At the same time, this kind of perspective is absolutely necessary to complement the more objectivist approaches that are currently prominent in research and discourses on agri-food system sustainability (Turnhout et al., 2021): it is vital to study facets of food systems that cannot easily be measured or quantified (e.g. food sovereignty, the cultural and aesthetic value of landscapes, and farmers' bonds with the soil and their animals) because they are at risk of being sidelined for approaches that lend themselves more easily to scaling and rapidly measurable impact. Our project, while not perfect, has demonstrated that an inter- and transdisciplinary approach can generate valuable insights with a team that includes scholars with different epistemological perspectives and methodological preferences.

3. Implications

Empirically, we explored in great detail the ways in which the Dutch agri-food system is stuck: knowledge-related, regulatory, economic, and sociocultural path dependencies lock the system into functioning unsustainably. At the heart of these path dependencies lies a strong incumbent regime built around a productivist paradigm. We also explored how farmers have deviated from this paradigm despite the aforementioned structural path dependencies, highlighting a variety of strategies and personal characteristics that have enabled them to get "unstuck". Recognizing that the actors that make up the Dutch agri-food system are unlikely to disappear, we also explored the potential for initiating regime reorientation through a facilitated redesign of a demonstration farm. This yielded some promising initial results, but this intervention's potential for regime reorientation can only be judged by studying the implementation of ideas generated in the intervention, which we were not yet able to study. Conceptually, we make two main contributions. First, the personal sphere and its links with structural factors are crucial to better understand agency and behavior in transformations. Second, frameworks to study the transformation of sociotechnical systems can be enriched with concepts from related scholarly communities. The idea of a social contract broadens the scope of change beyond niche and regime, and indicates the possibility of actively reshaping an otherwise exogenous landscape.

3.1. Empirical research

Regenerative agriculture is a promising paradigm around which to organize agri-food system transformation. However, it has deep and shallow interpretations, and if the latter prevail it risks remaining a buzzword (Feola, 2015). It is the role of scientists to give them a solid foundation, and the role of practitioners to give them meaning. Corporate and policy interest in regenerative agriculture has been too focused on biophysical aspects (Cabral & Sumberg, 2022), so an important way to add depth is to further explore its social, cultural and political implications.

Another way to add depth to the regenerative agriculture debate is to research aspects that are difficult to quantify. The fact that food sovereignty, landscape quality, rural quality of life and farmer wellbeing are more difficult to quantify than, say, soil carbon content, water quality, or crop yields, doesn't mean that these aspects deserve less attention. This calls for alternative, context-specific measurement and monitoring methods. Work on territorial agri-food systems (Lamine et al., 2019) and rural territorial pathways (Bastiaensen et al., 2021) points in an interesting direction.

Much research on agricultural sustainability focuses on farmers as actors with the most direct influence on producing food more sustainably. This is logical and necessary, but there needs to be more attention on the role of value chain actors, government, and civil society in this transition. As this thesis showed, these actors can present both barriers against and opportunities for change. Moreover, from the perspective of justice and legitimacy in transitions it is prudent to explore what they can contribute (Hebinck et al., 2021; Tschersich & Kok, 2022). At the policy level, a specific point of attention should be the coordination and governance of innovation in agriculture, which currently is biased towards technologies and leaves changes in practices and management underexplored (Rose et al., 2022).

Another interesting question to explore as research on regenerative agriculture is expanded down the value chain, is the role of consumers and diet change. The concept of regeneration has a lot of potential from a public health perspective, as demonstrated by the landmark report on human *and* planetary health of the EAT-Lancet commission (Willett et al., 2019). Assuming current food consumption patterns in organizing the reorientation of agriculture may be a missed opportunity of addressing the cost of "welfare diseases" like diabetes, cancer and cardiovascular disease (Afshin et al., 2019).

Lastly, and related to the previous point, links between food production and sectors like energy and housing, as well as cross-sectoral issues like labor availability and demographic change, need to be further explored. This requires a better understanding of the embeddedness of food and agriculture in broader political and economic processes. This ties in well with the emergent concept of a looming global polycrisis, the potential failure of interconnected natural and societal systems that could irreversibly degrade human wellbeing (Homer-Dixon et al., 2022). To that end, we need to explore the sustainability transition of food and agriculture both at a broader spatial scale and in connection with other sectors.

3.2. Conceptual and methodological advances

The potential for research on transforming complex systems with a view to reorienting politics and economics for sustainability could have interesting conceptual implications. Research is increasingly adept at identifying and analyzing these links, as is evident for example in transitions research on institutional logics and regime destabilization (Frank & Schanz, 2022; Turnheim & Sovacool, 2020). A new challenge is to develop prescriptive and action-oriented approaches that can more actively guide such processes with concrete policy recommendations. The concept of the social contract, a prominent analytical lens in deliberate transformation research, could be a fruitful starting point: how can the relationship between citizen (i.e. in this case farmers, consumers, rural residents) and state be improved? How do the actions and strategies of value chain actors, banks, research institutes and other institutional actors affect this social contract, and how could their strategies change to improve it? What are the implications for policymaking and business models?

Other opportunities for more conceptual work lie in the domain of innovation studies. One of the foundational theories in this field is the diffusion of innovation, well-known for generating the S-curve model of innovation adoption as well as a typology of innovation adopters (innovators, early adopters, early majority, late majority, laggards) which we applied in **chapter four**. This literature has its roots in rural sociology and the adoption of hybrid corn varieties in the United States in the decades before and after World War Two. Much has changed since then: whereas seventy years ago the main challenge for agriculture was to produce more food to prevent starvation, the task now is to maintain or increase food output at a much lower environmental footprint. It may therefore be time to update the categories of innovation adopters and their characteristics in the modern setting. To illustrate, the original typology of Rogers (2005) characterized innovators as metropolitan and worldly if they regularly traveled to larger towns. This is a severely outdated indicator in the digital age, where virtually all farmers in North-West Europe have the world at their fingertips by way of smartphones. Furthermore, as discussed in **chapter five**, more conceptual work needs to be done on the adoption of practices rather than technologies, as well as processes of retro-innovation and exnovation (Van Oers et al., 2021).

One of the key findings from **chapter five** of this thesis was the difficulty of including institutional reorientation in the redesign of a farming system with the reflective interactive design method. While the theoretical links between designing new practical solutions and institutional change are elaborated in the concept of anchoring (Elzen & Bos, 2019), it was difficult to generate concrete proposals for institutional redesign in the intervention we studied. It is therefore important to continue adapting this method to identify practical ways to plan and facilitate such interventions in different forms. Concurrently, and particularly in the event that these types of interventions are not able to generate new institutional arrangements, we need to explore alternative ways of doing so; "traditional" lobbying and advocacy may yet prove to be a "good enough" way to push for institutional change (Sabatier, 1988).

3.3. Policy

A general recommendation for policymakers is to consider the overall societal cost of maintaining the current way of determining priorities for Dutch land use. There is currently a fairly strict separation between agriculturally productive land, protected nature, and industrial and residential land use. Upholding this separation while focusing on downsizing the agricultural sector while further increasing its (already high) efficiency may not be the ideal way forward. More multifunctional land use – for example through nature-inclusive agriculture that provides habitats for wild animals, or through care farming that integrates child-, elder-, and disabled care with farming – could address societal challenges in sectors beyond agriculture. A new farming paradigm could also improve landscape quality and rural-urban relations. In the domain of research, going beyond the current intensification and efficiency-oriented paradigm could also help maintain the Dutch reputation for excellence in research on agricultural sustainability.

A more specific recommendation is for policymakers to take the considerable diversity of Dutch farmers into account. In addition to sectoral and spatial (soil type) differences, they differ in their ambitions and abilities, their motivations, their propensity to experiment and take risks, and their entrepreneurial instincts. One-size-fits-all policies will not improve strained relations between farmers and government, and could lead to missed opportunities of capitalizing on farmers' different characteristics.

A second recommendation for policymakers is to level the playing field between farmers pursuing different business models with different ecological footprints. The "polluter pays" principle should be consistently applied across sectors, but the harmful effects of farming on nature and society are currently not systematically penalized; this is difficult when it is not yet feasible to clearly attribute certain levels of environmental damage to certain farming practices. Conversely, efforts of farmers to restore natural capital and regenerate social and ecological processes are not structurally rewarded. This requires, among other things, better monitoring and accountability mechanisms. On a related note, if modern and urbanized society places a higher value on goods and services other than food (Zasada, 2011), we could again turn to the personal sphere of transformation as a useful lens through which to try and better understand society's values and priorities (Horcea-Milcu et al., 2019). A broader recognition of farmers not simply as producers of calories, but also as stewards of landscapes and cultural heritage, would be an important project for sustainable farming advocates.

Third, fundamental change in the reorganization of a complex system like agricultural production is associated with foreseeable and unforeseeable burdens (i.e. cost of practice or technology adoption, sunk costs in infrastructures to be abandoned, potentially higher cost of food). Spreading these risks and burdens equitably over the value chain, or in fact society as a whole, is therefore recommended. Currently, farmers carry a high economic risk of transforming their businesses; this needs to be better supported by the state and value chain. To that end, the government can establish a transition support fund, or take on bank guarantees when commercial banks consider the risk of a farmer's plans too high. Value chain actors could be mandated to channel a portion of their profits back up the value chain to help finance this transition, in addition to orienting their sourcing strategies or purchasing criteria towards sustainability.

Fourth, the public sector should take steps to reshape the knowledge production and diffusion landscape. Currently, agribusiness actors are both prominent in the initiation and framing of research projects, as well as one of the main sources of information and innovation for farmers. This is not in the public interest, as potentially more sustainable innovations or alternative practices can carry risks and go against agribusiness interests. Therefore, the government should change requirements for private sector cooperation in research funding, and establish an extension service that is informed by publicly funded research rather than the interests of corporate actors. To aid the legitimacy of such a service, data on the economic viability of pursuing more sustainable farm business models needs to be consolidated.

3.4. Value chain, civil society, consumers and activists

Virtually all societal actors - inside and outside the food value chain, and from individuals to large organizations - bear some responsibility for creating the current agri-food system crisis. They also possess different kinds of power to affect the outcome of any effort to address this crisis. This needs to be widely recognized. At the same time, all actors can potentially play a positive role in reorienting this system towards sustainability and justice. This also needs to be recognized - by the cynics and the complacent alike. Changing this system will not be accomplished with one or two "silver bullets"; rather, it should be seen as a large and complex puzzle where no single actor has a view of all the pieces or the dexterity to place them in the right spot. We need to recognize the diversity of roles we can play and the influence we can have.

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A

Appendix to chapter two: Table of workshop participants and activities

Activity	Aim	# of participants	Participant background	Role of authors	Length	Data capture
Internal author workshop 1	Operationalize IS framework	8	Researchers	Active discussion	1h	Written notes
Internal author workshop 2	Develop indicators and coding scheme	8	Researchers	Active discussion	1h	Written notes
Stakeholder workshop 1	Discuss stakeholder perspective on issues	6	Researchers, policy-makers, civil servants	Active discussion	2h	Written notes
Focus group session	Verification of initial desk research and score system functions	12	Researchers, policy-makers, sector representatives, independent experts, NGO, financial institutions	Moderation	3h	Written notes; audio recording
Stakeholder workshop 2	Verification of results	12	Researchers, policy-makers,	Active discussion	2h	Written notes

Appendix to chapter four (A): Farm and farmer characteristics

TABLE A.1 | Overview of interviewees.

#	Farm type	Farm size (ha / herd size)	Farmer gender	Farmer age (y)	Time since transformation (y)	Adopter category
1	Livestock (dairy)	92 ha / 115 dairy cows	M	47	1-5	Early adopter
2	Livestock (dairy)	55 ha / 120 dairy cows	M	39	0	Early / late majority
3	Arable	25 ha	M	29	1-5	Innovator / early adopter
4	Arable	53 ha	M	38	1-5	Innovator
5	Arable	125 ha	M	58	0	Late majority
6	Dairy	313 ha / 265 dairy cows	M	52	>10	Innovator
7	Mixed	20 ha / 10 beef cattle, 20 pigs, 245 chicken	M	58	1-5	Innovator
8	Mixed	20 ha / 10 beef cattle, 20 pigs, 249 chicken	M	41	1-5	Innovator
9	Mixed	20 ha / 10 beef cattle, 20 pigs, 237 chicken	M	28	1-5	Innovator
10	Livestock (beef)	120 ha / 130 beef cattle	M	46	1-5	Innovator
11	Arable	370 ha	M	50	1-5	Innovator
12	Horticulture	84 ha	M	59	5-10	Innovator
13	Arable	44 ha	M	57	0	Late majority
14	Livestock (dairy and beef)	100 ha / 25 beef cattle, 85 dairy cows	F	53	>10	Innovator
15	Livestock (dairy)	50 ha / 99 dairy cows	M	38	0	Late majority
16	Livestock (dairy)	89 ha / 109 dairy cows	M	48	1-5	Innovator

A

#	Farm type	Farm size (ha / herd size)	Farmer gender	Farmer age (y)	Time since transformation (y)	Adopter category
17	Livestock (dairy and beef)	81 ha / 20 beef cattle, 80 dairy cows	M	55	>10	Innovator
18	Livestock (dairy)	225 ha / 253 dairy cows	M	53	5-10	Innovator
19	Livestock (beef)[17]	55 ha / 2 beef cattle	M	42	0	Innovator
20	Livestock (dairy)	82 ha / 89 dairy cows	M	42	1-5	Late majority
21	Mixed	50 ha animals, unknown herd size	M	72	>10	Innovator

Appendix to chapter four (B): Regenerative farming themes

TABLE B.1 | Regenerative farming themes (Groot Koerkamp et al., 2021).

Theme	Description
Soil quality & fertility	Maintenance and improvement of soil quality and fertility as the basis of soil-based food production
Primary productivity	Output of high-quality and safe food
Carbon & climate regulation	Maintenance of soil carbon content, reduction of energy use and production of renewable energy
Water purification & regulation	Reduction of leaching and blue water use; improvement of soil water retention
Provision & cycling of nutrients	Use of fertilizers from renewable sources and reduction of emissions of nitrogen and phosphor
Local air quality	Reduction of particulate matter and nitrous oxide emissions
Biological control	Enabling the presence of natural predators of pest insects
Pollination	Enabling the presence of pollinators
Genetic diversity	Maintaining a diversity of flora and fauna, both in nature and on productive areas of the farm
Habitats for species	Maintaining habitats for biodiversity and targeted protection of priority species
Farmer income	Having financial means for a good life of farmer and their family as well as for investment in the farm
Animal welfare	Attention for animal health and striving for good facilities
Attractive work	Having opportunities for attractive and meaningful work
Attractive landscapes	Attention for a visually appealing and culturally appropriate landscape
Farmer-consumer connection	Improving relations between farmers and non-farmers
Significance for local economy	Contributing to societal needs beyond nutrition

17 This farm is currently run as a hobby; plans for a farm building license are pending with the municipality. Once granted, the ambition is to create a mixed farm.

Appendix to chapter four (C): Interview questions

Intro & process (15-30 minutes): Introduce each other, ask for permission to record and take photos, sign data agreement, explain the process of the visits and goals of the study.

Basic information about the farm and farmer:

- Age
- Year they started farming (in general / on this farm)
- Highest level and type of education
- Profession of parents, spouse, children (if applicable)
- Farm succession: are there plans, if so with farmer's children or someone else?
- Farm size: land owned vs leased / rented
- Which crops / animals (in general; details on rotation etc. will come out of second visit)
- Other products / services generated by the farm
- Farmland history: what was there before?
- Side activities (LTO, collective, NGO)
- Income sources other than farming, and their importance for the livelihood of the farmer
- Value chain farm is embedded in / main customers
- Participation in agri-environmental schemes

Tour (30-60 minutes): See the farm and get a sense for what actually happens (differently) here. If permission granted, take photos. Ask what they are particularly proud of.

Self-assessment Donut - method in separate ppt (30 minutes): Get an overview of how the farmer thinks they are performing on the 16 RF criteria.

Timeline (60 minutes): Understand moments and events of significant change.

1. Explain idea behind the method: to understand which changes were important in the history of the farm(er), what brought them about, how they were dealt with, what was learned from them.

2. Set up and explain how it will work:
   a. Ask farmers to write down significant events, moments of change or turning points on post-it notes
   b. Ask farmers to add a date and a short description
   c. If necessary, the following examples can be used to prompt:
      i. starting or stopping to use a certain farming practice or technology
      ii. buying or leasing additional land
      iii. a change in laws / regulations with an impact on the farm
      iv. a moment of realization, shock, wonder

3. Events can include changes that were not / could not be made / that failed

4. Once farmer has recorded all events, ask for a moment of reflection to see if anything is missing; if so, allow them to add (with additional sheet if necessary)

5. Deepen understanding of events with the following questions:
   a. If the event was a change initiated by the farmer:
      i. What led you to implement something new?
      ii. How did you make this decision? Did you discuss it with anyone (family, neighbors, advisors, customers)?
      iii. Did you feel positive or negative encouragement (motivation / pressure) to take the decision (from a certain actor like the bank, or more generally from society or fellow farmers)?
      iv. Would you have done anything differently in this situation if you had had more knowledge, experience or resources?
   b. If the event was a change in laws / regulations:
      i. How did you experience and adjust to this change?
      ii. Did it have long-term consequences? If so, which ones?
      iii. Did it influence the way you make decisions, weigh up your options?
   c. If the event was a learning moment:
      i. Who or what did you learn from?
      ii. Do you generally trust this source of information?
   d. If the event was a personal insight or realization:
      i. What was your thought process here?
      ii. Do you remember what kinds of feelings or emotions you had?
6. General questions at the end:
   a. How did you experience these change personally? Have they influenced what you believe in or how you see the world?
   b. How did the people around you (family, friends, neighbors) experience these changes? Did their experience influence your own subsequent behavior?
7. Lastly, ask the farmer to continue the timeline: what does the future of the farm look like in 5 / 10 years? What will be the significant events and changes both on the farm and in the wider context?

Additional questions (15-30 minutes):

- How do you see the future of agriculture in the Netherlands in the coming decades?
- Which opportunities, challenges and solutions do you see?
- What makes a good farmer?
- How do you think Dutch people view farmers in general, and farmers like you specifically?
- Do you consider your farmland to be part of nature? Where does nature start for you, and what's your understanding of nature in general?

Summary

Why are European food systems seemingly "stuck" in a pattern that produces large quantities of cheap food, but also contributes greatly to today's environmental and social problems? And what can farmers, agribusiness companies, and governments do to get these systems "unstuck" and onto a more sustainable path? These questions lie at the heart of this thesis, which analyzes the potential transformation of the Dutch agricultural sector. The Netherlands is emblematic of Northwestern European farming sectors, characterized by a productivist farming paradigm that, on the one hand, produces large volumes of agricultural commodities, but which on the other hand results in the highest per-hectare farmland environmental pressure in the EU. By analyzing the context in which farmers operate and transform their businesses towards sustainability, we identify knowledge-related, sociocultural, economic, and regulatory types of lock-in that prevent a system-wide transformation. To overcome these types of lock-in, the persistent underlying paradigm of growth, resource extraction, and control over nature must be repudiated. The seeds of such a reorientation can be seen in the bottom-up transformations of individual farmers and regional initiatives. At the farm level, personal characteristics like risk appetite, open-mindedness, reflective ability, and sociability with peers are instrumental in overcoming the aforementioned structural barriers. At the regional level, we observed some signs of bottom-up regime reorientation through the facilitated redesign of a farm in collaboration with the farm's stakeholders.

Samenvatting

Waarom zijn Europese voedselsystemen vastgelopen op een traject waarin zij grote hoeveelheden goedkoop voedsel produceren, maar ook massaal bijdragen aan hedendaagse maatschappelijke- en milieuproblemen? En wat kunnen boeren, ketenpartijen en overheden doen om van dit traject los te komen en een duurzamer pad in te slaan? Dit zijn de vragen die in deze proefschrift over de potentiële transformatie van de Nederlandse landbouw behandeld worden. Nederland is kenmerkend voor Noordwest-Europese landbouwsectoren: de Nederlandse landbouw volgt een productivistisch paradigma dat aan de ene kant een hoog volumen aan voedsel produceert, maar aan de andere kant ook de hoogste milieudruk per hectare van de EU veroorzaakt. Door de context te analyseren waarin boeren opereren en hun bedrijven verduurzamen, identificeren we kennis-gerelateerde, sociaal-culturele, economische en regelgevende vormen van padafhankelijkheid die een systeembrede transformatie voorkomen. Om deze padafhankelijkheden te overkomen, moet het hardnekkige paradigma van groei, extractie van grondstoffen en heerschappij over de natuur worden verworpen. De kiemen van een dergelijke heroriëntatie zijn te zien in de bottom-up transformaties van individuele boeren en regionale initiatieven. Op boerderijniveau spelen persoonlijke kenmerken zoals risicobereidheid, ruimdenkendheid, reflectievermogen en sociabiliteit met leeftijdsgenoten een grote rol bij het overwinnen van de bovengenoemde structurele barrières. Op regionaal niveau zagen we enkele tekenen van een bottom-up heroriëntatie van het regime door het gefaciliteerde herontwerp van een landbouwbedrijf in samenwerking met de belanghebbenden van het landbouwbedrijf.

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About the author

I was born (1992) and grew up near the town of Minden, within view of the forested ridge that divides Germany's northern plains from the central uplands' rolling hills. My childhood and youth were spent mostly reading books and playing music, but also roaming the local woods and farmland with hunters and farmers. I have the great fortune to belong to the first generation of my family that, to my knowledge, never had to flee war or persecution and had the opportunity to pursue secondary and higher education to the fullest.

Between 2010 and 2014 I obtained a Bachelor of Arts in Liberal Arts and Sciences from University College Utrecht, and a Master of Sciences in Environmental Sciences and Policy from Central European University. Inspiring teachers at both universities, as well as a four-month field school and internship in East Africa in 2012, instilled in me a drive to address urgent and complex societal problems. I started my career at NewForesight Consulting, where I worked on developing and scaling a multi-stakeholder initiative for organic cotton, analyzing farmer-value chain interactions in tropical commodity sectors, and a variety of research and writing assignments. Realizing that the latter was where my passion and talents lie, I started my PhD at Utrecht University's Copernicus Institute of Sustainable Development in October of 2018.

This dissertation was finished in December 2022. I continue to research the Dutch agricultural transformation at the Copernicus Institute, now focusing on landscapes and institutional actors as avenues for change. I derive great fulfilment from teaching students that are, for the most part, tremendously interested in sustainability issues and eager to make a change in the world.

I live in Amsterdam with my wonderful wife Shelby, our five bikes, and countless house plants.